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The Effect on Classroom Modality on The Learning Outcomes of Latinx Students in STEM

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Professor Fahad Khan is a Mechanical Engineer with a Ph.D. in Mechanical Engineering from Worcester Polytechnic Institute. Professor Khan's background includes: a ten-year work in the energy sector in Saudi Arabia, graduate research in thermos fluids, and a Master of Business Administration in Industrial Management. For the last 10 years, Professor Khan has been teaching at Springfield Technical Community College (STCC) in the Department of Energy Systems Technologies. During his time at STCC, Professor Khan developed a curriculum in building heating efficiency and restructured the hands-on portion of the heating program to focus on providing traditional and non-traditional students with the fundamental skills required for workforce development.

The Effect of SLOs Focused Lectures and Class Modality on STEM Latinx Students' Success

In schools serving minority students or Hispanic-Serving Institutes (HSIs), the restructuring of class material delivery methods is crucial for improving student learning outcome (SLO) attainment. The recent pandemic has accelerated the shift towards online platforms, impacting classroom modality significantly. These institutions have experienced a notable decline in SLOs, evidenced by reduced class retention (staying in the program) rates and assignments completion.

This paper examines the impact of incorporating best practices identified in the literature and students' feedback to enhance Latinx students' SLOs and academic success over a nine-year period. The research investigates the correlation between Latinx student retention and: (1) course material delivery format/structure (comparing in-person, hybrid, and fully online modalities); (2) the impact of group activities versus individual assignments (assessing student performance on multiple-choice quizzes, essays, and projects designed for identical SLOs, and subsequently comparing cumulative overall SLO attainment); and (3) the role of classroom social interaction (analyzing students' performance on problem-solving tasks completed collaboratively and individually).

The data presented in this paper pertains to students enrolled in a technical STEM program, specifically Heating, Ventilation, and Air Conditioning (HVAC). This program integrates theoretical knowledge delivered through lectures with practical skills development in a laboratory setting. Upon completion, graduates are prepared for entry-level HVAC technician positions, earning either a one-year Certificate of Completion (C.O.C.) or a two-year Associate of Science (A.S.) in Energy Systems Technology.

Changes implemented in classroom structures are detailed for each academic year, with a corresponding analysis of Latinx student program completion rates. The findings indicate that retention, as measured by course completion, improved with the implementation of face-to-face, classroom-based lectures. The method of assignment submission (online or hard copy) did not demonstrate a significant impact on retention. Furthermore, increased interaction among students correlated with both improved retention and higher assignment submission rates. The relationship between teaching methodologies and SLOs, along with other key findings and directions for future research, will be discussed in detail in the conclusion .

Background and literature review: the need for equitable teaching practices

Latinx students remain underrepresented in STEM fields in the U.S. [1]. While their enrollment in higher education is increasing and approaching equality with majority student populations, there is still a need for effective support systems within Hispanic-Serving Institutions (HSIs). This increase also suggests positive changes within HSIs that are mitigating factors contributing to Latinx underrepresentation, such as academic preparedness, sense of belonging, and the creation of a more inclusive campus environment [1] [2] [3]. However, existing literature indicates that traditional STEM class structures and student learning outcome (SLO) evaluation methods are often outdated and do not adequately serve the needs of many minority students, including Latinx students [4] [5]. This observation has been validated by preliminary findings within the program under study.

While Latinos have historically valued education as a pathway to economic, political, and social mobility [2], gaps in educational attainment persist. Community college completion rates for Latinx students were also low, at approximately 33% [2]. HSIs have sometimes been criticized for being "Hispanic-enrolling" rather than "Hispanic-serving" [3] [6]. Alvarado-Young [7] suggests that HSIs face significant challenges in effectively supporting Latinx student success and that community college leaders must adopt innovative strategies to help these students achieve their educational goals. Changing the lecture delivery methods, and moving toward nontraditional assessment that fits nontraditional students seems to be necessary for equitable teaching at a community college level [8] [9]. Dr. Salazar highlights that “HSIs are ideal places to study what works ” in order to develop best practices for teaching and learning [10]. This resonates with the present study, which demonstrates improved enrollment and completion rates for Latinx students following the restructuring of SLO delivery methods. Description of the studied program and changes that took place are elaborated on in the following section.

