



Multimodal Literacies in Elementary Teacher Education: Facilitating Culturally Relevant Pedagogy with Mathematics

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ABSTRACT

This study presents qualitative action research conducted in elementary teacher education coursework. Teacher candidates were introduced to multimodal literacies in mathematics by representing and communicating content through multiple modes such as signs, symbols, images, text, gestures, manipulatives, music, videos, and more. Teacher candidates used multimodal literacies to implement and understand culturally relevant pedagogy in their assignments as students, in lesson plans, and in-field experience exercises during a semester course. Three focal participants are outlined to highlight similarities and differences across cases through the ways teacher candidates navigated coursework with multimodal literacies and mathematics while enacting culturally relevant pedagogy. Multiple assignments from each participant were collected and analyzed, culminating with a post-term semi-structured interview. Findings illuminate intricate interactions within teacher candidates' multiple identities through their cultural awareness with others and in disciplinary connections. Their learning and teaching development illustrates a dynamic interplay of literacy, multimodality, and mathematics with the implementation of culturally relevant pedagogy, ultimately suggesting the need for teacher educators to consider how these connections can be best facilitated.

KEYWORDS

multimodal literacies; disciplinary literacies; culturally relevant pedagogy; teacher education

Researchers, educators, and students often differ in their perspectives toward effective mathematics instruction and elementary pedagogy. Frequently, descriptions of mathematics “best practices” vary, which can leave teacher candidates (TCs) and their own possible students confused, frustrated, and ill-prepared (Greenberg & Walsh, 2008; Lee & Ginsburg, 2009). This article reports on the investigation of elementary TCs as they navigated multiple identities in an elementary mathematics methods course. Participating TCs were future or current teachers undergoing the certification process, while also engaging as students of mathematics, literacy, and mathematics pedagogy.

The research took place in multiple cycles and semesters of instruction for the same required course at a university in the Southeastern United States. The study was designed to explore teacher education with multimodal literacies (Kress, 2010) and culturally relevant pedagogy (CRP; Ladson-Billings, 1995) for undergraduate and Master of Arts in Teaching (MAT) candidates as they participated in elementary mathematics coursework. As the TCs' professor in the course, I sought to answer the following research question and sub-questions:

- How do teacher candidates utilize multimodal literacies to represent, understand, and enact CRP in elementary mathematics?

- In what ways do teacher candidates' experiences with multimodal literacies facilitate changes over time in their understanding of CRP in elementary mathematics?
- What do teacher candidates' choices when utilizing multimodal literacies reveal about their understanding of CRP in elementary mathematics?

In exploring these questions, I aim to contribute to the developing literature surrounding CRP and mathematics instruction. Interestingly, though studies have intentionally investigated TCs and CRP, including some that specifically focus on mathematics teaching, very few explicitly also recognize their important intersections with literacy practices (Leonard et al., 2014). In turn, the findings of this study proffer the use of multiple literacies to further understand and frame these possibilities.

Literature

It is essential for elementary TCs to be effectively prepared in mathematics pedagogy as they develop in coursework. Significant attention has been given to mathematics anxiety common in TCs and how to help them grow in confidence and self-efficacy in teacher preparation programs (Isiksal et al., 2009; Tassell et al., 2020). To this end, related research has supported utilizing many facets of reflection throughout elementary TCs mathematics coursework and field placements (Saylor & Johnson, 2014; Wickstrom et al., 2018). These and other studies affirm the need to tactfully consider, value, and acknowledge the multiple identities of TCs while they learn conceptual elementary mathematics alongside elementary mathematics pedagogy (Lutovac, 2020; Lutovac & Kaasila, 2014).

Further, research in elementary mathematics teacher education problematizes how teachers frequently instruct mathematics the same way they were taught (Blanco et al., 2013), and how mathematics instruction generally involves decontextualized and procedural methods lacking a sociocultural lens (Taylor, 2018). Relatedly, studies demonstrate that students and teachers can often resist notions of incorporating or validating culture in mathematics and dismiss possibilities for relevant associations and connections of culture with mathematics content. Nevertheless, disciplinary experts and proponents of CRP argue that CRP with mathematics topics and instruction is not only a possible consideration but a vital one (Brown, 2020; Dominguez et al., 2014; Enyedy et al., 2011). Students of multiple ages can be provided opportunities to engage with mathematics concepts in agentic, engaging, and empowering ways that promote social justice, critical thinking, and problem-solving. However, implementing this instruction within certain paradigms requires an intentional, invested, and persistent shift in perspectives on pedagogy and mathematics, thus illuminating the complexities of effectively incorporating CRP into mathematics classrooms at various levels (Maloney & Matthews, 2020; Wiggan et al., 2020).

Studies that consider the challenges of apprenticing TCs into CRP with their students and contexts frequently involve coursework that incorporates assignments with community engagement, reflective work, and critical conversations (Aguirre et al., 2012; Kelly, 2020; Turner & Drake, 2016). Moreover, they often use iterative implementations of a study design through multiple semesters where teacher educators (TEs) refine their courses and investigate TCs' experiences (Leonard et al., 2014; Mark & Id-Deen, 2020). Since applying CRP to mathematics instruction can be seen by TCs as difficult or improbable, researchers in these areas illustrate the continuing call to facilitate and redirect possibly resistant perspectives of TCs toward embracing

culturally relevant innovations and options in mathematics instruction (Averill et al., 2009; Brown et al., 2019).

Accordingly, research suggests content literacy instruction and children's literature as effective approaches for integrating CRP into elementary mathematics instruction and TC preparation (Hintz & Smith, 2013; Leonard et al., 2014; Sheppard, 2011). These combined considerations demonstrate a need for investigating ways elementary mathematics instruction and teacher education can reflect and incorporate multiple literacies with CRP. Specifically, research recommendations often allude to or utilize what are known as multimodal literacies without explicitly identifying or explaining their role in instruction.

