Chapter 8
The Impact of Culturally Responsive Teaching on Underrepresented Students Persistence in STEM:
Culturally Responsive Instructional Strategies

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ABSTRACT

There is a consistent economic need to increase diversity in science, technology, engineering, and math (STEM) disciplines and to increase diversity in groups of STEM professionals graduating from colleges and universities in our nation. However, research notates that minoritized populations such as women and/or persons of color, continue to be underrepresented in STEM disciplines. Furthermore, literature suggests that teachers who implement culturally responsive instructional strategies in the classroom positively impact and empower students to develop positive attitudes towards STEM, hence aiding in an increase in the recruitment and retainment of underrepresented groups in STEM disciplines or STEM-related careers. This book chapter will trace research and provide culturally responsive teaching strategies, lesson plan adaptation strategies, and instructional practices that can be used in STEM classrooms in an effort to positively influence underrepresented student's decisions to persist in STEM careers and/or STEM-related fields.

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INTRODUCTION

Research supports the notion that there is an alarming decline in the representation of women and minorities in STEM fields and their decisions to work in STEM disciplines due to disconnections that occur between students' elementary and middle school years (Braund & Reiss, 2006; MacPhee, Farro, & Canetto, 2013; Carlone, Scott, & Lowder, 2014; Fisher et al., 2019). Data reports that early interest in STEM is directly linked with whether or not students pursue a STEM major in higher education (Phelan, Harding, & Harper-Leatherman, 2017). Minority groups or underrepresented minority groups (URMs) such as Women, Black/African Americans, Latino/a/x, and American Indian/Alaska Natives represent under 10% of STEM scholars in higher education (Fisher et al., 2019). Although other research has shown that there have been some gains and improvements in representation of URMs in STEM fields, these gains have stagnated over time (Nassar-McMillan, Wyer, Oliver-Hoyo, & Schneider, 2011). For instance, African Americans held 3,077 of 62,356 awarded engineering bachelor's degrees in the United States (U.S.) in 1997; and 3,097 of 78,099 awarded engineering bachelor's degrees in 2011 (as cited by the National Action Council for Minorities in Engineering [NACME], 2014). According to NACME (2014), African Americans represented only 3.6% of employed engineers in 2010 and 2.5% of engineering faculty in 2011. Furthermore, Nassar-McMillan et al. (2011), reported that woman held 49 percent of doctoral degrees in science and engineering between 1997 and 2006. However, these gains among URMs seemed to only be ubiquitous in specific STEM disciplines such as psychology, biology, health sciences, and the social sciences and still remain limited in STEM disciplines such as physics, computers science, and engineering (Nassar-McMillan et al., 2011; Dika & D'Amico, 2015). NSF (2013) later reported that a lack of diverse representation in these fields cause significant barriers for college students to have access to diverse role models from STEM-related disciplines in higher education. According to NSF (2017), underrepresented men and women have still only earned 11.8% and 8.4% of science and engineering bachelor's degrees as of the year 2014. In addition, NSF (2015) reported that 70% of workers in science and engineering occupations were White in 2013.

Consequently, the lack of representation in STEM is an issue of critical importance. The need for a prolific and diverse STEM-educated workforce is imperative as the United States and other countries aim to keep stride with advances in STEM both locally and globally (Xie & Shauman, 2003; Pierszalowski, Vue, & Bouwma-Gearhart, 2018). According to the National Science and Technology Council (NSTC) 2013, one of the pathways for increasing representation in STEM degree programs and STEM-related careers is through teaching pedagogy that guides future implementation efforts in the classroom. Specifically, teachers should be trained to fully engage in

STEM subjects to improve students' experience of, and attainment in STEM (Royal Society Science Policy Centre, 2014). Teachers hold a high responsibility to capture and ignite the talent and creativity of students throughout elementary and secondary school to promote and help increase an ethnically and culturally diverse scientific workforce (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013).

Furthermore, literature suggests that culturally responsive teaching (CRT) is one strategy that helps to empower and inspire underrepresented students to persist in STEM disciplines. Research also supports the notion that when teachers integrate STEM teaching, they enhance their abilities to be culturally responsive while STEM and CRT become intertwined and mutually beneficial to both the teacher and the students (van Ingen, Davis, & Arndt, 2018). Gay (2001) defines culturally responsive teaching as using the cultural characteristics, experiences, and perspectives of underrepresented students as conduits for teaching them more effectively. Culturally responsive teaching is also designed to inspire underrepresented students by using relevant cultural connections to increase their engagement and motivation to learn. According to Gay (2001), efforts to retain underrepresented students in STEM should improve when they are taught through their own cultural and experimental filters.

The purpose of this chapter is to emphasize evidence based culturally responsive strategies that will improve teachers' instructional practices in elementary and middle school classrooms. This chapter also intends to review prior relevant literature guiding teachers on how to develop instruction and activities that incorporate a student's culture into learning, possibly improving underrepresented students' persistence in STEM disciplines. The specific components of this chapter are based on research findings, theoretical claims, and personal stories of educators researching and working with underrepresented students. Retainment and recruitment of more URMs, enhances the STEM workforce with more advanced skills and creativity from a diverse pool of individuals. The specific strategies highlighted in this chapter were assembled for teachers' who desire to improve their instructional practices and positively influence and impact underrepresented students to be our nation's next generation of STEM professionals.

Culturally Responsive Teaching and Historical Perspectives

Culturally responsive teaching (CRT) is a comprehensive pedagogy predicated on the notion that culture directly impacts teaching and learning and plays an essential role in the way we communicate and receive information. This pedagogical approach demands that schools acknowledge and adapt to differentiated learning and teaching based on multicultural norms, including the respectful integration of students' cultural backgrounds and references that veer from the dominant culture (Byrd, C. 2016). Culturally responsive teaching pedagogy has been referred to by several names and has been developed from phenomenon such as "multicultural education", "culturally compatible", "culturally appropriate", "culturally congruent", and "culturally relevant".