Description of the studied program

This study focuses on the Energy Systems Technology (EST) program, part of the STEM school offered technology programs at Springfield Technical Community College (STCC), an HSI-designated institution since 2015 [11]. Located in Springfield, Massachusetts, STCC serves a region with a significant Hispanic population. According to the 2020 Decennial Census, 47% of Springfield residents identify as Hispanic or Latino, with 31.8% speaking Spanish at home [12].

The Energy Systems Technology program provides training in basic Heating, Ventilation, and Air Conditioning (HVAC), power plant operation, and building control systems. The curriculum includes courses on fundamental electrical theory and related hands-on laboratory experiences. Students receive theoretical instruction through lectures, which are then reinforced through practical application in the HVAC laboratory. The program emphasizes the development of manual dexterity and problem-solving skills essential for successful graduates. Upon completion, students are expected to demonstrate proficiency in: (1) electrical wiring of residential and commercial boilers and air conditioners; (2) troubleshooting malfunctioning HVAC equipment; (3) performing heat load analyses for residential and commercial buildings; (4) understanding relevant codes for entry-level power plant technician roles (second fireman);

(5) obtaining EPA 608 certification required by law prior to handling refrigerants; and (6) qualifying for the state oil burner technician license exam.

Full-time students can complete the Certificate of Completion (C.O.C.) in two semesters. An Associate of Science (A.S.) degree track is also available, requiring four semesters of full-time enrollment. All C.O.C courses are transferable to the A.S. degree. Admission to the certificate program requires placement in basic algebra, although many students initially enroll in pre-algebra during their first semester.

Methodology

This paper analyzes the retention rate, enrollment, and completion percentages of Latinx students following annual adjustments to teaching and SLO evaluation methodologies. These modifications were implemented based on feedback from current students, program graduates working in the HVAC field, senior HVAC technicians, the program's advisory board, relevant literature, and ESCALA training. A detailed account of the changes implemented each year is provided, with a discussion of lessons learned, best practices, and future research directions presented in the conclusion section.

Evolution of classroom structure and observations (2015-2021)

In 2015, all courses followed a traditional, in-person lecture format with timed, exam-based evaluations (midterm and final). Instruction relied heavily on lectures, with students expected to take notes in preparation for exams. PowerPoint presentations and digital course materials were not utilized; all examples were presented on a chalkboard and through handouts. Course grades were determined by midterm, final exam scores, and attendance, with a strict attendance policy allowing no more than two absences and absolutely no make ups for any exams.

The first restructuring effort involved transitioning to a combined learning approach (web assisted). Course content was made available on Blackboard in PowerPoint and other downloadable formats. Grading was revised to include six hard-copy homework assignments, six quizzes based on the homework, and a final exam (weighted at 10% of the final grade). This shift towards more frequent, lower-stakes assessments proved popular with students, who appreciated the opportunity to recover from missed quizzes and preferred not being evaluated on large amounts of material at once. Furthermore, the initial attendance policy and grading structure were recognized as needing greater flexibility to accommodate the needs of non-traditional students, particularly Latinx students at STCC, many of whom balance full-time jobs and family responsibilities.

The move to more frequent, lower-stakes assessments was driven by student feedback indicating difficulty recalling large amounts of information at the end of the semester. This prompted a program-wide review of curriculum content, with the goal of eliminating unnecessary material and focusing on field-relevant skills. The following changes were implemented between 2015 and 2019:

- **Lean Teaching:** Lecture material was continuously evaluated and refined, with unnecessary content removed based on feedback from the advisory board. Greater emphasis was placed on emerging technologies and practical field experience.

- **Flexible Attendance:** The attendance policy was revised to allow students to make up quizzes or assignments with prior arrangement, providing flexibility while maintaining accountability.

- **Collaborative Homework:** Students were permitted to complete homework assignments in groups of two or three. Student performance on subsequent homework-based quizzes was monitored to assess the impact on SLOs. This practice also fostered increased student interaction.

- **Peer Support:** Extra credit was offered for students who assisted classmates with assignments. The STEM center also offered in-person and remote peer tutoring.

