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Effect of a Flipped Classroom Teaching Approach on Improving Students' Performance and Decreasing the Academic Equity Gaps in Gateway Chemistry Course

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Abstract: Currently, the transformation of lower division courses with high-enrollment, or gateway courses, to include evidence-based teaching practices is one of the fundamental ways in transforming high education in the fields of science, technology, engineering, and mathematics. In gateway courses students learn the foundational skills and knowledge to succeed in upper division courses. Unfortunately, the rate of student success in gateway courses is low. This slows down students' progress, leading to poor pass rates and retention rates. A redesign of the gateway General Chemistry course in favor of a high-impact active learning practice (flipped classroom teaching/learning model) was evaluated using the logistic regression analysis and qualitative summative content analysis. It was shown that simultaneously implementing two evidence-based teaching approaches (the flipped classroom teaching/learning model offered in conjunction with the supplemental instruction faculty-facilitated learning enhancement tutoring) significantly enhances student academic achievements and leads to a decrease in the academic equity gaps among several groups of students.

***Keywords*:** Flipped Classroom, Academic Equity Gap, Gateway Course

Theoretical Framework of Research History and Context

Gateway courses intend to help students learn the foundational skills and knowledge to succeed in upper division courses in a department or major. Unfortunately, for many students, these courses can work as "roadblocks" that slow down students' progress, leading to poor success rates, pass rates, and retention rates. Historically, underrepresented college students, first-generation college students, or lower-income students have had the lowest rate of success in these courses. Increasing the success and completion rates in gateway courses is a goal for all institutions of higher education.

Higher than average failure rates in these courses highlights existing inequity that is caused by several major factors. Gateway courses typically have large enrollments and often cover significant amounts of content that make it difficult for instructors to meaningfully engage students. The diverse student population poses another meaningful obstacle, especially for students in minority or underserved groups that have different backgrounds, expectations, and experiences. Properly fixing these inequities means overcoming socialjustice issues and addressing even more challenging questions to allow institutions to move from an equality paradigm to an equity paradigm in higher education.

According to The American Association of Colleges and Universities' (AAC&Us') report titled Bringing Equity and Quality Learning Together, "More than half of AAC&U member institutions have equity goals to close racial and/or ethnic gaps in retention and on-time graduation. Far fewer have goals to address inequities in achievement of learning outcomes or participation in high-impact learning practices" (Hart Research Associates 2015, 10).

It is known that students' participation in evidence-based practices or high-impact learning practices (HIPs) leads to higher student success and higher levels of achievement in terms of student learning outcomes (SLO). Many in higher education believe that students' success requires reciprocal engagement from the students as well as from educators, and student-centered pedagogy based on active learning is the key to improving students' performance and decreasing the academic equity gaps in underserved student populations. Traditional teaching can be ineffective at helping students understand complex concepts and develop problem-solving skills. Therefore, the goal of our study was to evaluate the impact of a course redesign of the gateway General Chemistry course in favor of active learning highimpact practice, a flipped classroom teaching/learning model on (SLO) and decreasing academic equity gaps in a diverse student population.

The flipped classroom teaching/learning model is a relatively new pedagogical method, which employs asynchronous video lectures with practice problems as homework and active, group-based problem-solving activities in the classroom (Elazab and Alazab 2015). Because video lectures are as effective as in-person lectures at delivering basic information, they can be assigned to students as homework, leaving class time available for interactive group-based problem-solving activities. In contrast to a traditional lecture-based, instructor-centered instructional model, the flipped classroom model is composed of two phases of instruction that are "flipped," "inverted," or "reversed" (Bergmann and Sams 2012).

The first phase of the flipped classroom model is the pre-class learning phase. In this phase, students gain knowledge by viewing instructor-provided learning materials in various media formats, such as online videos, podcasts, or text-format materials prior to class (Baker 2000). The second phase of the flipped classroom model is in-class learning, in which students have student-centered active learning activities in class, such as interactive lectures, problemsolving, laboratory experiments, role-playing, and collaborative design and creation (Gerstein 2011; Strayer 2012). Thus, in terms of Bloom's revised taxonomy (2001), students do the lower levels of cognitive work (acquiring knowledge and understanding) outside of class and concentrate on the higher forms of cognitive work (analysis, application, synthesis, and assessment) in class (Bergmann and Sams 2012).

Elazab and Alazab outline five benefits of problem-based learning within a flipped classroom model for students—1) flexible knowledge, 2) effective problem-solving skills, 3) selfdirected learning skills, 4) effective collaboration skills, 5) intrinsic motivation—and six characteristics of problem-based learning: 1) learning is student-centered, 2) learning occurs in small student groups, 3) teachers are facilitators or guides, 4) problems form the organizing focus and stimulus for learning, 5) problems are a vehicle for the development of clinical problem-solving skills, and 6) new information is acquired through self-directed learning (Elazab and Alazab 2015). The students control the pace and time it takes to learn the material.

Instructors also benefit from a flipped classroom teaching model because they can strategically provide help to a significantly higher number of students, something that is not

feasible during limited class time and standard office hours. According to Elazab and Alazab,

From the instructor's perspective, key opportunities of the flipped classroom include effective classroom time to present content, discuss complex topics and work with students – either individually or in small groups; minimize time spent answering basic questions and repetitive questions – due to students' ability to review lectures online; using recorded lectures in multiple course sections – year over year, with easy tools for updating content. (Elazab and Alazab 2015, 208)

The benefit from utilizing the flipped classroom is evident at the university level. As universities try to expand their reach to students through online programs and e-learning platforms, the flipped classroom as a form of hybrid learning suits this goal well. Students who have internet access can watch videos uploaded by professors and listen to podcasts. Therefore, classroom spaces and teaching resources become more efficient. Tuition at most universities continues to rise, although creating a flipped classroom requires little to no additional infrastructure cost, allowing universities to allocate funds elsewhere. Further, incorporating a flipped classroom model may help to manage large course offerings, preserving faculty research time (Hutchings et al. 2012).

Previously Established Approaches

Gateway courses Chemistry 201/202 intend to lay the foundation for later work in higher level courses and are required for all degrees in chemistry or biochemistry and several other majors in biological sciences and other non-science majors. Unfortunately, for many students, these courses (especially Chemistry 201) have higher than average failure and withdrawal rates; 35 to 50 percent of the students enrolled in Chemistry 201/202 receive grades of C-, D, F, or withdrawal, W. The underrepresented groups of students, first-generation college students, or lower-income students have the lowest rate of success. During the three most recent academic years (2018–2019, 2019–2020, and 2020–2021), the rate of receiving a grade of D, F, or W among students of color (SOC) exceeded that of white students by 11.0 percent. Class size of seventytwo to ninety-six students is also an obstacle to making these courses engaging for student participation. This strongly suggests that course redesign should be evaluated.

Recognizing the benefits of a supplemental instruction (SI) model and understanding how difficult chemistry courses can be, we decided to modify the SI model in fall 2019 and implement a faculty-facilitated learning enhancement tutoring model to help students in addition to normal lectures. With this modification, 1.5 weekly office hours were converted by Dr. Stackpool to separate optional tutoring/help sessions conducted by the author to enhance and support classroom discussions. The students were organized into learning teams. Each team included three to five students. The team worked together to complete the assignment, which involves a set of seven to ten problems relating to lectures offered during the previous week. All group members participated and contributed equally because only one set of answers/solutions can be submitted by a team. Each student succeeds when all group members succeed, and each member of the team receives a bonus point added to their examination score on an upcoming exam.

