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Moving beyond content knowledge: Examining the impacts of a culturally responsive microbiology curriculum

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This paper describes the application of James A. Banks' Levels of Integration of Multicultural Content to develop a culturally responsive curricular framework for a traditional 16-week microbiology course to determine its impact on classroom discourse. The study sought to qualitatively examine how the integration of multicultural content into a traditional microbiology course would, (1) change students' impression of science and its relevance to their lived experiences, (2) impact students' interest and perceived academic performance as it relates to retention of information, and (3) shape students' understanding of sociopolitical issues. The multicultural curricular framework is summarized with a specific example described in detail. Qualitative data collected from two semesters of assignment prompts, classroom discussions, and end of semester focus groups are presented and discussed. Based on the results of the examined qualitative data, the multicultural curricular framework helped students better recognize the relevance of microbiology in relation to their lived experiences, increased their interest in science, improved their perceived academic performance, and increased their understanding of sociopolitical issues related to microbiology. Challenges and implications regarding integration of multicultural content into traditional microbiology courses are also discussed.

KEYWORDS

microbiology education, multicultural education, culturally responsive teaching, social justice and equity, intersectionality, critical theory

Introduction

Despite federal, state, and local policy initiatives aimed at promoting the integration of multicultural content into instructional practices, educators remain largely unaware of the importance, aims, and scope of multicultural education. This is especially true in science, technology, engineering, and mathematics (STEM) education given it is viewed as an apolitical and bias free space despite historically serving as a system

of oppression (Somerville, 1994; Barder, 2019; Yakushko, 2019). At present, the STEM enterprise remains a highly politicized space fraught with implicit and explicit biases that maintain achievement gaps, thereby deterring marginalized groups from pursuing careers in STEM (Perry et al., 2012; Betancur et al., 2018). The ones who make it through the STEM pipeline are more likely to exit the field, citing discriminatory practices based on race, gender, and sexual orientation (Funk and Parker, 2018; Cech and Waidzunas, 2021; Arredondo et al., 2022). Interestingly, race has been shown to play a role, with white and Asian educators reporting less multicultural awareness compared to teachers from non-white and non-Asian groups (Vavrus and Ozcan, 1995; Cherng and Davis, 2019). Such groups are also more likely to view intelligence as inherent and engage in discursive "weed out" practices that prevent prospective students interested in pursuing careers in STEM from succeeding (Canning et al., 2019; Rozek et al., 2019).

It has been demonstrated extensively in a variety of STEM disciplines that integration of culturally responsive instructional practices helps students from marginalized groups to become more invested in science, perform better on assessments, and communicate science more effectively. Some instructors have achieved this by making the course content relevant to their students' lived experiences. Research suggests that culturally responsive teaching practices may aid in the narrowing of the STEM gap (Eijck and Roth, 2007; Atwater, 2010; Russell, 2014). Elective courses and research projects have even been designed to focus on historic and contemporary issues in science and to place emphasis on inclusivity and cultural relevance. For example, Reese (2020) described the benefits of an undergraduate elective course focused on science, ethics, and society that allowed students to make connections between race, gender, sexual orientation, and ability. Students participating in the course mentioned how topics related to ethics and society are often absent from typical science courses. Favero and Van Hoomissen (2019) partnered with their former students to examine traditional anatomy and physiology textbooks for opportunities to ingrate culturally relevant examples for faculty to use in their instruction. In doing so, the authors of the study found that they were able to examine the ways in which their student partners were finding, learning, and connecting the material in a manner that differed from traditional classroom instruction.

Promoting inclusivity and cultural relevance requires faculty possessing multicultural awareness and a desire to modify their existing curricular framework. This has led to the creation of programs intended to help faculty develop the ability to integrate culturally relevant instruction into their classrooms. O'Leary et al. (2020) demonstrated that faculty participation in an immersive culturally responsive teaching workshop helped them to develop an awareness of social identities and barriers present in the classroom that are inhibitory to engagement, interest, and success. Following the completion of the workshop, faculty were able to shift their views regarding learning abilities and were more likely to make modifications to their existing curricula to reflect a more inclusive, culturally relevant classroom. Creating an inclusive and culturally relevant classroom may be done independently, however, a supportive system can create sustainable practices and resistance to opposition. Johnson and Elliott (2020) provide a model to guide departmental transformation focused on academic success, cultural competence, and critical consciousness. In transformative STEM departments, students succeed academically through encouragement and hard work, eliminating the fixed mindset often held by faculty that intelligence is innate. Culturally competent faculty are intentional in their efforts to create a classroom culture where students feel they belong and do not have to sacrifice aspects of their identity to be successful in STEM. Critically conscious faculty are aware of the biases and discriminatory practices that have historically favored certain groups over others, actively working to resist cultural norms.

Despite efforts to promote culturally responsive teaching in the classroom, little research has been conducted to determine the impact multicultural content integrated into microbiology courses has on student thinking, student engagement, and student success. Fuller and Torres Rivera (2021) applied a culturally responsive approach to place students' lived experience and cultural knowledge at the forefront to increase student engagement, success, and retention in a microbiology laboratory course. They found that students were more engaged, gained a deeper understanding of the course content, were able to better communicate scientific information, and had increased levels of retention when information was presented in a culturally responsive manner. Shoemaker et al. (2020) designed a curricular framework for an 8th grade class consisting of students from an underserved community, bringing in local experts to speak to and facilitate a culturally relevant and inclusive instructional module. Students reflected on what a scientist looks like, leading to the discussion of inclusivity in STEM and fostering a sense of belonging. Martinez (2020) developed a course curriculum that enabled students to collect bacteria from local frogs that serve as a cultural symbol. In addition, students sampled soil from the local environment in search of novel antibiotics.