Stein (2008) describes multimodality as the combinations of different modes individuals use to represent and communicate meaning like speech, writing, image, gesture, and sound. Thus, mathematics instruction is inherently multimodal (Arzarello & Robutti, 2010; Daher, 2014; Freeman et al., 2016). Nonetheless, not all educators recognize the value and/or nature of multimodal literacies and how influential they may be in cultivating CRP in STEM subjects (Hsu et al., 2013; Taylor, 2018; Youngjoo & Jayoung, 2015). There is a significant dearth in research around multimodal literacies in higher education, specifically with teacher preparation (Cardoso, 2017). Consequently, teacher education must evolve in its instructional pedagogies with multimodal literacies (Craddock, 2022; Serafini, 2015).

Studying and blending views of multimodal literacies and CRP in mathematics requires a framework that joins disciplinary and social literacy perspectives. While the discipline of mathematics uses specific literacies germane to its content and context, its discourse also involves sociocultural perspectives (Shanahan & Shanahan, 2017). In other words, mathematics discourse and literacy practices are more than isolated multimodal representations; rather, they encompass individuals' identities and social ways of "doing" mathematics in particular contexts (Gee, 2014). The multimodal register of mathematics cannot be separated from social and cultural ways it is communicated and represented. Finally, while disciplinary literacy is often emphasized in secondary and higher education fields, it is increasingly recognized as a valid, relevant consideration for elementary contexts, which merits more investigation and attention in application (Shanahan & Shanahan, 2014).

Theoretical Framework

Though CRP is a widely accepted framework in the educational field, this research's combined perspective on multimodal literacies in mathematics as being both discipline-specific and social engenders a more focused lens grounded in sociocultural literacy perspectives and the three tenets of CRP including academic success, cultural competence, and critical consciousness (Ladson-Billings, 1995). Through previous iterations of action research that took place in my own classroom, I developed a framework with key aspects to approach instruction and research when utilizing multimodal literacies in content areas known as ICARE: Identity engagement, Critical engagement, Authentic engagement, and Relevant engagement (Craddock, 2022). Accordingly, I detail and support with salient literature individual aspects of the framework.

Identity Engagement

McCarthy and Moje (2002) propose a reciprocal, influential relationship exists between identities and literacy practices, that student identity, literacy, and learning are intricately connected. Additionally, Gee's (2014) previously cited theory on Discourses grounds identity as a social literacy construction that draws upon multiple modes. Discourses are identity kits including how

to dress, act, talk, and often write. Therefore, disciplinary literacies are examples of Discourses; educators must apprentice students into the practices of different disciplines to participate meaningfully.

Critical Engagement

Critical literacy practices, like constructing and critiquing arguments during instruction, are evident in multiple content areas, though they vary across disciplines. Individuals who engage in critical literacies can be empowered to problem-solve, challenge structures, and develop agency in learning (Freire & Macedo, 1987; Janks, 2013). Critical literacy engagement is often articulated through multimodal literacies since proving, justifying, and explaining can require multiple modes in different contents (Brown et al., 2019).

While critical and social connections can be seen as more difficult to make in mathematics, especially at the elementary level, I encourage educators to adopt a dynamic, innovative lens for content applications of critical literacy engagement. That while pertinent practices involved in justification and explanation differ depending on content and age, developing creative connections is not only a plausible consideration in mathematics, but by very nature, a powerful one. For example, mathematical standards can naturally facilitate critical concepts of equity, fairness, sharing, and justice when educators are inspired to imagine and cultivate these possibilities through literacy practices.

Authentic Engagement

Authentic literacy practices are described as combining language, literacy, and learning to make instruction functional, accessible, and socially constructed through problem-posing and problem-solving (Dominguez et al., 2014; Goodman & Goodman, 2011). This authenticity is also characterized by literacy experiences purposefully connected to students' lives (Behizadeh, 2015; Wargo, 2020). Specifically, authentic disciplinary literacies include critiquing and sharing work with students and communicating to real audiences. In elementary mathematics, these practices innately engage multiple modes like pictures, signs, symbols, videos, manipulatives, tables, graphics, and food (to name a few).

Relevant Engagement

Individuals engage with content they identify as relevant to their lives, desiring connections between disciplinary literacies and typical, familiar practices (Wynter-Hoyte et al., 2019). Burns (2008) posits relevant literacy practices often involve multimodal text rather than print-only instruction, which can be irrelevant and disengaging. Consequently, multimodal literacies are one possible means of making relevant connections to the disciplinary literacies of elementary mathematics through games, art, music, crafts, tactile puzzles, emojis, comics, and storybooks. To clarify, I differentiate authentic engagement as “functional” and relevant engagement as “familiar.” Thus, authentic and relevant engagement are indicated separately in the framework; though, they are not necessarily mutually exclusive and can often evoke similar applications.

The elements of ICARe emphasize how multimodal literacy practices can cohesively facilitate student engagement that would promote the academic success, cultural competence, and critical consciousness central to CRP in ways that often overlap and are not always distinct; Table 1 aims to clarify potential connections in the frameworks.

Table 1: Framework Correspondence

ICARE components	CRP domains
Identity engagement (validates and incorporates individuals)	Cultural competence Critical consciousness
Critical/Civic Engagement (promotes possible critical/civic applications)	Cultural competence Critical consciousness
Authentic engagement (illuminates real purposes/audiences)	Academic success Critical consciousness
Relevant engagement (facilitates and relates familiar practices)	Academic success Cultural competence

I taught TCs about ICARE and multimodal literacies during coursework and discussed with them how I intentionally incorporated aspects of ICARE into our assignments. I likewise encouraged them to consider leveraging multimodal literacies in tasks and lesson plans for their own students to mirror these same goals. I follow with my approach to the study's design through this instruction.

Methodology

I engaged in practitioner inquiry positioning myself, as teacher-researcher, and TCs enrolled in elementary mathematics methods as central to identifying and improving the problem of practice (Glesne, 2016; McCutcheon & Jung, 1990). This action research design of “inquiry as stance” emphasizes researcher reflexivity, critical inquiry, and multiple sources to ensure trustworthiness (Cochran-Smith & Lytle, 2009).

