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Mathematical Literacy and the Secondary Student

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ABSTRACT

Public education is a continually evolving field, with new research, policies, and practices explored by professionals who are driven to provide America's youth with high-quality education. Research literature since 2000 has highlighted the importance of disciplinary literacy and its unfortunate neglect in a majority of secondary classrooms (Shanahan & Shanahan, 2008). Students who are literate in a particular discipline, such as math, view themselves as fluent in the language of mathematics, comfortable with reading, discussing, and practicing complex mathematical concepts while using appropriate vocabulary (Buehl, 2017). As seasoned professionals and novice educators consider the role of disciplinary literacy in their own classrooms, it is necessary to ponder the practices that are implemented within classrooms. Do they align with current research on the matter? What role do motivation and culture play in the process of becoming mathematically literate? How do these ideas influence classroom literacy practices? These are the central questions that have guided the construction of this research study, which will seek to examine the phenomena that occur within a classroom as teachers implement practices which promote and teach mathematical literacy. The exploratory nature of this study dictates that no judgement on the effectiveness of observed and discussed instructional strategies is considered, rather, a comparison of the latter with those strategies recommended by current educational researchers and literature. Interviews and classroom observations will work in tandem with a review of the current publications that address the areas of motivation, mathematical literacy, and culture.

Keywords: mathematical literacy, disciplinary literacy, culture, motivation, literacy strategies

INTRODUCTION

Background

The current body of research pertaining to mathematical literacy has its foundation in the study of content-area reading, which led to the related yet distinct concept of disciplinary literacy (Shanahan & Shanahan, 2012). Disciplinary literacy is a natural extension of content-area reading, which refers to intermediate level literacy skills with cross-curricular references, while disciplinary literacy places greater emphasis on cultivating advanced literacy in the discourse of a particular discipline, such as mathematics (Buehl, 2017). With any discussion of literacy, whether mathematical or linguistic, meanings are assigned to words, phrases, and symbols. Bruner (1996) proposes ideas regarding the psychology behind meaning-making without relating them to a specific subject area, but in relation to the culture that shapes an individual's education. As the individual is socialized into the culture, meanings are attached to words in relation to their unique contexts, whether mathematical or not, and it is necessary for a teacher to bear in mind the significance of culturalism when teaching mathematical literacy (Bruner, 1996; Moje, Ciechanowski, Kramer, Ellis, Carrillo, & Collazo, 2004).

Statement of Purpose

The purpose of this research study is to focus on the strategies and techniques recommended for teachers who wish to invite their students to become mathematicians, compare them to the actual classroom practices of secondary math teachers in a handful of Greater New Orleans area schools, and explore these teachers' perceptions of how these strategies impact student motivation and learning. The central question posed to achieve this purpose is: **What is the relationship between mathematical literacy, motivation, and culture?** The comparison will be performed using a two-pronged method of qualitative data collection, predicated by a review of current literature on motivation, mathematical literacy, and culture.

Overview

This research report contains five sections. The first section presents the background and statement of purpose that led to the study. The second section contains a review of current literature on mathematical literacy, motivation, culture, and the pedagogy related to each topic. The third section outlines the research methodology, including descriptions of the procedures, study participants, instruments of data collection, qualitative data analysis, and limitations and strengths. The fourth section presents the central findings of the study and the connections found between mathematical literacy, motivation, and culture. The fifth section describes the implications for classroom practices, future research into these topics, and the conclusions of this research. Appendices with pertinent documentation and references conclude the report.

LITERATURE REVIEW

Introduction

Secondary teachers face many challenges every day. Chief among them is motivating students to take interest in learning the basic concepts that apply to their daily lives and will be necessary for subsequent education and a meaningful career. In today's society, the ability to reason quantitatively, work with numbers and symbols to represent ideas or data, and question the strength of conclusions based on mathematical logic is of utmost importance (NCTM, 2000). These are some of the skills included under the umbrella term of mathematical literacy (IRA, 2006; Jablonka, 2003). As education professionals have studied the way adolescents learn, new theories and ideas have evolved around the ways to build secondary students' mathematical literacy skills (Shanahan & Shanahan, 2008). The current consensus on mathematical literacy is predicated on the similar but distinct concepts of reading in the content area, general disciplinary literacy, and mathematical knowledge acquisition (Buehl, 2017; Shanahan & Shanahan, 2008).

For teachers to build this level of mathematical knowledge in their students, there must also be a consideration of cultural, motivational, and pedagogical factors which are necessary for effective mathematical literacy instruction (Buehl, 2017; Shanahan & Shanahan, 2008). Bruner (1996) argues that meaning is constructed within the culture surrounding an individual seeking to understand that particular meaning. Mathematical meaning is assigned to words, symbols, and modes of thinking by experts in the discipline, teachers, and members of the wider cultural community of mathematics (Bruner, 1996; Buehl, 2017). Teachers must integrate this exterior culture with a classroom culture which encourages students to build mathematical literacy and motivates them to succeed with complex mathematical content by setting high-expectations, creating a positive atmosphere, and guiding mathematical discourse (NCTM, 2015; Buehl, 2017; Gee, 2001).