In effort to contribute to existing microbiology education literature pertaining to the impact of culturally responsive teaching practices on student thinking, student engagement, and student success, the author developed and integrated a multicultural curricular framework into a traditional 16-week microbiology lecture and laboratory from two different semesters. The research was guided by the following questions: How will the integration of multicultural content into a traditional microbiology course (1) change students' impression of science and its relevance to their lived experiences, (2) impact students' interest and perceived academic performance as it

relates to retention of information, and (3) shape students' understanding of sociopolitical issues.

Materials and methods

Setting and participants

This study took place during a microbiology lecture and laboratory held at a community college designated as a Minority Serving Institution (MSI). The demographic makeup of the college is: 60% female and 40% male; 59% Hispanic, 22% Black, 12% White, and 7% Other; and non-traditional students over the age of 25 (27.5%) and part time undergraduates (69.4%). Participants (N = 38) included in the study were students registered for a microbiology lecture and laboratory from two different semesters.

Theoretical framework

The theoretical lens through which this study was viewed is Paulo Freire's Critical Pedagogy, which involves challenging power structures and examining ways in which education is bias, unjust, and unfair, often to the detriment of students from marginalized, underserved groups (Freire, 2018). Traditional instruction often focuses on what Freire refers to as the banking method of education, where the students are passive learners while the instructor serves as the knowledgeable other responsible for "depositing" information. Using this method, students simply memorize content without critically thinking about how it relates to their lived experiences and are not allowed to contribute to the knowledge building process (Freire, 1970). Freire described an alternative instructional model known as the problem-posing model, an instructional method that allows students to participate in the knowledge building process and requires instructors to view them as active learners who hold equal stake in education. Using this method, instructors and students can examine ways in which the educational system contributes to oppressive practices, how to resist systems of oppression, and how to utilize the information as means to empower themselves. Content integrated into the course is presented from a local context with emphasis on demographic factors such as socioeconomic status, race, and gender in relation to the students' lived experiences. Instructors and students possess agency in the classroom in a manner that enables both to act as educators.

The relationship between capitalism, science, and education has led to the creation of an oppressive educational system that prioritizes profits and competitive practices, thereby limiting the placement of culturally responsive instruction at the forefront of science education (Barton, 2001). In light of this, Critical Pedagogy has been applied in a variety of STEM education contexts. Strapasson et al. (2022) highlighted the use of certain technologies in the classroom to promote environmental awareness and political engagement regarding system dynamics and policy. Lynch and Ovens (2021) examined the application of critical pedagogy in physical education, citing the importance of creating spaces where student voice is valued, deconstruction of power structures related to how the body is perceived in society, and encouraging collaboration and community building. As seen in many cases of the application of critical pedagogy in STEM, challenges associated with going against standardized education are present. Instructors often cite lack of support in curriculum, instruction, and administration at the local, state, and national level.

Methodological framework

The research framework used in this study was participatory action research (PAR). This research framework can be applied in educational contexts to promote liberation from an unjust society that limits students' ability to make decisions that may impact social outcomes (Kemmis and McTaggart, 2005). In this study, the curriculum was designed to encourage students to engage in community-based analysis of social problems that would, (1) increase their interest in science, (2) increase their retention and perceived academic performance, and (3) increase their awareness of sociopolitical issues.

Participatory action research involves ongoing cycles of reflection, examination, action, and revision with the aim of increasing understanding and improving educational practice related to questions or issues being studied (Hendricks, 2017). Modifications can be made during and after the intervention due to the cyclical nature of PAR. The iterative process may lead to the discovery of novel information that has the potential to contribute to the conceptual understanding of the issues being examined (Herr and Anderson, 2015). This study consisted of two action research cycles that took place between two semesters. Data collected during the first semester underwent an interim analysis during the cycle and a post-intervention analysis at the end of the semester. Revisions from the first semester were included in the second research cycle. The data collected from the two research cycles were compared for consistency between outcomes and for the emergence of new information.

The research cycles involved examination of an issue, development of an action plan, execution of developed action plan, reflection of action plan, revision of action plan, an additional round of the executed action plan, and reexamination of the issue. The issues that were examined in the context of this study were (1) the persistence of the STEM performance gap that impacts students from traditionally marginalized group, (2) discursive instructional practices that deter traditionally marginalized students from pursuing careers

in STEM, and (3) the absence of multicultural content from traditional science courses. The author of this study developed an action plan that included the development of a multicultural curriculum using the traditional curriculum as a foundation. Topics related to gender, race, socioeconomic status (SES), and sexual orientation were viewed through a microbiological lens and led to the creation of various discussion topics and classroom assignments that were embedded into the existing curriculum. Upon creation of the multicultural curricular framework, the author created a 16-week course syllabus that allowed them to efficiently execute the action plan. As the author navigated the 16-week microbiology course, they engaged in frequent reflection and revision of the action plan. Reflection and revision of the multicultural curriculum also occurred at the conclusion of the 16-week course. The revisions were included in the second iteration of the research cycle that took place during a second 16-week microbiology course. At the conclusion of the second 16-week course, the author reexamined the issue to determine if the multicultural framework had any impact on student interest, retention, perceived academic performance, and awareness of sociopolitical issues.

The multicultural curriculum

James A. Banks' Levels of Integration of Multicultural Content was used in the development of a culturally responsive curriculum relevant to the lived experiences of students enrolled in a microbiology course at a community college designated as a MSI. Banks and Banks (1989) developed the Levels of Integration of Multicultural Content as a tool to rate how aligned curricula were with the scope and aims outlined in the five dimensions of multicultural education. These five dimensions include content integration, the knowledge construction process, prejudice reduction, equity pedagogy, and an empowering school culture and social structure. Drawing from these dimensions, Banks outlined the contributions approach, the additive approach, the transformation approach, and the social action approach. The four levels are summarized as follows:

> Level 1-*The Contributions Approach:* Focuses on heroes, holidays, and discrete cultural elements.
>
> Level 2-*The Additive Approach:* Content, concepts, themes, and perspectives are added to curriculum without changing its structure.
>
> Level 3-*The Transformation Approach:* The structure of the curriculum is changed to enable students to view concepts, issues, events, and themes from the perspectives of diverse ethnic and cultural groups.
>
> Level 4-*The Social Action Approach:* Students make decisions on important social issues and take actions to solve them (Banks and Banks, 1989, p. 233).

