Enacting Culturally Relevant Pedagogy for Underrepresented Minorities in STEM Classrooms: Challenges and Opportunities

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Keywords: culturally relevant pedagogy, culturally relevant teaching, racial/ethnic minorities, STEM.

Introduction

Historically, the process of learning and teaching has been theorized from the perspective of novice and experienced practitioners [1]. However, in the 1990s, a period that has come to be described by some as the golden age of resource pedagogy research [2], a change came to the deficit-based thinking that underscored earlier theories of learning, particularly for marginalized populations like children of color. In her seminal work, Gloria Ladson-Billings [3] published her theoretical framework for culturally relevant pedagogy (CRP). As she proposed, for pedagogy to be described as culturally relevant, it needed to satisfy three criteria: foster academic achievement among students, develop students who demonstrate cultural competence, and support students' growth of critical consciousness. To practice CRP in the classroom, culturally relevant teachers were required to consider three core components: their *conception of themselves and others*; their *conception of knowledge*; and how they *structured social relations and interactions in the classroom* [4]. For close to three decades, many empirical studies have shed light on the difficulties associated with enacting culturally relevant pedagogy in elementary to high school classrooms, whether from the perspective of teachers [5] or specifically related to the teaching of science and math [6]. In this article, we synthesize some of these difficulties and highlight the solutions that have been proposed in response to those challenges.

Method

We performed a systematized review of relevant literature [7] on culturally relevant pedagogy in this work. A total of 35 articles were included in this study. We thematically structured

our findings from the review by grouping the challenges identified under the three core components described by Ladson-Billings. In this section, we discuss the process by which we defined our inclusion criteria. These begin with a clear articulation of our research topic, its alignment with our research questions, the selection of a search strategy, and the preliminary analysis of the articles found.

Research Questions

Our research questions are as follows: what are the challenges associated with enacting culturally relevant pedagogy in teaching underrepresented minorities in secondary and post-secondary STEM-classrooms; and, what are some potential solutions that have been proposed to these challenges? In defining inclusion criteria for the selection of literature for this systematized review, we referenced the stepwise process described by Borrego, Foster, and Froyd by considering a set of combinations of search words, selecting appropriate databases, and identifying guidelines for selecting and analyzing the articles.

The following keywords were extracted from the research questions search – "culturally relevant pedagogy" and "STEM". For each keyword, the synonyms and the explanations are presented in Table 1.

Table 1. Search string keywords, synonyms, and justifications

Keywords	Synonyms	Justification
CULTURALLY RELEVANT	Culturally responsive; culturally inclusive; culturally sensitive	These synonyms were suggested by experts in the field and justified after a preliminary review of the literature
PEDAGOGY	Teaching; Teacher; Instruction; Instructor; Education	These words have been used synonymously with pedagogy in the literature and were all considered in this search string
STEM	Science, technology, engineering, mathematics, math, or maths	Since 2001, the STEM acronym introduced by scientific administrators at the U.S. National Science Foundation (NSF) has become synonymous with science, tech, engineering, and mathematics education

SEARCH STRING
(culturally relevant or culturally responsive or culturally inclusive or culturally sensitive) AND (pedagogy or teaching or teacher or instruction or instructor or education) AND (stem education or science or technology or engineering or mathematics or math or maths)

Search Database

The topic informed the choice of the following subject-specific databases used in conducting the search:

- Education Research Information Centre, ERIC – an online digital library for education research and information.
- Education Source – the world's largest and most complete source of full-text educational journals [8].

For the search string, we used OR logic operators for the synonyms. Then, all search results were combined using AND logic operators to find results that appeared at the intersection. Following this process, ERIC turned out 1758 articles and Education Source 1362.

Search Guide (Inclusion criteria)

The specific inclusion/exclusion criteria prescribed to increase the validity and reliability of the articles for this literature review are:

1) Sources: Articles present in a scholarly/peer-reviewed study and published in an academic journal (to justify validity, reliability, and replicability of search results); conference papers; books; and book reviews.
2) Year of Publication: We decided to scope our articles to those published after the year 1990, the year Gloria Ladson-Billings published her foundational work [9], which led to the proposition of culturally relevant pedagogy.
3) Target class/subject area: Articles that focused on studies conducted in classes lower than post-secondary education were considered.
4) Language: Articles published in the English Language.