The benefits of the suggested model are numerous. Students gain knowledge through interaction and conversations articulating their understanding. The informal atmosphere supports students' ability to socialize and study together. Success becomes achievable for

all team members, and it impacts the students' motivation and desire to learn. In fall 2020 and spring 2021, the tutoring sessions were conducted via Zoom in view of the COVID-19 pandemic. In fall 2021, we resumed offering the tutoring sessions in person.

Research Objectives and Methods

The research objectives in this study address two key questions:

1. Will the implementation of a flipped classroom teaching approach decrease the nonpassing grade rate of C-DFW in the diverse student population of Chemistry 201 in spring 2022 compared with spring 2021, and, if so, to what extent?
2. Will a flipped classroom teaching model supported by a faculty-facilitated learning enhancement model for tutoring contribute to decreasing the academic equity gaps in Chemistry 201? The data analysis includes the following:
   a. A logistic regression analysis of the data to determine whether there is any significant relationship between a flipped classroom model for the course delivery and the C-DFW rate in the gateway course Chemistry 201.
   b. A qualitative summative content analysis to analyze data obtained from surveys.

Methodology

Getting involved in Scholarship of Teaching and Learning (SoTL) on evidence-based teaching practices, including a flipped classroom teaching model, and to make research more sophisticated, complete with controls, statistical analyses, and quantitative measures, one may answer questions such as the following:

1. What constitutes good evidence? How do you define learning? Answer: in our research, we compared the (SLO) before and after implementation of the flipped model: the data about the course grade in Chemistry 201 for two spring semesters 2021 and 2022 were collected, compared, and analyzed.
2. How to set up control correctly? Answer: we consider that a comparison of (SLO) for the two spring semesters 2021 (control) versus 2022 (experiment) is valid and meaningful because regular mandatory Zoom study sessions are the only difference in the course delivery methodology in spring 2022 compared with spring 2021 (Table 1). Along with the video lectures, these sessions are the core of the flipped classroom teaching model.

Table 1: Comparison of the Course Delivery Methodology in 2021 vs. 2022

Course Delivery Description	Spring 2021	Spring 2022
Online asynchronous lecture component[a]	Yes	Yes
Regular study sessions[b] (three times a week)	No	Zoom[f]
Optional weekly tutoring sessions[c] (ten total)	Zoom	Zoom
Optional review sessions before hour exams[d] (four total)	Zoom	Zoom
The hour and final exams[e]	Face-to-face	Face-to-face
Laboratories	Face-to-face	Face-to-face
Online homework	Yes	Yes

[a]Online asynchronous lectures are pre-recorded videos posted on D2L. The videos have two formats: 1) explanations of concepts using PowerPoint presentations and 2) videos with examples of solving problems. Students can watch the videos based on their schedules and as many times as they want to grasp the concepts. b The mandatory study sessions help enhance students' knowledge of the concepts learned in the course and provide time to practice and build solid skills in problem-solving and answering conceptual questions. The worksheets for

each session included several problems. Student groups were randomly selected. Active participation and attendance were required. The attendance varied from 73 to 86 percent (much better than that of regular lectures). c The remote (Zoom) optional weekly tutoring sessions help provide additional help and enhance and support lectures, study sessions, and lab-related content. The students were encouraged to take part in tutoring sessions. Usually, 60 to 65 percent of students took part in the tutoring sessions in spring 2022. The worksheets were graded each time, and each student received a bonus point added to the examination score of an upcoming exam. d The remote (Zoom) optional review sessions before each hour exam were offered on the examination day, 50 minutes in duration. The attendance varied from 65 to 75 percent in spring 2022. e During the two semesters in the research, all exams were conducted in person. Therefore, malpractices such as cheating were not considered a material factor as they might be if exams were conducted remotely. f In spring2022, owing to the COVID-19 pandemic, Dr. Stackpool converted the originally planned face-to-face in-class study sessions to remote (Zoom) sessions.

To overcome the possible lack of students' preparation before mandatory study sessions (which was identified in [Long, Cummins, and Waugh 2017] as a main obstacle in the flipped classroom instruction), the researchers used a strategy of learning through "desirable difficulties." These low-stakes assignments (two-page worksheets with five to seven openended questions/problems) used generalization, elaboration, and reflection and were provided electronically thirty minutes before each mandatory session. Each student received two class participation points per completed worksheet. Desirable difficulties slow down learning and may not feel as effective as other strategies, but they produce better results (Brown, Roediger, and McDaniel 2014). For example, asking students to generate answers on a "fill-in-the-blank" quiz requires students to use recall more effectively, and it takes effort compared with giving them a multiple-choice quiz.

Overall, suggested methodology incorporates constructivism principles. Constructivism is a theory of learning in which students actively construct knowledge (Machanick 2007) through actions well suited to the flipped classroom as opposed to passively receiving information. The educational philosophies of progressivism and reconstructionalism, the student-centered philosophies, may speak to the effectiveness of the flipped classroom (Ebert and Culyer 2007). This approach implied a greater role for learners in the educational process: learners were responsible for discovering and creating knowledge, the learners' role is to synthesize, discover, and create knowledge. Knowledge is not something that is dictated by the all-knowing instructor but rather what learners uncover and develop. The role of the teacher in student-centered philosophies is to organize, guide, and help learners make sense of the results of the educational process.

A distinctive feature of the flipped classroom methodology is regular and systematic use of interactive technologies in the learning process. A mixture of face-to-face classroom experiences with online learning experiences received the name "blended learning" (Bluic, Goodyear, and Ellis 2007; Chandra and Fisher 2009; Donnelly 2010). Its implementation requires the incorporation of three pillars (content, pedagogy, and technology) and representation of these pillars in the teaching and learning processes. It was noted by Bluic, Goodyear, and Ellis that the most significant need in the blended learning model is how to effectively integrate the online and face-to-face components of the course into a coherent whole (Bluic, Goodyear, and Ellis 2007). Strayer, J.F. warns against ill-connected online and face-to-face components in a blended learning environment: "Because the two different learning experiences are so different, there is a real opportunity for a blended learning environment to have a synergistic effect in which the whole is greater than the combined parts" (Strayer 2012, 191). His study shows, based on a comparison with the traditional classroom, how crucial this integration is for success in a blended learning course.

Our experience with the flipped classroom teaching model in spring 2022 agrees with this conclusion and confirms that if well connected, the online asynchronous video

lecture component, mandatory study sessions, optional study sessions, and face-to-face laboratories enhance, complement one another, and lead to efficient course delivery and increased SLO.

Another recommendation supported by the literature was confirmed in our study, namely, that the students in flipped classrooms need to have more support structures built into the course and that it is beneficial to deliver a course so designed and structured as to give students an opportunity to view course content in several different formats (Nijhuis, Segers, and Gijselaers 2005). This effective delivery of material allows the instructor to eliminate much, if not all, lecture time in class, using study session time to develop understanding at more complex levels. Therefore, to deliver course content the Quality Matters (QM) template on D2L was utilized. QM allowed us to structure the course content effectively in a format of weekly educational modules and submodules and made it easy for students to navigate through numerous instructional materials. Learning objectives and schedules for assignments, laboratories and exams, video lectures, online lecture notes including assigned pages from the textbook and pre-lab instructions, were included in each weekly educational module. The "flipped" blended/hybrid Chemistry 201 course still included mini lectures (~ 5 minutes) offered at the beginning of mandatory study sessions and a variety of SI/tutoring opportunities: ten weekly tutoring sessions and four examination review sessions.