The finalized multicultural curricular framework was integrated into a 16-week traditional microbiology course, drawing upon the instructor's and students' cultural knowledge to promote meaningful discourse. It was designed to include the objective scientific elements of a traditional microbiology course while including multicultural content. Lectures and laboratory exercises derived from the textbook and laboratory manual had additional information added, including national, state, and local statistics and excerpts from peer-reviewed scientific journals, all of which were multiculturally relevant in the context of microbiology education. The additional information was identified through an extensive literature review and relied upon peer-reviewed scientific journals to avoid inaccurate information. The modified curricular content led to the development of various assignments, classroom discussion prompts, laboratory activities, each of which were rated using the Levels of Integration of Multicultural Content. Components of the curricular framework were largely rated at a level 3, with some aspects being rated at a level 4. For example, students were able to contribute to the knowledge building process and thought about concepts, issues, events, and themes from the perspective of diverse ethnic and cultural groups. The students were also able to utilize the information presented in the course to make empowering decisions that may have a positive impact on their lives, their family's lives, and their community. To avoid the implementation of an additive multicultural curricular framework where information is presented superficially, culturally responsive assignments, discussions, and laboratory activities took place throughout the entire 16-week term. The instructor was explicit in stating textually in the syllabus and verbally during the course introduction that the course would contain multicultural themes. Students were encouraged to contribute to the knowledge building process using their own cultural knowledge to shape their responses in the assignments and discussions.

Multicultural topics discussed in the context of microbiology included gender, race, sexuality, and socioeconomic status. The following section discusses how objective scientific content can be combined with sociodemographic factors related to multicultural content to promote diversity, equity, and inclusion in microbiology education. A summary of various topics presented throughout the course is followed by an example with a more descriptive approach.

When discussing growth media in the laboratory, the class focused on the history of agar being used as a solidifying agent, highlighting Fanny Angeline Hesse's contribution that transformed bacteriology. Students reflected and discussed why her contribution is seldom discussed or mentioned in microbiology books. As the topic of bacterial transformation was discussed during the microbial genetics chapter, the class examined the contribution made by Lydia Villa-Komaroff, one of the first Mexican Americans to receive a Ph.D. in the natural sciences and lead author in the landmark paper demonstrating that bacteria could be used to synthesize insulin (Villa-Komaroff et al., 1978). This topic highlighted the intersection between race and gender, providing students with an opportunity to examine overlaps that exist between aspects of social identity. When learning the differences between prokaryotic and eukaryotic cells, students had the opportunity to learn about the contributions made by Ernest Everette Just, a prominent African American cell biologist who made significant contributions to the field of cellular biology. He suggested studying cells in their natural environment as opposed to a laboratory setting. Despite his scholarship, he was discriminated against based on his race and was rejected for professorships at institutions in the United States (Manning, 1985). When learning about signs and symptoms associated with disease transmission, students had the opportunity to examine the historical contexts related to HIV/AIDs and syphilis. Students reflected on the political ideologies that impacted the public health response to HIV/AIDs in the 1980s and how they shaped discriminatory practices that exist today (Shilts, 2011). The exploitation of African American men living in poverty that led to the Tuskegee Syphilis Study was examined and discussed. The original published paper containing the racist statement, "Perhaps here, in conjunction with tuberculosis, will be the end of the negro problem. Disease will accomplish what man cannot do" (Murrell, 1906, p. 307), was presented to students. They were able to provide a textual response and verbal responses during lecture regarding how they felt. When learning about control of microbial growth, students had the opportunity to examine historical aspects regarding the antimicrobial properties of copper in ancient civilizations (Grass et al., 2011). Further, they reflected on how copper can be applied in modern day healthcare settings to prevent nosocomial infections. Students also examined a study demonstrating the stability of COVID-19 on various surfaces, with copper having the shortest time before the virus is inactivated (Hasan et al., 2020). When discussing Ebola, students had the opportunity to learn about Jean-Jacques Muyembe, the Congolese doctor responsible for discovering Ebola (Peralta, 2019). They further examined how his contribution was overshadowed by white, male researchers in the United States. When discussing the potential for foodborne illness, students examined studies demonstrating that children of color from communities of low-SES are at a higher risk of developing foodborne illnesses compared to white children from communities of high-SES (Newman et al., 2015). They were able to reflect on issues of infrastructure that lead to food deserts, which are more likely to contain contaminated food products.

The following example of *Streptococcus mutans* and its relation to diet, dental hygiene, and cardiovascular health demonstrates how the traditional microbiology content was modified in a way that allowed students to think of the multicultural science content, issues, events, and themes from diverse perspectives using a classroom assignment. The modified assignment contains information from the course textbook and peer-reviewed articles substantiating the claim that links dental carie formation to sucrose consumption, oral health literacy, and action of *S. mutans*. Probing questions presented at the end of the assignment asked students to draw connections between articles. The goal was for students to think of how *S. mutans* behaves differently in the oral cavities of individuals depending on a variety of sociological factors, including race and socioeconomic status. Probing questions encouraged students to think of ways in which they can develop solutions to help educate themselves, their families, and their community on the impact their diet has on the activity of their oral microbiome. The standard information within the textbook used in the course regarding *S. mutans* states the following:

> Increased bacterial growth in the mouth can cause inflammation and infection in other parts of the body. For example, *Streptococcus* in the mouth, the main contributor to biofilms on teeth, tartar, and dental caries, can spread throughout the body when there is damage to the tissues inside the mouth, as can happen during dental work. *S. mutans* produces a surface adhesin known as P1, which binds to salivary agglutinin on the surface of the tooth. P1 can also bind to extracellular matrix proteins including fibronectin and collagen. When Streptococcus enters the bloodstream as a result of tooth brushing or dental cleaning, it causes inflammation that can lead to the accumulation of plaque in the arteries and contribute to the development of atherosclerosis, a condition associated with cardiovascular disease, heart attack, and stroke. In some cases, bacteria that spread through the blood vessels can lodge in the heart and cause endocarditis (an example of a focal infection) (Parker et al., 2018, p. 1060).