- **Group Projects:** Semester-long, in-class group projects and accompanying papers were added to the course evaluation. Student feedback on this change was overwhelmingly positive, with many students reporting improvements in interpersonal communication and team-building skills.

- **Enhanced Material Accessibility:** All lectures and labs were video-recorded and made available on Blackboard. Live lectures were also recorded and shared via Google Drive for students who missed class. This addressed student concerns about disruptions to learning continuity due to absences.

- **Increased Evaluation Frequency:** The number of quizzes was increased from five to seven, with final quiz grades calculated based on the top five scores.

- **Opportunities for Improvement:** Students were given the option to make up labs, assignments, and quizzes, as well as complete extra credit work to improve their grades.

- **Small Group Dynamics:** Class discussions were conducted in small groups rather than with the entire class, facilitating greater student engagement and interaction with both peers and the instructor. Limiting the laboratory hands- on exercises to eight students

per section improved the instructor student's interaction and feedback. This approach aligns with research suggesting that creating a supportive, inclusive, family-like environment is particularly beneficial for Latinx students [13]. Culturally responsive teaching in HSIs emphasizes the importance of validating students' cultural backgrounds and experiences [14]. Building trust and rapport is essential for creating a comfortable learning environment where students feel safe to explore new ideas and work towards achieving learning outcomes.

- **Classroom Engagement:** Students were actively encouraged to participate in discussions and provide feedback throughout the class. Material delivery moved beyond traditional lecturing to incorporate interactive activities. Sessions between students and Latinx graduates from the program currently working in the field were conducted. these sessions resulted in a stronger sense of belonging. Review material was transformed into trivia games to promote engagement. An online discussion board for online lectures promoted more interaction between the students who have to take an online lecture.

- **Accessible Communication:** Communication with students was facilitated through multiple channels, including email, phone, text, and a dedicated Google number.

Faculty members collaborated with technicians and former students to refine teaching methods and focus on SLOs, exploring alternative evaluation methods, such as offering students a choice between writing a paper, giving a presentation, or taking a quiz.

In 2019, faculty participated in ESCALA ("equity based professional development for practitioners in Hispanic Serving Institutions (HSIs) and emerging HSIs") training. Concepts such as high-context and low-context communication were integrated into lecture delivery, with a greater emphasis on repetition of key material and less focus on supplementary information [14].

Student accommodations, including access to quiet study spaces and technology, were also considered. Students were given flexibility in submitting assignments (online, email, phone photo) and preferred being given a choice between in-class multiple-choice quizzes and take-home essay quizzes.

During the pandemic years (2020-2021), the program was able to maintain in-person labs due to sufficient shop space that allowed for social distancing. However, the transition to fully online lectures had a negative impact on students, particularly minority students, due to disparities in access to technology and varying socioeconomic circumstances. This resulted in significant drops in enrollment and graduation rates.

Post-pandemic, the program offered lectures in three modalities: in-person, hybrid, and online. In-person classes met for full credit hours. Hybrid classes combined in-person meetings (1-1.5 hours per week) with online coursework via Blackboard. Online classes were fully asynchronous, with recorded lectures, online homework submissions, and virtual project

presentations. Optional attendance, recorded Zoom meetings (30 minutes per week) were also offered for online students.

Latinx student enrollment and graduation (2015-2023)

The data collected after 2020 reveals a decline in both enrollment and graduation rates, particularly for students enrolled in fully online lecture courses. Students reported feeling disconnected from the material, especially when lectures were not paired with in-person lab components.

In Fall 2022, following the pandemic, lectures were offered in both in-person and online modalities. The online sections maintained a completion rate of approximately 45%, consistent with the rates observed in 2020 and 2021. Latinx and underrepresented minorities were reported to be less successful than their white counterparts in online learning [15]. However, a noticeable decrease in classroom interaction was observed in the in-person sections compared to pre-pandemic levels. Students were less inclined to answer questions or participate in group discussions. This required a further restructuring of the class lecture material.

The revised format involved starting each class with a discussion based on a pre-recorded video available on Blackboard. Students were asked to discuss the learning outcomes and provide input on their preferred method of evaluation (quiz, take-home exam, or project). This participatory approach resulted in students reporting a greater sense of involvement and empowerment. The restructured class format consisted of online recorded lectures, homework assignments, in-person small group discussions of the homework, a group project or paper, and bi-weekly quizzes or take-home exams.