The researchers hypothesized that a student-centered active learning pedagogy such as flipped classroom enhanced by supplemental faculty-facilitated tutoring is the key to improving the gateway courses by decreasing the academic equity gaps among the diverse groups of students. Effective teaching is not about establishing high standards and registering how many students can be weeded out. The opposite is true: it is about helping every student develop learning skills to meet those standards and committing to equity and inclusive excellence.

Implementation of the Flipped Classroom Teaching/Learning Model

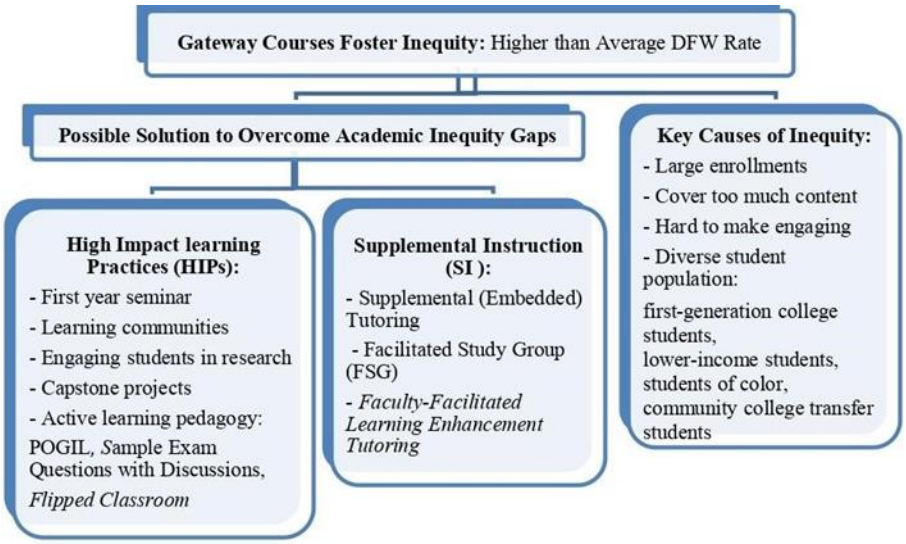
Approval of the current research project from the IRB was received in November 2021. In spring 2022, and in addition to the optional tutoring sessions, faculty-facilitated learning enhancement tutoring (Figure 1), the flipped classroom teaching/learning model was implemented in Chemistry 201. All 86 General Chemistry 201 students enrolled in Dr. Stackpool's class in spring semester 2022 were cordially requested to participate in this research project and to sign the Informed Consent Form available through Qualtrics.
By participating in this study, the students have agreed to the following learning strategy:

1. Study Chemistry 201 concepts using prerecorded video lectures, online lecture notes, and the textbook.
2. Participate in the mandatory study sessions Mondays, Thursdays, and Fridays from 8:00 a.m. to 8:50 a.m. via Zoom. The worksheets for each study session were available on the D2L site in the submodule Study session at 7:30 a.m. (30 minutes before the study session starts). Each student's performance was graded, and each member of the team received up to two class participation points per session for a total of eightyfour points for forty-two study sessions.

3. Participate in two anonymous surveys available through Qualtrics. The first survey was offered at the beginning of the semester (January 10–23).

The second survey was conducted at the end of the semester (April 25–May 2). Student surveys are the most reliable assessment of an instructor's effectiveness and are highly predictive of student achievement growth.

Figure 1: Gateway Courses: Solutions to Address Inequity and Improve Student Performance



Data Collection/Participant Demographics

The course grades for Chemistry 201 students enrolled in Dr. Stackpool's sections were requested from the Office of Institutional Analytics and Strategic Effectiveness for the following groups of students enrolled in spring 2021 and spring 2022:

1. College Generation (First generation of a college student or non-first generation)
2. Gender Identity (female, male, non-binary, choose not to disclose, other)
3. Student's major
4. The household income of the student (low-income students, non–low-income students)
5. Ethnicity:
   a. Student of color (Hispanic /Latino/ Spanish origin; African American; Asian American; Native American or Alaska Native; Native Hawaiian/other Pacific islanders).
   b. Caucasian (White)

The data does not include names or tech IDs, but they are linked to each other. The participants' demographics are presented in Figures 2–6.