While the excerpt provides an in-depth description regarding the impact *S. mutans* can have on body systems from a scientific perspective, it in no way addresses that people in areas of low-SES, who are often people of color, are disproportionately impacted by a multitude of issues related to the concept being described. People of color in areas of low-SES have been reported to have a higher chance of developing dental caries compared to white people in areas of high-SES (Ortiz et al., 2019). It has also been reported that people of color in areas of

low-SES also have higher access to and consume more sucrose rich foods and beverages compared to areas of high SES (Han and Powell, 2013). This could be attributed to the fact that food advertisements in areas of low-SES are significantly different and perpetuate consumption of unhealthy food sources (James et al., 2014). Pussinen et al. (2019) carried out a prospective cohort study beginning in 1980 and tracked the development of atherosclerosis based on childhood oral infections. Their results found an association between childhood oral infections and the development of atherosclerosis in adulthood, which substantially increases the risk of having a heart attack or stroke. When examining CDC statistics, it is apparent that people of color from areas of low-SES have higher reports of cardiovascular disease, heart attack, and stroke. Had these modifications not been made to the assignment, students would have strictly learned about the objective information without thinking of its relation to their lived experiences and the impact on marginalized groups.

The laboratory component provided students with an opportunity to aseptically transfer *S. mutans* from a pure stock to the bacterial growth medium, Mitis Salivarius, which is useful in the isolation of streptococcal species. They were able to identify *S. mutans* based on colony characteristics when grown on the medium and further analyzed the microscopic characteristics to determine size, shape, arrangement, and gram reaction. Further, students biochemically identified *S. mutans* using various differential media. Students were then asked to reflect on the results and how their behaviors (e.g., food consumption, oral hygiene) may impact the presence of *S. mutans* in their own oral cavity.

Data collection

Data collected for this study was derived from teacher-researcher data and student data. The term *teacher-researcher* pertains to the author acting as both the instructor for the course and the researcher of this study. The teacher-researcher data consists of field notes and reflections and was used to increase validity and reliability of the study. The student data consists of course pre-tests, assignments, course post-tests, and transcripts from two optional focus groups that took place at the conclusion of each semester.

During lecture and laboratory instruction, the author took field notes to document what was being said during lecture and laboratory discussions. The author referenced the field notes and reflected following the conclusion of each lecture and laboratory session using a reflective journal. During the first lecture session, students were given a pre-test that contained general microbiology questions, multicultural based microbiology questions, and reflection-based questions, all of which related to the research questions posed by the author. Throughout the 16-week semester, students engaged in various lecture and laboratory activities containing general microbiology content and multicultural content that encouraged discussion and reflection. The multicultural based questions embedded within the classroom assignments were developed to encourage student responses that assisted in answering the research questions. Key phrases and terms from the research questions were included in many of the questions present within the data sources that were collected. On the last day of class, students were then given a post-test containing the same questions contained in the pre-test to determine if the multicultural course had any impact on student responses. Following the post-test, an optional focus group was held and documented using a recording device. During this focus group, the teacher-researcher asked students questions regarding their experience in the course. The recorded files were later transcribed using transcription software.

Data analysis

This study consisted of an interim data analysis that took place throughout each research cycle and a post-intervention analysis that occurred at the conclusion of each research cycle. Pre-determined themes directly related to the research questions were used in the analysis of pre-tests, assignments, post-tests, field notes, and focus group transcripts during and after the research cycle. Questions within the pre-tests, student assignments, post-tests, and post-course focus group contained key phrases and terms found within the research questions. These included responses pertaining to students describing the following: impression of science and its relevance to their lived experiences, their interest and perceived academic performance as it relates to retention, and their understanding of sociopolitical issues.

Pre-tests, student assignments, post-tests, field notes, reflections, and post-intervention focus group transcripts were analyzed using a coding scheme developed from the pre-determined themes. This coding scheme allowed the author to categorize and organize the data based on the research questions. Data from the interim and post-course data analysis for each semester was coded and organized using a color-coding scheme that allowed the author to quickly identify data related to the research questions. Responses that pertained to students describing their impression of science and its relevance to their lived experiences were highlighted in green. Responses that pertained to students describing their interest and perceived academic performance as it relates to retention were highlighted in yellow. Responses that pertained to students describing their understanding of sociopolitical issues were highlighted in blue.

The author read through the data sources several times to minimize the possibility of overlooking meaningful responses that could aid in answering the research questions. Markers were added to indicate whether the notes were created during the interim data analysis (e.g., IDA) or the post-cycle analysis (e.g.,

PCA). This was to assist the researcher in differentiating between the analysis in the event they interpreted PCA statements differently from the IDA statements. Multiple data sources were reviewed during the interim analysis, which occurred at the conclusion of each lecture and laboratory session. The author examined field notes, instructor reflections, pre-tests, student assignments, and post-tests. Interim analysis of the data sources led to revision, addition, and omission of questions that were administered in future iterations of the study.

