

# Youth of Promise: Supporting Youth Who Have Been Pushed Out, In the Science Classroom

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## ABSTRACT

Providing an equitable and critical science education to youth who have been “pushed out” of traditional schools is an issue of social justice. Lack of equitable learning opportunities in the traditional science classroom is a contributing factor to youth being pushed out. Alternative education programs have the potential to support youth who have been pushed out to re-engage in science. The purpose of this study was to understand what factors contribute to the academic achievement of students in their class-based science courses at Xinaxtli, an alternative education program for youth who have been “pushed out” in Southern California. This study utilized Structural Equation Modeling to analyze a conceptual model of academic achievement in the Xinaxtli science classes. The best predictors of student academic achievement came from the following factors: (a) relevance of science to students, (b) student sense of agency to create knowledge, and (c) critical science education. Findings from this study underscore that a paradigm shift must occur in STEM education for learning opportunities to become commonplace for all youth.

**KEY WORDS:** Alternative education, push out, science education, structural equation model

## INTRODUCTION

A critical understanding and practice of scientific thought is imperative to the future of our global society. The issues we now face that are not remedied by those presently in positions of power will be inherited and solved by the youth. However, as things stand today, participation in STEM fields is majority white and male (Landivar, 2013; National Science Foundation, 2019). Representation is an issue because a more diverse STEM culture can more creatively and effectively identify and propose solutions to problems, drawing on a range of life experiences and the lenses different people bring to the field. Given the lack of representation by people of color – such as Black and Latinx youth – in STEM fields, it is necessary to promote a culture of science that is more inclusive, diverse, and critical of oppressive ideologies. Criticality is important because current science research, and by extension science education, is geared toward militarism, consumerism, and for profit (Harding, 1993; Conner, 2020).

One arena that can support equitable and critical science education is the science classroom. Supporting the success of Black and Latinx youth in the science classroom is crucial. We must contribute to the development of a diverse generation that has the agency to not only understand the knowledge we currently have and be critical of it but also contribute to it. The population of youth that has been neglected are young people who have been pushed out of their traditional secondary schools. Youth who have been pushed out are youth of promise who can and should be re-engaged in science. Xinaxtli Charter

School is a space where youth who have been pushed out can be re-engaged in science education. The central research question of this study is: What factors contribute to academic achievement in the Xinaxtli science classroom?

### Students Who Are Pushed Out of Traditional Secondary School

Inadequate education has a deleterious effect on children’s academic achievement, perpetuating the low socioeconomic status of the community. One way that social inequality is reproduced is when a young person is pushed out of their traditional high school. That is, when a young person’s education is discontinued before high school graduation. Students of color (i.e., Black and Latinx) are pushed out at higher rates than their peers at the national level. The term pushout is used to emphasize the school-based and social factors that lead to students leaving school (Youth United for Change, 2011). Students who are pushed out of a secondary education program can be categorized as a status dropout or an event dropout (Child Trends Databank, 2018). A status dropout refers to a youth, ages 16–24, who was not enrolled in school and did not complete high school. In 2017, a combined 15% of Black (6%) and Hispanic (Latinx) (9%) were considered status dropouts, compared with 5% of non-Hispanic White youth (Child Trends Databank, 2018). An event dropout is when a youth, ages 15 to 24, enrolled in grades 10 through 12, drops out between October of a current academic year and October of the following academic year. In 2017, a combined 12% of Black (5.5%) and Hispanic (Latinx) (6.5%) were considered an event dropout, compared to 3.9% of their White

peers (U.S. Department of Commerce, 2018). More recently, we notice similar patterns across demographics. Although we notice a downward trend at the national level for total status dropout rates from 2012 (7.0%) to 2022 (5.3%), the highest status dropout rates in 2022 were for students categorized as American Indian/Alaskan Native (9.9%), Pacific Islander (9.1%), Hispanic (7.9%), and Black (5.7%) (National Center for Education Statistics, 2024).

Youth who are pushed out of their traditional secondary education programs do so for several reasons. A study by Doll et al. (2013) looked at seven nationally representative studies that focused on “drop out” causes from a student’s perspective and examined them together. Key findings from the study were that, from 1950 to 1980, the causes of “dropping out” were mostly due to pull factors; whereas from 1980 to 2002, the causes of “dropping out” had shifted more to push and fall out factors. However, in the most recent study (2002), both male and female students reported push factors as the most prevalent factor, an interesting finding as it shows a shift that points at factors within the school as a major cause of students “dropping out.”

Students who have been pushed out of their traditional secondary educational programs are able to reintegrate and complete their secondary education; however, this population has historically struggled with the completion of secondary education. Once a youth is pushed out of school, it is less likely that they will complete their secondary education (ACLU, 2017). This population is largely composed of students of color (Child Trends Databank, 2018; National Center for Education Statistics, 2018).

Youth are pushed out for many reasons, and being underserved in the classroom is just one of them. When students do not receive an equitable education, one that is engaging and provides them with support to succeed academically, they may become apathetic and lose the drive to stay in school. For many students who are pushed out, challenges in the science classroom only perpetuate the push-out phenomenon. These challenges are exemplified by lower test scores and lower credits earned in science class by Black and Latinx students compared to their White peers (Dalton et al., 2018; National Research Council, 2011).

### Why Science Education?

Standardized assessments are not the best tool to measure one’s ability for participation in science, but they are a measure that is frequently used. When looking at academic achievement in the science classroom, students of color, such as Black and Latinx students, test at lower levels than their White peers (National Science Foundation, 2016). According to the National Science Foundation (2016), regarding the National Assessment of Educational Progress (NAEP), which provides the largest nationally representative and continuing assessment of what America’s students know and can do in various subject areas, there is an “achievement gap,” or rather an opportunity gap in science (Kendi, 2019). When looking at this data, one could conclude that students of color are not

“good” in science. However, the perspective we will pursue is that the traditional education promoted in secondary science classrooms is based on a worldview that does not allow for the success of all students (Kincheloe, 2008).

Providing an equitable and critical science education to Black and Latinx youth who have been pushed out of their traditional schools is a significant issue for three reasons: (a) it can provide a pathway to a quality employment opportunity, (b) success in science classes can contribute to success in other classes, and (c) development of youth who have an efficient and critical understanding of science phenomena is an issue of social justice. Developing effective pathways for youth who are interested in going into STEM careers is crucial. STEM pathways are a growing source of employment. According to the PEW Research Center, “Employment in science, technology, engineering and math (STEM) occupations has grown 79% since 1990” (PEW Research Center, 2018). Providing youth who are returning to complete a high school diploma with a positive disposition toward STEM may be encouraged to pursue a STEM career. Although a pathway to a STEM career should not be the main objective of science education, it does provide an opportunity for Black and Latinx youth from low-income communities.

In addition to employment opportunities, researchers have found that exposure to and achievement in STEM courses, such as science, improves critical thinking skills as well as achievement in other classes (Becker and Park 2011). Connections have also been made between high school graduates and the science courses they have taken. According to a study by the National Science Foundation (2016), all ninth-graders who began high school in 2009 and completed it in 2013 took at least one science course, with 79% taking at least one general science course with no advanced science, and 21% taking at least one advanced science course; effectively, all students, 98% took biology, 76% took chemistry, and 41% took physics. What the data shows us is that nationally, there is a stark difference by racial/ethnic background for those high school graduates who earn credits in STEM advanced mathematics courses, STEM advances science and engineering courses, and STEM-related technical courses (National Science Board, 2023). For all three course types, Asian or Pacific Islander and White high school graduates earned more credits on average than Black or Hispanic high school graduates.

