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Unpacking Elementary Preservice Teachers' Beliefs on Culturally and Linguistically Responsive Mathematics and Science Teaching for English Language Learners

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Abstract

With an increasing number of English Language Learners (ELLs), the landscape of public schools in the United States has been rapidly changing. However, ELLs' academic performance is consistently lower than their native English-speaking peers' and many in-service teachers feel ill-prepared to teach ELLs in a culturally and linguistically responsive way. This is especially true for mainstream teachers who teach STEM-related subjects. This study explores how pre-service elementary school teachers perceive culturally and linguistically responsive mathematics and science teaching practices for ELLs. A qualitative research design with interviews and constant comparative analysis was employed. Pre-service teachers' lively voices that unpack their beliefs on the characteristics of culturally and linguistically responsive math and science teaching are illustrated around teachers' scaffolding strategies, ELLs' learning experiences, and environments. Suggestions for teacher educators, education scholars, and practitioners are provided to advance the discourse of how to better prepare teachers to teach mathematics and science to ELLs.

Introduction

The landscape of public schools in the United States has been changing rapidly, with a growing number of students from diverse cultural and linguistic backgrounds. English language learners (ELLs), who use languages other than English at home are the fastest-growing student population (Guler, 2020). According to the National Center for Education Statistics (2020; 2022), the percentage of public-school students who were identified as ELLs more than doubled (from 5.1% to 10.4%) between 1993 and 2019. The National Education Association (2020) even projected that ELLs would make up 25% of the students in every classroom in U.S. public schools by 2025. This exponential growth rate has been observed across the country, including rural areas (Hansen-Thomas et al., 2016; Oudghiri, 2022; Reed, 2010).

On both state and national assessments, ELLs' performance is consistently lower than their native English-speaking peers, especially in mathematics, science, and reading (Courtright, 2016; Diaz et al., 2016). Some scholars have noted lack of English proficiency as the main cause, as the students need to develop language skills while also acquiring course content (Abedi & Gandara, 2006; Turgut et al., 2016). Similarly, others have found

that lack of support for their social and emotional well-being along with low socioeconomic status can potentially sustain these gaps (Hair et al., 2006; Krashen & Brown, 2005; Mangone, 2020; Soland, 2019).

Teachers are widely recognized as critical agents for supporting the academic success of students from racially, ethnically, culturally, linguistically, and socioeconomically underrepresented backgrounds (Hollie, 2018; Ladson-Billings & Paris, 2021). Mainstream classroom teachers can choose to learn and implement social justice–oriented pedagogies that could benefit all of their students (Aimiuwu, 2022; Akman et al., 2022; Bourn, 2016; Brown et al., 2020; Min et al., 2022; Pantić & Florian, 2015; Schreder, Alonzo, & McClure, 2023). Culturally and linguistically responsive (CLR) pedagogy is a well-known practice that advances the discourse of culturally relevant teaching in classrooms. Hollie (2018) introduced the term, defining it as "the validation and affirmation of the home (indigenous) culture and home language for the purposes of building and bridging the student to success in the culture of academia and mainstream society" (p. 23).

To dismantle barriers ELLs encounter in the current school climate and support them academically, CLR pedagogy is essential for mainstream teachers. However, the majority of classroom teachers are predominantly white, monolingual, female, and middle class. Thus, many teachers feel they lack the knowledge, skills, and confidence to teach ELLs in a culturally and linguistically responsive way (McGee & Hostetler, 2014; Moser et al., 2018). To this end, many scholars and educators have highlighted the significant role of teacher education programs in preparing pre-service teachers to be culturally and linguistically responsive (Jimenez-Silva et al., 2012; Kelly, 2018; Whitaker & Valtierra, 2018; Yuan, 2018).

This study examines pre-service teachers' beliefs about what culturally and linguistically responsive teaching consists of for elementary school students. It focuses on beliefs about culturally and linguistically responsive mathematics and science teaching, which have been explored less extensively than other subject areas. The following question guided this study: How do pre-service elementary school teachers perceive culturally and linguistically responsive mathematics and science teaching for ELLs?