Prior to beginning the post-cycle data analysis, the folder containing consent forms collected at the beginning of the semester were opened and examined to determine which students consented to participating in the study. The consent forms contained a number that was linked to the student number assigned to students at the start of the class. To ensure anonymity, all student collected data was deidentified and tracked by an assigned number. A spread sheet was created with student numbers and an indication of their consent to the use of their assignments and the focus group. All student folders that did not contain a consent form were moved into a different folder and not considered for further data analysis and reporting.

Following the conclusion of the first cycle, all data sources were re-examined, re-coded, and revised in ways that would enable students to provided rich descriptions that would aid in answering the research questions. Any changes that occurred were included in the second research cycle. For example, the pre-tests and post-tests had some rephrasing to existing questions and additional questions added. In one instance, the author realized there was not a question related to probing student thinking on their awareness of multicultural issues in microbiology. It became obvious after the interim analysis that many students did not understand the meaning of multiculturalism in the context of science education. Therefore, the author revised the cycle to include an article briefly defining multiculturalism in context of science education. The student assignments had similar revisions made to them. Following the interim analysis of one of the multicultural based student assignments, the author realized they did not include a question that would allow students to indicate whether the inclusion of the multicultural content helped them to better retain information and potentially perform better on an assessment. As a result, the author included the question, "In what ways did the inclusion of multicultural content help you to retain the objective information? How do you feel this inclusion would impact your performance on an assessment?" Given the author forgot to include this question in a single assignment, they went through every other assignment to ensure the question was included.

Validity

In action research, validity can be used to describe the trustworthiness of the study. Hendricks (2017) lists the following types of validity that must be used by practitioners engaging in action research: credibility, transferability, dependability, and confirmability. The credibility of the study is determined by the believability, accuracy, and truthfulness of the findings. Transferability of a study is determined by its ability to be applied in similar research contexts. Dependability of a study is determined by the yielding of similar results when studied in similar research contexts. Lastly, confirmability of a study is determined by the findings demonstrating an accurate depiction of what took place during the study rather than what one may think took place based on their own biases. Hendricks (2017) further describes the following strategies to increase validity of an action research study: Engage in peer debriefing, engage in persistent and prolonged observations, record data accurately, triangulate data sources, provide thick description of the setting and study, employ techniques in negative case analysis, make clear any researcher bias, make an audit trail available, engage in continuous, ongoing reflective planning (p. 65–66).

The author debriefed with a fellow colleague who has been instructing microbiology courses at the college for 20 years. They also debriefed with a fellow doctoral student to discuss the study each week. The debriefing sessions allowed the instructor to gain insights and opinions regarding the assignments and instruction. In addition, the sessions uncovered potential biases held by the instructor and led to discussions on how to address such biases so they would not negatively impact the study. The author later reflected to make necessary revisions to the action research cycle. The study took place over a 16-week period, which allowed the author to collect and analyze

TABLE 1 Triangulation matrix for data sources.

Research questions	Data source				
	1	2	3	4	5
Impression and relevance?	Pre-test	Post-test	Student assignments	Instructor Field notes/Reflection	Focus Groups
Interest and perceived academic performance?	Pre-test	Post-test	Student assignments	Instructor Field notes/Reflection	Focus Groups
Sociopolitical issues?	Pre-test	Post-test	Student assignments	Instructor Field notes/Reflection	Focus Groups

data gathered from persistent and prolonged observations. Field notes from student observations were taken during instruction to document events as they occurred. The process of triangulation, described in the following section, allowed the author to compare multiple data sources such as artifacts (e.g., student generated work, group assignments, student generated projects), observational data (e.g., field notes), and inquiry data (e.g., focus groups, open ended surveys) during the post-course analysis. The aim was to describe the setting, participants, intervention, and research methods in detail so readers interested in integrating multicultural content can apply the same methods in their study context. During the interim data analysis and post-cycle data analysis, the author applied a negative case analysis to report findings that did not agree with the other findings in support of the research questions. The author stated their positionality and listed potential biases, assumptions, or preconceived ideas about the study. These factors were checked during the data collection and analysis to ensure they did not influence the outcome of the study. Reflections occurred as both an instructor and a researcher throughout the entire cycle.

Triangulation

Triangulation is the process of collecting multiple data sources to answer research questions as opposed to relying on a single data source, thus allowing researchers to corroborate their findings (Mills, 2000). **Table 1** is modeled after the triangulation matrix developed by Sagor (2000). The triangulation matrix allowed the author to quickly reference each data source and its usefulness in answering the research questions. Each data source in this study was analyzed individually and compared to other data sources.

Results

Qualitative data were collected from pre-tests, post-tests, probing questions presented at the end of assignments,