Lastly, an efficient and critical understanding of science phenomena is an issue of social justice. According to Finkel (2018), attacks on science and scientific ways of knowing have contributed to a climate in which unsubstantiated claims permeate our ways of thinking and are accepted without question. Further:

Over the past decade, attacks on science knowledge and attempts to legislate and restrict science teaching have again become a regular part of the U.S. landscape around a variety of issues that include the theory of evolution, human-caused climate change, and the safety of vaccinations. (Finkel, 2018, p. 42)

Therefore, to disrupt this phenomenon, every citizen must feel confident and willing to use science to make personal and societal decisions. However, the history of Western science, which is what is taught in traditional secondary science courses, is embedded with Eurocentric, imperialist, and racist beliefs. In addition, (Lodge, 2021; Galamba and Matthews, 2021) remind us that science as a social enterprise may be influenced by inherent biases from practitioners, and utilizing a critical lens within science can contribute to a more democratic culture of science. Therefore, incorporating a critical perspective in science education will require an analysis of the worldview and values that have shaped Western science and allow a dialogue on the impact of Western science, both the progressive and the regressive. Further, a critical perspective would benefit those who decide to pursue a STEM career by engaging them to ask questions such as: What are the consequences of my work and research? Who is benefiting from my work and research? Who is being negatively impacted due to my work and research? What values and beliefs are my work and research promoting?

### Alternative Education Programs

Providing pathways, such as alternative education programs, for young people to complete a high school diploma is essential to having an equitable society. With the understanding that young people who are pushed out their traditional secondary schools do so for a number of reasons – lack of motivation due to school-based factors, apathy toward academics, lack of school support for pregnant students, incarceration, financial hardships, family responsibilities, or whatever the reason may be – schools and educators must make a concerted effort to provide supportive learning environments to re-engage young people. According to the Center for Promise, “Re-engagement is the process by which young people who have either left school without graduating or who are at risk of dropping out of school re-connect with systems that allow them to complete a high school diploma or equivalent” (America’s Promise Alliance, 2014, p. 3). Programs that focus on re-engaging young people must provide a quality education and be designed to be malleable to the multiple contexts of each of their members.

## LITERATURE REVIEW

When accounting for youth who have been “pushed out,” there is limited literature that provides ways this group of students can be supported to engage and thrive in the science classroom. Considering factors that may contribute to student academic achievement, this study drew from various literature on (a) student perceptions of science teachers, (b) relevant science pedagogy, (c) relevance of science to students, (d) engagement in science class, and (e) students’ sense of agency to create knowledge. We then review the model for critical science education promoted by XCS.

### Student Perception of Science Educators

Science educators play a pivotal role in students’ academic success. The attitude an educator has regarding who can and

cannot succeed in school can be communicated in a number of ways, explicitly and implicitly, to students (Rosenthal and Jacobsen, 1968). This messaging can impact a student’s success in the science classroom. Given this understanding, another reason students do not engage in school and underperform can be because of deficit thinking by teachers. If a teacher does not believe that students can do well academically or that they have a deficit when it comes to learning, then this can lead to the construction of a negative zone of development for the students (Diaz and Flores, 2001). From a deficit view, teachers can be influenced to create lessons that are focused on dead-end skills, instead of developing lesson plans optimal for advancing the student’s zone of development (Diaz and Flores, 2001).

Valenzuela (1999) argued for authentic caring by educators. Authentic caring is defined as a trusting relationship developed by educators with students that is the cornerstone for all learning (Valenzuela, 1999). Authentic caring requires the development of a trusting teacher-student relationship, which includes an understanding of the students’ cultural world and their structural positions (Valenzuela, 1999).

Educators must develop as transformative intellectuals (Giroux, 1988), which means that the educator must possess the knowledge, skills, values, and attitude to question, understand, critique, and act as a change agent of structural inequities. The transformative educator strives to develop discourse that unites the language of critique with the language of possibility, works to create conditions that give students opportunities to develop as democratic citizens, and supports students in developing values that enhance their critical powers (Giroux, 1988).

### Relevant Science Pedagogy

According to Giroux (2006) critical pedagogy maintains that school practices must be directed toward the empowerment of young people, the development of a democratic space, rewriting the curriculum to address the lived experiences of students, educating teachers to be publicly engaged intellectuals, and creating new forms of knowledge by deconstructing disciplines and recreating them as responsive to the everyday knowledge of students’ lived experiences.

The problem-posing model of education, proposed by Freire (1970), can support students who have underperformed in a school. Incorporating this critical pedagogy into a classroom, through project-based learning, can make the content more applicable in the lives of students and, in turn, more engaging. Conventionally, schools have worked under what Freire (1970) calls the “banking model” of education. Under this model, the teacher is seen as the one who holds knowledge, and the students are depositories for this knowledge. Under this model, students are not seen as creators of knowledge, rather as receivers.

In the problem-posing model proposed by Freire, educators and students see knowledge as something that allows them to be free and become agents of change. Knowledge is not received from a teacher only; rather, it is gained by critically analyzing

what you study and the world you live in. According to this pedagogy, knowledge is not static, but constantly changing and being created. This pedagogy allows the student to develop a sense of agency in creating knowledge by encouraging praxis. Praxis is the action of putting knowledge to practice; that is to say, to actually apply the knowledge that one has on a given topic toward a purpose (Layton, 1991). Another pedagogical model support for students who have underperformed in school can be the community of learners model in a science classroom. According to Rogoff (1994), “In a community of learners, all participants are active: no one has all the responsibility, and no one is passive”; that is to say, teachers and students alike are participants in learning and share active roles in the management of this learning process. This model can be adapted to many different subjects, including a science classroom. Through this practice, students are socializing with their peers to learn and create knowledge.

### Relevance of Science to Students

It is critical for students to feel a connection to science and that they find science relevant to them. When students feel that science is relevant to them, then they experience more success in the science classroom. A meta-analysis by Schroeder et al. (2007) found that in science education from 1998 to 2004, the largest impact on student achievement was teachers using “enhanced context strategies” in which they related learning to students’ previous experiences or knowledge, or engaged students’ interests by relating learning to the students’/school’s environment setting. A growing body of research shows that students who do not find personal meaning or relevance in science will not pursue science beyond what is required in school (Basu and Barton, 2007; McClure and Rodriguez, 2007).

Hattie (2009) argued, “It is less the content of the curricula that is important than the strategies teachers use to implement the curriculum so that students’ progress upwards through the curricula content” (p. 159). The science classroom is no exception. In analyzing two meta-analyses that consisted of 84 studies, he found that certain strategies had a higher effect size on academic achievement in the science classroom. Strategies that impacted academic achievement in science class in descending order were as follows: enhanced content strategies (e.g., relating topics to previous experience or learning and engaging students’ interests), collaborative learning, inquiry, manipulation and laboratory experience, and instructional technology strategies.

### Student Engagement

Students who are engaged in school are likely to achieve greater academic success (Skinner et al., 2008). Fredricks et al. (2004) conceptualized student engagement in three dimensions: (a) behavioral engagement, referring to participation effort, attention, persistence and positive conduct; (b) emotional engagement, referring to positive and negative reactions to teachers, peers, classroom activities, and value they find in learning; and (c) cognitive engagement, referring

to self-regulated learning and exerting the necessary effort for the comprehension of complex ideas. Drawing from expectancy-value theory, which posits that engagement is most directly influenced by expectancy beliefs and subjective task. Eccles (2009) argued that individuals are more likely to participate in science learning activities when they have high perceptions of their chance of succeeding and also find these learning activities interesting, important, and compatible with their own experience.

### Student Sense of Agency to Create Knowledge

Support for student learning is imperative for success in a science classroom. From a constructivist perspective, learning occurs through an individual’s prior knowledge and experiences (Cakir, 2008). Constructivism includes the importance of prior knowledge, existing cognitive frameworks, and the use of relevant information for conceptual change or learning to occur. Further, according to sociocultural theory, learning occurs through social interactions, where ways of thinking become internalized (Vygotsky, 1978). Learning is culturally and historically situated, meaning that a person’s background will influence how they perceive and learn information (Vygotsky, 1978). With this understanding, making content relevant to learners is necessary for academic achievement. In addition to relevant content, it is important for students to be engaged in knowledge creation within the science classroom.

Barton et al. (2012) have argued, “Learning is less about practicing the routines of knowledgeable others than it is about re-creating those practices in socially and culturally situated ways that confer the students with more agency with which to participate across communities.” This is the epitome of knowledge creation. A student must be able to understand a science concept and have the agency to understand it in the context of their life, then be able to re-create that science content to add to it. Given that science is a community, as individuals join a community, they bring with them resources in the form of experiences, which, with their agency, create knowledge that can transform the discourse and practices of that community (Barton et al., 2012).