After these limiters were applied, the articles from ERIC reduced to 326, the articles from Education source to 51. A web citation management tool was used to remove 46 duplicate articles. Stricter inclusion and exclusion criteria were considered in order to get articles that were specific to the research questions. Again, aligning closely with the aim of the research, the following criteria were introduced in screening the abstracts of the primary articles:

5) Research participants/focus: Articles focused on either students' learning or teacher's needs or both; research focusing on the experiences and challenges of minoritized groups or less dominant cultures in multiracial or multicultural settings. To scope our work, our review centered on formal and informal STEM classrooms in the USA.

After this process, 279 articles were excluded. Of the 52 that were left, 17 articles were also removed in relation to the subject matter of this paper. The following criterion was considered:

6) Subject matter: Article talks about culturally relevant pedagogy under the following subcategories – learning and teaching, history, potential, epistemology, impact, problems, limitations, understanding, expanding, opportunities for CRP.

Thirty-five articles were selected for the final review. The selection process is captured in Figure 1.

Selection Process

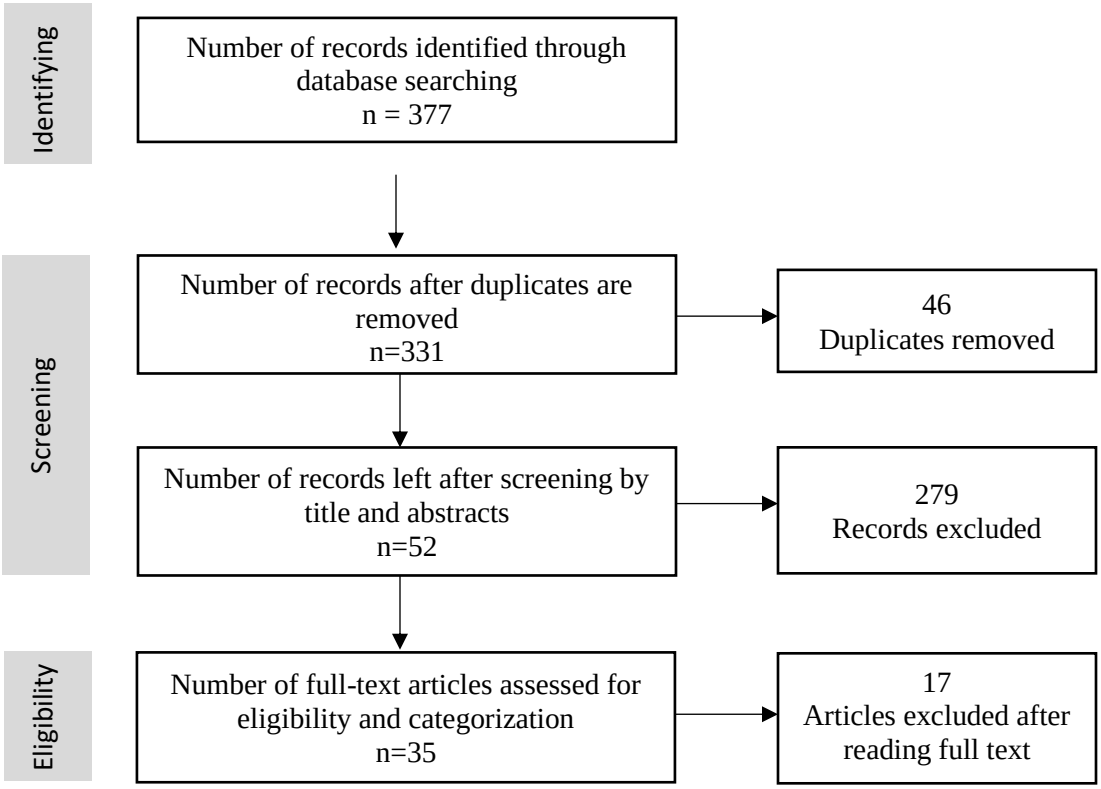

Figure 1. Search and selection process extracted from the PRISMA flow. Adapted from [10, p. 4].

Analysis

Research suggests that a rubric can be used for organizing research component findings in tables [11], [12]. We used tables to categorize our findings and developed themes as suggested by Harden and Thomas [13]. For this systematized literature review, we conducted a three-step analysis. In the first pass, we assessed the abstracts of the primary articles to generate an overview.

In the second, we performed an in-depth analysis of findings of the articles by reading in detail, the methods sections, the results and the discussions in each article with a focus on the difficulties and opportunities associated with enacting culturally relevant pedagogy in STEM classrooms. In the third pass, we looked for general themes that emerged as common threads across the articles, referencing the tables as well as the primary articles in the process.