Literature Review

Culturally and Linguistically Responsive (CLR) Pedagogy

Since Ladson-Billings (1994) introduced culturally relevant pedagogy as a theory that "empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes" (p.13), it has evolved through different names and foci. Examples include "culturally connected teaching," "culturally matched teaching," "cultural competency," "culturally responsive pedagogy," and "culturally sustaining pedagogy." CLR pedagogy is one variation of Ladson-Billings' theory that focuses on linguistic identities as the most powerful representations of who students are (Hollie, 2018). Unlike the more traditional "sink-or-swim approach," CLR pedagogy calls for proactive efforts by teachers to dive into the pool to reach students who do not swim well, through *validation*, *affirmation*, *building*, and *bridging,* informally denoted as "VABB" (Hollie, 2018, p. 27).

Validation refers to "the intentional and purposeful legitimatization of the home culture and language of the student," and a*ffirmation* to "the intentional and purposeful effort to reverse the negative stereotypes, images, and representations of marginalized cultures and languages promoted by corporate mainstream media" (Hollie, 2018, p. 28). *Building* is the process of "understanding and recognizing the cultural and linguistic behaviors of students and using those behaviors to foster rapport and relationships with the students," while *bridging* is "providing the academic and social skills that students will need to . . . navigate school and mainstream culture" (Hollie, 2018, p. 28–29). According to Hollie (2018), becoming a culturally and linguistically responsive teacher is a continuous process of implementing VABB in daily practices.

Hollie (2018) further described five specific areas teachers can be culturally and linguistically responsive in for ELLs: (1) classroom management, (2) academic vocabulary, (3) academic literacy, (4) academic language, and (5) learning environment. According to Hollie, CLR teachers have the knowledge and skills to reflect on whether their work is culturally and linguistically responsive in these areas and to implement such practices. He also claimed that CLR teachers are competent to create learning environment that are conducive to effective VABB and facilitate ELLs' language and literacy development. Aspects to consider in creating a responsive learning environment include how classrooms are organized and how learning materials are selected and placed.

CLR Mathematics and Science Teaching

Many in-service teachers feel ill-prepared to work with ELLs due to their limited interactions with and opportunities to learn about teaching the population (Grabe & Zhang, 2013; Lucas, 2011; Rubinstein-Avila & Lee, 2014). This feeling is especially true for mainstream teachers in mathematics and science. Some studies have reported that math and science teachers found their subject areas less suitable for culturally responsive pedagogy than social studies and English language arts, as they perceived them as culture-free and neutral (Min et al., 2022; Ukpokodu, 2011). In addition, these fields tend to emphasize evidence-based practices and devalue students' sociocultural knowledge, which is subjective (Abdulrahim & Orosco, 2020; Ukpokodu, 2011). Moreover, according to Besterman et al. (2018), STEM teachers have less access to professional development opportunities and instructional resources on CLR pedagogy than teachers of other subject areas. By identifying the unique obstacles mathematics and science teachers encounter in enacting CLR pedagogy, scholars have developed strategies for helping these teachers to be culturally and linguistically responsive in teaching ELLs. Examples include:

(1) connecting mathematics with students' lived experiences and existing knowledge (Barwell, 2003; Secada & De La Cruz, 1996);

(2) creating a classroom environment that is rich in language and mathematics content (Khisty & Chval, 2002);

(3) emphasizing the multiple meanings of words through gestures, drawings, and students' native languages (Morales et al., 2003; Moschkovich, 2002);

(4) using visual supports such as concrete objects, videos, illustrations, and gestures in classroom conversations (Moschkovich, 2002; Raborn, 1995);

(5) connecting language with various mathematical representations (Khisty & Chval, 2002);

(6) discussing examples of students' mathematical writing and providing opportunities them to revise their writing (Chval & Khisty, 2009);
(7) building on students' personal experiences in science investigations to make the material meaningful to them, which should improve their scientific knowledge and communication (Mackenzie, 2021), and
(8) focusing on local issues that are relevant to students, such as toxic land or water or carbon dioxide emissions, and combining literacy with science while exploring these issues (Wiggin et al., 2020).

Pre-service Teachers' Beliefs about CLR Pedagogy for ELLs

Teachers' "unconsciously held assumptions about students, classrooms, and the academic material to be taught" (Kagan, 1992, p.65) are a critical factor in their teaching practices (Bahcivan & Cobern, 2016; Buehl & Beck, 2015; Fives & Buehl, 2016). As teachers' beliefs affect students' learning experiences directly, teacher preparation programs have urged pre-service teachers to examine their own beliefs to help them be more critically conscious with regards to curricular elements. This is especially true in helping pre-service teachers become culturally and linguistically responsive.