### Xinaxtli Charter School Critical Science Education

XCS practices an interdisciplinary project-based approach to education. According to XCS:

*XCS schools are collaborative learning communities in which every student reclaims his or her right to an authentic education, plays a meaningful role in creating positive social change, and becomes an active participant in restorative justice. Our vision is that students have access to an education that will prepare them to counter social inequities and historical forces of oppression. This large vision does not always fit comfortably into the dominant paradigm of assessment, which has historically marginalized low-income youth of color. However, it is critical that we continue to search for meaningful and authentic ways to measure the growth of our students.*

In contrast to traditional science education, where content tends to be fragmented and compartmentalized, XCS strives to teach science in a multifaceted and integrated manner, through an authentic learning approach. As a school, each XCS location develops a Community Action Project (CAP) to bridge academic learning with relevant issues that concern students and the communities they live in. The focus of the CAP is developed by the students, staff, and community members through a social investigation. Within each classroom, then, XCS educators are charged with the development of curricula that are: (1) relevant to students' lived realities in their communities, (2) challenge dominant ideologies that are embedded in the humanities, math, and science disciplines, and (3) make learning an authentic and empowering experience that challenges existing inequities. To support the aforementioned charges, the XCS science curriculum is tied to both science competencies and culture competencies (Appendix 1). According to XCS, the science competencies are meant to frame a learning environment for young people who are traditionally underrepresented in STEM fields, including women and students of color, to become scientific thinkers who can use STEM to solve 21<sup>st</sup> century issues, globally and in their communities. They include the following: questions and defining problems, models, investigations, interpret and analyze data, construct explanations and design solutions, engagement in arguments from evidence, use of tools, and obtain, evaluate, and communicate information. According to XCS, the culture competencies are meant to bridge the gap between the classroom and the community and are essential to fulfilling the school's vision of social justice. They are meant to incorporate consciousness of social issues as well as skills that are needed to act and build collaboration. They include the following: love and care, leadership, success, social consciousness and action, support and healing, and collaboration. Together, science and culture competencies promote a critical science perspective that runs counter to the worldview promoted by traditional secondary schools.

## METHODOLOGY

The purpose of this study was to better understand what factors contribute to the academic achievement of students in their class-based science courses at XCS. The research question that guided this study was: What factors contribute to academic achievement in the Xinaxtli science classroom? Specifically, this study looked at how each of the following areas – the student perception of teachers, critical science education, the student sense of agency to create knowledge, the student engagement in science class, and the relevance of science to the student – impact student academic achievement in their class-based science course. A quantitative study was conducted with adult students from XCS to understand their experience in science classes.

### Location of Study

Xinaxtli Charter School is a Western Association of Schools and Colleges accredited, alternative education program for

youth who have been pushed out of their traditional schools. At the time of this study (2019), this alternative education program provided a pathway for completion of the high school diploma for youth ages 16–29, thereby extending the age for admission. Such a consideration and its other approaches highlight the ways in which XCS took a project-based approach rooted in social justice. A classroom-based program was provided for youth ages 16–26 and an independent studies program for youth ages 18–29. For many youth who came to XCS, academic success had been foreign to them, even more so in their science classes. According to XCS, their students came from low-income families and underserved communities and had left their traditional school systems. Many students enrolled over-aged, under-credited – or both – with the goal of completing their high school diploma. Moreover, indeed, at XCS, many youth succeeded academically and completed their degrees. According to XCS, 85% of youth who committed to XCS for one- and one-half years graduated with a high school diploma.

### Data Collection

The sampling strategy used was a convenience sample gathered from 18 locations across the XCS network. The sample consisted of adult students from XCS. The Adult Student Science Survey was used as a tool to measure student experience in their science classroom. The survey consisted of a total of 51 questions. Of the 51 questions, 44 were statements that asked students to respond on a Likert scale as to how they felt on topics pertaining to aspects of their science classes at XCS. For this section, students could respond strongly agree, agree, disagree, or strongly disagree. Primarily, the statements revolved around student perception of the teacher, critical science education, student engagement, sense of agency to create knowledge, and relevance of science to students. Following the statements were four demographic questions that asked for the age of student, gender of student, ethnic background of student, and grade point average of student. Finally, the survey consisted of three open-ended questions that asked the students what XCS location they attend, how many science classes have they passed through XCS, and why they came to XCS. The distribution of the XCS Adult Student Science Survey was conducted from September 2019 through November of 2019. A list of all current adult students and their school email was provided to the researcher by the XCS administration. In the first phase of survey distribution, the survey was emailed to each adult student individually via an anonymous link and was prefaced with an informed consent form. A follow-up email was sent out every two weeks, for a total of four emails to students. There were a total of 78 participants in the study. We received 100 responses for the survey, of which only 78 were completed. If we estimate that all, roughly 621 adult students, were given the survey, then the response rate was 12.5%.

### Data Analysis

To analyze the survey data, a conceptual model (Figure 1) was developed based on literature. The model links together the