Results

Our findings revealed that cultural discontinuity, epistemological dissonance, linguistic barriers posed by technical jargon, and restrictive school policies were among the most common difficulties associated with culturally relevant pedagogy in STEM classrooms. We categorize our discussion of these findings under the three core components: teachers' *conception of themselves and others*; their *conception of knowledge*; and how they *structured social relations and interactions in the classroom* [4].

Difficulties associated with enacting CRP

Regarding *the conception of "self and others"*, teachers struggle to recognize and address their own biases and how they relate to others. They either wrongly infer their students' academic capabilities [14], fail to recognize the existence of systemic forms of oppression and inequality around them [15], or struggle to assimilate into the local communities of their students due to historically established racial discords [5]. Thematically categorized as cultural discontinuity, we found many cases where teachers felt out of touch with the experiences of their students, by virtue of their lived experiences, which were culturally different from their students' home, community, and school experiences. As an example, a systematized literature review article suggested the need to recognize that cultural discontinuity exists between gifted girls of color and their teachers [16]. Notably, this cultural distance was not guaranteed to be bridged even if the teacher themselves were teachers of color. Cultural discontinuity was a key factor that many studies had found to be

an impediment for teachers and students to be able to fully interact, particularly outside the classroom as they attempted to enact CRP [5], [17], [18].

With regard to the *conception of knowledge*, teachers have reported dissonance between the constructivist perspectives of CRP and the objectivity demanded in the "hard science" and math subjects that they taught [6]. Thematically categorized under epistemological dissonance, we identified the challenge that teachers faced as they attempted to reconcile the epistemological foundations of their discipline with the constructive, critical elements that CRP required [14], [19]. This case was particularly highlighted by high school math teachers as they attempted to employ CRP in their mathematics classes [6, p. 12].

In analyzing the challenges posed by the *structure of classroom interactions*, we employed a systemic view of formal and informal school environments, the mode of knowledge propagation within these environments, and the intermediating factors which affect them. Our review revealed that teachers believed that technical language serves as a significant barrier for linguistically and culturally diverse students to learn STEM. Also, formal learning environments were restrictive in terms of classroom and school policies, while teachers demanded more time to structure and deliver lessons that were culturally relevant. Finally, due to misconceptions about cultural norms, teachers wrongly diagnosed the behaviors of racially dissimilar students as rude, leading to a higher rate of disciplinary action against racially minoritized students especially blacks, than their white peers.

Participants of one study expressed concerns about adding an extra layer of difficulty for students in reconciling the objective/universal jargon of STEM. Teachers have reportedly complained that language unavoidably serves as an unnecessary barrier to learning, leading them to ask whether the goal is to test for vocabulary or STEM reasoning [14]. Using words or

expressions that students are not familiar with in exams could throw students off, leading them to make mistakes that are not intended and are not accurate representations of students' aptitudes.

Teachers enacting CRP in STEM classrooms expressed concern over the need to submit to and uphold school policies in the classroom while trying to provide students with the best environment to help them succeed. This showed up in two ways. First, teachers were concerned about their school requirements for students to perform exceptionally in standardized tests [14]. Second, some teachers were unsure how to provide students with the freedom to work in ways they felt most comfortable without squinting over certain school policies. For example, in a study, teachers mentioned that some of their students liked to listen to music in the classroom, as it helped them concentrate and it boosted their performance, but this was not allowed in the school policy [6].

Finally, to effectively teach culturally relevant STEM classes, teachers reportedly demanded time to plan lessons and make learning meaningful. However, the findings from the review of the literature suggest that traditional classroom settings are limited in the provision of the time and space teachers need. As an example, a mixed-methods study conducted with attendees of a conference workshop designed to help high school and middle school mathematics teachers become culturally responsive educators found that some of the major challenges that teachers face in CRP implementation were logistic – specifically, the time taken to design and execute class sessions [19].

Opportunities for Culturally Relevant Pedagogy in STEM Classrooms

Our review also identified various opportunities for CRP in STEM classrooms, which include informal and out-of-school time (OST) STEM learning spaces, systematic teaching of STEM language, complementarity of inquiry-based and culturally responsive teaching,

multicultural stories as pedagogical tools, and parental and community involvement as valid funds of knowledge (see Table 2).