Figure 2: College Generation Distribution, Percent in 2021 vs. 2022

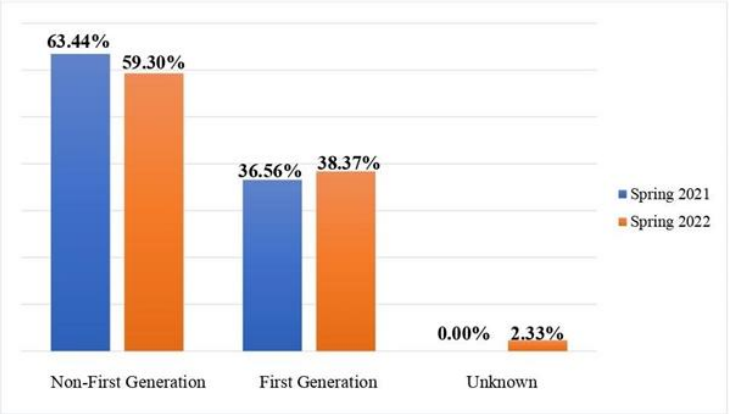


Figure 3: Gender Identity Distribution, Percent in 2021 vs. 2022

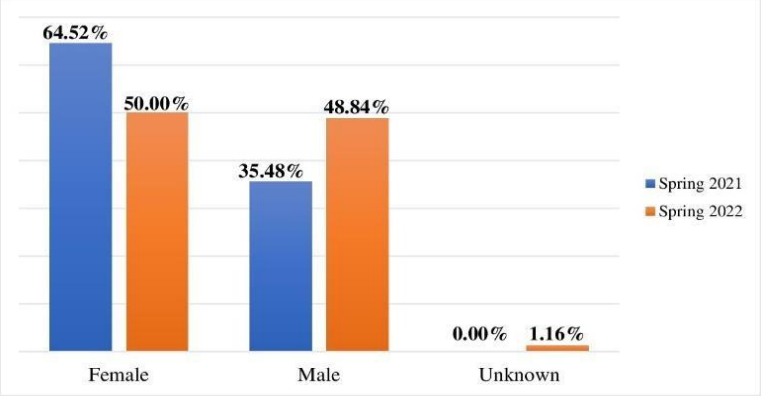


Figure 4: Ethnicity Distribution, Percent in 2021 vs. 2022

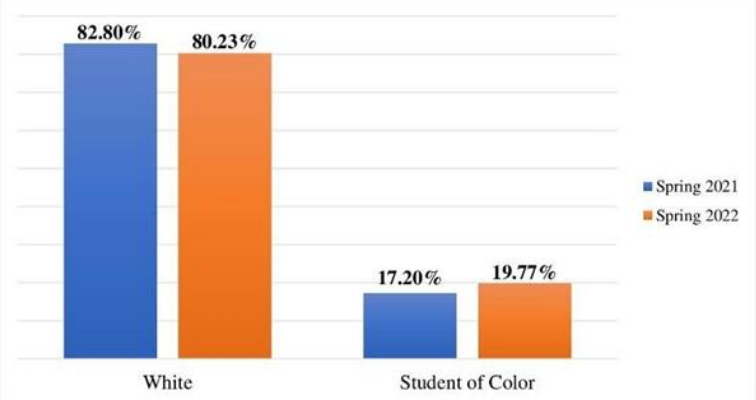


Figure 5: High- and Low-income Distribution, Percent in 2021 vs. 2022

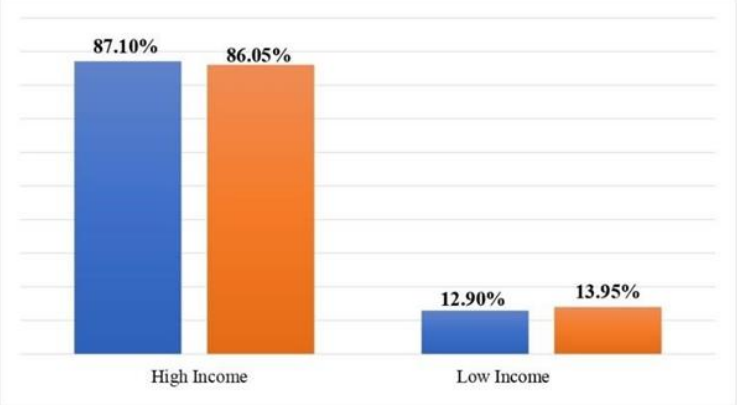
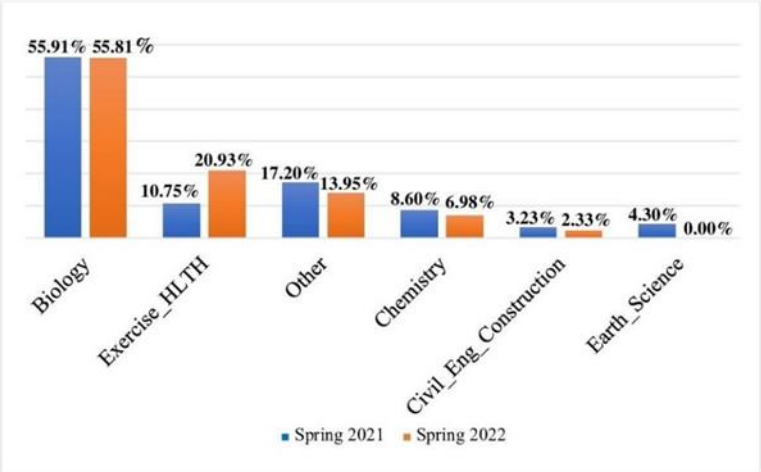


Figure 6: First Major Distribution, Percent in 2021 vs. 2022



Results

The bar graph, Figure 7, reveals a significant increase in the students' Chemistry 201 passing rate, from 40.86 to 56.98 percent, and a decrease in the rate of failure, from 59.14 to 43.02 percent in 2022 vs. 2021. A decrease in the rate of withdrawal, from 34.41 to 20.93 percent (Figures 8 and 9), in 2022 is a primary contributor to the failure rate decline in 2022. An increase in the rate of A-, B, C+, and C grades (Figure 9) in 2022 results in a significant increase in the passing rate in 2022.

Figure 7: Fail/Pass Distribution, Percent in 2021 vs. 2022

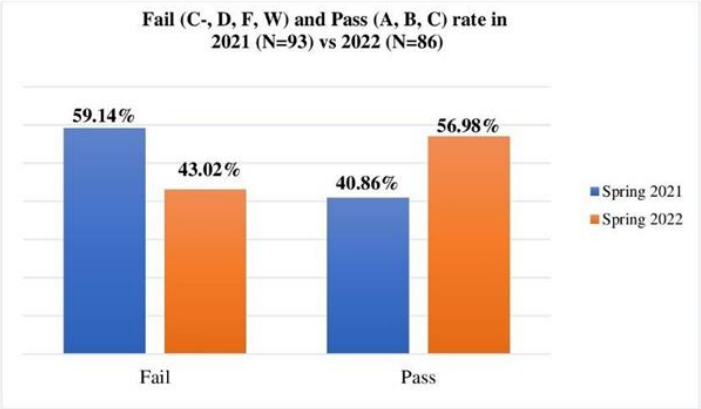


Figure 8: Non-Pass/Pass/Withdraw Distribution in 2021 vs. 2022

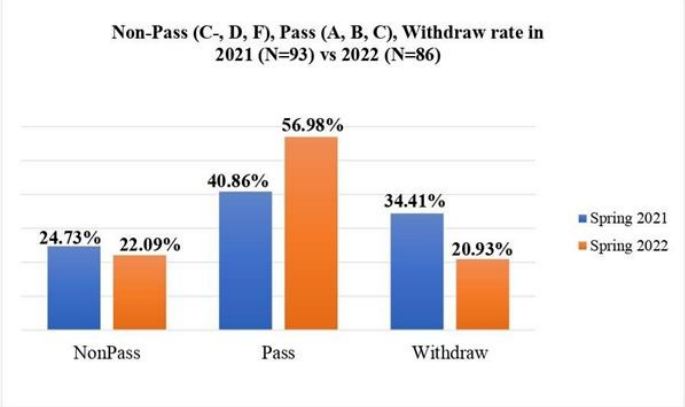
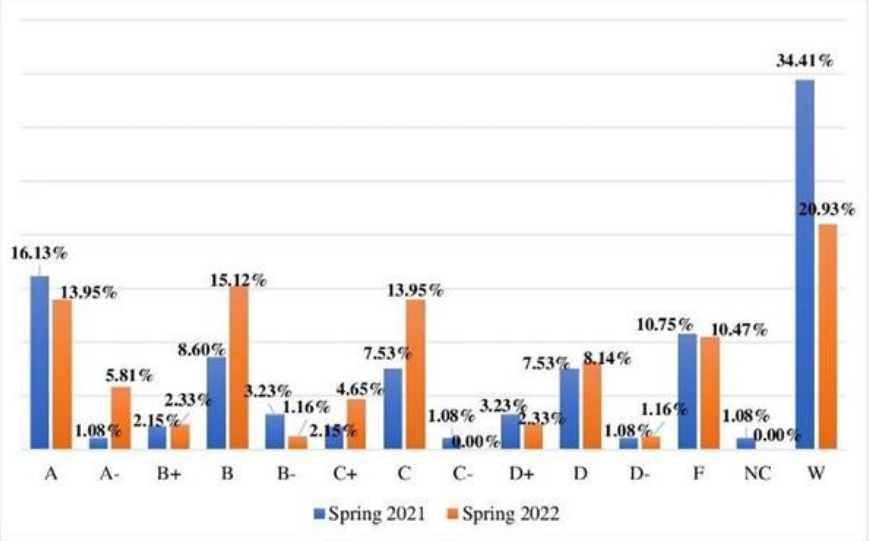


Figure 9: Chemistry 201 Grade Percentage Distribution in 2021 vs. 2022



Data Analysis

The main objective of this study is to determine the effectiveness of a flipped classroom teaching model compared with the regular lecture-based classroom teaching model. The variables that the researchers focused on for the analysis are shown in Table 2.