Teacher educators have thus put considerable effort into helping pre-service teachers develop positive beliefs about ELLs (Fischer & Lahmann, 2020; Polat et al., 2019; Siwatu et al., 2016). For example, Kolano and King (2015) described clinical experiences and documentaries about ELLs as effective in changing negative attitudes toward these students. Clark-Goff and Eslami (2016) reported that after coursework involving ELLs, pre-service teachers showed a greater acceptance of native languages. And Scott and Scott (2015) reported that immersion and authentic experiences, such as using public transportation to come to school or jumping rope on asphalt at an apartment complex on a hot day, helped teachers develop practical understanding instead of just abstract and surface-level understanding of their students.

Although several studies have described pre-service teachers' beliefs about ELLs and changes in them, little is known of their beliefs about CLR pedagogy in mathematics and science teaching for ELLs (Rutt et al., 2021; Turkan & Jong, 2018). Given that pre-service teachers perceive themselves as better prepared to teach ELLs when they have had learning experiences tailored to that group, they are also more apt to contribute to the discourse on promoting educational equity in math and science. This study aims to fill the literature gap in terms of pre-service teachers' beliefs about CLR pedagogy, particularly with regards to how pre-service teachers perceive CLR pedagogy for ELLs in the context of math and science.

Methods

This research study employs a qualitative research design, following Glaser and Strauss's (1967) grounded theory approach. Grounded theory provides researchers with "a structured approach to sorting through data that, in turn, frees the researcher to fully dive into the data, explore the happenings in the data, and discover the analytic stories the data tell" (Thornberg et al., 2014, p. 405–406). Because it allows the exploration of complex phenomena and the construction of new theories from data, grounded theory has been widely used to explore teachers' beliefs

about education (Bonner & Adams, 2012; Chen & Phillips, 2018; Cronin-Jones, 1991). In using grounded theory, the aim is not to generalize findings from the data but to explore what pre-service elementary teachers believe about culturally and linguistically responsive math and science teaching for ELLs.

Participants

Eleven pre-service elementary teachers enrolled at a teacher education institution in the southeastern United States voluntarily participated in this study. Before recruiting participants, the research team went through the institutional review board process, and the study was exempted from review. The participating teachers had all taken both a student-diversity course led by the first author and a mathematics-methods course taught by the second author. Although the teachers came from diverse backgrounds, most were white and all were female, which reflects demographic trends in the current teacher workforce. Specifically, they consisted of one Asian, one Hispanic, two Black, and seven White students. Pseudonyms are assigned to each participant throughout the paper to protect their anonymity.

Context

The participants were all enrolled as a cohort in a teacher preparation program that included mathematics and reading method courses, a special-education course focused on creating inclusive learning communities, and a course on student diversity during the semester of the study. The student diversity course was designed to help pre-service teachers explore unique characteristics and needs of ELLs, develop positive dispositions to those students and their families, and learn the material and skills to teach them effectively. This course focused on effective ways of developing and implementing translanguaging lessons and helping ELLs develop oral (speaking and listening) and written (reading and writing) language skills in general. It did not provide direct instruction on subject-specific pedagogy. Students in the course were also given opportunities to meet and teach ELLs in local public schools for field experiences.

In the course, teachers completed a video case analysis project in which they watched videotaped mathematics and science lessons taught by national board-certified teachers in a variety of classroom settings with ELLs, and critically analyzed the teachers' teaching from the perspective of CLR practices. They watched two such lessons, which were selected by the first author from the Accomplished Teaching, Learning and Schools (ATLAS) website (https://www.nbpts.org/support/atlas/). On the website, participating pre-service teachers could not only watch classroom videos but could also read commentaries by the teachers describing their classroom contexts, design thinking, pedagogy, and individual reflections. Another feature of ATLAS allowed pre-service teachers to make their own notes directly in the videos and commentaries. For their project, the pre-service teachers were asked to annotate the parts that they believed showed good examples of CLR pedagogy for ELLs. They were then placed in groups and given access to the annotations made by their group members. When course sessions were held virtually (due to COVID-19 restrictions), participants were given time to meet in groups and discuss where they found CLR pedagogy for ELLs in the videos and comments. They were also asked to describe why they believed that these parts were good examples.