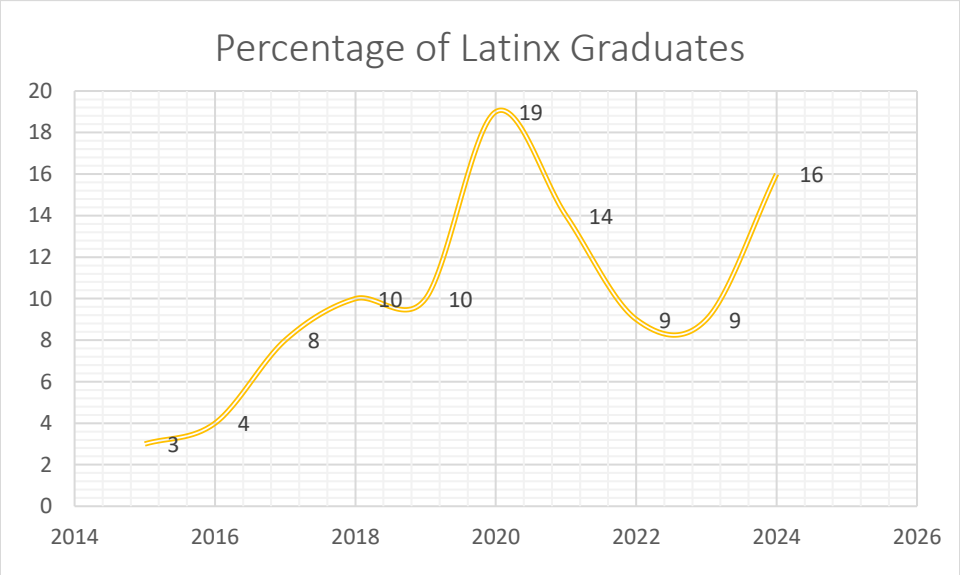
Small group work fostered interpersonal connections among team members and reinforced learning outcomes. Students appeared to benefit from peer learning and mentoring within these groups. Groups were encouraged to utilize shared Google Drive folders to collaborate on project components.

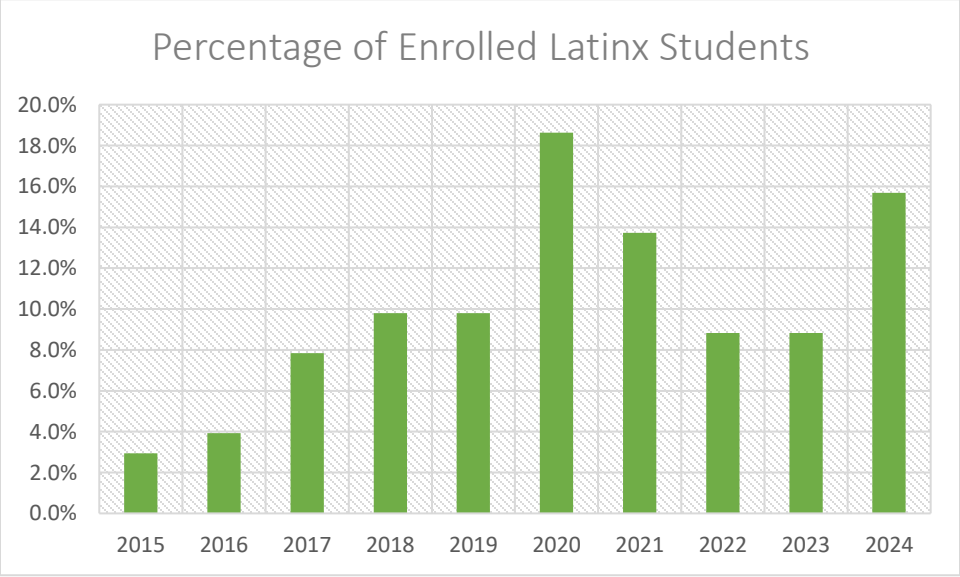
This restructuring affirms the findings of Correll [16], who noted that "in STEM, minority undergraduates who recreated family-like relationships and infrastructure on campus were less likely to drop out."