A generation of theorists concerned about the disparities in academic achievement between white, middle class students and underrepresented minority students, conducted research that developed these theories and instructional strategies which address cultural differences among diverse student populations (Au, 1993; Ladson-Billings, 1994; Delpit, 1995; Irvine, 2003; Moll & Gonzalez, 2004; Nieto, 2010). The layers of CRT were founded upon the theories and practice of James Banks (1988). Banks' focused his research on multicultural education and the development of multicultural curricula. Bank's idea of multicultural education centered on content incorporation that included more of underrepresented groups' history in curriculums (Tucker, 1998). Banks curricula referred to as Afrocentric curriculum, focused on implementing educational instruction with techniques that were relatable to African American students and also aligned with their unique learning styles (Giddings, 2001). The bases of Banks (1988) research and ideas also focused on the behaviors and learning characteristics of the language of low-income students, minority students, or ethnically diverse students to improve cultural diversity in the classroom. These theoretical claims solidify the importance of science teachers' implementation of curriculum that provides instruction that is suitable for all students (Banks, 1993; Giddings, 2001; Cipani, 2018).

Along similar lines, in 1989 Jacqueline Irvine addressed the lack of cultural synchronization between teachers and African American students and its negative impact on academic achievement. Eleven years later, she expounded upon and described culturally responsive teaching as strategies that were student-centered, transformed curriculum, fostered critical problem solving, and focused on building relationships with the students, their families, and communities (Irvine & Armento, 2001). Irvine (2002) further explained that a curriculum is transformed with culturally responsive teaching because the subject matter is viewed from multiple perspectives, including the lens of oppressed and disenfranchised groups. She strongly believed that in order for teachers to teach culturally responsive, teachers must incorporate elements of the students' culture in their teaching.

Irvine (2002) also developed evidence-based strategies through interviews with African American teachers who incorporated culturally responsive teaching into their curriculums. Irvine highlighted and summarized African American teacher's beliefs about culturally responsive teaching as the following:

- Teaching is caring for the whole student, providing honest feedback to students about their performance, maintaining authority in the classroom, and using culturally specific instruction.

- Teaching requires educators to engage in 'other mothering' or a feeling of kinship toward their students.
- Teaching is believing in one's own teaching and ability to influence the achievement of students. That is, teachers must have multicultural self-efficacy.
- Teaching is demanding the best of students holding them to high expectations.
- Teaching is a calling and has a special purpose.

Additionally, in the late 1980s, Gloria Ladson-Billings was inspired to establish a theory known as "culturally relevant" or culturally relevant pedagogy (CRP) theory when people began to recognize alarming achievement gaps between mainstream students and underrepresented students (Ladson-Billings, 1990). Ladson-Billings (1995) believed teachers must provide a way for students to maintain their cultural integrity while succeeding academically. Ladson-Billings (1994) argued that teachers were responsible for developing students academically, were responsible for nurturing and supporting cultural competence, and should work in developing students' sociopolitical or critical consciousness. According to the Billings' theory of culturally relevant pedagogy, teachers must work to understand and learn about their student's' lives before effective learning could take place in the classroom.

Following several other dimensions of cultural theories and practice, Gay (2002) described teachers who implemented culturally responsive strategies, as teachers who recognized the power of instructional techniques that could lead to higher learning potentials of underrepresented students when culture was included in their instruction. Gay (2010), strongly believed that there was a place for cultural diversity in every subject taught in schools and the use of culturally responsive strategies was implemented when multicultural instruction was added to an existing curriculum. Specifically, Gay (2010) argued that culturally responsive teaching guided and gave hope to educators who wished to improve instruction for the betterment of students who are from diverse racial, ethnic, cultural, linguistic, and social-class groups. As time went on, several culturally-centered strategies have been implemented to ensure that all students were afforded an opportunity to receive a quality education.

CRT was developed to create relationships and unity between teachers and their students by teachers taking the time to understand their students' diverse cultural backgrounds (Cochran-Smith, Piazza, & Power, 2012; Darling-Hammond, 2013). Hence, teachers who include CRT in their classrooms, work to include relevant characteristics of their students' backgrounds into instruction (Banks & Ambrosio, 2010; DeCapua, 2016). Gay (2000) suggested that culturally responsive teachers use the "cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for them" (pp. 29). Integrating STEM lessons with CRT outside of simply acknowledging a student's culture is essential as we live in a multicultural world that is in increasing need for all students to have an opportunity to thrive. Furthermore, the use of STEM learning is synergistic with engagement in CRT in the context of elementary and secondary education (van Ingen, Davis, & Arndt, 2018).

FACTORS AFFECTING UNDERREPRESENTED STUDENTS CHOICE OF STEM CAREERS

There are many factors that affect underrepresented students' decision to persist in STEM careers, counteracting the need for more diversity in the U.S. STEM workforce or STEM disciplines. One factor affecting underrepresented students' choice to persist in STEM, is the consistent issue of teacher candidates not being adequately prepared to demonstrate the content knowledge or self-efficacy to teach the specific subjects of STEM (Yoon & Martin, 2017). While teacher preparedness to teach STEM content is a major problem, a significant challenge to engaging students in the STEM content is correlated with the cultural divide between the lived experiences of youth from racial-ethnic minority backgrounds and the cultural lens through which STEM content is traditionally presented. According to Learning Science in Informal Environments (National Research Council,2009), science is a culture unto itself, with its own rituals, behavioral norms, values, and language. When the science is presented to students, it is often with the expectation for students to assimilate to the norms of science culture and situates science as historically an endeavor of Western European white males (Lee, 2011; National Research Council, 2009). This becomes a problem for leveraging students' existing funds of knowledge and lived experiences for advancing STEM learning in the classroom. The combination of the cultural bias of traditional STEM instruction and sociopolitical history results in many youths from these backgrounds feeling as though they don't belong in STEM careers (Quality Education for Minorities Network, 2010).