Data Collection

The pre-service teachers' four discussion sessions were videotaped. Only the accounts of the eleven who gave signed consent to participate in this study were transcribed for use as data. The mathematics lessons the pre-service teachers watched were on (1) using T-charts to understand and solve addition and subtraction word problems (grade 2); (2) learning about perimeter and area through singing, partner work, and problem solving (grade 3); and (3) discussing and recognizing the characteristics of pentagons (grade 2). The science lessons were on (1) conceptualizing food webs and describing energy relationships (grade 5); (2) understanding muscular and skeletal systems by experimenting with hand joints (grade 3); and (3) exploring different mixtures and solutions (grade 5).

Data Analysis

The transcripts of the discussion sessions were used as data for this study. They included detailed discussions of what the teachers believed CLR mathematics and science teaching for ELLs consisted of. To analyze the data, a constant comparative approach was employed, with three steps: (1) open coding, (2) axial coding, and (3) selective coding (Corbin & Strauss, 2015). The constant comparative method is considered "a key element of grounded theory" and helps researchers code qualitative data and develop categories in a systematic and critical process of building a theory (Chun Tie et al., 2019, p. 2).

First, three researchers independently read all the transcripts multiple times to increase their familiarity with the data and identify emerging categories. Then the three had several meetings to review and compare their open coding results. They next proceeded with axial coding to identify interconnections among the categories and organizing them into main and sub-categories. Lastly, they used selective coding to interpret the results by building a storyline from the main categories. To ensure reliability and validity of the data analysis, the three researchers discussed disagreements about how to code data or name categories until full agreement was reached. Additionally, member checking and comparing data to the annotations made on video cases and commentaries of ATLAS website was conducted. For example, the following statement was coded as "extra linguistic supports" under the main category of "effective scaffolding strategies":

> But what she does do is use the students' senses to absorb the information. For example, she had a song, so that's auditory learning. She had visuals. And she had kinesthetic movement, so she was having them do this [gestures in a square pattern] to learn perimeter, and this [wax on gesture] to learn area and things like that. I think she did a really good job of keeping them engaged.

Finally, the following statement was coded as "promoting students' agency" under the main category of "nurturing culturally and linguistically responsive environment':

> I liked how she . . . was incorporating student leadership in her discussion, like she had one student stand up, like to the anchor chart that they had made some time previous and just pointing at the steps, making sure they did everything they said.

Results

The teachers' beliefs about CLR pedagogy for ELLs centered around three major ideas: (1) effective scaffolding strategies, (2) authentic learning experiences, and (3) culturally and linguistically responsive environments. This section illustrates each theme with quotations from the teachers.

Effective Scaffolding Strategies

The first theme that emerged focused on pre-service teachers' beliefs about the strategies the videotaped teachers used to provide scaffolding for ELLs' understanding of mathematics and science. Specifically, the pre-service teachers focused on the use of extralinguistic supports, modified or accommodated instructions, and provision of clear and detailed instructions.

Extralinguistic Supports

The participants believed that CLR pedagogy used extralinguistic supports, such as visual aids, auditory cues, and body movements to help ELLs understand mathematics and science.

> Ava: But what she does do is use the students' senses to absorb the information. For example, she had a song, so that's auditory learning. She had visuals. And she had kinesthetic movement, so she was having them do this [gestures in a square pattern] to learn perimeter, and this [wax on gesture] to learn area and things like that. I think she did a really good job of keeping them engaged.

> Isabella: The teacher used the index core organizer and the sticky notes, and then she . . . placed it on the pentagon, so it was like labeling, almost. And I thought that was a great example of an extralinguistic support.

The pre-service teachers also believed that CLR pedagogy engages ELLs in hands-on activities that help them understand mathematics and science concepts:

> Emma: . . . teaching the scale tool system. I felt like that shows them hands-on what each part of their joints actually do.

> Harper: I liked how she was doing hands-on activity, because it gives them a chance to be involved and be engaged in what they're doing and not just focusing on . . . "I've got to use sentences" or "I have to comprehend something."