Prior to the pandemic, the average annual graduation rate for Latinx students in the program was 19 %. During the fully online period (2020-2021), this rate dropped to 7%. Following the implementation of the hybrid model in Fall 2022, the graduation rate for Latinx students enrolled in the hybrid sections increased to 12%, while the rate for those in fully online sections remained the same. While the overall student course completion rate was 90% for hybrid courses, fully online courses saw a completion rate of only 60%, suggesting the importance of in-person interaction for student success in this program.

Enrollment and graduation rate analysis

The data were collected from Spring 2015 to Spring 2024. The data include total enrollment and the percentage of Latinx students enrolled and graduated in that academic year. Both enrollment and graduation rates steadily increased between the year 2015 and 2020, which coincides with the classroom changes stated earlier. It is worth mentioning that around 15% of enrolled students have introduced family, friends, and coworkers to join the program after they have graduated or while they are in their second semester.





The data also show a decline after the pandemic where most lecture classes were switched to fully online. The enrollment started to pick up after classes were switched back to in person and hybrid format. Graduation was tracked based on the Fiscal Year, which closely aligns with the Academic Year. From 2015 through 2024, the following numbers represent the students who graduated from the program certificate of graduation (COC).

The following timeline for the past 9 years shows the change incorporated in the classroom structure based on the highlight points mentioned earlier. The time line can be compared with the enrollment and graduation rate shown in the previous graphs.

Hispanic Enrollments in ENGY.COC Academic Year 2015 through 2024				
	Hispanic		Total Headcount of Students	Total % of Students
Fiscal Year	Headcount of Students	% of Students		
2015	3	2.9%	20	4.8%
2016	4	3.9%	26	6.2%
2017	8	7.8%	33	7.9%
2018	10	9.8%	50	11.9%
2019	10	9.8%	46	11.0%
2020	19	18.6%	60	14.3%
2021	14	13.7%	45	10.7%
2022	9	8.8%	41	9.8%
2023	9	8.8%	44	10.5%
2024	16	15.7%	54	12.9%

Figure 1Hispanic Enrollment in the Energy Systems Technology certificates program