Table 2: Variables in the Analysis

Category and Definition	Levels within Category
Term: Semesters that are used for this study	Spring 2021—Before the flipped classroom teaching model was implemented Spring 2022—After the flipped classroom teaching model was implemented
Chemistry 201 grade	A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F, NC, W
Grade: Chemistry 201 grade is categorized into pass–fail grades	Pass–a grade of A, A-, B+, B, B-, C+, C Fail –a grade of C-, D+, D, D-, F, NC, W
Grade: Chemistry 201 grade is categorized into pass, nonpass, and withdraw grades.	Pass—a grade of A, A-, B+, B, B-, C+, C Non-Pass—a grade of C-, D+, D, D-, F, NC W—Withdraw from the course
Income: Total family income	Low—Total family income < $41,625 High—Total family income => $41,625
Gender: Student Gender	Female, Male, Unknown
Ethnicity: Student Ethnicity	SOC—Students of Color White—Caucasian students
Generation: First-Generation status and Non–FirstGeneration status	First Gen—First Generation Students Non–First Gen—Non–First-Generation Students
Major: All majors were categorized into six categories	Biology—Biology, Biotechnology, Environmental Science, Agricultural Science, Food Science Technology, Life Science Teaching, Medical Lab Science Exercise HLTH—Exercise Science, Applied Health Science Chemistry—Chemistry, Biochemistry, Chemistry Teaching Civil-Eng.-Construction—Civil Engineering, Construction Management Earth Science Other —Major not specified, Geography, Elementary Education, Psychology, Family Consumer Science, Management, Cognitive Science, Computer Engineering Technology, Criminal Justice, Physics Teaching, Computer Science, Finance, Computer Information Technology, Music

Association between the Grade Variable and All Other Variables

The grades with all other variables have been compared to determine whether grades are significantly associated with other variables, Grades vs. Term, Grades vs. Income level, Grades vs. Gender, Grades vs. Ethnicity, Grades vs. First-generation status, and Grades vs. Student major. The analysis was performed using Chi-square test and the Fisher's exact test (Table 3). The following are the findings from each test.

Table 3: Association between Grades vs. Other Variables

Testing Variables	p-value	Decision
Grades vs. Term	0.04488	There is an association between grade and the type of teaching model
Grades vs. Income level	0.1648	There is no association between grades and the income level.
Grades vs. Gender	0.2897	There is no association between grades and gender.
Grades vs. Ethnicity	1	There is no association between the student of color status and grades.
Grades vs. First-Generation Status	0.1251	There is no association between grades and first-generation status.
Grades vs. Student Major	0.01651	There is an association between grades and the student major.

The hypotheses testing reveals that grades are significantly associated with the Term variable, which illustrates the change of teaching method from the regular classroom model to the flipped classroom model. That illustrates that grades have a significant association with the teaching method. It was also found that grades are significantly associated with students' majors. All the other variables have no association with the grades.

Comparing Passing Rate of Different Groups of Categorical Variables

Even though Grades show significant association with only Term and Major, the researchers compared the passing rate of different groups of each category (Table 4). For all the hypotheses, the Chi-square test was used. The decision rule was based on the p-value of the testing procedure with the significance level of 0.05 as the cut-off point.

Table 4: Passing Rate of Grades vs. Other Variables

Testing Variables	p-value	Decision
Grades vs. Term	0.02244	Passing rate in 2021 is significantly less than that in 2022 with the flipped classroom teaching model implemented.
Grades vs. Income level	0.1648	There is no significant difference in the passing rate when compared with the income level.
Grades vs. Gender	0.2982	There is no significant difference in the passing rate when compared with gender.
Grades vs. Ethnicity	1	The p-value of 1 suggests no significant difference in the passing rate when compared with the student of color status.
Grades vs. First-Generation Status	0.2091	The p-value of 0.2091 suggests no significant difference in the passing rate when compared with the students' first-generation status.

According to the preceding p-values of Grades vs. Term, passing rate is significantly lower in 2021 compared with 2022. That indicates that the flipped classroom method shows a significant positve impact on passing rate, whereas other variables do not show any impact on the passing rate.

Grades vs. Students' Major

Chi-square test was performed to test if at least one of the major's passing rates is significantly different from all other majors specified. To simplify and perform the Chi-square test correctly, the counts of Civil-Eng.-Construction and Earth-Science majors were added to the Other major category. The p-value of 0.006682 suggests a significant difference in the passing rate of at least one major category.

Because this suggested more analysis on the pairwise comparison, the researchers looked at the passing rate of all six pairwise cases (Biology vs. Chemistry, Biology vs. Exercise HLTH, Biology vs. Other, Chemistry vs. Exercise HLTH, Chemistry vs. Other, Exercise HLTH vs. Other). Out of all these pairs, the testing procedure gave a p-value of less than 0.05 for pairs with the major "Other." That shows students with majors in Biology, Chemistry, and Exercise HLTH have a higher passing rate than students with other majors.

The hypothesis testing procedure reveals that the change of teaching method from the regular classroom model to the flipped classroom model leads to an improved rate of success for the Chem 201 students and a decrease in the C-DFW rate. It also shows that Biology, Chemistry, and Exercise HLTH major students' passing rate is higher than that of students with other majors. All other variables did not show any significant change in the passing rate when their groups are changed.

Logistics Regression Modeling

These observations on the association between the grades and other variables provided helpful information for constructing logistic regression models to determine the relationship between grades and the other predictor variables. The following logistic regression model explains the contribution of the teaching model to the pass–fail grades. It examined how all the predictor variables contribute to the pass–fail grades. The SAS software for modeling purposes was used.

MODEL 01: Grade vs. Term

Table 5 shows the testing procedures to test the significance of the model.

Table 5: Testing Global Null Hypothesis: BETA = 0

Test	Chi-Square	DF	Pr > Chi-Square
Likelihood Ratio	4.6653	1	0.0308
Score	4.6459	1	0.0311
Wald	4.6049	1	0.0319

Table 6: Type 3 Analysis of Effects

Effect	DF	Wald Chi-Square	Pr > Chi-Square
Term	1	4.6049	0.0319

The likelihood ratio chi-square of 4.6653 with a p-value of 0.0308 indicates that our model fits significantly better than an empty model. The Score and Wald tests are asymptotically equivalent tests of the same hypothesis tested by the likelihood ratio test. These tests also indicate that the model is statistically significant.

The section labeled Type 3 Analysis of Effects (Table 6) shows the hypothesis tests for each of the variables in the model individually. According to the table, a small p-value indicates that the predictor variable Term improves the model.

Analysis of Maximum Likelihood Estimates (Table 7) shows the coefficients (labeled Estimate), their standard errors (error), the Wald Chi-Square statistic, and associated p-values. Introducing the flipped classroom model in Spring 2022 versus a regular classroom model in 2021 increases the log odds of passing grades by 0.6506.

Table 7: Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square
Intercept	1	−0.3697	0.2109	3.0723	0.0796
Term Spring 2022	1	0.6506	0.3032	4.6049	0.0319

The Odds Ratio Estimates (Table 8) give the coefficients as odds ratios. An odds ratio is the exponentiated coefficient and can be interpreted as the multiplicative change in the odds for a one-unit change in the predictor variable. There is a moderate association between Terms and Passing Grade. The chance of obtaining a passing grade with the flipped classroom model (2022) is about 1.9 times that with a regular classroom model (2021).

Table 8: Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
Term Spring 2022 vs. Spring 2021	1.917	1.058	3.473

Table 9: Calculated Academic Equity Gaps (%) Within Groups 2021 vs. 2022

	SOC	First Generation	Low Income	Male	Female	Biology	Chemistry	Exercise Science	Other Major
2021: Rate of success is 40.86% for all groups									
Groups' success rates, % A, B, C	43.75	32.35	25.00	36.36	43.33	50.00	75.00	40.00	13.04
Gap: Group % −40.86%	2.89	−8.51	−15.86	−4.50	2.47	9.14	34.14	−0.86	−27.82
2022: Rate of success is 56.98% for all groups									
Groups' success rates, % A, B, C	52.94	51.52	41.67	50.00	65.12	54.17	66.67	72.22	40.00
Gap: Group % −56.98%	−4.04	−5.46	−15.31	−6.98	8.14	−2.81	9.69	15.24	−16.98

Evaluation of Academic Equity Gaps

The calculation of academic equity gaps was performed according to (Klonoski, Barker, and Edghill-Walden 2017). The percentage of students who passed the course and received grades of A, B, and C for the entire population and the percentage of students who achieved this criterion for target groups were calculated first. Next, the percentage of students who

passed the course within the entire population is subtracted from the percentage of students achieving the criterion in the target group (see Table 9).