Design

I used purposive sampling of multiple participants as qualitative case studies to gain a natural, holistic perspective of social context in practice (Creswell, 2014; Glesne, 2016). Participants were recruited and consented to participate by my colleague at the institution in the beginning of each semester. TCs' development and perceptions of CRP in elementary mathematics pedagogy were facilitated through instruction with, and their uses of, multimodal literacies including written reflections, lesson plans, online class forums, online Zoom sessions, creative writing assignments, children's literature selections, games, tactile and virtual manipulatives, mathematics exercises and assessments, and presentations (such as PowerPoints, Prezis, storybooks, songs, or videos). Some of the most popular digital presentation modalities I suggested to TCs included Flipgrid and a site called Canva which allows the user to choose from many different graphics, templates, and images to make a variety of visual displays that can include music, comics, infographics, slides, and posters. Through consenting, TCs allowed their assignments to become a part of research and could opt into an opportunity for a focus group or individual interview after the semester ended.

Participants

From the courses, 27 participants' work samples were collected and six TCs agreed to some form of interview opportunity. Because each participant illuminated different multimodal experiences and interpretations that are best understood through thorough description, this article will detail only three focal participants from the courses (pseudonyms provided). While one course was for

undergraduates and delivered face-to-face, the other was a fully online graduate course with asynchronous and synchronous components. Though the majority of the assignments for the courses were the same, I will distinguish which participants took certain courses because the study reveals a relationship between course delivery on TCs' uses and interpretations of different modalities related to the research questions.

Britney was an elementary education TC in her final block of coursework just before student teaching. She is a white female and a local mom who was born and raised near our university while taking full-time face-to-face coursework for her undergraduate degree. Jackie was a TC in our elementary MAT program completing her final semester of courses before student teaching. She also is a white, female mom who formerly had a career background in business/accounting (her undergraduate degree field). She was working part time assisting in a school near her home. Kyla was employed as a teacher and concurrently enrolled in our elementary MAT program to gain certification. She had a background in music and music education, teaching it at multiple levels including college music courses. Interestingly, she, too, is a female mom and was working full time as a first-grade teacher of record in a school near her home. More than once in class sessions she self-identified as a Pacific Islander and commented on this as a notable aspect of her identity.

Data Sources

Each of the three participants engaged with me after their terms in a semi-structured interview lasting approximately 30–60 minutes on Zoom to discuss coursework, key takeaways, and assignments. These interviews were transcribed for accuracy. To reinforce trustworthiness and validity, I conducted member checks with participants after drafting a final manuscript.

Multiple assignments were collected from participants, but only 12 for each participant were included in analysis based on the assignments that had a paired match between courses. This included two formal lesson plans taught during field experience assignments accompanied by reflections. Additionally, participants completed pre-assessment and post-assessment reflection papers which detailed their feelings and perceptions toward mathematics as both teachers and students. Other noteworthy assignments included presentations of a culturally relevant “lesson seed” based around a children’s literature book of their choice and a reflection paper detailing disciplinary literacies observed during their field experience hours.

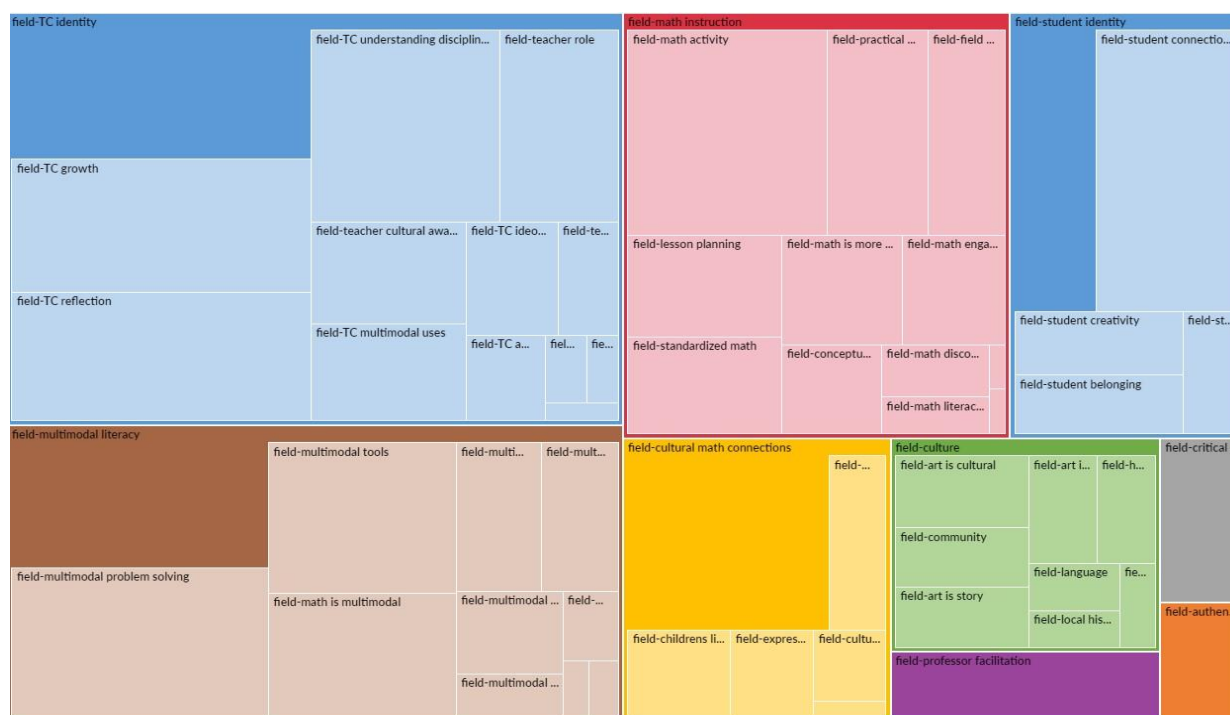
Specifically, Britney also created a multimodal presentation on Canva in response to a place-based multimodal literacy “field trip” we took in our face-to-face class. This trip involved visiting a local, downtown art museum along with walking to and through a sculpture memorial garden celebrating southern American and Black history in our university’s city. Although Jackie and Kyla’s class did not go on this trip because online candidates enroll in our program from various locations, they completed a corresponding online module and discussion about empirical research articles involving children’s literature, multimodal literacies, and CRP in mathematics.

Finally, video recordings of online instructional sessions were collected to capture the complex multimodal interactions which field notes and observations could not afford, especially given I was the researcher and instructor. These videos bolstered trustworthiness with the opportunity to revisit participants’ strategies and conversations while collaborating, manners and gestures in presenting, class dynamics and structure, and interactions among TCs during discussions when multimodal literacies were utilized.