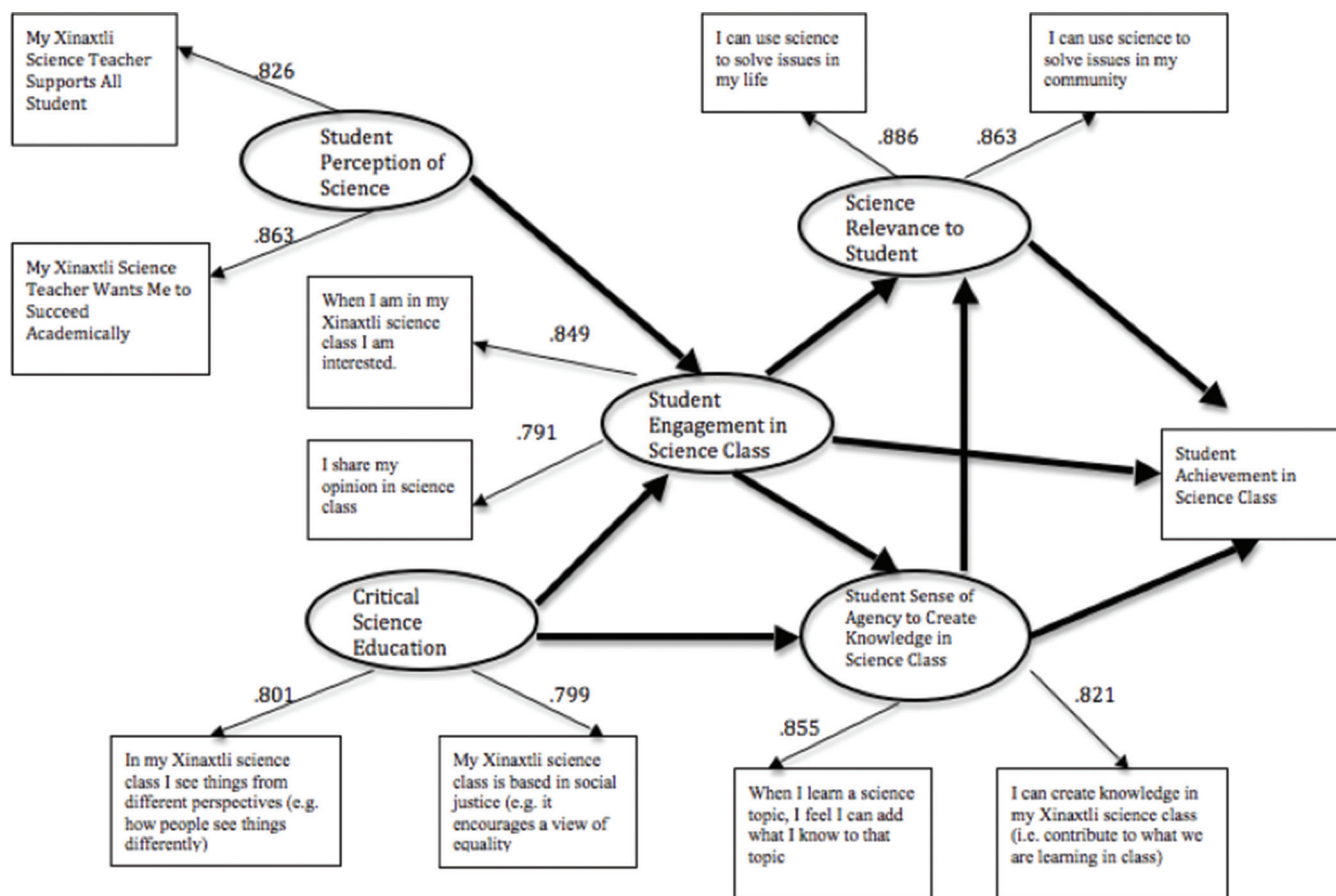


**Figure 1:** Conceptual model and before path diagram for student academic achievement in science class

factors that were hypothesized to either directly or indirectly affect student academic achievement in the XCS science classroom. The conceptual model has six factors. The key variables being used to measure each factor can be seen in Table 1. To create each factor, a set of items was selected for that factor, and a principal components analysis was performed of those items only. Each factor that is indicated in the structural equation model yielded an eigenvalue  $>1$ . All items in the factor yielded a factor loading  $>0.3$ . Further, all items in each factor were tested for internal consistency and yielded a Cronbach's Alpha  $>0.8$ . The conceptual model was evaluated using structural equation modeling (SEM). The conceptual model was used to evaluate a sample of mixed male and female students. A stepwise algorithm was used to determine path coefficients. Lastly, IBM SPSS Statistics Version 25 was used to analyze the data.

## Factors

Key variables and their operational definitions can be seen in Table 1. Sense of agency to create knowledge is operationally defined as the ability one feels they have to create knowledge and contribute knowledge. Academic achievement is operationally defined as the number of science classes passed by the student at XCS. Engagement is operationally defined as a student being actively involved in the class content and activities, as well as the student's interest in the course

(e.g., You feel that you are gaining from and contributing to the science class). Student perception of the science teacher is operationally defined by the support, encouragement, and overall positive relationship that a student experiences with respect to their science teacher. Science relevance to students is operationally defined as the student's understanding and relevance of science education with respect to their worldview and experiences. Critical science education is operationally defined by the XCS science curriculum philosophy and the impact it has on students' disposition to academics. Academic achievement was measured by the number of science classes a participant had passed at XCS, ranging from zero to three science classes.

## Ethical Considerations

Ethical guidelines provided by the Claremont Graduate University Institutional Review Board were used throughout the entire research portion. Several steps were taken to protect participants' privacy and inform them of the study. Participants were provided with a voluntary informed consent form that explained the purpose of the research and the expected duration of their participation. Participants received a description of the procedure that explained their role in the study. Participants were informed that their participation was voluntary and that refusal to participate would not result in any repercussions. Participants were also informed that they did not have to

**Table 1: Factors and items used to create them**

| Factor                                                       | Items (Factor loadings)                                                                                                   | Cronbach's alpha ( $\alpha$ ) |
|--------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| Student engagement in science class                          | When I am in my Xinaxtli science class, I am focused. (0.803)                                                             | $\alpha=0.885$                |
|                                                              | When I am in my Xinaxtli science class, I am interested. (0.849)                                                          |                               |
|                                                              | When I am in my Xinaxtli science class, I want to succeed. (0.696)                                                        |                               |
|                                                              | When I am in my Xinaxtli science class, I participate. (0.771)                                                            |                               |
|                                                              | When I am in my Xinaxtli science class, I feel motivated. (0.696)                                                         |                               |
|                                                              | I share my opinion in science class. (0.791)                                                                              |                               |
|                                                              | I participate in discussions in my Xinaxtli science class. (0.779)                                                        |                               |
| Student sense of agency to create knowledge in science class | I can contribute to science knowledge. (0.834)                                                                            | $\alpha=0.863$                |
|                                                              | When I learn a science topic, I feel I can add what I know to that topic. (0.855)                                         |                               |
|                                                              | I can create knowledge in my Xinaxtli science class (i.e., contribute to what we are learning in class). (0.821)          |                               |
|                                                              | When I am in science class I feel empowered (e.g., I can contribute and have value). (0.856)                              |                               |
| Student perception of science teacher                        | My Xinaxtli science teacher encourages me. (0.824)                                                                        | $\alpha=0.925$                |
|                                                              | My Xinaxtli science teacher is patient. (0.829)                                                                           |                               |
|                                                              | My Xinaxtli science teacher wants me to succeed academically. (0.863)                                                     |                               |
|                                                              | My Xinaxtli science teacher has high expectations of me. (0.788)                                                          |                               |
|                                                              | My Xinaxtli science teacher respects my contributions to science class. (0.805)                                           |                               |
|                                                              | My Xinaxtli science teacher supports all students. (0.826)                                                                |                               |
|                                                              | My Xinaxtli science teacher uses content relevant to my life. (0.674)                                                     |                               |
| Science relevance to student                                 | My Xinaxtli science teacher is engaging. (0.825)                                                                          | $\alpha=0.895$                |
|                                                              | Science knowledge is relevant to my life. (0.633)                                                                         |                               |
|                                                              | I use science outside of school in my everyday life. (0.784)                                                              |                               |
|                                                              | When I learn a new topic in science, I can connect it to my life. (0.856)                                                 |                               |
|                                                              | I can use science to solve issues in my life. (0.886)                                                                     |                               |
|                                                              | I can use science to solve issues in my community. (0.863)                                                                |                               |
| Critical science education                                   | In my Xinaxtli science class, I learn science that I can use to solve problems important to me. (0.866)                   | $\alpha=0.902$                |
|                                                              | In my Xinaxtli science class, I see things from different perspectives (e.g., how people see things differently). (0.801) |                               |
|                                                              | In my Xinaxtli science class, I conduct science investigations. (0.786)                                                   |                               |
|                                                              | My Xinaxtli science class is based in social justice (e.g., it encourages a view of equality). (0.799)                    |                               |
|                                                              | In my Xinaxtli science class, we use evidence to support conclusions. (0.820)                                             |                               |
|                                                              | In my Xinaxtli science class, my voice and experience is valued. (0.823)                                                  |                               |
|                                                              | When I work on Authentic Performance Tasks (APT), I am creating knowledge. (0.802)                                        |                               |
|                                                              | My Xinaxtli science class encourages me to think of social issues (e.g., inequality and oppression). (0.757)              |                               |

answer all questions and that they could stop at any point during the survey. Participants were assured that their information would remain anonymous for survey respondents. Anonymity was maintained because survey respondents did not have to give their name. The name of the school has been changed for the purpose of this study.

### Limitations

Sample size is always a concern when conducting a quantitative study. The decision to limit the sample size for this analysis to 78 was made with consideration of the proposed rule for a minimum ratio 10–25 subjects for each estimated parameter in an SEM (Stoffels et al., 2023; Violato and Hecker, 2007). However, other scholars have found some bias in SEM that utilize a small sample size (<100) with regards to meaningful patterns or associations (Wolf et al., 2013).

## RESULTS

The sample consisted of 78 survey responses, because 22 participants did not give a response for the ultimate endogenous

variable “Achievement in Science Class.” Therefore, the researcher filtered out cases in which respondents did not provide a response to how many XCS science classes they had passed. Based on the 78 completed surveys, the demographics were as follows. With regards to gender (Table 2), the sample was composed of 50 (51.3%) respondents who identified as “Male” and 38 (48.7%) respondents who identified as “Female.”

With regards to age group (Table 3), the sample was composed of 45 (57.7%) respondents between the ages 18 and 20, 16 (20.5%) respondents between the ages of 21 and 23, and 17 (21.8%) respondents age 24 or above.