Research shows that teachers seem to neglect subjects of STEM such as science; and devote significantly less time on science learning than other subjects such as reading and language arts at the elementary level (Elementary Science Education Position Statement, 2019). Studies also show that many elementary and middle school teachers' science content knowledges are not very strong, and teachers are less likely to have a strong commitment to creating impactful science learning experiences for their students (Michaluk, Stoiko, Stewart, & Stewart, 2018). Additionally, over 40 years of research reports that positive teacher self-efficacy sets the tone for high quality classroom environments that advance students' abilities and has also been found to exert positive influence over student and teacher outcomes (Armor et al. 1976; Midgley, Feldlaufer, & Eccles, 1989; Woolfolk, Rosoff, & Hoy, 1990; Chacon, 2005; Klassen, Tze, Betts, & Gordon, 2011; Wyatt, 2014; Zee & Koomen, 2016).

Literature suggest that the lack of diversity in STEM fields is also linked to structural barriers in educational access and opportunity; social/psychological barriers; and responses to disparities and social stigmatization (Scott & Martin, 2013). Structural barriers impact underrepresented students by their inability to attain equitable school funding, science resources, and/or technology and computer resources. In addition to structural barriers, underrepresented students also face social/psychological barriers that negatively impact their decision to persist in STEM. According to research, this barrier is usually associated with negative stigmas and marginalization attached to underrepresented students.

Major and Obrien (2005) used four categories to summarize the mechanisms of stigmatization. These categories consisted of: negative treatment and direct discrimination; expectancy confirmation processes; automatic stereotype activation; and stigma as identity threats towards underrepresented students or groups. The researchers reported that these concepts could usually be observed in underrepresented groups due to inequitable access to resources and educational opportunities, self-fulfilling prophecies and stereotype threats, the avoidance of certain subjects and fields of study, perceptions of bias and anticipation bias, and endorsement of stereotypical beliefs.

Educational access barriers to STEM refers to students experiencing prevalent racial biases and discrimination in school (Sellars et al., 2006). As a result, these racial inequalities have been negatively associated with students' academic outcomes (Jarosinski, 2018). In one study, researchers found that female high school students were more likely to perceive barriers to STEM education and STEM career goals than males, and Latino students perceived greater educational and career barriers than white students (Long, Henderson, & Williams, 2018).

Few studies have examined the perceptions of structural and psychological barriers to pursuing STEM studies in higher education held by underrepresented students, and the impact of these perceptions on STEM career aspirations. In several studies concerning underrepresented groups and career trajectory, several findings have indicated that self-efficacy and outcome expectancy are factors that affect unrepresented groups decisions to persist in STEM careers (Sellars et al., 2006). In addition to understanding stigmatization, self-efficacy, and outcome expectancy; stress and coping processes have been recognized as factors that impact underrepresented student groups decisions to persist in STEM (Harrell, 2000). In viewing the context of STEM education, the exposure to stressful stimuli could include direct discrimination/bias, stereotype threat activation, and inequity in educational access and opportunity. According to this process, the individual's assessment of the demands and the availability of resources to cope directly influence coping responses (Scott & Martin, 2013). Thus, it is imperative to examine not only the perceptions of barriers to STEM education, but to also examine the availability and types of resources available to assist underrepresented students with ways to cope with these perceived barriers. Past literature strongly believed that coping responses to race-related stress and structural disparities could influence underrepresented students' resilience and desire to strive harder to overcome obstacles (Steele & Aronson, 1995; Sanders, 1997; Major & O'Brien, 2005). Specifically, the existence of these factors correlates with the negative impact of underrepresented students' desire to pursue STEM careers; and these factors can be addressed or avoided with the use of culturally responsive teaching in STEM classrooms.

TEACHER PERSPECTIVES OF CULTURALLY RESPONSIVE TEACHING

In today's teacher preparation programs, teacher educators must be intentional in preparing teachers to be culturally responsive. There is a need for teachers to have the knowledge, disposition, and skills to effectively teach students of color. Teacher preparation programs must have professors that are culturally competent and knowledgeable about culturally responsive pedagogy to effectively prepare teachers and principals to teach (Ebersole, Kanahele-Mossman, & Kawakami, 2016). In many cases professional development should be provided in schools to further prepare teachers to be culturally competent and schools must work diligently to increase the number of teachers to be ready to effectively accommodate the dynamic mix of race, ethnicity, class, gender, region, religion, and family that contributes to every student's cultural identity. Teacher education curricula often includes courses about cultural diversity intended to promote a just and equitable education for all (Ebersole et al., 2016). Professional organizations such as the National Board for Professional Teaching Standards (NBPTS) and the Interstate New Teacher Assessment Support Consortium (INTASC) include standards that emphasize culturally responsive teaching practices (Mills, 2008).

In a recent study completed by Yoon & Martin (2017), the researchers evaluated the impact of early childhood teacher preparation that combined American teacher education with South Korean practices and how these practices impacted teacher candidates' ability to teach science using culturally responsive science curriculum. The candidates of their study were evaluated on their self-efficacy for teaching science, their ability to create a culturally responsive multicultural/diverse science lesson plan, and their response to open-ended questions (Yoon & Martin, 2017). Yoon & Martin reported that there was a statistically significant increase in teacher candidate's personal science teaching efficacy after their roles in developing and implementing multicultural/diverse lesson planning for science instruction. Teacher candidates indicated that they felt better prepared on teaching science and integrating cultural instruction into their classrooms (2017).