Data Analysis

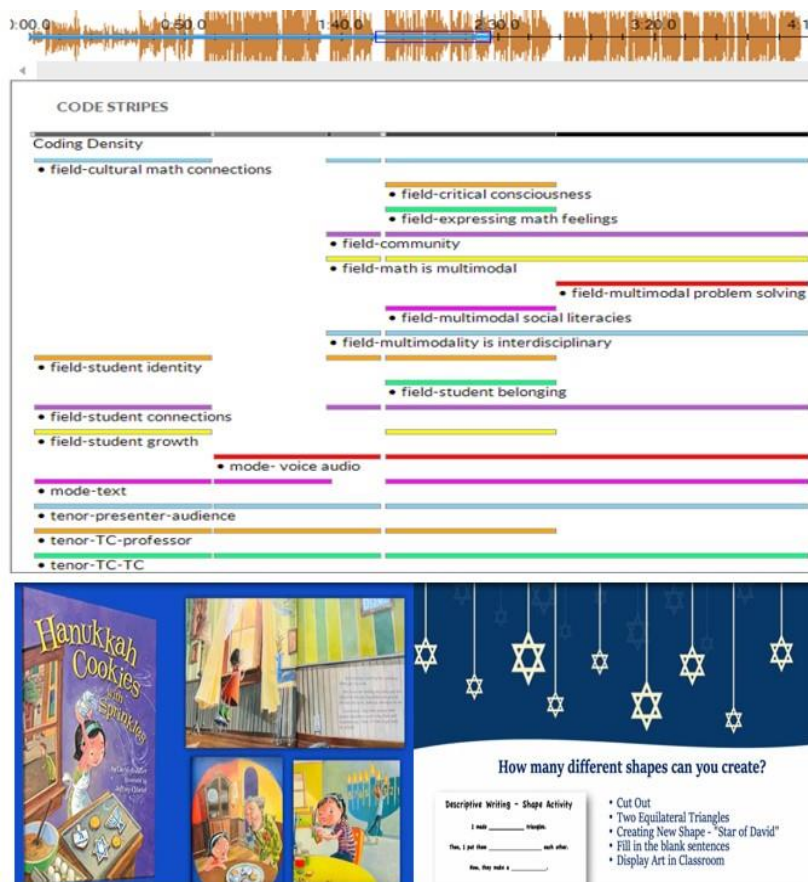
I analyzed data through a social semiotic multimodal framework according to social context (Kress, 2010). I incorporated multimodal analysis suggested by Kim and Kim (2016) who utilized Halliday and Hasan's (1989) analysis of language according to field, tenor, and mode. Field describes the topic of the language involved, tenor describes relationships between participants in the language interaction, and mode describes the role of the language in context. With field, tenor, and mode as a frame, I coded class videos and TCs assignments. Through this approach, I analyzed participants' gestures, images, videos, dialogue, and text throughout their work, class interactions, and discussions. I utilized CAQDAS software, NVivo, to directly code selected portions of each of the data sources including video recordings (Paulus et al., 2014). Codes were generated with an inductive approach using initial coding, leading to a second cycle of focused coding (Saldaña, 2009).

Figure 1: Hierarchy Chart of Codes to Suggest Emerging Themes



True to the heart of the study and design, I utilized NVivo's multimodal functions for cross-case visual comparisons within participants to recognize growth, changes, and commonalities of codes between pre- and post-reflection assignments. I also used a similar hierarchy chart function, which takes qualitative text codes and displays them in a multimodal, mathematical model grouped by percentage, frequency, and subcategories. One example I used to ultimately indicate pervasive themes is depicted in Figure 1. Lastly, an analysis of language in social context through coding of field, tenor, and mode is illustrated by a specific example from one of Kyla's multimodal video presentations. Figure 2 presents the coding stripes that correspond to the subsequent video slides and timestamps depicted below them.

Figure 2: Coding Stripes of Data Analysis for Kyla's Video Presentation



Findings

The findings can be grouped by key themes present in the data analysis. Each clarifies ways in which TCs utilized multimodal literacies to make culturally relevant connections during coursework. These connections will be further clarified in sections that include intrapersonal and interpersonal connections along with interdisciplinary and intercultural connections.

Negotiating Intrapersonal Connections

Multimodal literacies are shown to be valuable resources for integrating student identity with learning in diverse contexts (Kelly, 2012; Taylor, 2018). This study confirms multimodal literacies were a vehicle to negotiate connections between TCs own mathematics learning experiences and CRP in mathematics instruction. The findings illuminate a multifaceted perspective of TCs identities as both students and teachers. Interestingly, even the ways they articulated their own identities as students and teachers were not singular.

TCs were given options in responding to classroom exercises through multiple modes (though more frequently in the online course) which included video recordings using Flipgrid, multimodal presentations, and more traditionally written discussion forums and essays. Through these choices, participants utilized multimodal literacies to acknowledge multiple intrapersonal student identities and consider themselves as college students of mathematics and college students

Participants' intrapersonal teacher identities also included multiple parts reflecting as: TCs, acting teachers (during field experience or if currently employed), and contemplative future teachers. Kyla's description of her uses of multimodal literacies indicates her considerations as a TC that eventually blended into her current teaching:

It was really fun . . . And, we're using them for my first-grade classroom. Those standards are perfect for a classroom, and they're visual for the kids, and it was great to see that. But the multimodal [text] where you're using all the images, I really started to migrate towards that [when] I have a lot of thoughts I want to share. And I felt the multimodal [text] got my emotions and my feelings about it . . . And so all my visuals I created were colorful, and I don't know—they were bubbly. So I liked that opportunity. But it was very much a choice every time for me . . . I've always been artsy. I've always loved images and to create posters. I would take an idea of an opera and create an entire program and posters and advertisements, and I loved that . . . But I never thought about doing it in the academic side, especially with math.

Kyla reveals her own interests in music and how multimodal literacies gave her the agency to make relevant connections in mathematics with a new lens. This self-reflection and awareness demonstrate an interaction of identity in cultivating a deeper understanding of multimodality and CRP as a TC, to eventually be applied to her instruction.