With regards to ethnicity (Table 4), respondents were asked to “check all that apply,” further they were given the option to self-identify or decline to state. The sample was composed of 1 (1.3%) respondent who identified as “White.” The sample had 14 (17.9%) respondents who identified as “Black or African American.” The sample had 2 (2.6%) respondents who identified as “Asian or Asian American.” The sample

had 1 (1.3%) respondent who identified as “Native Hawaiian or Pacific Islander.” The sample had 60 (76.9%) respondents who identified as “Hispanic/Latina/o.”

With regards to the number of science classes, the respondents were asked to state the number of science classes they have passed at XCS (Table 5). This included courses such as Life Science, Natural Science, Biology, Physical Science, or Chemistry. The sample had 9 (11.5%) respondents who have passed zero science classes. The sample had 27 (34.6%) respondents who had passed one science class. The sample had 30 (38.5%) respondents who had passed two science classes. The samples had 12 (15.4%) respondents who had passed three science classes.

### Structural Equation Model for Student Academic Achievement in XCS Science Classes

The conceptual model presented in Figure 1 uses SEM to evaluate factors that were hypothesized to either directly or indirectly affect student academic achievement in XCS science classes for a sample of mixed female and male

students ( $n = 78$ ). That model is presented as a before path diagram.

As can be seen from the before path diagram (Figure 1), there are four endogenous variables and two exogenous variables. This means that to identify the path coefficients, I computed four regressions. Table 6 indicates the dependent and independent variables for each of those four regressions, as well as the Pearson Correlation Coefficient and other significant statistics for dependent and independent variables. The resulting post-fmodel diagram is presented in Figure 2. This final diagram includes path coefficients for each variable that entered a regression equation, as well as the  $R^2$ . If a variable did not enter an equation, its arrow, reflecting non-significant effects, was removed; therefore, those variables were also removed.

Table 6 shows the significant statistics for each regression I ran in the SEM. If no statistics are present for a variable, it means that variable did not enter the equation. Notice that for regression 1, where “science relevance to student,” “student engagement in science class,” and “student sense of agency to create knowledge in science class” were used to predict “student academic achievement in science class,” the  $R^2$  was 0.076. This indicates that 7.6% of the variance in “student academic achievement in science class” was predicted by “science relevance to student,” the only independent variable that made it into the equation. This  $R^2$  indicates a weak fit. The Beta for “science relevance to student” was 0.275. Notice that for regression 2, where “student engagement in science class” and “student sense of agency to create knowledge in science class” were used to predict “science relevance to student,” the  $R^2$  was 0.428. This indicates that 42.8% of the variance in “science relevance to student” was predicted by “student sense of agency to create knowledge in science class,” the one independent variable that made it into the equation. This  $R^2$  indicates a moderately strong fit. The Beta for regression 2 was 0.654. Notice that for regression 3, where “student engagement in science class” and “critical science education” were used to predict “student sense of agency to create knowledge in science class,” the  $R^2$  was 0.736. This indicates that 73.6% of the variance in “student sense of agency to create knowledge in science class” was predicted by the two variables that made it into the equation. This  $R^2$  indicates a strong fit. Examination of the Betas shows that the best predictor was “critical science education,” with a Beta of 0.540. Notice that for regression 4, where “student engagement in science class” was predicted by “student perception of science teacher” and “critical science education,” the  $R^2$  was 0.650. This indicates that 65% of the variance in “student engagement in science class” was predicted by the two independent variables that made it to the equation. This  $R^2$  indicates a strong fit. Examination of the Betas shows that the best predictor was “critical science.

The decomposition of bivariate covariation based on the post-model diagram is presented in Table 7. The clearest measure of which variables have the greatest impact on student academic

**Table 2: Frequency of gender**

| Gender | Sample size | Valid percent of total |
|--------|-------------|------------------------|
| Male   | 40          | 51.3                   |
| Female | 38          | 48.7                   |
| Total  | 78          | 100                    |

**Table 3: Frequency of age group**

| Age group   | Sample size | Valid percent of total |
|-------------|-------------|------------------------|
| 18–20       | 45          | 57.7                   |
| 21–23       | 16          | 20.5                   |
| 24 or above | 17          | 21.8                   |
| Total       | 78          | 100                    |

**Table 4: Frequency of ethnicity**

| Ethnicity                           | Sample size | Valid percent of total |
|-------------------------------------|-------------|------------------------|
| White                               | 1           | 1.3                    |
| Black or African American           | 14          | 17.9                   |
| Asian or Asian American             | 2           | 2.6                    |
| Native Hawaiian or Pacific Islander | 1           | 1.3                    |
| Hispanic/Latino                     | 60          | 76.9                   |
| Total                               | 100         | 100                    |

**Table 5: Frequency of number of science classes passed at XCS**

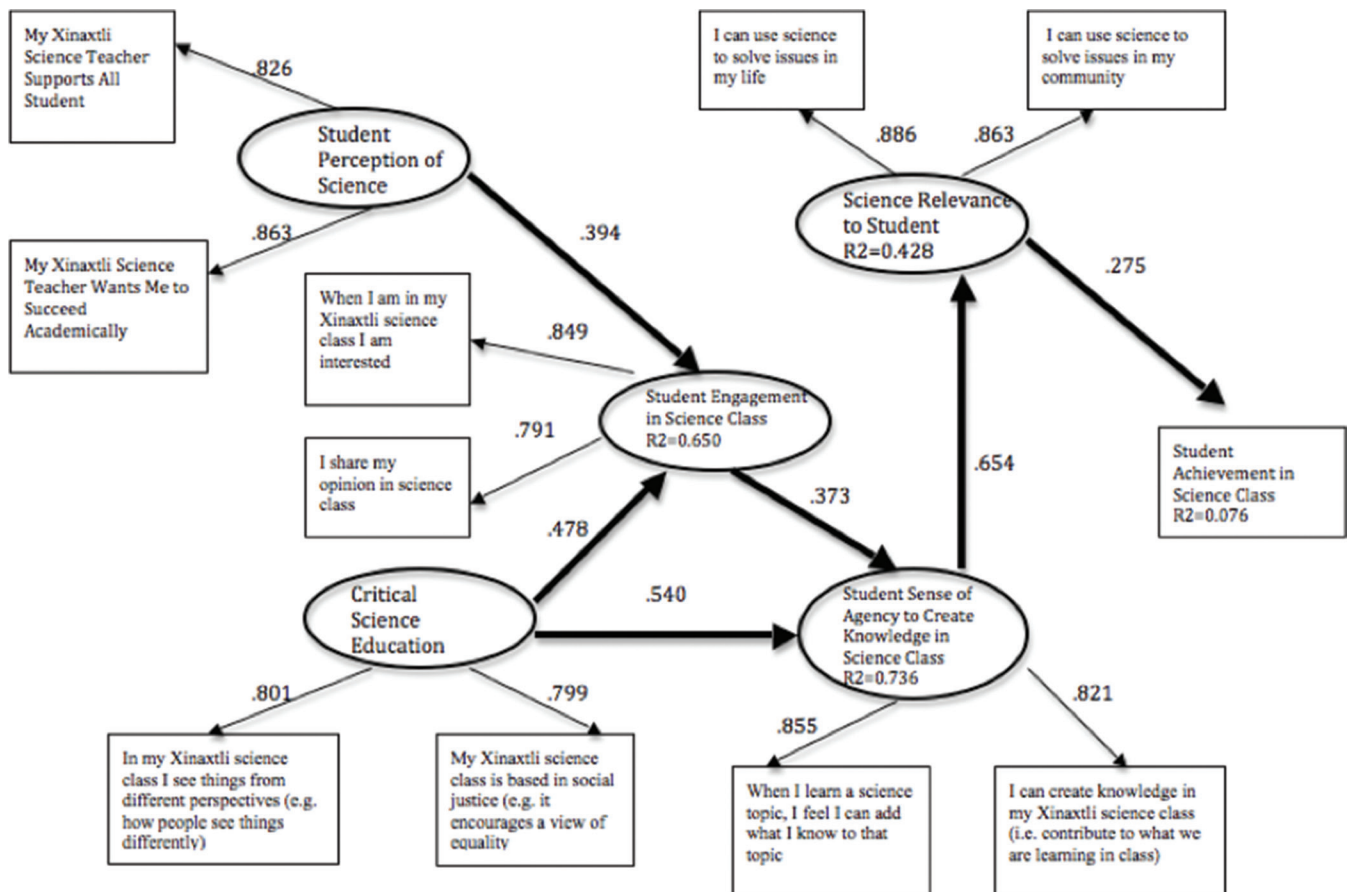
| Number of science classes passed | Sample size | Valid percent of total |
|----------------------------------|-------------|------------------------|
| Zero classes                     | 9           | 11.5                   |
| One class                        | 27          | 34.6                   |
| Two classes                      | 30          | 38.5                   |
| Three classes                    | 12          | 15.4                   |
| Total                            | 78          | 100                    |