A literature review with gifted girls of color recommended using informal and OST STEM learning spaces as great avenues to solve the issue of restrictive school policies, time demand, and cultural discontinuity [16]. OST, they suggested, provides a wide range of content-rich opportunities in the hours outside of school, including summer camps [20], which would be impractical in many traditional school settings. Furthermore, OST and informal learning spaces such as worksites, STEM businesses, science labs, museums, and imagination stations could reinforce students' connections outside the class. This recommendation seems fitting as some teachers had complained about not having enough time to culturally engage with students in school-prescribed times [19]. Further, it allows teachers to build cultural ties with students and their communities outside the school.

A paper suggested ways by which linguistic challenges with STEM can be solved for STEM teachers and their students. Technical jargon can be taught systematically, for example being intentional about helping students realize that terms such as ''solve for,'' ''find,'' and ''evaluate'' are synonyms. Teachers can be explicit about linguistic changes made to questions making sure tests are accurate assessments of students' intended learning outcomes and not vocabulary [14]. Another recommendation from the article was that STEM educators should be exposed to non-STEM vocabulary as well to make connections more meaningful for students.

Parental involvement has been found to be one of the strongest predictors of school success for children, especially for English language learners [21]. The case to expand the vision of parental involvement is therefore valid [22]. Thus, if teachers view parents as valuable allies and not adversaries [23], research suggests that they can help to address the issue of cultural discontinuity by further serving as conduits to broaden the scope of students' funds of knowledge

[18] and a means for teachers to be better acculturated into the students' communities. More broadly, the communities and their extended kinship and guardianship networks, serve as key allies for teachers enacting CRP. Parents and others in the community can be out-of-school, complementary resources for teachers. Parents and senior members of the community are sources of funds of knowledge [29] that teachers can draw on to enact more culturally relevant teaching practices.

Conclusion

Today, there is a high demand for teaching that is culturally relevant to the diverse body of students that receive formal and informal STEM education. However, enacting culturally relevant pedagogy for underrepresented minorities in STEM comes with many challenges. While the conception of knowledge, of the self and others, and the structure of classroom interactions serve as essential components of CRP, each poses peculiar challenges to teachers and students including cultural discontinuity, epistemological dissonance, linguistic barriers posed by technical jargons, and restrictive school policies. To address each of these challenges, this review reveals that teachers need to learn to reconcile the epistemological dissonance they experience between the foundational beliefs of their STEM disciplines and the constructivist nature of a culturally responsive classroom. They also need to recognize that the technical jargon that poses an extra layer of difficulty for linguistically and culturally diverse student populations can be systematically taught. Also, and certainly not least of all, teachers need to recognize that informal and out-of-school STEM learning spaces can circumvent the challenges of restrictive school policies and the demand for more time with students and opportunities to pool from existing funds of knowledge while involving parents and assimilating into the society.

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Appendix

Table 2. Findings and critical comments from SLR articles

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
"It's important for them to know who they are": Teachers' efforts to sustain students' cultural competence in an age of high-stakes testing [24]	Urban elementary school teachers in Texas	Ethnographic study; over 130 observations of classrooms and meetings.	• Classroom texts are designed and intended for a monocultural population.	• Linguistic barriers to conception of knowledge
"It's worth our time'': A model of culturally and linguistically supportive professional development for K-12 STEM educators [14]	K-12 STEM Educators; Maryland, Virginia	Mixed methods; pre- and post-workshop surveys, interviews.	• Linguistic microaggressions - everyday biases and indignities faced by members of marginalized groups that can result in damaging psychological and social consequences [25]. • Common concern among participants: how to reconcile the common belief that STEM jargon and subject matter are more objective or universal, as opposed to the humanities or ''soft'' sciences. • Authors assert that he language of STEM can be taught systematically, so that educators can help balance the burden of	• Linguistic microaggressions • Epistemological dissonance • STEM language can be taught systematically