Date source	Student responses in relation to research questions
	Impression and relevance to lived experiences
Pre-test	• When asked about their impression of science and its relevance to their lived experiences, no student was able to provide an example.
Post-test	• I had little interest in science before this course, however, after taking this course, it has heightened to want to dig deeper into things that are within my community. Regarding health and wellbeing of those in low-income areas (Student 25).
Student assignments	• Well my mom last summer got sick from pancreatic disease meaning that she was not producing enough insulin. Therefore, she needed to start taking insulin. My mom would tell me how expensive insulin is, sometimes she would only buy a certain amount due to her not being able to afford it (Student 19). • Having had a history of being discriminated against in elementary school because of my ethnicity, it's sad to learn that minority groups were (and still are) treated this way (Student 11).
Focus group	• All right. So I think it's helpful to add the extra information because it is helpful. Okay, we're going back to the dental assignment stuff like, you know, like there are like, some dental clinics that are available for low income people, but still there are still obstacles that get in the way for them to get treated versus as in, you know, someone who say in Highland Park or something like that, it's like really easy for them to get dental treatment, and not have those issues and suffer from you know, um, uh, atherosclerosis. Right there, you know, stuff like that is very informational. So I think it's good to add extra informational for people to be aware of to just, you know, help people (Student 7).
	Interest and retention/perceived academic performance
Pre-test	• When asked about their interest and perceived academic performance, no student was able to provide an example.
Post-test	• I was more interested in the assignments because they related to me. I could understand how many people suffered for us to have the information that we have to do. Not everybody follows ethics in science, and it opened my eyes to the reality of experimentation. I think I have more motivation to finish these assignments and actually look into the material (Student 32).
Student assignments	• An interesting point brought up during lecture was that these men from the experiment were barred from being drafted into WW2. It was mentioned that the penicillin that would be prescribed to soldiers to treat illness would likely eradicate the bacteria, thus healing the test subject. That little mention helps me remember that the treatment for syphilis today is a simple penicillin injection (Student 36).
Focus group	The story about the syphilis really helped me about guys that have syphilis. The story really inspired me, and I learnt a lot from the, and I was able to understand it very well. The story aspect really helped me to understand better, because is kind of very interesting and when something is interesting you can remember. So it really helps me to remember most of those things (Student 18).
	Awareness of sociopolitical issues
Pre-test	• When asked about their awareness of sociopolitical issues, no student was able to provide an example.
Post-test	• The course helped broaden my view of not only science, but political issues overall. I am now less likely to view information given from a single lens, and instead shift my perspective to see how others may interpret that same information" (Student 8).
Student assignments	• This assignment helped me to understand how inflated insulin costs are not the result of unaffordability, but are directly controlled by corporations that seek to make a profit. I also learned that there are ways to prevent this injustice by taking legislative and regularity action, increasing patient education so that patients are better equipped to make informed decisions in regard to their health (Student 15).

Date source	Student responses in relation to research questions
	• It is apparent that institutional racism still plays a large role in quality of healthcare service despite the perceived equality we should have in the 21st century (Student 29).
Focus group	• Knowing the history about HIV has given me a more understanding about it. It's not the "gay/men people" disease it doesn't just happen in certain types of people which is something that you always hear (Student 27).

classroom discussions, and a focus group that took place at the end of the semester. The following table summarizes the student generated data collected throughout the 16-week multicultural microbiology course followed by a descriptive overview of responses generated from a single assignment.

As it relates to relevance to lived experiences, students reported that the culturally responsive content pertaining to *S. mutans* helped them understand the impacts of their behaviors and encouraged them to make personal changes to their family's existing behaviors. The following statements are in line with Banks' Levels of Integration of Multicultural content in that students were able to make important decisions and actively work to solve problems. Student 1 stated, "I will be honest I do not always make great choices in beverages or food choices. I go with what I can afford. I like the sugar taste in the soda and teas. But after reading this article and the food choices I make for my family it can have a great effect on their health. I will be making some changes." Similarly, student 2 stated, "I was naive even though I have missing teeth and sometimes they do hurt I would not care, I needed my candy and all my junk food. Now I am trying to do better with my hygiene." Student 15 was from a more affluent background and had an interest in dental hygiene. They mentioned that exposure to the multicultural content enabled them to acknowledge their privilege and cited the value of learning such information to the benefit of future patients they will be serving:

> I was aware that oral bacteria played a role in oral health, but I was unaware to what extent. I was surprised to learn how extensive the health problems could be when one has poor oral health and limited access to appropriate dental care. I was not very familiar with its impact on marginalized communities. I was fortunate to have easy access to dental care growing up, but I now better understand that this is not the case for many, if not most. As a prospective dental hygienist, this topic greatly relates to my daily experience. Having a knowledge of how minority communities are disproportionately impacted by problems related to oral health will help me to better serve those under my care in the future, as well as help to spread the word about the importance of oral health and hygiene.

As it relates to impact to students' interest and perceived academic performance, students felt the content helped them to retain information easier than being provided with the objective facts alone. For example, student 3 stated, "Reading articles like this and answering questions will help me on my exams, because I'm putting my own experience and input. It also helps me to research and learn more about the topic." Student 10 stated, "It helps especially when others give feedback or say personal stories. It makes it easier to remember or link stories to the topic." The storytelling aspect of the course that discussed the content from a historical and contemporary perspective appeared to help students to understand the information as indicated by the following response from student 8:

> You know, from my personal experience, at least it's easier to remember something when you have like, a story associated with it, it seems like you tried to present, especially with, like I mentioned earlier the diabetes thing, you know, I remember when we first went over the plasmid stuff. Really, really complicated. That it felt really complicated. Um, but then having, there's something about having that story. And just like that narrative, it helps that information stick. It's not just, you know, x plus y equals z. There's a whole lot more encompassed with that. And I found it easier to take with that story.

The multicultural course appeared to help shape students' understanding of sociopolitical issues. The content presented helped them become aware of issues they may have not otherwise encountered, underscoring the importance of multicultural content. Student 16 stated the following, "you usually hear in the news, and it's like politics, but you don't hear it, um, in science, in labs. And, like I'm glad that you share stories about it, cause I never even thought about any of that. And, uh, like a science history." Student 8 felt that learning information from the perspective of diverse social and cultural groups helped them to be more cognizant of the lived experiences of others outside of their sociocultural group:

> Over the course of the semester, [the assignments] kind of like shift your perspective a little. Or it shifts my perspective a little bit when looking at information that's presented and seeing how it affects other people and not so much seeing how if affects just you. You know, I guess while in there it did kind of. I started getting a little bit more about Corona [virus]. It's really easy to, like, read something or see something of news or policy related and think, oh, this is not gonna benefit me. And you sometimes subconsciously push

> those other marginalized groups out of your mind. And don't think about it now, after this especially when looking at science, it's, uh, a bit easier to include those groups.