Figure 4: Consecutive Slides from Britney's Multimodal Field Trip Presentation



For Britney, she made authentic and relevant connections to her identity through the art she enjoyed and through new knowledge of history in her local community (Figure 4). She used multiple modes of aesthetic slides, geometric shapes, images, and text, through tenor that included relationships between her, her past and future self, me, and her peers (since it was posted to a discussion forum). She described our class trip, depicting a multimodal learning experience for her as a growing, lifelong student about art and local history that could also influence her as a future teacher.

Thus, the dynamic interplay between learning and planning with multimodal literacies was unique and necessary for TCs' intrapersonal development, as they integrated prior mathematics experiences with new pedagogical ones, while simultaneously beginning to analyze how they

might facilitate this process and CRP for their own students. Markedly, this interaction dually raises the question of TCs' identities and their interpersonal relationships with their professor, their peers as classmates/colleagues, and their students.

Navigating Interpersonal Connections

Data indicate the clear role of a TE in facilitating classroom and coursework experiences to demonstrate possibilities with multimodal literacies and CRP in teaching elementary mathematics. For instance, both Jackie and Kyla noted how even though they were graduate students getting their first and second Master's degrees, respectively, they had not been given chances to explore and understand applications of multimodality until our course. Notably, they had each already taken the two required conceptual elementary mathematics courses for their degrees. Jackie shared in her interview:

Most of the time you don't get options to be able to be creative with responses. You have to be tailored. The way I've always been in school is basically just reactive. I mean, you can't be creative so much when you're in school. At least when I was in school for my bachelor's program, I felt, which I was in the finance/accounting world. So, most of it was just like, are you following the rules? Yes, or no? Because accounting is just black and white—for the most part, anyways.

Here Jackie recognizes even in a degree and career background based in mathematics, the new opportunities I gave her to reason mathematically with multimodal literacies fostered creativity that empowered her to be proactive rather than reactive. Likewise, Kyla commented on how assignments I created facilitated this process for her:

I think one of the reasons why it was difficult for me to do the multimodal [text] is I haven't been given that opportunity, or even been given the opportunity to think that way . . . But I felt it actually combined . . . it helped me understand the concepts. It helped me remember everything, and it's so effective.

These revelations suggest if TCs often teach mathematics as they were taught, how they are taught mathematics pedagogy must also be modeled with similar regard in a way that honors identity and culture in authentic ways. Correspondingly, Jackie articulated how what I modeled through multimodal literacies and interpersonal relationships in our coursework would translate into her teaching identity and philosophy with future students:

You kind of just slowly let us step up on the stairs with 'Here's how you can kind of allow multimodal[ity] to help you in your classroom, connect with the kids, and have the kids connect with the material.' And at the same time, you've got this sincere—care—for lack a better term, for how the kids feel, and how they learn and how they interact in the classroom in their learning environment. So, I can see that you care as a teacher for your kids . . . and so I built kind of my teacher person on that. And so that's the culturally responsive part I'm talking about, is to actually care about how they're growing as a person in who they want to be, and not necessarily who the [State Math] standards want them to be.

When I assigned mathematics exercises, reflections, or planning assignments, I let students know I provided multimodal options, open-ended interpretations, and flexibility as a pedagogical choice. I indicated to them my purpose in this was to supportively enable what we know in

mathematics as productive struggle—or discovery, problem-solving, and critical thinking. Kyla expressed similar adaptations she was already taking from instruction into her teaching practices with her students. She allowed them the agency through exploration, options, and choice in multimodal tools they used to explore concepts based on their individual identities and interests:

And so, I think you expanded my idea of what I can use, and . . . not limiting my students and what they can do. And while I'll admit your lack of telling me exactly what you wanted, and the vagueness . . . I knew it was purposeful, and I knew it was helpful . . . And I think my students, I'm hoping by the end of this year they'll struggle less with that. Because I try to be vague with them, taking a page out of your book and letting them discover and create their own learning . . . I mean it's first grade. So, they're so imaginative. And I have, I call it a manipulative bar. And it's like their candy [stores] and they just pick which manipulatives they want, and all of them love it. And they all do better than when I decide 'Okay—we're all doing cubes. We're all doing counters. We're all doing bears.'

Specifically, Kyla recalled how through providing multimodal choices, one student was empowered to make culturally relevant connections:

I had one [student] pick out books the other day as their manipulatives, and so while it wasn't necessarily on the table, it worked. And he's my perfectionist. He loves books, and he created how to do these addition and subtraction problems with pages. Something I would never have chosen. But he would find that page, and then click back or scroll back to the page that it was supposed to be on. It was an interesting thing I hadn't thought of, but it works for him because everything for him is in a book that he can put pages on.

Through this, Kyla shows true attention to interpersonal relationships and her students' academic success by creating opportunities for mathematics to relate to their culture through multimodal representations.

Britney articulated a comparable sentiment in her final reflection paper as she referenced a hands-on classroom experience where she made interpersonal connections with me, her peers, and her future students at the same time:

As a student I struggled with math anxiety. Even now, I get frustrated and feel alone if I do not understand a concept as easily as my peers. I now know that I am not the only student who feels this way. I enjoyed the sharing activities we did in class. My favorite was when we held up the emoji signs to describe how we felt about mathematics. That activity helped ease my math anxiety. It made me realize I am not the only person who feels this way. I want to include this activity and many others in my future classroom to create a positive learning environment.

Here Britney describes a task during class discussion when TCs were given multiple die-cut emojis and asked to display their feelings in response to presented tasks, quotes, and excerpts from our math exercises and readings. She felt this type of activity did, and would, acknowledge student culture and identity through relevant literacies. Using modes of text, emojis, speech, and gesture, through the tenor of professor to TC, we discussed fields of mathematics anxiety with problem-solving and created an interpersonal community where individual voices were welcome, and mathematics discussion could be an open, safe space.