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
			communication for students in their classrooms.	
A case for culturally relevant science education in the summer for African American youth [20]	High school students in Southeastern US	Focus group interviews	• Guest speakers of color (most significant for students); knowledge for future aspirations	• Opportunities for STEM in OST
A case for culturally relevant teaching in Science education and lessons learned for teacher education [26]	Elementary pre-service teachers	Qualitative interviews	• PSTs need collaborative support with diverse others • PSTs need to teach in language that resonate with students, elicits students' roles, empowers them to learn and do science	• Allies, out-of-class resources for teachers • STEM language can be taught systematically
A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning [27]	K-12 science education;	Literature review; 52 articles	• Ongoing debates of the irreconcilable epistemological incompatibility between inquiry-based science instruction in K-12 settings and culturally responsive learning experiences [28] • Complementarity of K-12 culturally responsive and inquiry-based science education demonstrated consistently across studies	• Epistemological differences between CRP, indigenous knowledge, and western culture/objective science • Inquiry-based teaching is complementary to and synergistic with CRP
A qualitative metasynthesis of culturally relevant pedagogy & culturally	Pre-K-12 Math students and educators, preservice	Literature review; 20 articles (1994 – 2016)	• Synthesized articles suggest that researchers interpret CRP/CRT math teaching practices in target class	• High teacher expectation (asset-based thinking) as opportunity for CR Math teaching consistent

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
responsive teaching: Unpacking Mathematics teaching practices	teachers within the United States		under 5 categories: care, contextual knowledge, cultural competency, high teacher expectation, teaching efficacy/beliefs	in literature and across reviewed qualitative studies
Creating a model of acceptance: Preservice teachers interact with non-English-speaking Latino parents using culturally relevant Mathematics and Science activities at family learning events [18]	Pre-service teachers (South Texas)	Mixed – Qualitative interviews and surveys.	• Teachers fail to see parental engagement as part of their professional obligation, often have limited to no experience communicating with parents.	• Parents as allies and sources of funds of knowledge [29]
Culturally relevant STEM Out-of-School Time: A rationale to support gifted girls of color [16]	Out-of-school (OST) STEM	Literature Review	• Typical cases of teachers and students not having congruent home, community, and school experiences.	• Cultural discontinuity
			• OST opportunities including summer camps that support student achievement in mathematics and science content [30]	• OST STEM Opportunities
			• Involve socializing agents (parents, teachers, and peer groups); including academic and professional mentorship	• OST resources
Culturally relevant teaching in Science	High school and post-secondary	Commentaries, case studies	• Commentaries on introducing difficult socio-political	• Exemplars for introducing CRP in science classes

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
classrooms: Addressing academic achievement, cultural competence, and critical consciousness [31]	US science classrooms		concepts like scientific racism	
Designing for culturally responsive science education through professional development [32]	High school life science teachers	Case study	• Design and theoretical conjectures support examination of students' out-of-school experiences and the evaluation or implementation of culturally relevant science teaching exemplars.	• Enacting models of culturally responsive pedagogy through connections with student experiences
Effective teachers: Culturally relevant teaching from the voices of Afro-Caribbean immigrant females in STEM. [33]	Afro-Caribbean immigrant STEM students and graduates from Panama.	Qualitative study	• Significance of cultural identity on academic persistence. • Teachers expressed low academic expectations of students and parents. • Slowing the pace of class for struggling students to catch up results in restlessness of high-performing students which teachers interpret as bad behavior.	• Cultural identity as a determiner of persistence • Deficit-thinking • Cultural misinterpretation of student behavior. "*Might maintaining same standards for students be detrimental to progress of gifted students?*"
Getting started: Exploring pre-service teachers' confidence and knowledge of culturally responsive pedagogy in teaching	Final-year undergraduate pre-service teachers (PSTs) enrolled in a Maths and	Case Study	• Level of perceived indigenous knowledge and instructional confidence declined following an indigenous educator's talk.	• Cultural discontinuity, uncertainty, apprehension of offense

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
mathematics and science [34]	Science Bachelor of Education program		• Authors argue that teachers, in their fight to ditch deficit thinking, should not succumb to the fear of getting things wrong [35]	
Impact of a multiyear professional development intervention on Science achievement of culturally and linguistically diverse elementary students [36]	Elementary students	Pre- and post-quasi experimental study	• Significant positive difference between pre- and post-intervention results	• Incorporation of students' home languages and cultures in science instruction
Moving culturally relevant pedagogy from theory to practice: Exploring teachers' application of culturally relevant education in Science and Mathematics [37]	Elementary Science and Math teachers	Qualitative study	• Meaningful problems instead of Abstract, Modelling, Coaching	• Cognitive Apprenticeship as a tool for translating theoretical CRP to CRT
Perspectives and insights from preservice teachers of color on developing culturally responsive pedagogy at predominantly white institutions [38]	Preservice teachers of color at predominantly white institutions (PWIs)	Longitudinal study	• The assumption that preservice teachers of color already know how to enact culturally responsive pedagogy is not true • Lack of Commitment to Culturally Responsive Pedagogy from Programs & Professors (preservice	• Being a teacher of color does not guarantee cultural appropriation • Systemic barriers to enactment of CRP