**Table 6: List of regressions and significant statistics for mixed SEM with student academic achievement in Xinaxtli science class as ultimate endogenous variable**

| Number | Dependent Variable                                           | Independent Variables                                        | r Between DV and IV | Beta  | t     | Sig t  | R     | R <sup>2</sup> | Adj R <sup>2</sup> | F       | Sig F  |
|--------|--------------------------------------------------------------|--------------------------------------------------------------|---------------------|-------|-------|--------|-------|----------------|--------------------|---------|--------|
| 1      | Student achievement in science class                         | Science relevance to student                                 | r=+0.275            | 0.275 | 2.496 | 0.015  | 0.275 | 0.076          | 0.064              | 6.229   | 0.015  |
|        |                                                              | Student engagement in science class                          | r=+0.070            | -     | -     | -      | -     | -              | -                  | -       | -      |
|        |                                                              | Student sense of agency to create knowledge in science class | r=+0.185            | -     | -     | -      | -     | -              | -                  | -       | -      |
| 2      | Science relevance to student                                 | Student engagement in science class                          | r=+0.574            | -     | -     | -      | -     | -              | -                  | -       | -      |
|        |                                                              | Student sense of agency to create knowledge in science class | r=+0.654            | 0.654 | 7.544 | <0.001 | 0.654 | 0.428          | 0.421              | 56.908  | <0.001 |
| 3      | Student sense of agency to create knowledge in science class | Student engagement in science class                          | r=+0.784            | 0.373 | 4.119 | <0.001 | 0.858 | 0.736          | 0.729              | 158.968 | <0.001 |
|        |                                                              | Critical science education                                   | r=+0.823            | 0.540 | 5.964 | <0.001 | 0.858 | 0.736          | 0.729              | 158.968 | <0.001 |
| 4      | Student engagement in science class                          | Student perception of science teacher                        | r=+0.731            | 0.394 | 4.086 | 0.003  | 0.806 | 0.650          | 0.640              | 101.395 | <0.001 |
|        |                                                              | Critical Science Education                                   | r=+0.756            | 0.478 | 4.965 | <0.001 | 0.806 | 0.650          | 0.640              | 101.395 | <0.001 |

**Table 7: Decomposition of bivariate covariation for mixed sample predicting academic achievement**

| Factor               | Student sense of agency to create knowledge in science class | Science relevance to student | Student engagement in science class | Student perception of science teacher | Critical science education |
|----------------------|--------------------------------------------------------------|------------------------------|-------------------------------------|---------------------------------------|----------------------------|
| Original covariation | 0.185                                                        | 0.275                        | 0.070                               | 0.210                                 | 0.309                      |
| Direct               | 0.000                                                        | 0.275                        | 0.000                               | 0.000                                 | 0.000                      |
| Indirect             | 0.179                                                        | 0.000                        | 0.067                               | 0.026                                 | 0.129                      |
| Total causal         | 0.179                                                        | 0.275                        | 0.067                               | 0.026                                 | 0.129                      |
| Non-causal           | 0.006                                                        | 0.000                        | 0.003                               | 0.184                                 | 0.180                      |

**Figure 2: Final path diagram for student academic achievement in science class**

achievement in science class, the ultimate endogenous variable, would be the total causal statistic. Note that the two factors that had the greatest impact on student academic achievement in science class were “science relevance to student” and “student sense of agency to create knowledge in science class,” with a total causal value of 0.275 and 0.179, respectively. Furthermore, notice that the greatest direct effect ( $\text{Beta} = 0.275$ ) on student academic achievement in science class came from “science relevance to student,” and the greatest indirect effects ( $\text{Beta} = 0.179$  and  $0.129$ ) came from “student sense of agency to create knowledge in science class” and “critical science education,” respectively. The non-causal statistic represents the influence of variables outside of the model. The non-causals from the decomposition of bivariate covariation show some excellent fits for “science relevance to student” and “student sense of agency to create knowledge in science class” and some weak fits for “student engagement in science class,” “student perception of science teacher,” and “critical science education.” Overall, these parameters indicate that the model provides a moderate fit.

## DISCUSSION OF FINDINGS

### General discussion

When seeking to re-engage youth who have been pushed out of their traditional high school, education programs and educators must provide multiple forms of support for their academic success. XCS is an alternative education program that strives to re-engage youth who have been pushed out of their traditional secondary schools. Through its small classroom setting, project-based approach, and focus on social justice, it works to provide an equitable and critical learning opportunity to all students who attend.

This study found that XCS science classes supported student academic achievement. Through direct and indirect impacts, all factors evaluated in the structural equation model – the student perception of teachers, critical science education, the student sense of agency to create knowledge, the student engagement in science class, and the relevance of science to the student – had an effect on student academic achievement in science class.

### Relevance of Science to Students

The traditional science curriculum found in the classrooms of many traditional high schools consists of units, lessons, and assessments that are unrelated to students’ everyday lives. It is reflective of a view of science practice that is too far removed from the students’ worldview and the issues or questions they may face in their communities (Brickhouse et al., 2000).

Relevance of science to students was the only factor that had a direct effect on student academic achievement in science class. Based on our principal components analysis, students identified science as relevant because they learned topics in science class that they could connect to their everyday lives; they could use science to solve issues in their lives; they could use science to solve issues in their community; and they learned science topics in their XCS science class that they could use to solve problems important to them.

These findings align with the tenets of culturally relevant education (Aronson and Laughter, 2016; Gay, 2013; Ladson-Billings, 1995), in which underrepresented students’ cultural and linguistic practices are viewed as assets rather than deficits or barriers to the learning process. The data show that culturally relevant science is a powerful framework for supporting student academic success. The power here is in valuing the student experience and using it as a source of generative themes that can ground the science curriculum. Lesnefsky et al. (2023) found that centering students’ experiences within science content through modeling can support students in linking disciplinary knowledge, with societal injustices while also supporting their development of socioscientific reasoning skills.

If a student views science as relevant to their lives, it may be the case that they view this subject as important, as useful, and as a worthwhile endeavor. This finding harmonizes with a meta-analysis by Schroeder et al. (2007), which found that the largest impact on student achievement was the use of enhanced context strategies in the classroom. Enhanced context strategies relate student learning to the students’ previous experiences or knowledge.

If a student views science as a subject that provides them with strategies, skills, and knowledge to pursue further education or to take action against issues important to them then it may be that they are motivated to perform well academically in science class. This idea corresponds with justice-centered science pedagogy, which posits that through relevant and critical science, education students can achieve academically, while taking up issues of urgent social and environmental justice in their communities (Morales-Doyle, 2017).

### Student sense of agency to create knowledge

Aksakalli (2018) has spoken to how the marketization of education has led to a transformation of schools into businesses and – by extension – has changed science education. This shift is concerning, as it encourages current science education to focus on what Aikenhead (2006) has called the “pipeline” approach, whereby science education is seen primarily as a tool to develop future engineers, doctors, or science professionals. With such a mode, students who do not want to go into these fields may lose a sense of agency to engage with science and thus may lose motivation to perform well in science courses.

In contrast to this marketization model, our findings from the XCS program showed that the student’ sense of agency to create knowledge in science class had an indirect effect on student’ academic achievement in science class. Based on principal components analysis, students identified a sense of agency to create knowledge in science class when they could contribute to science knowledge; when they learned a science topic and felt that they could add what they know to that topic; and because they felt empowered in science class (e.g., they could contribute knowledge and have value).