Negative case analysis

While most of the class felt exposure to the multicultural curriculum strengthened their ability to retain information, some students stated it was interesting but not helpful. For example, student 19 stated, "in terms of helping me remember information, I don't think it will be the most effective way in helping me prepare for exams." They further explained they would rather be given questions that would mirror what would be on the exams. Exposure to certain sensitive topics elicited feelings of anger and upset some students. It was noted by some students that discussing certain topics could lead to classroom conflict and caused them to be apprehensive in engaging with the course content. Some students reported having a positive experience with the multicultural curriculum, but that a single 16-week course would not be sufficient, and they would likely never take future courses with that form of instruction. Some students' description of multicultural science education certainly changed from the start to the end of the course, but a majority perceived it as only dealing with race and did not think of a collection of social factors. In other cases, students did not appear to gain heightened sense of sociopolitical issues, especially those that left them blank or stated "I don't know."

Discussion

Following participation in a 16-week multicultural based microbiology course, students reported an increased interest in science. The results pertaining to the first research question are important considering studies investigating the impacts of multicultural content has been shown to increase interest in STEM. Students from traditionally marginalized groups are typically uninterested in science courses presented from an objective viewpoint, nor are they interested in pursuing careers in the sciences. When science content is presented in a way that relates to students' lived experiences rather than focusing on memorization of discrete facts, they may become more invested in the material (Ainley and Ainley, 2011; Christidou, 2011; Dou and Cian, 2020; Stöckert and Bogner, 2020). Learning science in a manner that is relevant to their lived experiences may help them to change their perceptions of science as it relates to their own lives and career choices. Integration of multicultural content also has the potential to increase their level of scientific literacy and health literacy if they are given opportunities to make connections between the content and their lives (Paasche-Orlow and Wolf, 2010). Charleston and Charleston (2014) utilized culturally responsive practices in a computer science course and found it was an effective method to increasing interest and participation by African American students. Kant et al. (2018) applied culturally relevant activities in STEM and found that there was an increased interest in STEM studies and careers, with a particular acknowledgment of female role models and indigenous ways of knowing as key indicators.

Regarding responses pertaining to the second research question, students reported feeling they had performed better on assessments and were able to retain the objective scientific information following their exposure to the 16-week multicultural-based microbiology course. This outcome supports research highlighting the value of culturally relevant course content in helping students retain information. Howard and Terry (2011) conducted a 3-year study examining the impact of a culturally relevant pedagogical intervention program on retention and success rates of African American college students. Their findings indicated an increase in academic performance and graduation rates. Alexiades et al. (2021) created a culturally responsive undergraduate STEM course that allowed the integration of traditional ecological knowledge from indigenous groups and found it led to an increase in mean grade point average. In support of the first research question posed in this study, they also found students had an increased interest in pursuing a career in STEM. Dewsbury et al. (2022) conducted a 5-year study comparing academic performance outcomes between students registered for introductory biology, with one section modeled after the traditional instructional approach and the other with an inclusive and active pedagogical instructional approach. They reported students registered for the biology course containing the inclusive and active pedagogical instructional approach had improved academic performance and narrowed the ethnic performance gap that persisted in the traditional biology course. It is clear multicultural curricular frameworks help to propel students from traditionally marginalized groups into STEM, thereby narrowing the STEM gap. This occurred in this study with a student who stated, "this course has honestly made me consider switching my major and working with something microbiology related." They attributed their academic success in the course to a combination of their interest in the laboratory component of the course and exposure to multicultural content. This student now feels more confident in their abilities to pursue an advanced education in STEM.

Following participation in the 16-week course, most students developed a heightened awareness of sociopolitical issues that were previously unknown to them. Many of the students felt they had developed cultural competence that would assist them in their careers as healthcare professionals. Exposure to multiple assignments related to various sociopolitical topics (e.g., race, gender, ethics, socioeconomic status, sexuality) and

class discussions likely led to their heightened awareness. The results of this study are in support of research underscoring the importance of sociopolitical awareness in shaping cultural competence in healthcare. Boucher and Johnson (2021) found that hospice care staff participation in cultural competence training led to a higher quality of care of patients from marginalized groups. This is especially significant considering people from traditionally marginalized groups are not as likely to enroll in hospice care and if they do, they tend to receive a lower quality of care. Medina-Martínez et al. (2021) noted health disparities occurring among the LGBTQIA population resulting from a lack of cultural competence. The authors identified interventions that could be applied in nursing curricula such as inclusive sex education, defining sexual and gender diverse populations, and prevention of suicide and bullying. Unfortunately, cultural competence training may not readily translate into healthcare curricula. Chen et al. (2021) carried out a cross-sectional study across pharmacy schools across the United States and Canada to determine the degree of inclusion culturally competent material present in the curricula. While they noted inclusion of culturally relevant content was present across institutions, there was wide variation between colleges within the United States and Canada and differences within each country. They concluded there were opportunities to increase programmatic consistency across institutions. Many of the students registered in this study are seeking careers in the healthcare professions. Therefore, their potential advocacy would not only occur from a personal standpoint but a professional standpoint as well. It is incredibly important for students to become aware of the various sociopolitical issues that exist in the sciences considering the topics directly impact their lives and the lives of their future patients. If students are aware of sociopolitical issues related to science, they may be encouraged to advocate for themselves, their families, and their communities. Educators must consider the present-day healthcare continues to engage in exclusionary practices that impact people of low-SES, people of color, and people from the LGBTQIA+ community (Gallo et al., 2009; Hoffman et al., 2016; Kano et al., 2016). Students who identify with such groups as well as students from out-groups need to understand these issues so they can better advocate and check their own biases to create a more just and equitable delivery of healthcare.