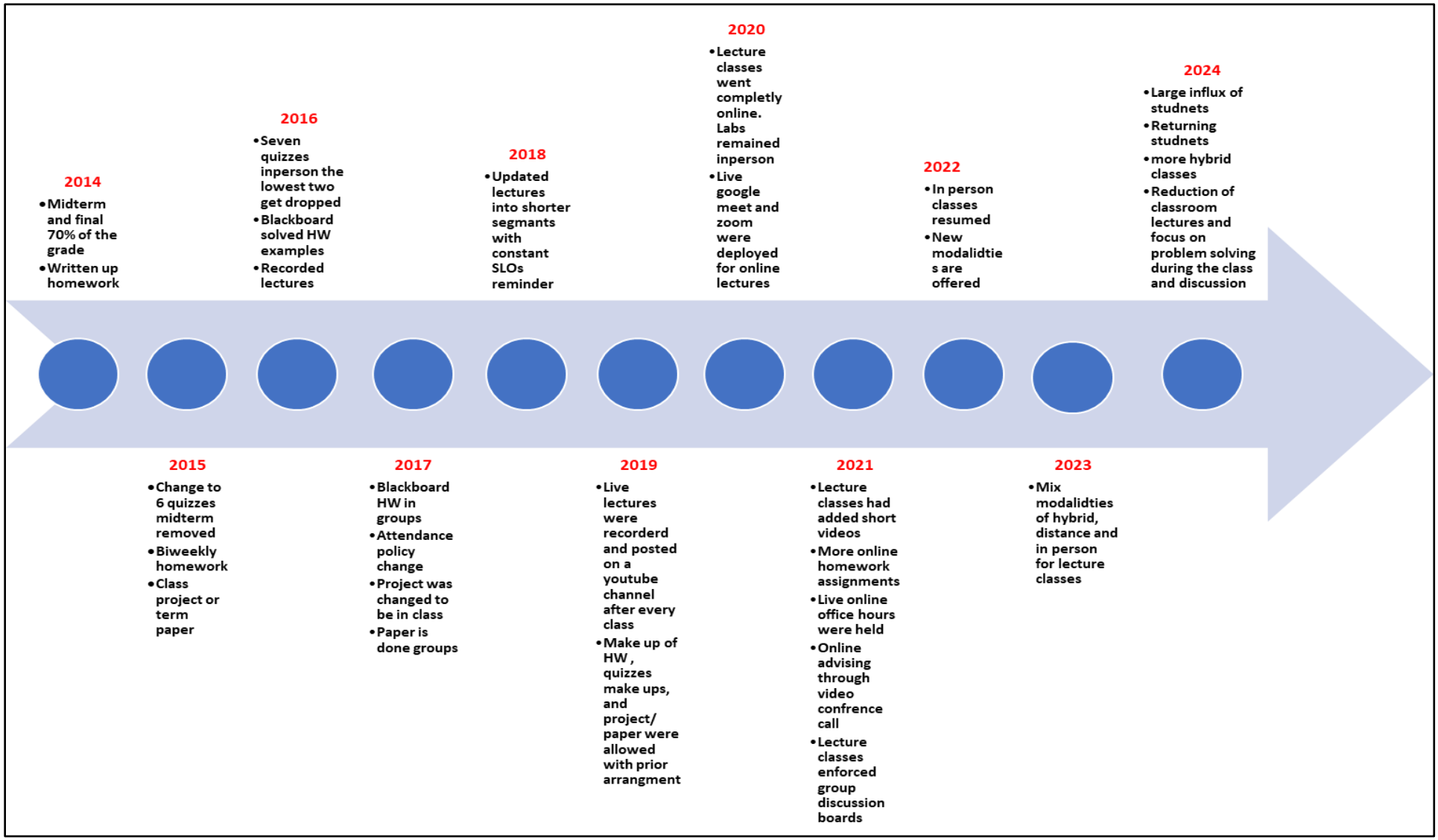


Figure 2Course restructure changed based on SLO's yearly from 2014 to 2014

Conclusion and future directions

This study demonstrates that implementing evidence-based strategies tailored to the specific needs of the HVAC program at STCC has yielded improvements in both graduation and enrollment rates for Latinx students. Achieving equitable teaching requires a commitment to continuous, often significant, adjustments to instructional delivery methods. Educating faculty on the importance of maintaining current, equitable, and attainable SLOs is essential. Furthermore, the exchange of best practices between HSIs and minority-serving institutions, coupled with insights from professionals in the field, has proven crucial for ensuring the relevance and effectiveness of SLOs. For example, the program must regularly evaluate whether HVAC students should use manual/analog equipment or go straight to digital software-supported instruments. The use of technology such as tablets, phone apps and internet-based references has to be continuously examined and cross checked with field work for validity and practicality.

The HVAC/Energy sector is experiencing rapid growth due to increasing climate awareness and the drive for decarbonization. This trend, combined with a nationwide shortage of HVAC/Energy technicians, has brought increased attention to the program. The program's ability to adapt and serve students with diverse backgrounds has contributed to improved enrollment. However, maintaining student engagement and ensuring the comprehensive delivery of all SLOs remain ongoing challenges.

Future initiatives under consideration by STCC faculty and staff include a comprehensive mentoring program. Each student would be assigned a dedicated mentor throughout their academic journey and beyond graduation for career guidance. Mentoring has been identified as a key factor in post-graduation career success [1].

The STCC STEM C enter is also developing an outreach program that will invite Latinx alumni and professionals to periodically visit the program and share their experiences with current students. Recent pilot visits have already demonstrated a positive impact on student morale and encouraged recent graduates to pursue careers in HVAC and building controls.

To enhance student-faculty interaction, the program is exploring the possibility of hiring a full-time lab technician, as well as additional full-time and adjunct faculty. Increased one-on-one interaction has been shown to foster a greater sense of belonging and encourage student engagement. The current student-faculty ratio of 32:1 significantly exceeds the recommended ratio of 16:1 suggested by the National Center for Educational Statistics [17], and addressing this imbalance is a priority.

Finally, as previously noted, the program must commit to the ongoing review and revision of program SLOs to reflect the rapid pace of technological advancement in the HVAC field, and particularly in building automation systems.

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