In addition, the participants found the teachers' use of body and hand gestures to be characteristic of CLR pedagogy:

> Olivia: My first comment was about how she uses different hand motions, and repeated hand motions. Like, one hand motion per word, so if they don't understand the word or if they didn't hear her, the motions help them understand the words.

> Charlotte: They were also doing like the motions. When they did "energy," they'd sit there and make energy. So it helps them keep that in their brains.

Modified or Accommodated Instruction

The participants focused on how the teachers in the videos modified their instructions for ELLs to evaluate whether they incorporated CLR pedagogy. Specifically, they discussed how the teachers broke down or repeated words and mathematics and science concepts to help ELLs acquire academic language:

> Luna: She took the time to explain that 'pentagon' means five, and that the second half just means angle, and I think it's good for emerging bilingual learners to actually focus on what the vocabulary words mean, because I remember when I was learning that I . . . didn't necessarily know what it meant, I just know that pentagon was five. I have to look for five. I never got a true explanation, and I think it's really good because you're enforcing concepts and you're making sure students actually know what they're being taught.

> Emma: She liked to repeat a lot, repeat key words while doing the hand motions. . . . I thought that was good, so that they could really get it, whereas if she just said it one time then they're trying to focus on what it means rather than understanding what's being said.

They also discussed how the teachers responded to ELLs' needs, made in-the-moment decisions, and modified their instructions to aid understanding:

> Charlotte: I thought she did a really good job of, like, when they did get stuck, because I mean [it's] science, it's a difficult kind of subject. When they were getting stuck, she would be . . . asking them more questions to kind of get them further along in the lesson, so I thought that was awesome.

> Ava: The teacher displayed really well her shifting stage. She was able to provide the students that were struggling with manipulatives that she hadn't originally planned for. That's [being] flexible and deviating from her original plan because she saw students struggling.

Clear and Detailed Instruction

The pre-service teachers also pointed out that the videoed teachers were conscious in their decisions to make instruction clear and detailed:

> Ava: It speaks to her ability to be detailed and really outline everything as they're doing it, but I also think that speaks to the amount of anticipation that this teacher put into this lesson, because for me, as a student, I could very easily follow the streamline of this lesson plan. And if on the off chance one of the students did not answer the way that the teacher expected, there was a way for her to critique that and to get back on track. So I think that is so. Especially as new teachers, we're going to have to figure out everything as we go. And so we can cut down on the improvisation on the lesson plans and anticipating how students may or may not respond.

> Ella: She provided very clear instruction for the students, and that's something that's really important for not only emergent bilingual students [but] for all of our students, giving them very clear and direct instructions, and I think it helps when students know what they need to do. They're able to really actively engage in the lesson.

Authentic Learning Experiences

The second primary theme that emerged was the authenticity of ELLs' learning experiences. The participants believed that CLR teachers should provide ELLs with authentic experiences as much as possible to aid language development and content learning in mathematics and science. Specifically, the pre-service teachers suggested promoting students' English use through social interactions and connecting academic contents to solve students' real-life experiences as ways to promote authenticity in lessons.

Promoting English Use through Social Interactions

The participants focused on the way teachers organized groups of students at different proficiency levels to promote their language use:

> Ella: Some [students] might be at a higher level and some might be at a lower level, but she would put them in a group together. That way they could talk with each other and one student could help the other, and I thought that really showed how she values the social interaction between students in order to achieve conversational language proficiency.

> Luna: I really did like . . . that she did group them together. Didn't she start the lesson just being like, "Okay, this is what we're going to do, now everybody split off"? And she circled around, and she made sure to get to different levels. She would give them slightly harder problems, and just have some of the more proficient students work with the ones who needed extra support. I thought that was really interesting because she didn't say as much about knowing their backgrounds, but she did just think about who needs to work with who, because collaboration is really important when you try to learn.

They also mentioned how the teachers facilitated social interaction through small group activities:

> Sophia: The first thing that I noticed was in the beginning, where all the students are just discussing and talking with each other about what they think has happened so far. And I said that that was really important because it's one of the key principles of second-language learning, and the students are able to just have natural conversations with each other and practice speaking with their peers.