There have many teacher educators who have been successful at helping teachers teaching in culturally responsive ways, (Cochran-Smith, Davis, & Fries; 2003; Gay, 2000; Gay & Kirkland, 2003; Nieto, 2000). In many ways the development of culturally responsive teachers can present several layers of complexity for teacher educators. Teacher educators must help teachers understand their own socio-cultural history first (Villegas & Lucas, 2002) and help teachers see that they come with their own cultural identity which positions a person to various forms of oppression and privilege (Cochran-Smith, 2004). Most times this initiates the exploration of the notion of culture and culture group (Gay, 2000). A lot of times it is uncomfortable for most teachers to discuss and deconstruct their own socio-cultural history and values. It can be even more uncomfortable to share their cultural identity. This can be challenging and uncomfortable for teachers who have grown up in an environment where historical truths have been hidden and in which they have been encouraged to believe stereotypical and mis conceptional views that may resurface in their classrooms.

Furthermore, building culturally responsive practices requires teachers to construct a broad base of knowledge that shifts as students, contexts, and subject matters change (Banks, et al., 2005). To further complicate the situation teachers, have to understand that their students come to the classroom with multiple cultural identities. One author of this paper reported that when teachers were asked to plan a culturally responsive lesson in their existing course, they listed activities within their plans which seem more as a supplement to the existing curriculum or serve as separate units to be taught at a specific time of year. As a methods instructor, who had my students placed in field experiences, the author of this paper asked a middle school teacher about her plans. The teacher responded, "At this point, my plans are the same. However, that (culturally responsive) teaching unit will not be included until the later part of the school year." This implied to the author that culturally responsive teaching was a separate unit to be taught at a particular time during the school year and not a particular perspective or stance taken toward teaching. Teachers who attempt to "do culturally responsive activities" attempt to connect with students' cultural backgrounds.

CULTURALLY RESPONSIVE INSTRUCTIONAL STRATEGIES

It is imperative that teachers implement culturally responsive instructional strategies, as schools in the U.S. are more diverse today than they have been since the early 1900s when a multitude of immigrants entered the U.S. from Southern, Central, and Eastern Europe (Gay, 2010; Valla & Williams, 2012; Aronson & Laugher, 2016). Often, teachers who do not implement CRT can cause underrepresented students to believe he/she is unable to learn. Hence, implementing CRT strategies provide a safety net that allows underrepresented students to feel they can learn because they are able to see themselves in the literature and curriculum they are presented (Gay, 2015; Souto-Manning & Martell, 2017). Using CRT strategies, materials and activities help to peak more student's interest and stir up a desire for them to engage in STEM learning, so they can discover and connect with what interests them from these subjects (Cartledge et al., 2016).

CRT strategies not only create a safety net, but also creates comfortable learning environments for underrepresented students. According to Bui & Fagan (2013), students have a level of comfort with CRT materials because there is a connection between the lessons and the students' lives. Specifically, students are able to understand and can make connections with STEM learning because the material addresses topics the students can relate to. Therefore, teachers must recognize and overcome the power of differential, stereotypes, and barriers that prevent students from seeing themselves in STEM learning in the classroom (Delpit, 1995).

According to Banks (2009), transformations to curriculums are processes that never end because of continuous changes within the United States and the world. Banks & Banks (2010) argue that teachers who continued to center curriculum on the experiences of mainstream Americans and failed to acknowledge the experiences, cultures, and histories of ethnically, racial, cultural, language, and religious diverse groups, were associated with negative consequences for both mainstream students and underrepresented students. To educate students for a culturally diverse world, teachers much include the perspectives and voices of those who are not traditionally included in curriculum. Banks & Banks (2010) also argue that cultural induced curriculum allowed students to view their own culture through lenses of other diverse cultures. Hence, these experiences help provide students with opportunities to understand their own culture more richly, to discover how unique and different they are form other cultures, and to also understand how their culture relates to other cultures.

Ultimately, culturally responsive instruction deals with studying a wide range of ethnic individuals and groups and including multiple kinds of knowledge and perspectives during instruction (Gay, 2002). Gay (2010), advised teachers who wished to adopt culturally responsive principles to acquire more knowledge about the contributions of different ethnic groups from a wide variety of disciplines; make changes to curriculum to improve their overall quality and multicultural strengths; focus on the quantity, accuracy, and authenticity of narrative texts, visual illustrations, learning activities, role models, and sources used in instructional materials. Culturally responsive instructional activities can also include: discussion about ethical icons, diversity celebrations, use of cultural artifacts, cultural bulletin board decorations, images of diverse heroes and heroines, trade books, and activities where students learn valuable lessons about ethnic and cultural diversity in a particular subject area (Gay, 2002; 2010; Aronson & Laughter, 2016)

Prodigygame.com, a well-known website for engaging teachers and students in games and platforms provides 15 ways a teacher can make lessons more culturally-responsive by

- Learning about their students;
- Interviewing their students by finding out their hobbies, and favorite lessons and activities;
- Integrating relevant word problems;
- Presenting new concepts by using student vocabulary;
- Bringing in guest speakers;
- Delivering different forms of content through learning stations to understand how students interact and learn in different stations;
- Gamifying lessons to help students within different cultures demonstrate better understanding of content;
- Calling on each student to keep them engaged while enabling them to share their thoughts and opinions;
- Using media such as books and movies that positively depicts a range of cultures;
- Using various types of free study time such as audiobooks, dedicated quiet space for students to complete work, or stations for group games;
- Encouraging students to propose ideas for projects;
- Experimenting with peer teaching activities that involve students discussing and rationalizing concepts in their own words;
- Establishing cooperative base groups;
- Run problem-based learning scenarios; and
- Involving parents by using take home letters.