The resulting difference is a positive number for the female group and for chemistry majors (Table 9), indicating no academic equity gap exists for these groups. Because the resulting difference is a negative number for the other groups, they are performing below the level of the entire population, and an equity gap exists. Quantifying academic equity gaps among diverse student groups is an important step in providing students the support necessary to succeed without changing the complex backgrounds and circumstances that students bring to college.

The data in Table 9 and Figures 10 and 11 reveal a decrease in the academic equity gaps in several groups: students of color, first-generation, exercise HLTH, and Other major in 2022 compared with 2021.

Figure 10: Academic Equity Gaps within Groups 2021 vs. 2022

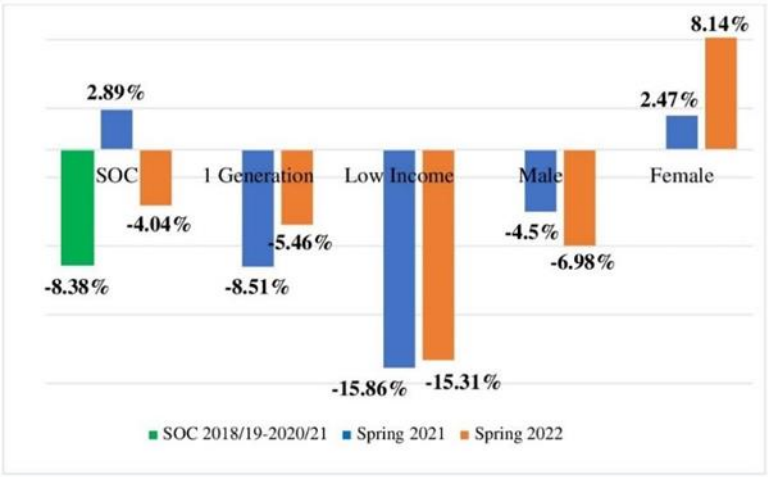
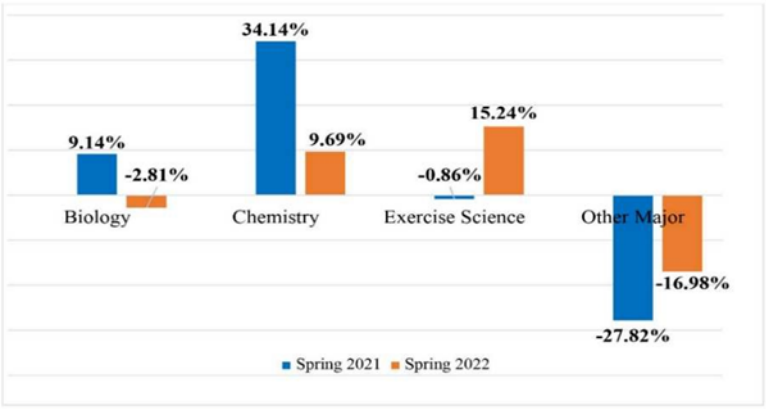


Figure 11: Academic Equity Gaps within the Student Majors 2021 vs. 2022



This may suggest that a decrease or elimination of the academic equity gaps is caused by redesigning the gateway Chemistry 201 course in favor of a flipped classroom teaching/learning model, which helps underserved students (students of color and first generation students) to overcome a lack of cultural responsiveness both in and out of the classroom, improve their academic performance, and their sense of belonging. The low-income student's equity gap shows almost no positive change (Figure 10): students from low socioeconomic backgrounds often have greater demands on their time compared with the other groups because of the need to work, sometimes, multiple jobs to afford college attendance. These academic and nonacademic pressures can have a more significant impact

on the academic performance of this group. Our data regarding the existing academic equity gap in the male group compared with no such gap in the female group (Figure 10) is consistent with the conclusion drawn by Andrew Koch and Brent Drake: "Males consistently have higher DFWI rates compared to their female counterparts in the key gateway courses. The differences are greatest in chemistry, followed by accounting, and then calculus" (Koch and Drake 2018, 2).

Qualitative Summative Content Analysis

Sentiment Analysis

Consideration of students' needs and expectations is important in determining their satisfaction and willingness to take the course. Therefore, all participants were prompted to complete survey 2 during the last week of the semester and evaluate the helpfulness of each course delivery component (see Table 10).

Table 10: Helpfulness of Course Components, Q 8

	Least				Most
Components of course delivery	1	2	3	4	5
Online videos and lecture notes provided by your instructor	○	○	○	○	○
Mandatory study sessions	○	○	○	○	○
Optional weekly tutoring sessions	○	○	○	○	○
Review sessions before exams	○	○	○	○	○

Students were also asked to provide suggestions to improve the Chemistry 201 course related to three aspects integral to the flipped classroom design: 1) lecture delivery (virtual and asynchronous), 2) mandatory study sessions (virtual and synchronous), and 3) optional tutoring sessions/review sessions (virtual and synchronous). To analyze the open-ended responses, sentiment analysis was conducted by researchers first, in which each comment was rated on a one to five scale, from "very negative" to "very positive." The sentiment analysis was compared with the feedback on survey, Q 8 Helpfulness of the Course Components (see Table 11).

Table 11: Sentiment Analysis vs. Helpfulness of Course Components, Q8

	Average	*SD*	*Average*	*SD*
Course Components	Sentiment Analysis		Helpfulness	
Online Lectures	2.48	1.19	3.29	1.39
Mandatory Sessions	2.81	1.13	4.03	1.32
Optional Sessions	3.70	1.10	4.40	0.81

As we can see in Table 11, the sentiment analysis and the ratings of helpfulness reveal the same general trend. The lowest results are for online lectures and the highest for optional sessions, with the mandatory study sessions in the middle. As rating increases, we also see that the standard deviation decreases. On examination, many students prefer in-person, synchronous lectures. When virtual, many voiced that they prefer synchronous, which may help explain the more positive ratings for mandatory sessions relative to the online lectures. Optional sessions, especially the exam review sessions, were largely

popular, and many students included pleas to maintain them in future iterations of the course.

It is important to note that one explanation for lower sentiment ratings than helpfulness ratings is that the survey explicitly asked, "What suggestions do you have to improve this course?" With this prompt, it is more likely that the sentiment and themes in the open response comments would be more negative, because students are highlighting ways to improve the course (and, similarly, highlighting imperfections of the course). Because of this, the helpfulness ratings may, in fact, be more representative of actual attitudes toward the course, but the open-ended feedback is still useful for continual improvement of the course.