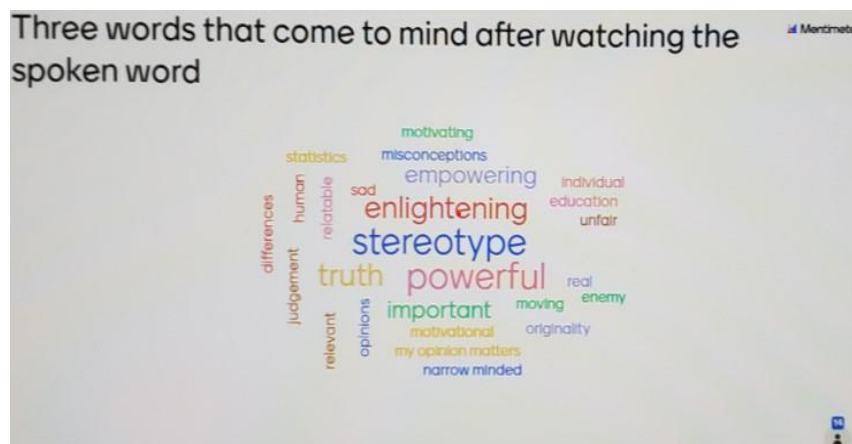
In sum, TCs often referenced and utilized instruction and examples from class lectures, assignments, and activities that served as instances when they were explicitly taught or directed how multimodal literacies were facilitating CRP in their understandings of mathematics content and pedagogy. In making these connections, the TCs' multiple identities were evolving in and through interpersonal relationships with their professor, their fellow TCs, and their considerations for students.

Developing Interdisciplinary and Intercultural Connections

TCs gained nuanced views for recognizing mathematics instruction, literacy instruction, and CRP as integrated, blended practices that inform, engage, and support one another as if in braided strands rather than mutually exclusive contents, lessons, or considerations. They learned that through multimodal literacies, mathematics instruction could be a space for connecting disciplines and cultures without being forced. The multimodal literacies provided opportunities for authentic, relevant engagement that facilitated meaning and connections in novel ways.

During face-to-face instruction, I endeavored to model interdisciplinary and intercultural connections in course sessions through multimodal formative assessments that included technology polls, manipulatives, drawings, sticky note responses, gallery walks, group stations, and a collaborative discussion strategy involving music and passing die-cut animals (to name some). We also watched multiple clips, one of which included a spoken word about cultural misconceptions. The modes of text, color, and image depict Britney's whole class response to the spoken word as they thought about how to make cultural considerations in mathematics instruction. In the word cloud, the most common word submissions are calculated mathematically and displayed multimodally as the largest and most central (Figure 5).

Figure 5: Word Cloud of TCs' Reactions to Spoken Word Video in Class



Britney's class also thought about how to define culture in their own words and capture commonalities between each other's definitions to articulate ways it could be incorporated into mathematics lessons. TCs used modes of colorful puzzle pieces to collaboratively arrange and then create a larger visual text display of their takeaways for our class to compare with one another (Figure 6).

Figure 6: Multimodal Definitions of “Culture” in Elementary Mathematics



TCs also routinely discussed how these multimodal formative assessments could be adaptable to their own classrooms with mathematical concepts and problem-solving strategies. Through these activities and others, I intended to demonstrate how multimodal literacies cohesively facilitate mathematics instruction as a viable space for engaging with critical and civic concepts authentically and reciprocally.

We also talked about incorporating multimodal children’s books to motivate, encourage, and promote literacy along with cultural and critical conversations through mathematical concepts. A specific example I provided in coursework highlighted the concept of division that can be taught and introduced through various stories or books about sharing and equality, alongside multimodal manipulatives (especially food or something desirable) to be distributed, divided, and shared in a classroom community. This instruction could then be related to current events or local history with videos, images, or multimodal websites that bring to light questions of fairness and equity through discussion or writing. TCs then made similar interdisciplinary and intercultural connections by incorporating children’s literature into lesson plans and presentations. As previously shown in

slides from Figure 2, Kyla and her partner used combined modes of images, text, audio, and shapes while considering the tenor between themselves, me, their future students, and their peers when presenting. They chose a book on Jewish traditions to introduce multi-day lessons about geometry and holiday traditions, centered around values of generosity and kindness from the book:

I always thought this when it came to teaching—all subjects can relate to each other. But math was the one that was harder for me to figure out, even though yes, I can say word problems. And in music, yes, obviously there is a huge connection to math. But to me multimodal[ity] expanded my ability to connect everything. And even in our last presentation, where we were taking a book that has not necessarily anything with math. We wanted to pick a book that I would just read and find different ways to add the mathematical concepts, and then have them use different modes of expressing this book and these terms, and these processes, and these standards that we're trying to learn across different subjects.

She described the reasoning behind their multimodal and cultural choices and related them to her prior learning and teaching in the the discipline of music:

And I think multimodal[ity] is the key to all of them and it's been interesting because my teaching has always focused around cultural relativism in music. I mean, how do you even get people to care about opera that listen to rap? You have to make some kind of connection, and if I had utilized a multimodal way of going back to images of 'Draw what rap feels, draw what you think of with rap, draw images, or pull images, create a rap poster,' I think multimodal[ity] could have expanded my teaching.

In this, Kyla demonstrates her new recognition for the potential role multimodal literacies can play in facilitating interdisciplinary and intercultural connections.

Figure 7: Slides from Jackie's CRP "Lesson Seed" Presentation

Read book

- After each chapter, read aloud or assign for reading for students to read a story chapter.
- Read aloud to students in small groups. Read aloud to students in small groups. Read aloud to students in small groups.
- Assign students to read aloud to you with the book in the classroom.
- Assign students to read aloud to you with the book in the classroom.

AMY WU and the PATCHWORK DRAGON
by KAT ZHANG Illustrations by CHANGLING DING

Draw a picture of a house

"People may live a different lifestyle than you."

Draw pictures...