Each of the above culturally responsive instructional strategies were developed to help educators to teach more effectively for our growing diverse student population.

PREPARING A CULTURALLY RESPONSIVE LESSON

In addition to culturally responsive instructional strategies found throughout literature, there are a number of instruments to support teachers in preparing culturally responsive lessons. The authors created a culturally responsive science teaching lesson analysis tool, Science Lesson Analysis Tool (SLAT) that could be used to promote intentional teaching discussions and critical reflection on science lessons with a combined focus on student's science thinking and equity. This instrument is adapted from the National Center for Research in Mathematics Education (1992), Wisconsin Center for

Educational Research Madison, WI, University of Wisconsin-Madison and Bartell, & Foote (2012). This analysis tool is to be used as a self-reflective professional tool that supports the implementation of a science lesson/unit design for teachers. There are six important categories of the SLAT. Each category connects to a rubric rating scale 1-5 that provides descriptors of classroom practice including task design, implementation, and interaction. In addition, there are corresponding reflection prompts to help with lesson analysis (Table 1 & Table 2).

To help teachers get started in using the SLAT it is suggested that three strategies be introduced before the tool is actually used in the class. These strategies are listed below:

- Analyze a videotaped lesson using the Science Lesson Analysis Tool (SLAT). Some good videos are available at www.learner.org. In pairs, rate the lesson based on evidence from the video. Discuss ratings and evidence with a peer.
- Analyze a lesson plan using the tool. Check how your lesson plan reflects these various dimensions. After your analysis, brainstorm with a peer what adaptions you can make to make the lesson more culturally responsive.
- Have a peer use the tool to give feedback on an observed lesson. Select one category from categories 1-3 and one from categories 4-6. Make a conscious effort to focus your instruction and feedback based on those selected categories.

Table 1. Science lesson analysis tool (SLAT)

	Category	Reflection Prompts
1	Cognitive Demand	How does my lesson enable students to closely explore and analyze science concepts(s) and procedure(s)/
2	Depth of Knowledge & Student Understanding	How does my lesson make student thinking/understanding visible and deep?
3	Science Discourse	How does my lesson create opportunities to discuss Science in meaningful and rigorous ways (e.g. critical thinking, problem solving, use scientific method, develop explanations, communicate inquiry, and/ or generalize)?
4	Power and Participation	How does my lesson distribute Science knowledge authority, value student science contributions, and address status differences among students?
5	Academic Language Support for ELL	How does my lesson provide academic language support for English Language Learners?
6	Cultural/Community-based funds of knowledge	How does my lesson help students connect science with relevant/ authentic situations in their lives? How does my lesson support students' use of to understand, critique, and change an important equity or social justice issue in their lives?

Table 2. Guiding questions: how does my lesson enable students to closely explore and analyze math concepts(s), procedure(s), and reasoning strategies?

Category Rating	1	2	3	4	5
1) Cognitive Demand	Students receive, recite, or memorize facts, procedures, and definitions. There is no evidence of conceptual understanding being required. No opportunities for mathematical analysis or exploration	Students primarily receive, recite, or perform routine procedures without analysis or connection to underlying concepts or mathematical structure. Some opportunities for mathematical exploration, but tasks do not require analysis to complete.	There is at least one sustained activity involving analysis of procedures, concepts, or underlying mathematical structure. There is at least 1 sustained activity that requires mathematical exploration and analysis	At least half of the lesson includes task(s) that require close analysis of procedures, concepts or underlying mathematical structure. Or tasks that require significant mathematical analysis, involves complex mathematical thinking, utilizes multiple representations or demands explanation/justification There is evidence of sustained mathematical analysis for at least half of the lesson.	The majority of the lesson includes task(s) that require close analysis of procedures and concepts, involves complex science thinking, utilizes multiple representations AND demands explanation/justification A large majority of the lesson sustains mathematical analysis.
Guiding Question: How does my lesson make student thinking/understanding visible and deep?					
1) Cognitive Demand	Students receive, recite, or memorize facts, procedures, and definitions. There is no evidence of conceptual understanding being required. No opportunities for mathematical analysis or exploration	Students primarily receive, recite, or perform routine procedures without analysis or connection to underlying concepts or mathematical structure. Some opportunities for mathematical exploration, but tasks do not require analysis to complete.	There is at least one sustained activity involving analysis of procedures, concepts, or underlying mathematical structure. There is at least 1 sustained activity that requires mathematical exploration and analysis	At least half of the lesson includes task(s) that require close analysis of procedures, concepts or underlying mathematical structure. Or tasks that require significant mathematical analysis, involves complex mathematical thinking, utilizes multiple representations or demands explanation/justification There is evidence of sustained mathematical analysis for at least half of the lesson.	The majority of the lesson includes task(s) that require close analysis of procedures and concepts, involves complex science thinking, utilizes multiple representations AND demands explanation/justification A large majority of the lesson sustains mathematical analysis.