These results can be of great value to educators, administrators, and policymakers considering it has been reported that students from traditionally marginalized groups typically perform poorly in science classes, often due to discursive scientific practices (Basile and Lopez, 2015; Banerjee, 2016). A traditional microbiology course consists of memorization of facts pertaining to evolution, cell structure and function, metabolic pathways, information flow and genetics, microbial systems, and impact of microorganisms. Despite being incredibly significant to the lived experiences of students enrolled in science courses, opportunities to discuss issues related to race, gender, sexuality, scientific/health literacy, and socioeconomic status are often missed or ignored. Examination of student learning outcomes presented by Next Generation Science Standards (National Research Council, 2013) and the recommended curriculum guidelines for undergraduate microbiology education published by the American Society for Microbiology (Merkel et al., 2012) illustrates that faculty are not required to discuss microbiology in a sociopolitical context. Should microbiology educators attempt to develop a culturally relevant curriculum, they would largely have to conduct their own research considering culturally relevant curricular materials are not readily available.

Traditional curricular materials that include culturally relevant content usually present in a superficial manner that is inconsistent with the aims and scope of multicultural education. For example, some microbiology textbooks may contain sections on ethics, gender disparities, etc. . ., but they are included in an additive way that can easily be overlooked or misinterpreted by instructors who are not trained in integrating culturally responsive teaching into their instruction. Some instructors may actively resist the integration of culturally responsive teaching practices into their instruction, opting to sustain weed out culture and perceive intelligence as inherent. Such practices and ideologies contribute to the continued maintenance of the STEM gap (Park et al., 2020). Counter to implicit biases and discriminatory practices, exposure to diverse and inclusive curricula has been shown to help students from outgroups develop more positive attitudes toward marginalized students. It has also provided students from marginalized groups with a heightened sense of belonging in STEM, underscoring the value of integrating diverse and inclusive curricular framework in the classroom and laboratory (Murrar et al., 2020).

At present, microbiology educators do not have an available curricular framework that will allow them to achieve student learning outcomes while simultaneously addressing disparities that exist based on sociodemographic factors. Organizations such as the American Society for Microbiology have engaged in efforts such as forming the Diversity, Equity, and Inclusion Task force (ASM, 2020), reported disparities within their organization, and have pledged to continue working toward promoting DEI initiatives. However, such special initiatives may not readily translate into the microbiology classroom. It is with great hope that microbiology instructors use the information presented in this paper as a model to make intentional modifications to their existing curricular framework. They can also create their own multicultural framework based on their own experiences and their students experiences to enrich their course. The

existing curricular standards could also be revised to include a section on ethics, diversity, equity, and inclusion, which may encourage microbiology educators to create a multicultural-based course.

As students from more diverse backgrounds continue to enter science classrooms and laboratories, it is important for the curriculum to be reflective of their lived experiences. It should not be the sole responsibility of national organizations to create initiatives and release special issues. Educators have a responsibility to ensure such initiatives are carried out with due diligence in the classroom. Given the continued presence of the STEM gap, a phenomenon in which people from traditionally marginalized groups are not engaging in the sciences, now more than ever should we move beyond content knowledge and create educational spaces that are inclusive and culturally relevant.

Challenges

While it has been stated that multicultural content can be integrated in science courses without sacrificing time and content there are several challenges (Horowitz et al., 2018). From a curricular perspective, it takes a significant amount of time to prepare the content. From an instructional perspective, it is challenging to seamlessly integrate multicultural content in the course while still meeting the student learning outcomes outlined by the course objectives. Further, some instructors may have the desire to integrate multicultural content into their courses, but they may not know how or may feel uncomfortable discussing topics, especially if they belong to groups outside those that are being discussed. Because students are accustomed to rote memorization of scientific facts, they may not understand how to engage with a multicultural curricular framework, nor will they understand how to engage in critical discourse. In the context of this study, it took several weeks for students to understand the purpose of the multicultural framework. Once they became familiar, the students in this study really took to the information and began to engage in more meaningful ways as the semester progressed.

When asked if they felt it was appropriate to have such content in traditional science courses, most students stated they felt it was needed. Although there were some students that said they simply wanted to know what they needed to know to pass the examinations and laboratory practical and did not care about the addition of multicultural content, viewing it as busy work. For example, student 4 stated, "In terms of helping me remember information, I don't think it will be the most effective way to help me to prepare for exams. I would rather have multiple choice questions that mirror the type of questions that will be on the exam."

In a time where instructors placing emphasis on topics related to race, gender, socioeconomic status, and sexual orientation are under the political microscope, it becomes increasingly daunting to integrate culturally relevant instructional practices in the classroom. In several states, policy has restricted educators from bringing up certain topics that are deemed offensive, inappropriate, or elicit feelings of guilt. They run the risk of losing their jobs if they are accused of integrating culturally responsive instructional practices in their classroom instruction. Such policy sets a dangerous precedent and is a major threat academic freedom. Despite apprehension and unease, it is important for instructors to remain steadfast in their approach and to work consultatively and collaboratively with stakeholders to ensure practices of censorship by opposition groups do not continue to permeate instructional spaces.

Future research

Future research will examine the ways in which students from different social groups respond to the integration of multicultural content into a traditional science course. While this research study consisted of students from traditionally marginalized groups, students from colleges/universities from out-groups may not respond in the same manner. For example, application of this study to a university consisting of predominantly white students from high SES may not yield the same results. The research framework used in this study will also be applied to other disciplines within the biological and health sciences, such as human anatomy and physiology. Lastly, future research will examine other instructors' methods of integrating multicultural content into their courses, or if they would find the integration of such content appropriate for a traditional science course.

Data availability statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

Ethics statement

This study involved human subjects and was reviewed and approved by the Texas Christian University (TCU) Institutional Review Board (IRB# 1920-167). The TCU IRB approval was forwarded to and approved by the Mountain View College Institutional Review Board. Student participants provided written informed consent prior to participation in this study.

Author contributions

SV was the sole contributor to this study and was responsible for developing the curricular framework, implementing the curricular framework into classroom/laboratory instruction, collecting/analyzing data, and writing the manuscript.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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