Show globe/map

<https://www.google.com/maps/@44.091144,117.926213>

Introduce some shapes and identify them

OCCURRENCES AND SIMILARITIES AND DIFFERENCES

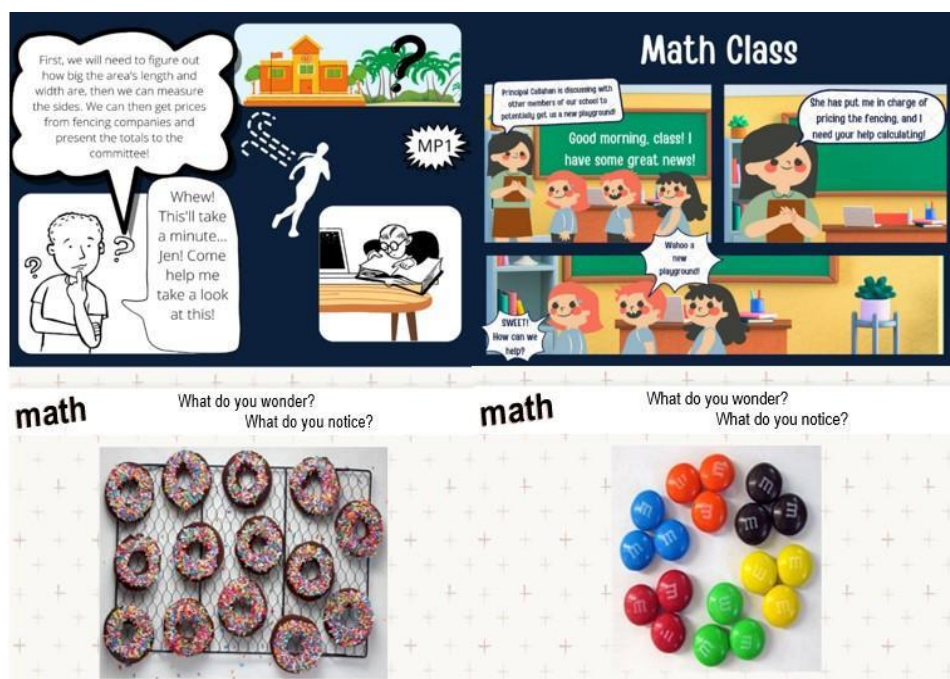
NOTICE AND WONDER DISCUSSION

Jackie also planned a lesson centered around children's literature. She engaged through the tenor of presenting to me and classmates using modes of images, text, audio, and symbols on shape attributes with a book from the Amy Wu series (Figure 7). She planned on using this to begin a discussion around embracing differences in others' lifestyles.

This discussion would then relate to an activity where students could observe housing structures across the world and create their own geometric homes. In both cases, Kyla and Jackie aimed to use children's literature and multimodal literacies as a foundation for connecting mathematics with a variety of disciplines such as art, history, and geography but also encouraged intercultural connections by cultivating space in mathematics to interrogate notions of giving, sacrificing, and honoring differences.

Not all connections were made through children's literature. Some samples from Jackie's lesson plans demonstrate how she planned to engage students with an interdisciplinary STEAM inspired playground problem using a Canva comic design, and multiple times she (and other TCs) utilized familiar foods or images to engage students in mathematical discourse and discovery related to teaching topics like counting by threes or understanding teen numbers (Figure 8).

Figure 8: Example From Slides of Jackie's Multiple Field Experience Lesson Plans



These slides show consideration for the tenor of teacher to student through modes of images, text, and symbols and involve fields of mathematical concepts, problem-solving, and critical thinking. She aimed to appeal to her students' cultures through relating intentional multimodal choices like relevant images, foods, and comics to elementary mathematics.

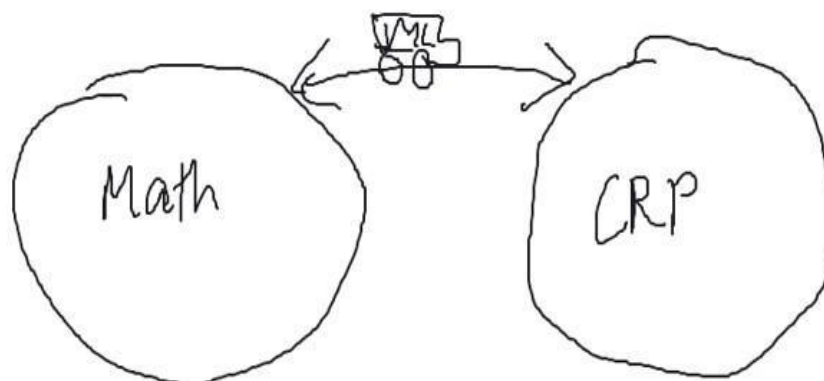
Additionally, Britney made interdisciplinary and intercultural connections on our historic community walk and trip to a local art museum that she expressed through the mode of text in her presentation slide:

It is important for me as an educator to teach my students material that is culturally relevant. Art can be used to make connections to other subjects, such as history, science, math, and ELA. The art at the museum was relevant to our community and I learned new things through the experience. The experience demonstrated to me a way that I can help my own students make real world connections. I can plan activities and field trips that will provide students with their own experiences.

She recognizes here that validating varied student interests in content areas through multimodal literacies can help them connect their daily lives and experiences. She equally notes the value in leveraging student assets through cultural connections to their local community and that one possible way this can be accomplished is through multiple literacies. Ultimately, learning about a specific community and/or culture through multimodal literacies, followed by lesson planning for direct field contexts, and subsequently teaching and applying these ideas in field experience were effective applications for this theoretical integration.

After the semester when I interviewed participants, I drew a rough model—intentionally a bit bare and general (Figure 9).

Figure 9: Multimodal Image Drawn to Represent Coursework Goals



I used it to describe how I conceptualize multimodal literacies, “ML”, as a small vehicle carrying some of our main course takeaways back and forth between “Math” and “CRP”. I asked participants what they would change or add to the representation and Kyla responded:

I like this. I honestly, I don’t think I would add anything to it . . . I think it’s just the connection we need for everything. So, when it comes to teaching . . . I think the image is perfect. I mean you could literally put CRP in the middle, and then put all of the subjects around and then draw to that. But then also draw them to each other, using the multimodal [vehicle] from math to literacy, literacy to music, to ELA—any of them—social studies. That’s what I was originally thinking when you drew it. It was a Venn Diagram with the ML in between. You could literally make a pretty little flower.

Kyla’s theoretical view on these connections excited me as her professor in terms of what I hoped she might glean from coursework. Though, in candor, some of the practical applications for what I consider CRP throughout all TCs assignments could still best be described as developing. At times, their interdisciplinary and intercultural connections left a bit to be desired in terms of what I would term critical, civic, and authentic engagement and what Ladson-Billings (2014) would suggest are deeper implications of cultural competence and critical consciousness that move toward culturally sustaining practices. In light of this, I aim to pose suggestions toward this finding and others in the subsequent discussion.