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Table 2. Continued

Category Rating	1	2	3	4	5
Guiding Question: How does my lesson make student thinking/understanding visible and deep?					
2) Depth of Knowledge and Student Understanding	Knowledge is very thin because concepts are treated trivially or presented as non-problematic. Students are not involved in the coverage of information they are to remember.	Knowledge remains superficial and fragmented. Underlying or related concepts and ideas might be mentioned or covered, but only a superficial acquaintance or trivialized understanding of these ideas is evident. Knowledge is treated unevenly during instruction.	Knowledge is treated unevenly during instruction. Deep understanding of some mathematical concepts is countered by superficial understanding of some other ideas. At least one idea may be presented in depth and its significance grasped by some (10%-20%) students, but in general the focus is not sustained.	Knowledge is relatively deep because the students provide information, arguments, or reasoning that demonstrates the complexity of one or more ideas. The teacher structures the lesson so that many students (20%-50%) do at least one of the following: • sustain a focus on a significant topic for a period of time; • demonstrate their understanding of the problematic nature of information and/or ideas; • demonstrate understanding by arriving at a reasoned, supported conclusion; • explain how they solved a relatively complex problem.	Knowledge is very deep because the teacher successfully structures the lesson so that most students (50%-90%) do at least one of the following: • sustain a focus on a significant topic; • demonstrate their understanding of the problematic nature of information or ideas; • demonstrate complex understanding by arriving at a reasoned, supported conclusion; • explain how they solved a complex problem. In general, students' reasoning, explanations, and arguments demonstrate fullness and complexity of understanding.

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Table 2. Continued

Category Rating	1	2	3	4	5
Guiding Question: **How does my lesson create opportunities to discuss science in meaningful and rigorous ways (e.g. debate science ideas/solution strategies, use science terminology, develop explanations, communicate reasoning, and/or generalize)?**					
3) Science Discourse & Communication	Virtually no features of mathematical discourse and communication occur, or what occurs is of a fill-in-the-blank nature.	Sharing and the development of collective understanding among a few students (or between a single student and the teacher) occur briefly	There is at least one sustained episode of sharing and developing collective understanding about mathematics that involves: (a) a small group of students or (b) a small group of students and the teacher. OR brief episodes of sharing and developing collective understandings occur sporadically throughout the lesson.	There are many sustained episodes of sharing and developing collective understandings about mathematics in which many students (20%-50%) participate	The creation and maintenance of collective understandings permeates the entire lesson. This could include the use of a common terminology and the careful negotiation of meanings. Most students (50%-90%) participate
Guiding Question: How does my lesson distribute math knowledge authority, value student math contributions, and address status differences among students?					
4) Power and Participation	The authority of math knowledge exclusively resides with the teacher. Mathematical contributions in lesson are almost exclusively from the teacher. Teacher has final word about correct answers/solutions. Student mathematical contributions are minimal. Status differences among students are evident.	The authority of mathematics knowledge primarily resides with the teacher and a few students. Teacher calls on/involves a few students. Their mathematical contributions by students are valued and respected. Student involvement is from a particular subgroup (gender, language, ethnicity, class, disability). Status differences among students remain intact and unaddressed.	The authority of math knowledge between teacher and students is **sporadically** shared. At least one instance where the teacher calls on several students so that multiple mathematical contributions are accepted and valued. Teacher elicits some substantive math contributions. At least 1 strategy to minimize status differences among students (and specific subgroups) is evident.	The authority of math knowledge is shared between teacher and students. Multiple forms of student mathematical contributions are encouraged and valued. Teacher and students elicit substantive mathematics contributions. Some strategies to minimize status differences among students (and specific subgroups) throughout the lesson are evident	The authority of math knowledge is **widely** shared between teacher and students. All mathematical contributions are valued and respected. Student mathematical contributions are actively elicited by teacher and among students. Multiple strategies to minimize status among students (and specific subgroups) are explicit and widespread throughout the lesson.

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Table 2. Continued

Category Rating	1	2	3	4	5
Guiding Question: How does my lesson provide academic language support for English Language Learners?					
5) Academic Language Support for ELLs	No evidence of a language scaffolding strategy for ELLs. Students who are not yet fully proficient in English are ignored and/or seated apart from their classmates.	Although there is no explicit use of language strategies for ELLs, students' use of L1 is tolerated. Focus on correct usage of English vocabulary.	There is at least one instance in which a language scaffolding strategy is used to develop academic language (i.e., revoicing; use of cognates; translated tasks/text; use of graphic organizers; strategic grouping with bilingual students).	Sustained use of at least a couple of language strategies, such as the use of revoicing and attention to cognates, direct modeling of vocabulary, use of realia, strategic grouping of bilingual students or encouragement of L1 usage is observed at least between teacher and one, or small group, of students.	Deliberate and continuous use of language strategies, such as gesturing, use of objects (realia), use of cognates, revoicing, graphic organizers and manipulatives are observed during whole class and /or small group instruction and discussions. The main focus is the development of mathematical discourse and meaning making, not students' production of "correct" English.
Guiding Question: How does my lesson help students connect mathematics with relevant/authentic situations in their lives?					
6a) Funds of Knowledge	No evidence of connecting to students' cultural funds of knowledge (parental/ community knowledge, student interest). Lesson incorporates culturally neutral contexts that "all students" will be interested in.	There is at least one instance in connecting math lesson to community/cultural knowledge and experience. Lesson draws on student knowledge and experience. Focus is with one student or a small group of students.	There is at least one sustained episode of sharing and developing collective understanding about mathematics that involves connecting to community/ cultural knowledge. Or, brief episodes of sharing and developing collective understandings occur sporadically throughout the lesson.	There are many sustained episodes of sharing and developing collective understandings about mathematics that involves connecting to cultural/ community knowledge (e.g. student experiences are mathematized, student/ parent connections with math work; math examples are embedded in local community/cultural contexts and activities – i.e. games).	The creation and maintenance of collective understandings about mathematics that involves intricate connections to community/cultural knowledge and permeates the entire lesson. This would include hook/intro, main activities, assessment, closure and homework. Students are asked to analyze the mathematics within the community context and how the mathematics helps them understand that context.