> Isabella: Yeah, I basically said the same thing in some of my comments, just about the one-on-one interaction. She was quickly like, "Okay turn next to your partner and talk about it," and just that simple. . . When that would happen to me when I was a kid, if I didn't know something, I would feel more comfortable asking the person beside me, and I feel like that also helps the comfortability of the students, and it can help them learn more.

Connecting Academic Contents to Students' Real-life Problems

In addition, the participants highlighted how CLR teachers helped their ELLs use what they learned in mathematics and science classes to solve real-life problems:

> Ava: She said her ultimate long-term goal was for students to be able to solve mathematical problems they would encounter in the real world. And one of the examples she gave was going to the grocery store, because that is a real challenge for students who don't speak English. . . . She really designed her assignments, and her homework, and her in-class worksheets to be contributing to this final goal of being independent, being strong English speakers and true contributing citizens.

> Camila: There was this one group where the question was about sandwiches and trying to determine, do you have a turkey, do you have a ham? And she said that she wanted to make the problems not only just math problems, but language problems as well. So they were taught things that would actually relate to the real world.

Culturally and Linguistically Responsive Environment

The last theme focused on facilitating learning environments for ELLs. The participants believed that teachers who used CLR pedagogy could create supportive classroom cultures for their ELLs by understanding their students' backgrounds and promoting their students' agency.

Understanding Student Backgrounds

The participants discussed how well the teachers in the videos understood their students' home backgrounds and the unique challenges and needs they had:

> Charlotte: In the comment section, she made a point to say that they were in an economically depressed area, and how many of the families had a lot of difficulties. . . . Like she mentioned how they had to work multiple jobs, multiple shifts, and . . . might not have English proficiency. She made sure to mention all of those things . . . and she keeps that in mind while teaching in the classroom to help her students out.

> Amelia: She talks about a student, and how she lives with her dad but has to go visit her mom in Mexico every weekend or something. She sort of brings that up and just says, "This is what my student is going through," so she is aware of this and accommodating the student. She's sort of stating this as a fact, and not using it as an excuse to dumb down the education for the student or anything like that.

Promoting Students' Agency

The participants pointed out how teachers provided students with opportunities to exercise their agency as a CLR pedagogical technique for creating effective learning environments for ELLs. First, they focused on how teachers respected and promoted students' leadership in their teaching:

> Ava: I liked how she . . . was incorporating student leadership in her discussion. Like she had one student stand up . . . to the anchor chart that they had made some time previous and just point at the steps, making sure they did everything they said. And I think that really gives the students a sense of pride. It gives them a sense of, okay, I did one thing right, my teacher noticed that and now she's having me help. And it's a good example for other students, because I'm sure now they're like, "Well, I want to be the one up there with the ruler and pointing at the steps."
>
> Isabella: One of the girls was reading off the directions as the other students in the group were actually following through with what she was saying, and just incorporating that leadership into whether they were taking turns reading the directions or whatever. . . . It was important that they communicated and that they also took initiative in that little small group event.

In addition, the participants discussed meta-cognitive skills that could facilitate self-monitoring and promoted student's ownership of their learning as a powerful CLR pedagogy:

> Ava: She asked one of the students in her group, Marley, why she changed her answer, and I think that is a really good technique as far as giving power back to the student, because when they can correct their own mistakes or a peer sees that it's okay to make mistakes, then they feel more included.
>
> Amelia: One of the students isn't quite sure, so she sends [them] to the wall where their math facts are and kind of directs them to the right board and has them produce the answer from that. And I thought that was a great way of teacher her, but also giving her ownership to go and find the answer herself rather than her waiting around and letting the teacher answer it.

Discussion

This qualitative study examines pre-service teachers' discourses on their beliefs about what culturally and linguistically responsive mathematics and science teaching are for English learners. The participants' collaborative analysis of and reflections on the videorecorded teachers' practices in teaching mathematics and science showed how they perceived effective CLR pedagogy for mathematics and science. The findings have valuable implications that can advance discussions of how to prepare teachers to teach mathematics and science to ELLs.

First, the pre-service teachers believed that CLR teachers were those who used effective scaffolding strategies to help ELLs learn mathematics and science. The participants recognized the value of visual and auditory aids, body movements, and hands-on activities for helping ELLs understand mathematics and science concepts. They also focused on how the teachers in the videos used modified strategies to accommodate ELLs to determine whether they were CLR teachers. They pointed out practices such as repeating vocabulary words and flexibly adjusting their lesson plans on the basis of ELLs' collective understanding as a characteristic of CLR teachers. Furthermore, they believed CLR teachers anticipate the areas in which ELLs will struggle and provided explicit, detailed instructions that clearly and directly described the students' activities.