According to Kincheloe (2008), traditional schools have a standardized view of knowledge. When students do not perform well academically, it is assumed that they are not proficient or lack the academic ability to learn the science content. Kincheloe argued that a critical complex epistemology, which is dedicated to bringing in the view of people who have been traditionally excluded from the scholarly conversation – in this case, science – is necessary. A critical complex epistemology is a multidimensional view of a phenomenon that goes against the one-dimensional view of a phenomenon, which is what we see in traditional science courses.

If a student feels that they can engage in knowledge creation within a science classroom, then they may feel that science is a discipline that aligns with their experiences. That is, they understand science, can integrate their personal experience with science content, and feel self-efficacy to contribute to science. In line with social justice education, which “perceives students as critical consumers and producers of knowledge capable and responsible for enacting their own sense of agency to bring positive social change for themselves and their community” (Rodriguez, 1998, 2015).

### Critical Science Education

While current trends in science education – such as standards and testing – cater to global economic objectives, they promote a generic science education that has no local ties and therefore no relevance to the students in a given class. Aikenhead et al. (2006) argued that school science, driven by standards and high-stakes exams, is a culture of science education grounded in a specific worldview and way of knowing that continues to be reproduced in traditional schools, thus normalizing this culture. According to Pratt (1994), this occurs through a process of “cultural transmission,” a perspective that maintains that the primary purpose of curriculum (in this case, traditional science curriculum) is to “transmit the best products of the intellectual culture” (p. 9). Researchers have argued that the science classroom should serve to develop students who challenge social inequality through teaching, curriculum, and social transformation (Dos Santos, 2009; Finkel, 2018; Mutegi, 2011; Rodriguez, 1998). Further, Moje (2007) maintained that teaching science for social justice “not only provides access to mainstream knowledge and practices but also provides opportunities to question, challenge, and reconstruct knowledge. Social justice pedagogy should, in other words, offer possibilities for transformation” (p. 4).

Critical science education had an indirect effect on student academic achievement in science class for the students in this study. The XCS science curriculum encourages a project-based approach in the classroom that integrates social justice-based content with the discipline content and is applied to the completion of authentic performance tasks. Based on our principal components analysis, elements of critical science education were seeing things from different perspectives; conducting science investigations; being based in social justice; using evidence to support conclusions; valuing student voice and experience; working on authentic performance tasks

that encourage student knowledge creation; and encouraging students to think of social issues (e.g., inequality and oppression).

With the goal of providing an equitable and critical education that supports student academic achievement in science class, the XCS science curriculum can be seen as a vehicle. The XCS science curriculum aligned with critical pedagogy as practiced through the problem-posing model (Freire, 1970). Like the problem-posing model of education, in which knowledge is not static, but rather is constantly changing and being created, students and educators critically analyze the science content in the reality of the community they live in. The curriculum is student-centered and provides students opportunities to engage in knowledge creation through authentic performance tasks. As proposed by social justice science education, the XCS science curriculum encouraged students to use science knowledge and skills to contribute to, navigate, critically question, and examine issues related to their social factors (Rodriguez, 1998, 2015; Galamba and Matthews, 2021).

### Student engagement in science class

Traditional science classrooms that promote a standardized view of knowledge that is pre-defined tend to employ universal teaching methods that are more managerial, with the goal of performing well on a test (Kincheloe, 2008). The issue here is that when performance on a standardized test is seen as a “true measure” to determine a student’s academic ability and the quality of education, it directly dictates the method by which educators teach (Aydeniz and Southerland, 2012). When educators are expected to “teach to the test,” they are not allowed to engage students in the practice of learning and knowledge creation; rather, their role is that of information deliverer. Such a pedagogical model has been found to have a negative impact on teacher practice and achievement by students of color in math and science (Lomax et al., 1995).

For participants in this study, student engagement in science class had an indirect effect on student academic achievement in science class. This finding concurs with a study by Skinner et al. (2008), which found that students who are engaged in school are likely to find greater academic success. Based on principal components analysis, students identified engagement in science class as being focused, interested, wanting to succeed, participating, feeling motivated, sharing their opinion, and participating in discussions. These findings are in line with Zambrano et al. (2022), who found strategies for engagement in high school science classrooms; a variety of student-centered strategies utilized by the teacher, connecting with peers, adjusted learning materials, and ability to express opinions.

### Student perception of science teacher

Hattie (2009) found that teachers play a major role in student achievement, where the quality of the teacher and the nature of the teacher-student relationship had the greatest effect, followed by teacher expectations of their students. Student perception of science teachers had an indirect effect on student academic achievement in science class. Based on principal

components analysis, students identified positive perceptions of their science educator at XCS. Science educators were identified as encouraging, patient, wanting students to succeed academically, having high expectations of students, respecting student contributions in science class, supporting all students, using content relevant to student's lives, and engaging.

The attitude an educator has regarding who can and cannot succeed in school can be communicated explicitly and implicitly to students (Rosenthal and Jacobsen, 1968). Tan and Maeda (2021) found that ninth-grade students' perceptions of their science teacher's practices (e.g. growth mindset practices) have a positive relationship with science identity development for students. Valenzuela (1999) showed that there is a disconnect between what educators view as caring and students view as caring. She posited that authentic caring requires the development of a trusting teacher-student relationship, which includes understanding the students' cultural world and their structural positions (Valenzuela, 1999). Love (2019) spoke about the important role educators play in protecting the potential of students. She stated that educators must be committed to developing relationships with students, their families, and their communities in ways that are authentic and that honor their knowledge of growing up how they did. Protecting the potential that students bring into the classroom by showing students that they matter, that they have a voice, is one of the most important roles of an educator.

### Implications for practice

This study was conducted with the hope of providing insights to educators, educational program directors, education researchers, and community organizations that strive to re-engage young people who have been pushed out of traditional high schools. In addition, this study sought to contribute to a critical pedagogy of science that supports the development of all students who enter a science space to be creators of knowledge. Based on the findings of this study, there are implications in applied practice for educators and science curriculum.

### Educators

Educators are tasked with facilitating the development of all young people who enter their classrooms. This study found that educators contribute to student academic achievement in several ways. The findings produce the following suggestions for science educators. First, science educators need to understand that traditional science education has worked from an epistemology that is not inclusive of many worldviews, that is a formal, intractable, universalistic, reductionist, and one-dimensional (Kincheloe, 2008). As an extension of this epistemology – and reinforced by this epistemology – many groups of people have been excluded and oppressed. Further, science educators need to understand that there are systemic inequities and institutionalized racism that extend into the education system and continue to impact achievement of students of color. Finally, science educators need to fully understand that the classroom is not a politically neutral site

and that it can serve to either reinforce oppression and inequity, or to politicize and empower students (Freire, 1970; Giroux, 2011; Kincheloe, 2008).

Second, science educators need to be real with their students; that is, they need to actively work to develop authentic relationships with their students, show students that they matter, allow a student's voice to be heard, and nurture a student's potential (Love, 2019). If a student does not know that you care for them, it will be very difficult for them to care about what you have to say. Part of building this authentic relationship is being honest with your students; educators should not lie to their students. If a student asks a question, be honest and real with them.

Third, science educators should practice community building in the classroom; that is, actively develop a community in their classrooms through activities that encourage the class to get to know each other. This practice can support student success by creating a space in which students feel comfortable making mistakes and communicating openly with their classmates.

Fourth, to support all students, science educators must develop a pedagogy that has the goal of engaging all young people – not just those who show interest in pursuing a STEM field; that is, educators must present science in a manner that is inclusive and representative of many worldviews (e.g., the view of people oppressed by science research), not a view of science as an abstract field for “smart people” or as a future financial opportunity. For example, educators should be open to supporting student's varying goals with regard to science.