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Table 2. Continued

Category Rating	1	2	3	4	5
Guiding Question: How does my lesson support students' use of mathematics to understand, critique, and change an important equity or social justice issue in their lives?					
6b) Use of critical knowledge/social Justice support	No evidence of connection to critical knowledge (socio-political contexts, issues that concern students)	Opportunity to critically mathematize a situation went unacknowledged or unaddressed when present.	There is at least one instance of connecting mathematics to analyze a sociopolitical/ cultural context.	There is at least one major activity in which students collectively engage in mathematical analysis within a sociopolitical/authentic or problem-posing context. Mathematical arguments are provided to solve the problems. Pathways to change/ transform the situation are briefly addressed.	Deliberate and continuous used of mathematics as an analytical tool to understand an issue/context, formulate mathematically-based arguments to address the issues and provide substantive pathways to change/transform the issue.

Note. Adapted from National Center for Research in Mathematics Education. (1992). Wisconsin Center for Educational Research. Madison, WI: University of Wisconsin-Madison. Also adapted from Aguirre & Zavala (In Press) CEMELA (2007), Kitchen (2005) and Turner, Drake, Roth McDuffie, Aguirre, Bartell, & Foote (2012). Aguirre, Turner, Bartell, Drake, Foote & McDuffie (2012). Please cite: TEACH MATH (2012)

In addition to the use of the SLAT, teachers can also use a lesson plan template that assist with creating culturally responsive lesson/unit designs (Table 3). This instrument was adapted from a lesson plan template used by elementary education teacher candidates in Curriculum & Teaching in the College of Education where one of the authors serves as the methods instructor. The lesson plan is a performance-based, subject-specific assessment. The template has an in-depth 5E lesson plan (learning cycle) format that allows teachers to reflect on their lesson by addressing a series of questions that ensures the teacher organizes a lesson around inquiry. This lesson plan template is also organized to provide clear goals and is designed to explore essential learning that will address differential learning styles for all students along with promoting critical discussion and reflection on science lessons with an integrated focus.

Table 3. Science culturally responsive lesson plan

Preliminary Information	
Created by: **Teacher A**	**Date developed:**
Lesson Title:	**Date of lesson:**
Grade Level/ Subject:	**Number of students:**
Unit/Theme:	**Period/Time/Estimated Duration:**
Where in the unit does this lesson occur? (Beginning, middle, or end?):	**Structure(s) or grouping for the lesson** (Select all that apply) Whole class, small group, 1:1: Other (specify):
What information will you share about how your lesson support culturally responsive teaching, the context, including diversity among the students?	
Resources and materials required for the lesson (e.g. textbook(s), module, equipment, technology, art materials):	
1. What are your goals for student learning and why are they appropriate for these students at this time?	
Big Idea or Concept Being Taught - - ESSENTIAL QUESTION **How are forces and motion used in day to day life?**	
Content Standards (Include the AL College & Career Readiness Learning Standards or Next Gen Sc. Standards addressed in this lesson. For CCSS, list strand, grade, and standard number, e.g., RI.4.3 Reading informational text, grade 4, anchor standard 3, and write out the standard.) **These are based on the appropriate state standards and the (NGSS)** **Next Generation Science Standard**	
Rationale/Context for Learning - - JUSTIFICATION FOR YOUR PLANS (Why this lesson at this time, for this group of learners? How does it connect to previous learning or succeeding lessons?)	
Prior Knowledge and Conceptions (What knowledge, skills and/or academic language must students already know to be successful with this lesson?)	

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Table 3. Continued

Prior knowledge: **Prior skills:** **Prior academic language** (ex figurative language, water cycle or multiplication): **Prior academic vocabulary** (similes, precipitation, or product):
Learning Objective(s) (These must be behavioral & measurable.) **STATEMENTS OF WHAT STUDENTS WILL <u>BE ABLE TO DO</u> AT THE END OF THE LESSON**
[Teacher version] Students will demonstrate . . . [**Learning target=**Student version] We will be able to . . . *or* I can . . .
2. How will you know and document students' progress towards meeting your learning objectives?
Evidence and Assessment of Student Learning (How will you know students are meeting objectives? What tools will measure their progress? How will feedback be provided to promote learning?)
Before/ Diagnostic/pre-assessment(s): **During Formative assessment(s)/feedback to learners:** **After assessment(s):**
Expectations for Student Learning - - STANDARDS & CRITERIA (Describe in detail the following levels of student performance. What will students' work look like when it exceeds expectations? When it meets expectations? When it falls below expectations? How will you communicate these expectations to students? Provide any rubrics you will use.)
Exceeds expectations: **Meets expectations:** **Below expectations:**
3. How will you support students to meet your goals? Describe EXPLICITLY what you will do! Scripting with bullets is extremely helpful. Put what you will say in regular font, expected answers should be underlined and things you will do (such as passing out materials to each table) will be in italics.
ENGAGE: Launch/Hook/Anticipatory Set (How will you get the lesson started? What questions, texts, inquiry, materials, modeling, and/or other techniques will you use to engage students? Initiate the learning tasks by accessing prior knowledge and learning experiences and mentally engaging students in the concept, process or skill to be explored. List at least 2 higher order thinking questions or tasks within the scripted portion of this lesson. Be sure to include the main answers/ points you want to draw from students in this section of the lesson and from each question/ task).
EXPLORE: Instructional Strategies to Facilitate Student Learning (Provide a <u>common base of experience</u> within which students identify and develop current concepts, processes or skills. Students use 'active' learning to manipulate materials or explore the environment. How will you engage students with ideas/texts/ materials to develop understandings? What questions will you ask? Be sure to list at least 2 higher order thinking questions/ phrases within the script & the main answers/ points you want to draw from students in this section of the lesson. How will you address the academic language demands? **Detail your plan.** Note: For math lesson plans, please write or attach every task/problem that students will solve during the lesson – with the correct answers).
EXPLAIN: Instructional Strategies to Facilitate Student Learning (Provide opportunities for learners to develop explanations of concepts that they have been exploring. Students must verbalize conceptual understanding, demonstrate skills, and attach formal labels and definitions to new ideas. How will you engage students in debriefing and building on the exploration of ideas/texts/ materials to develop understandings? What questions will you ask? Be sure to list at least 2 higher order thinking questions/ phrases within the script & the main answers/ points you want to draw from students in this section of the lesson. How will you address the academic language demands? **Detail your plan.** Note: For math lesson plans, please write or attach every task/problem that students will solve during the lesson – with the correct answers.).