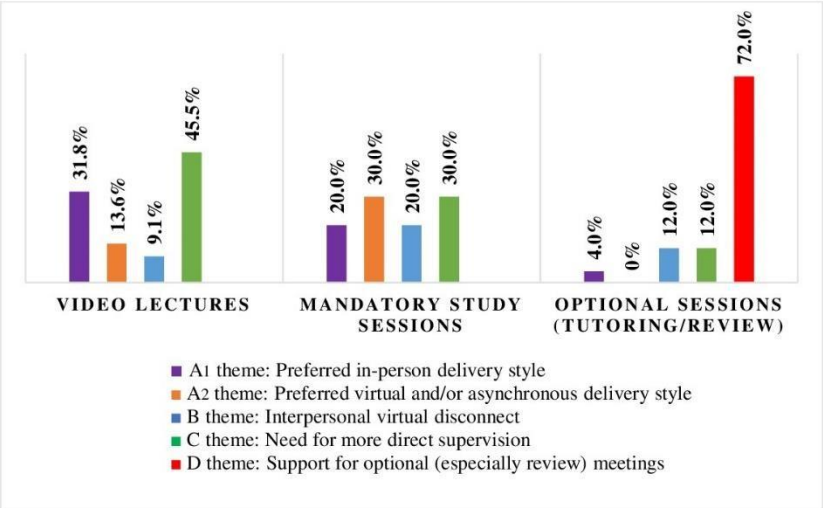
Inductive Thematic Analysis

Following the sentiment analysis, inductive thematic analysis was conducted following the process of thematic analysis by Braun and Clarke (Braun and Clarke 2006). First, researchers familiarized themselves with the data, then initial codes were generated to comprehensively summarize and differentiate responses. After the initial coding, themes were searched for, reviewed, and defined. After finalizing the themes, the data was summarized, and themes were quantified to calculate relative frequencies for each of the three elements of the flipped classroom, as well as overall. These frequencies are summarized and visualized (Figure 12). Researchers found four overall themes, one consisting of two subthemes.

Theme A (Preferred Delivery Style) Students demonstrated a personal preference on course delivery.

- A1: Students preferred to be in person and if meeting virtually, preferred to meet synchronously.
- A2: Students preferred to be virtual and/or asynchronous.

Figure 12: Relative Frequencies for the Theme Elements



Comments were largely split depending on whether students preferred the flexibility of the asynchronous recorded lectures or would have preferred synchronous and/or in-person instruction. The dependence on virtual learning since the start of the COVID-19

pandemic has transformed the academic world, but it has not been seen as beneficial to all. Many still prefer the traditional in-person instructor-centered instruction for a multitude of reasons; however, others seemed to embrace the virtual format. In large part, it seemed that this depended on participants' preferred learning style.

A1: I did not find the online/asynchronous lecture modules to be the most effective learning style for me. I noticed myself getting behind on videos, furthermore, lacking in the virtual study sessions and unable how to guide my own learning. Personally, I would have preferred this course to be in-person fully but understand the initial COVID-19 implications. I just feel that the online lectures were not the most effective learning style on my own learning experience.

A2: This is a great way to deliver lectures, especially the flipped classes, which is my favorite where you explain thoroughly, and ask questions after watching videos, sometimes we don't need to because we understood everything you explain at first. So, keep the flipped classes is a great idea.

Theme B (Interpersonal Virtual Disconnect)

The virtual meeting space specifically limited interstudent interaction, facilitation, and discussion. Some students shared more specific discontent related to the virtual style of meeting. Especially related to the mandatory study sessions and optional tutoring/review sessions, meeting over Zoom negatively affected the ability of the group to interact and discuss, which they saw as a major goal for those sessions. This does not necessarily imply that in-person would be needed to improve the sessions but only that the virtual meetings, as they exist now, could be improved by increasing interaction and communication.

Theme C (Need for Direction)

Students struggled to keep up with the work through the semester and could benefit from more direct supervision. More specific to a general dislike of the asynchronous recorded lectures, many students noted that they had trouble keeping up with the work, whether this was watching the lectures on time or adequately preparing for the mandatory study sessions. The responsibility of students to manage elements of their own learning in the flipped classroom environment seemed to be misunderstood by some students. Many commented that they would have preferred and benefitted from more direction or additional resources from the instructor to ensure they kept on track with lectures and work over the span of the semester.

Theme D (Support for Optional Meetings)

Optional meetings were largely effective and valued by students, especially for examination preparation. Responses related to improving the optional tutoring and review sessions were much more homogeneous than the other feedback. In large, feedback was simple but positive. Students liked the opportunity to meet for tutoring and review. They especially appreciated the option for extra credit and felt that the examination review sessions were the most helpful and impactful. This theme was only found within the open-response question related to the optional meetings but consisted of almost 60 percent of comments. Some of the positive feedback on the optional meetings also noted, however, that they could benefit from more direct interaction with the instructor.

Tutoring sessions and review sessions were awesome. Keep those the same as much as possible.

I liked being able to gain further insight about the exam and appreciated this component of the course.

These were very helpful, gave me a better idea about what I need to study, and how the exam material would look like. I would've preferred these study sessions in person so I could engage with my teacher more.

The analysis of themes A1, B, and C reveal that not all students liked the virtual format of class activities and the flipped teaching/learning model overall. It was challenging for some students. Our findings are consistent with a conclusion reached by Long, Cummins, and Waugh,

> Not all students enjoy active learning. Students, in general, are used to a passive learning format, more used to the traditional lecture in which instructors stand in the front of the classroom and explain everything. Some passive learners even kept silent when they had difficulties in learning. This presents a challenge for instructors to know whether the students have acquired the required knowledge or not. (Long, Cummins, and Waugh 2017, 188–189)

Ways for Improvement

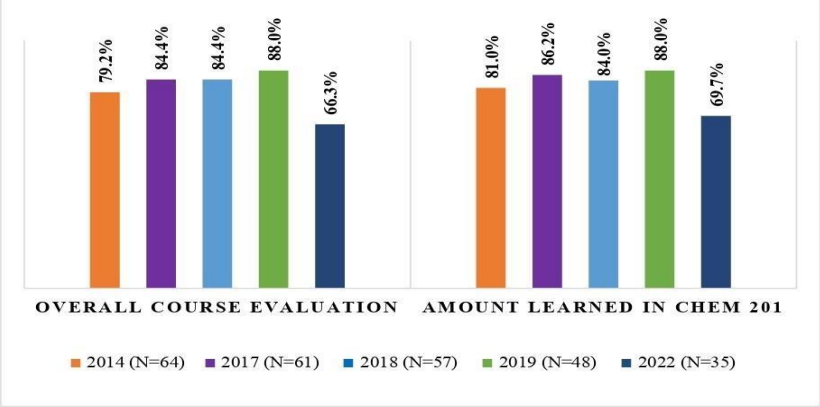
Another finding agreed with a study conducted by Deslauriers, McCarty, Miller et al. The students in the active-learning classroom scored higher on tests, but their perception of learning and rating of the quality of the instructor was lower. This study found a negative correlation between how much students learned, as measured by the test, and how they felt they were learning, as measured by the survey (Deslauriers et al. 2019).

Dr. Stackpool's Chem 201 students' evaluations based on the traditional lecture format (Spring: 2014, 2017, 2018, 2019) were compared with the Spring 2022 flipped classroom format based on the survey's questions for the course evaluations:

- Rating of the course as a whole
- Amount you learned in the course

In general (Figure 13), the ratings for the amount learned and overall course evaluation are similar. Amount learned is either the same or slightly better for each year (2014–2019) and decreases noticeably in 2022 after the implementation of the flipped classroom. This decrease may reflect a resistance of some students to a more challenging model of learning, which makes them feel like they're learning less.