Fifth, science educators must use a culturally relevant science that integrates student experience; that is, a curriculum that allows students to localize the science content to their community and their individual lives. This model promotes the development of students who can use science to make active decisions about their lives and their communities. What this informs is an approach to science that centers student experiences and seeks to merge them with the science content. For example, educators can utilize local phenomena (i.e. wildlife, waterways, environmental issues) to center the science content. In addition, educators should consider student experiences with science phenomena as generative themes to develop class lessons. For example, if there is a local water source that suffers from pollution, then student experiences and understanding of that issue of environmental justice can serve as the phenomenon for a science unit. Students can explore water systems, the chemistry of water, the ecology of that water source, and collect data to practice science inquiry.

Sixth, science educators should integrate action-based projects into science class, using science content and skills to facilitate student-led inquiry from inception toward an action. Encourage students to practice their inquiry skills by investigating a science phenomenon that revolves around an issue that is important to them, and then support them to act toward the issue. Throughout this process, educators must

actively dialogue with students to understand the purpose of the knowledge being used and that will be created. For example: Why is this knowledge valid? Whom is knowledge benefiting? Where are we getting our information? Whose voice is being empowered or silenced? This model can contribute to the development of young people who are empowered and critical science practitioners. For example, using the previous thought on developing lessons around a local issue of environmental justice (e.g. polluted water sources), through a science inquiry approach students can study the various causes and effects of the issue and develop remediation ideas for the benefit of that community.

## CONCLUSION

The purpose of this research was to better understand how each of the following areas – the student perception of teachers, critical science education, the student sense of agency to create knowledge, the student engagement in science class, and the relevance of science to the student – impact student academic achievement in their class-based science course. This study found that each of the aforementioned factors had either a direct or indirect impact on student academic achievement in their XCS science classes.

This study was motivated by the concern that science or STEM education has traditionally been grounded in epistemologies and practices that are not open to multiple worldviews. Rather they have been driven by a eurocentric view that values certain knowledge and ways of being, while devaluing and silencing others (Aikenhead, 2006; Aikenhead and Barton, 2006; Aksakalli, 2018; Kincheloe, 2008). The outcome of this approach can be seen in the lack of diversity curriculum, academic outcomes, and workforce outcomes (e.g. the overrepresentation of white males) (National Science Foundation, 2016; National Science Foundation, 2019; National Science Board, 2023). Additionally, this study was motivated by the understanding that a lack of success in science education may contribute to youth being pushed out of traditional public high schools (National Science Foundation, 2016; National Science Board, 2023).

Providing opportunities to re-engage in science education for students of color who have been pushed out of their traditional public high schools is an issue of equity and social justice. The findings from this study contribute to a necessary paradigm shift in science curriculum, culture, and pedagogy that supports the academic achievement and empowerment of students who have dropped out of their traditional high schools. It is a pedagogy that presupposes a future where students access science in a localized, critical, and action-based manner. A pedagogy that enacts students as science practitioners and contributors to science knowledge. A pedagogy where educators facilitate a science classroom that centers student experience, collaboration, and authentic relationships with students. A pedagogy where science epistemology is inclusive of multiple perspectives and worldviews.

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## APPENDIX

### Appendix 1: STEM and culture competencies implemented by XCS science educators

#### STEM competencies

|                                               |                                                                                                                                                                                                                      |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Questions and defining problems               | Learners formulate their own questions or hypotheses (if/then statements) to evaluate empirically testable questions.                                                                                                |
| Models                                        | Learners construct and revise models to explain phenomena and discuss the limitations and precisions of the model.                                                                                                   |
| Investigations                                | Learners develop original procedures and protocols to plan and conduct a full investigation to produce data that serve as the basis for evidence.                                                                    |
| Interpret and analyze data                    | Learners independently represent and analyze data to identify patterns, trends, or relationships. They interpret data in light of models and theories.                                                               |
| Construct explanations and design solutions   | Learners construct their own explanations for STEM phenomena and develop a design prototype for an evidence-based solution.                                                                                          |
| Obtain, evaluate, and communicate information | Learners can independently analyze evidence (often in the form of data) and formulate their own conclusions/explanations.                                                                                            |
| Engage in arguments from evidence             | Learners adequately describe content and layout to be used to communicate and justify their conclusions and explanations.                                                                                            |
| Tools                                         | Learners are sufficiently familiar with tools appropriate for their course to make sound decisions about when each of these tools might be helpful, recognizing both the insight to be gained and their limitations. |

#### Culture competencies

|                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Love and care                   | <ul style="list-style-type: none"> <li>• Listens with empathy</li> <li>• Honors &amp; respects the voices of others (staff-student, student-student, staff-community, student-community)</li> <li>• Honest &amp; open communication</li> <li>• Self-love and embracing of various identities</li> <li>• Unconditional love &amp; support for others</li> <li>• Respect and genuine relationship-building with others</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Leadership                      | <ul style="list-style-type: none"> <li>• Demonstrates commitment to the space's mission, vision, policies, established agreements, core values, and follows through on expectations</li> <li>• Sets goals, follows through on action plans, and self-reflects for improvement</li> <li>• Can envision and apply their leadership abilities in future post-secondary education, career pathways, and their own life</li> <li>• Can define and demonstrate ethics and integrity</li> <li>• Demonstrates effective communication, discovers their communication style, and applies in various settings</li> <li>• Acts as key players in culture-building and decision-making in the space</li> </ul>                                                                                                                                                                                            |
| Success                         | <ul style="list-style-type: none"> <li>• Develops and implements a plan for emotional, physical, spiritual/secular, intellectual, career, and financial growth &amp; transformation</li> <li>• Demonstrates intellectual curiosity &amp; humility</li> <li>• Self-knowledge of identity, positionality, talents &amp; skills</li> <li>• Sense of purpose: apply self-knowledge towards a goal that has a wider impact beyond oneself</li> <li>• Reframes "success" to counter dominant notions of success</li> </ul>                                                                                                                                                                                                                                                                                                                                                                          |
| Collaboration                   | <ul style="list-style-type: none"> <li>• Works to achieve the program vision, mission, goals, objectives, and outcomes</li> <li>• Engages in discussion &amp; dialogue for collaboration</li> <li>• Honors team agreements</li> <li>• Creates and participates in collective goals, objectives, process, and outcomes with people from diverse backgrounds</li> <li>• Honors collectively identified benchmarks, scheduled activities, and deadlines</li> <li>• Inclusive and acknowledging of all stakeholders (community, staff, students, alumni, family, etc.)</li> <li>• Utilizes resources (technological, material, human) to maximize collaboration efforts</li> <li>• Reflects on participation in collaborative projects</li> </ul>                                                                                                                                                 |
| Social consciousness and action | <ul style="list-style-type: none"> <li>• Embraces funds of knowledge: informs the school community of their lived/community realities</li> <li>• Participates in collaborative social investigation (needs assessment; asset-mapping; power analysis; identifies and understands injustice, oppression, and inequity)</li> <li>• Able to name key players, power dynamics, privilege, and how it plays out in a setting</li> <li>• Shows solidarity for self &amp; others through empathy, actions that respect needed support, raising awareness, and advocacy (e.g. lobbying, petitioning, filing a legal challenge, protesting, campaigning, story-based messaging)</li> <li>• Promotes self &amp; community autonomy (resource development, budget development, program development)</li> <li>• Participates in community action projects to address urgent community concerns</li> </ul> |

(Contd...)

**Appendix 1: (Continued)**

- |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Support and healing | <ul style="list-style-type: none"> <li>• Understands, upholds, and promotes restorative justice practices of building community and going through a process to restore relationships when people are harmed/experience conflict, violations, offensive behavior, and injustices</li> <li>• Contributes to and upholds collectively created respect agreements and the discipline process</li> <li>• Feels like a valued and appreciated member of the community where they are recognized for their assets, not their challenges</li> <li>• Feels safe to express their ideas and trusts that they will be supported if they share constructive feedback and/or break community agreements</li> <li>• Is committed to a transformative justice approach where there is critical reflection and efforts to combat systemic roots of harm, and promotes decisions that are grounded in the best interest of the collective</li> <li>• Upholds the collectively created system that proactively addresses retention and attendance.</li> <li>• Upholds and is committed to cultivating critical hope, critical agents of transformation, and self-determination as referenced in the PCCP framework</li> </ul> |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|