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Table 3. Continued

ELABORATE & EVALUATE: Closure (How will you develop in learners deeper and broader understanding and practice, applying newly acquired skills and behaviors to new or practical situations (such as related this to issues beyond the classroom or using the information in a new way? How will you end the lesson in a way that promotes student learning and retention? List at least 2 higher order thinking questions/ phrases or tasks in this section. Be sure to include the main answers/ points you want to draw from students in this section of the lesson. Be sure to clearly explain how you will learn if the students are able to do the objective.)
Differentiation/Extension (How will you provide successful access to the key concepts by all the students at their ability levels?
Supporting students with special needs (this includes an explicit and specific description of how you will implement accommodations/ modifications required by IEPs/504 Plans and other ways that you will address diverse student needs. If you do not have a student who meets this criterion, you still need to list a way you would support a student with a special need in this lesson): **Supporting ELL students:** **Challenging Early finishers:**
References (Cite all sources used in the development of this lesson including URLs or other references).
Reflection
1. What when well? What evidence do you have that it went well? 2. What didn't go well? What did you change because it wasn't going well?

Note. Adapted from lesson plan used by Elementary Education Program in Curriculum & Teaching to support EdTPA evaluation.

SUMMARY

The U.S. has persistent inequities in access, participation, and success in STEM subjects that directly affect underrepresented students' choice to persist in STEM disciplines. These inequities in STEM education threaten the nation's ability to close education and poverty gaps, meet the demands of a technology-driven economy, ensure national security, and maintain preeminence in scientific research and technological innovation (Tanenbaum, 2016). In January 2016, Obama solicited educators to fully invest in all four STEM disciplines for all children, including underrepresented students (Elementary and Secondary Education Act [ESEA], 2016). Educators, teachers, or teacher candidates can promote positive STEM learning for all students through implementation of culturally responsive teaching. Culturally responsive teaching generates change and improvement of learning for all students of socioeconomic class, language, ethnicity, and/or sex/gender. All students should be equally exposed to STEM learning in ways that they can identify and see themselves in the mist of the learning processes. Providing learning opportunities that involves students' cultural identities and descriptions, empowers and provides underrepresented and mainstream students with a desire to learn more about subjects that they can connect with. Teachers who teach culturally responsive are responsible for promoting lifelong learning that leads underrepresented students to believe that they can understand STEM in such a way that they too can shape the world by becoming the next generation of professionals in U.S. STEM careers.

CONCLUSION

There has been an increasing call over the past decade for connecting and integrating the four disciplines of STEM into elementary and secondary education (Honey, Pearson, & Schewingruber, 2014; van Ingen, Davis, & Arndt, 2018). Although integration of culture into curriculum is a necessary component for the success of the U.S. STEM workforces, few studies have focused on the importance of examining STEM pipeline persistence with a particular emphasis on STEM development for underrepresented students in elementary and secondary education. However, there is substantial evidence supporting the notion that the use of integrated STEM lessons creates positive effects and help influence students' interest and pursuit of STEM careers, but there is still ample evidence that underrepresented groups are not represented as profusely as mainstream groups in STEM disciplines (Wyss, Heulskamp, & Siebert, 2012; van Ingen, Davis, & Arndt, 2018). Moreover, teachers cannot afford to dismiss the integration of culture with STEM learning any longer. All teachers, especially elementary and secondary teachers, should be held at a very high standard to educate our increasingly diverse student population, ignite student's desire to learn science, and implement effective instruction that prepares a more diverse group of future scientists (Ladson-Billings, 2005). Furthermore, teachers who desire to effectively teach STEM, are able to enhance learning in a way that could lead to the development of a more diverse scientific pool of applicants that exploits "untapped talent and unlimited potential" (Ladson-Billings, 2005; Russell, 2005; Asim, 2018; Michaluk et al., 2018).

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KEY TERMS AND DEFINITIONS

Culturally Responsive Instructional Strategies: Strategies that involve learning goals that meet the needs of students from all culturally diverse backgrounds. Culturally responsive instructional strategies involve a teacher's dedication to building rapport with students both inside and outside of the classroom; including students' cultural heritages in lessons and activities; and/or developing and strengthening curriculum that involves multicultural learning.

Culturally Responsive Teaching: This theory involves teaching that initiates multicultural learning in the classroom. Individuals who implement culturally responsive teaching, work to include diverse cultural knowledge, multicultural experiences, and diverse learning styles for students from all culturally diverse backgrounds to see themselves in classroom learning.

STEM Disciplines: Science, technology, engineering, and math (STEM) disciplines that also include but are not limited to life sciences, physical sciences, computer sciences, and health sciences.

STEM Education: Education that focuses on standards-based, inquiry-based, and real world problem-based learning involving Science, Technology, Engineering, and Math disciplines.

Teacher Candidates: Individuals enrolled in a pre-service curriculum & teaching preparation program to obtain his/her certified teaching license.

Underrepresented Students: Students from racial and ethnic backgrounds who are not represented well in STEM disciplines and/or STEM occupations. These students consist of African American students, American Indian and Alaskan Native students, and/or Hispanic or Latino/a/x students.