These findings confirm that the pre-service teachers viewed CLR teachers as breaking language demands into manageable pieces with various tools and reducing ELL's linguistic barriers when teaching mathematics and science, as noted in previous studies (Moschkovich, 2002; Raborn, 1995). However, the participants could not extend their discussion to scaffolding strategies that view ELLs' home language as valuable assets for helping them understand mathematics and science materials. According to Hollie (2018), CLR teachers validate and affirm ELLs' home languages and provide learning activities that encourage them to use these to understand and acquire academic language. This implication calls for teacher educators to highlight the importance of asset-based perspectives on home languages, as opposed to seeing them as deficit-based. It also highlights a need for future teachers to learn effective scaffolding strategies for helping students use their home languages to learn math and science concepts.

Further, the participants believed that CLR teachers are those who promote authentic learning experiences for ELLs. Specifically, they discussed instructional strategies that facilitate social interactions to maximize ELLs' opportunities to speak English and to connect academic contents to real-life problems, as indicators of CLR pedagogy. This demonstrates that the pre-service teachers valued the creation of environments that nourish authentic language use for learning mathematics and science contents, as Khisty and Chaval (2002) addressed in their studies.

However, they did not consider promoting the use of students' native languages to learn academic contents when discussing the authenticity of learning experiences. In addition, as Barwell (2003), Mackenzie (2021), Secada and De La Cruz, (1996), and Wiggin et al. (2020) noted, making academic contents relevant to students' lives is an effective strategy for CLR pedagogy. Although the pre-service teachers did find practices that helped students solve real-life problems to be helpful, they did not extend their discussion into bringing students' lived experiences from their home cultures into class to help them understand academic contents.

The participants also pointed out how the teachers in the videos demonstrated CLR pedagogy by creating and nurturing environments conducive to ELLs learning math and science. They believed that CLR teachers have a good understanding of their ELLs, including their backgrounds and unique challenges they face in their daily lives. They also described the videotaped teachers' efforts to promote students' agency by giving them leadership and ownership of their learning and opportunities to examine their thinking as qualities of CLR teachers, which is consistent with Chval and Khisty (2009). It was encouraging to see that the pre-service teachers found CLR pedagogy not only in the instruction but in the learning environment.

Nevertheless, participants' discussion of learning environments did not extend to the physical classroom organization they saw in the videos or the materials the teachers selected for instruction, which Hollie (2018) described as important aspects of CLR environments that help ELLs learn. This omission implies that teacher education programs should provide curricula that consider not only strategies for instruction but for the design of classrooms and materials that promote diversity and inclusion. These might include building classroom libraries with inclusive children's literature, or designing classroom layouts that make all students feel welcome, regardless of cultural or linguistic backgrounds.

Conclusion

This study explored pre-service teachers' perceptions about culturally and linguistically responsive teaching of mathematics and science content to ELLs. The findings contribute to the field of teacher education in several ways. First, the evidence collected provides a window into how pre-service teachers perceive CLR teaching practices for ELLs in authentic contexts. Second, it reveals areas teacher educators need to address more intentionally in curriculum and instruction to help pre-service teachers grow into culturally and linguistically responsive ELL teachers. Third, analyzing video cases and articulating their beliefs about CLR practices in discussion helps pre-service teachers understand the influence of their beliefs on their educational practices. Lastly, given that little is known about how teachers enact CLR pedagogy to teach mathematics and science, the findings expand extant knowledge of how to promote inclusive practices for ELLs in these subjects.

Despite these contributions, this research is limited by the small number of participants and of video cases analyzed. Although the purpose of the study was not to generalize findings but to explore teachers' beliefs about CLR pedagogy in mathematics and science, a larger number of teachers and a diversity of classrooms would have potentially provided a more accurate picture of this. Therefore, studies that invite more pre-service teachers to analyze video cases from various grade levels and classroom types will benefit the field of mathematics and science teacher education in identifying ways to better prepare teachers to work with ELLs.

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