Figure 13: Comparison of the Student Course Evaluations (2014–2019) with Survey 2 Responses (2022)



Making learning more active improves knowledge transfer and teaching effectiveness. This is supported by the improved students' performance in our study and by research (Deslauriers, Schelev, and Wieman 2011). However, students may not necessarily feel that the active learning within the flipped classroom model is effective. Whereas some students struggle with the traditional instructor-centered lecture-based method, others have become so used to that style that they have a hard time adjusting to something new and innovative, with the role of the instructor changed from presenter of content to learning coach or facilitator. The active learning requires students to put in more time preparing for each study session and more effort during class to stay current with the pace of the course. "What the students did not say directly, but something to which they were alluding, was that they had to learn at the rate which the classroom was going rather than 'letting it slide' and cramming at the last moment" (Aronson and Arfstrom 2013, 4). Students' procrastination is not a reason to avoid implementing this teaching/learning approach. The student satisfaction is not the point if students are more engaged and are performing at a higher level (Brame 2013). Different students have different preferences, and some will tend to favor the flipped model, whereas others will not.

However, student satisfaction indicates the importance of addressing students' perceptions around active/blended learning and managing learners' expectations and understanding of this model upfront at the beginning of the semester. This also suggests that the transfer from virtual study sessions (Zoom) to the face-to-face format will promote more effective communication (instructor-to-student and student-to-student), enhance student engagement and performance from working in groups, and improve overall appreciation of this learning model.

Conclusion

The implementation of the flipped classroom teaching model can improve instructional delivery by providing additional help to a greater number of students, this being unfeasible with a lecture-based instructor-centered teaching model. Offered in conjunction with the supplemental instruction (faculty-facilitated learning enhancement tutoring), the flipped classroom teaching/learning model provides an opportunity to learn in a differentiated and more equitable fashion, which leads to a decrease in the academic equity gaps within several groups of students and significantly enhances student academic performance. This also indicates the importance of course redesign in favor of a high-impact active learning practice—the flipped classroom model—in better serving a steadily diversifying twenty-first– century student population and improving student performance in gateway courses.

Post-COVID-19 note: In Spring 2023, the authors continue their research. Dr. Stackpool replaced remote study sessions with in-person study sessions and will incorporate this variable change in the ongoing research and data analysis.

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Informed Consent

The authors have obtained informed consent from all participants.

Conflict of Interest

The authors declare that there is no conflict of interest.

REFERENCES

Aronson, Neil, and Kari M. Arfstrom. 2013. "Flipped Learning in Higher Education." https://www.flippedlearning.org/wp-content/uploads/2016/07/HigherEdWhitePaperFINAL.pdf.

Baker, J. Wesley. 2000. "The Classroom Flip: Using Web Course Management Tools to Become the Guide by the Side." Communication Faculty Publications, 15. https://digitalcommons.cedarville.edu/media_and_applied_communications_publications/15.

Bergmann, Jonathan, and Aaron Sams. 2012. Flip Your Classroom: Reach Every Student in Every Class Every Day. Eugene, OR: International Society for Technology in Education.

Bluic, Ana-Maria, Peter Goodyear, and Robert A. Ellis. 2007. "Research Focus and Methodological Choices in Studies into Students' Experiences of Blended Learning in Higher Education." Internet and Higher Education 10 (4): 231–244. https://doi.org/10.1016/j.iheduc.2007.08.001.

Brame, Cynthia J. 2013. "Flipping the Classroom." Vanderbilt University Center for Teaching. https://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/.

Braun, Virginia, and Victoria Clarke. 2006. "Using Thematic Analysis in Psychology." Qualitative Research in Psychology 3 (2): 77–101. https://doi.org/10.1191/1478088706qp063oa.

Brown, Peter C., Henry L. Roediger, and Mark A. McDaniel. 2014. Make It Stick: The Science of Successful Learning. Cambridge, MA: The Belknap Press of Harvard University Press.

Chandra, Vinesh, and Darrell L. Fisher. 2009. "Students' Perceptions of a Blended Web-based Learning Environment." Learning Environments Research 12:31–44. https://doi.org/10.1007/s10984-008-9051-6.

Deslauriers, Louis, Ellen Schelev, and Carl Wieman. 2011. "Improved Learning in a Large-Enrollment Physics Class." Science 332 (6031): 862–864. https://doi.org/10.1126/science.1201783.

Deslauriers, Louis, Logan S. McCarty, Kelly Miller, Kristina Callaghan, and Greg Kestin. 2019. "Measuring Actual Learning Versus Feeling of Learning in Response to Being Actively Engaged in the Classroom." PNAS 116 (39): 19251–19257. https://doi.org/10.1073/pnas.1821936116.

Donnelly, Roisin. 2010. "Harmonizing Technology with Interaction in Blended Problembased Learning." Computers & Education 54:350–359. https://doi.org/10.1016/j.compedu.2009.08.012.

Ebert, Edward S., and Richard C. Culyer. 2007. School: An Introduction to Education. Belmont, OH: Thomson Wadsworth.

Elazab, Samia Ragab, and Mohamed Alazab. 2015. “The Effectiveness of the Flipped Classroom in Higher Education.” In Proceedings of the 2015 Fifth International Conference on e-Learning, 207–211. https://doi.org/10.1109/ECONF.2015.34.

Gerstein, Jackie. 2011. “The Flipped Classroom Model: A Full Picture.” WordPress. https://usergeneratededucation.wordpress.com/2011/06/13/the-flipped-classroommodel-a-full-picture/.

Hart Research Associates. 2015. “Bringing Equity and Quality Learning Together. Institutional

Priorities for Tracking and Advancing Underserved Students’ Success.” Association of American Colleges and Universities. https://www.aacu.org/research/bringing-equity-andquality-learning-together-institutional-priorities-for-tracking-and-advancingunderserved-students-success-2015-2.

Hutchings, Maggie, Anne Quinney, Kate Galvin, and Vince Clark. 2012. “The Yin/Yang of Innovative Technology Enhanced Assessment for Promoting Student Learning.” In Proceedings of the 2012 European Conference on e-Learning, 230–237.

https://eprints.bournemouth.ac.uk/21818/1/ECEL%20Paper%202012%20Final.pdf.

Klonoski, Ed, Gregory Barker, and Vernese Edghill-Walden. 2017. “General Education: The Front Lines of Equity and Inclusion at a Midsize Public University.” The Journal of General Education 66 (1–2): 60–76. https://doi.org/10.5325/jgeneeduc.66.1-2.0060.

Koch, Andrew K., and Brent M. Drake. 2018. “Digging into the Disciplines I: Accounting for Failure – The Impact of Principles of Accounting Courses on Student Success and

Equitable Outcomes.” John N. Gardner Institute for Excellence in Undergraduate Education 1–4. https://www.jngi.org/blog/2018/11/6/digging-into-the-disciplines-the-impact-ofgateway-courses-in-accounting-calculus-and-chemistry-on-student-success.

Long, T., J. Cummins, and M. Waugh. 2017. “Use of the Flipped Classroom Instructional Model in Higher Education: Instructors’ Perspectives.” Journal of Computing in Higher Education 29 (2): 179–200. https://doi.org/10.1007/s12528-016-9119-8.

Machanick, Philip. 2007. “A Social Construction Approach to Computer Science Education.” Computer Science Education 17 (1): 1–20. https://doi.org/10.1080/08993400600971067.

Nijhuis, Jan F. H., Mien S. R. Segers, and Wim H. Gijselaers. 2005. “Influence of Redesigning a Learning Environment on Student Perceptions and Learning Strategies.” Learning Environments Research 8:67–93. https://doi.org/10.1007/s10984-005-7950-3.

Strayer, Jeremy F. 2012. “How Learning in an Inverted Classroom Influences Cooperation, Innovation and Task Orientation.” Learning Environments Research 15 (2): 171–193. https://doi.org/10.1007/s10984-012-9108-4.