Discussion

Participants' coursework, responses, and interactions with multimodal literacies demonstrate significant, new connections in their developing perspectives toward learning and teaching in elementary mathematics. The different connections negotiated through multimodal literacies created safe opportunities and choices for incorporating multiple identities, expressing feelings or interests, understanding various disciplines, validating others' cultures, and simultaneously valuing personal ones. For many, these perspectives are not typically associated with elementary mathematics, as admitted by participants in their pre assessments and interviews. Multimodal literacies began to shift their perceptions of mathematics from black and white, yes and no, right and wrong, or cut and dry, to position it through CRP as a potential space for negotiation and connection. This connective framing included freedom, expression, ownership, agency, exploration, empowerment, and discovery. This indicates growth and change within TCs understandings of the true nature of representing and communicating mathematics through CRP.

Despite this progress, the apparent lack of critical consciousness sometimes evident in TCs assignments is particularly noteworthy. Though presentations and discussions indicated expansion of TCs cultural competence, their integration of critical literacy and discussion into their lessons was still improving. As might be expected, TCs reflected varying levels of comfort in terms of cultural awareness and facilitating critical conversations. Some of the TCs takeaways became based around creative ways to promote academic success and mathematical engagement through multicultural, social, emotional, relevant literacy "supplements" or "injections" of sorts. By her own admission, Kyla wrote in a final online reading response "I find I have only scratched the surface of being culturally responsive and aware in my mathematical instruction."

However, these aspects of TCs identities should be acknowledged and addressed, not forcibly altered. I see their applications as promising in terms of supporting mathematical achievement or affinity, cultural competence, and disciplinary literacies even though I do not necessarily see them as full actualization of what is possible for CRP through multimodal literacies in mathematics. Incorporating critical consciousness into elementary mathematics pedagogy can be complex, but I corroborate Ladson-Billings' (2014) assertion it cannot be overlooked. I take this as a personal responsibility and challenge to continually interrogate, incite, and cultivate through further iterations of study.

Findings confirm the value in moving forward in additional research in multimodal literacies for teacher education across content areas, especially with a lens toward elementary TCs, since content literacy instruction often focuses on secondary teachers and candidates (Accurso, 2020). The study affirms the call for integrating multimodal literacy instruction into teacher education programs (Fang, 2014), while illuminating disciplinary literacy instruction as not limited to secondary settings. The results also point to important questions for TEs and programs in terms of intersecting needs of content literacy and CRP. As it can be uncommon to find faculty with expertise in both literacy and specific contents like mathematics, various institutions have attempted collaborative relationships between departments for integrating content literacy with TEs, though the focus is primarily among secondary TCs, literacy education faculty, and disciplinary faculty (Draper et al., 2012). This study illuminates a need for similar emphases in elementary teacher preparation.

For elementary TCs, if programs separate contents and coursework such as mathematics and literacy pedagogy, while TEs simultaneously uphold the value of integrating CRP and interdisciplinary approaches in elementary subjects, we could be creating an unintentional conundrum. Shifting this lens of distinct domains and courses in creative ways is worth

considering. A proposition is raised, that shared needs of educating TCs on multimodal literacies and CRP in content areas necessitates fresh perspectives toward collaborative faculty efforts in teacher education. Further, it directs attention toward innovative possibilities in partnerships with schools, administrations, and other community stakeholders who may already be implementing interdisciplinary afterschool, enrichment, or intervention programs that focus on these combinations. In practice, these results have led me to newly collaborate with a historian from our local Black History Museum and my colleague, the Children's Literature and Advanced Literacy professor. As first steps, we have been working together toward planning and taking extended, improved "field trips" together with our undergraduate TCs.

Conclusion

The study is limited by a few factors influenced by the research design. Though purposive sampling aimed to investigate diverse participants, the study was conducted in coursework at one university, limiting the sample. Including TCs of varied ethnicities, backgrounds, genders, mathematical and literacy abilities, and general perspectives toward both mathematics and teaching would benefit ongoing research in this area.

Additionally, the study was conducted in a single type of course with me as the professor. Since the study and instruction were designed and facilitated by me, this provided detailed understanding of both the instruction and research methods, accompanied by considerable rapport with my participants; however, it also is limited in how it may apply to different educators and institutions. Admittedly, my lens as their white, female professor can also be restricted to inform some of these perspectives. Moreover, while my unique position as someone with degrees and teaching experience in mathematics, language, and literacy afforded specific strengths to the design and applications, my knowledge and role as a professor with this combined interest and training may be hard to recreate or simulate when extending to other contexts.

Nonetheless, it is useful to consider both the difficulties and possibilities in how this can be further researched since similar studies may manifest differently in other contexts. I plan to continually collect data through future coursework and the newly formed cooperative partnership mentioned. I propose that with further research, applications of multimodal literacies and CRP in a learning community can move beyond a specific mathematics pedagogy course to provide students with opportunities to engage in meaning-making through ways that contribute to growth in literacy, learning, and multiple identities.

Research continues to call for developing CRP in TCs (Leonard et al., 2014) and university faculty in their own praxis (Ellington et al., 2021). This study confirms the value of investing into collaborative development for TEs and TCs to explore interdisciplinary implementations of literacy and CRP. Specifically, it is pertinent for TEs and TCs to understand the nature and value of multimodal literacies in content areas. TEs are a vital component in considering the practical ways coursework assignments can be leveraged to effectively promote and cultivate the connections for TCs.

Furthermore, understanding how TCs make sense of the relationship between mathematics, multimodal literacies, and cultural relevance will ultimately help them facilitate these connections in their own classrooms. If TCs can begin to understand their own multimodal and mathematical reasoning from the past into the present, it could lead to more meaningful integration of these same literacy practices into their instructional planning and assessment decisions. In turn, this would also influence mindful choices of modes they provide for their own students to use during instruction and assessment. Ultimately, more informed, thoughtful attention toward incorporating

and leveraging multimodal literacies in mathematics instruction can forge and validate relevant, accurate connections to students' cultural lives and other content areas. By focusing on this potential with elementary teachers and students, we can actively cultivate and invest in their development of enduring, rich perspectives toward mathematics and literacy as lifelong learners.

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