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
			teachers perceived that their presence as people of color "is only for statistics")	

Preparation and the real world of education: How prospective teachers grapple with using culturally responsive teaching practices in the age of standardized testing [39]	Preservice secondary mathematics teachers (PMTs)	Case Study	• Focus on standardized testing might improve student scores but fail as a measure of teaching efficacy
			• Predefined topics and rigid instructional guides limit the extent to which teachers can enact culturally responsive teaching
			• Time spent keeping pace with curriculum means less time to commit to designing culturally responsive lesson
				• Hinderances of CRP
				  • Excessive focus of standardized testing as measure of teacher efficacy
				  • Lack of classroom/curricular autonomy

Preparing science teachers for culturally diverse students: Developing cultural literacy through cultural immersion, cultural translators and communities of practice [40]	P-12 pre-service and in-service teachers' post professional development	Ethnographic case study	• Being learners in an unfamiliar Hawaiian language and cultural setting helped teachers understand why Native Hawaiian children struggled to understand school science. • "Science teachers trained in the objective, experimental paradigm of a supposedly culture-free science tend to be less sensitive to issues of	• Cultural immersion and reversal of teacher-learner status as an effective pedagogical training tool • Time and effort needed to build learning communities, and achieve cultural appropriation • Standardized tests viewed as a perpetuation of monoculturalism • Epistemological dissonance

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
			cultural difference" [40, p. 393]	
Preparing teachers to engage rural students in computational thinking through robotics, game design, and culturally responsive teaching [41]	Elementary, middle, and junior high school teachers in Wyoming	Mixed methods	• Instructor found out that his indigenous students were uncomfortable about embedding certain aspects of their culture into a computer game They debated respecting cultural heritage or pleasing the instructor	• Cultural dissonance
Teaching science from cultural points of intersection [42]	Science teachers in Montana	Quasi-experimental design & qualitative methods	Teaching self-efficacy and self-concept in ability to enable students make connections between science and their real-life issues significantly explained the 36.7% of the variance of student science test scores gains in treatment classrooms	• Impact of CRP PD workshop on student achievement
The complexities of culturally relevant pedagogy: A case study of two secondary Mathematics teachers and their ESOL students. [6]	High school Math and Science teacher.	Ethnographic study	• Listening to music during class lessons frowned upon in school policy although seemingly helpful for students. • Paricipant's concern that Math as a discipline is not amenable to constructive thinking.	• Teachers' interpretations of school policies in conflict with their willingness to enact culturally relevant instructional practice. • Dissonance between epistemology of STEM field and culturally relevant instructional practice.
The synergy between integrated STEM	Elementary education	Action Research	• Referenced three practices teachers use to incorporate	• Integrated STEM synergistic with CRT

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
lessons and culturally responsive teaching in elementary classrooms [43]			children's cultural backgrounds 1) using students' past experiences 2) connecting students' home experiences to school mathematics 3) identifying embedded mathematical practices in everyday experiences [44]	
Transformative professional development: A model for urban Science education reform [45]	Elementary Science teachers engaged in TPD	Mixed methods	Teachers improved science teaching effectiveness, transformed negative school climate, created positive classroom learning environments using instructional congruence model [46]	• Positive gains of TPD

Using a conference workshop setting to engage Mathematics teachers in culturally relevant pedagogy [19]	Elementary-grade, middle school, and high school Mathematics teachers	Sequential explanatory mixed methods; pre- and post-conference surveys, follow-up interviews.	• Participants complained that there is little time to plan and implement CRP in the classroom.
			• Some expressed their reluctance to include social issues like injustice and inequality into seemingly "objective" subject matters like mathematics [47]
			• Participants explained how difficult it is to reflect on their own implicit cultural biases.
				• Concerns about successful classroom CRP implementation
				  • Time
				  • Resolving epistemological dissonances
				  • Recognition of implicit biases

Title/Purpose of Study	Participants and setting	Type of Study	Findings	Critical comments
Using culturally responsive stories in Mathematics: Responses from the target audience [48]	Black students in third grade Math classes	Qualitative study; 11 classroom observations	• Extends the research of utilizing multicultural stories (specifically stories featuring Black characters) to teach mathematics.	• Multicultural stories as pedagogical tools