Teachers should also consider motivation in addition to culture when applying mathematical literacy in the classroom. Motivational strategies for students to learn math at a level that is indicative of mathematical literacy must be carefully planned, as motivation in secondary students tends to decrease through adolescence, particularly for mathematics (Peetsma & Van der Veen, 2015; Posamentier & Smith, 2015). Understanding motivation from a developmentally appropriate perspective allows for effective use of motivation to build mathematical literacy (Feinstein, 2009: Bransford & Darling-Hammond, 2005). Once students have a powerful motivation to pursue mathematics, the task of building mathematical literacy becomes much easier to implement (Buehl, 2017).

Effective instructional practices for building mathematical literacy are supported by an understanding of culture and motivation (Buehl, 2017). Those which bear the most relevance to this study will be examined in depth, including the underlying constructivist perspective, the gradual release model and zone of proximal development, questioning strategies, feedback, and the use of technology. Each of these strategies allows for varying levels of collaboration, and reflects the intersection of mathematical literacy, culture, and motivation. Deliberate collaborative learning activities are key to building a classroom culture of mathematical literacy, as they encourage students to use the language of the discipline in their questions, reasoning, conclusions, and comprehension (Wilkinson & Son, 2011). When scaffolds such as previewing vocabulary or differentiated practice problems are used appropriately within the zone of proximal development, students are motivated to interact with the mathematical texts and concepts independently (Buehl, 2017). Technological tools can also be effectively harnessed to hone skills related to mathematical literacy such as problem solving, justifying, reasoning, and quantitative visualization (NCTM, 2015).

Mathematical Literacy

For secondary teachers to develop strategies for building mathematical literacy, it is first necessary to define the term and understand its origins within the body of educational research. Mathematical literacy is just one example of disciplinary literacy, which refers to the ability of an individual to read, write, and verbally communicate knowledge of an academic discipline (Buehl, 2017). Disciplinary literacy is considered the culmination of literacy development, built on a foundation of basic literacy skills such as decoding words, and intermediate literacy skills such as comprehension of gradually broader vocabulary (Buehl, 2017; Shanahan & Shanahan, 2008). Interest in disciplinary literacy originated in the topic of reading in the content area, as well as the improvements made in elementary school students' basic reading and comprehension skills due to new literacy programs, initiatives, and interventions (Perle, Grigg, & Donahue, 2005; Shanahan & Shanahan, 2008). These phenomena coalesced in the years around 2000 and influenced the study of disciplinary literacy development during adolescence (Buehl, 2017). Content area reading strategies are designed to showcase similarities across subjects and improve reading, writing, comprehension skills which can be applied to any discipline (Buehl, 2017). By contrast, implementation of disciplinary literacy such as mathematical literacy accentuates the specific characteristics of mathematical texts and guides students to specialized skills based on mathematical means of communication (Shanahan, 2012; Hynd-Shanahan, 2013). Research at this time identified the need for guidance into advanced disciplinary literacy as the next logical step in literacy development (McCombs, Kirby, Barney, Darilek, & Magee, 2005).

Many organizations, including the National Council for Teachers of Mathematics (NCTM) in collaboration with the International Reading Association (IRA), issued recommendations for improved mathematical literacy strategies suited to middle and high school students based on the expanded pool of research on the matter (IRA, 2006). Additionally, the Common Core State Standards Initiative (CCSSI) address skills associated with mathematical literacy. As secondary students are given increasingly diverse content, they are expected to show proficiency with the deep knowledge, reasoning skills, and methods of communication specific to mathematics (CCSSI, 2018). This level of competence in the desired academic content area goes beyond applying generic reading comprehension processes to new information, and must include familiarity with meaning-making in the discipline (Fang, 2012a; Heller & Greenleaf, 2007). Students working to become mathematically literate tend to concentrate on "what" mathematical content is: the key ideas, facts, symbols, or explanations. However, the "what" must be equally balanced with the "how" and "why" the content is created, organized, and communicated in order for students to build mathematical literacy (Buehl, 2017; Hynd-Shanahan, 2013). A student who is mathematically literate can read, write, discuss, and reason with numbers and mathematical symbols with the same fluency as written language. A student who is mathematically literate can apply the broad concepts that govern the world of mathematics in real-world situations (IRA, 2006; Jablonka, 2003). In short, mathematical literacy is the interaction of reading, writing and speaking to build mathematical thinking.

Figure 1

(Reading + Writing) × Speaking = Thinking

Adapted from 2018-2019 National Ambassador for Young People's Literature Message: "READING + HOPE = CHANGE. What's your equation?" (Woodson, 2018). Woodson's equation for how reading impacts the building of knowledge uses mathematical symbols to create meaning. Without mathematical literacy, the equation means nothing, but the use of notation gives the reader a deeper understanding of the message. This adaption represents a construction of mathematical literacy to guide its discussion in this report. Each aspect of the equation will be addressed in greater detail to support this framework of mathematical literacy.

Reading

Since experts in each unique academic field employ the most specialized forms of disciplinary literacy, it is beneficial to identify the methods used by mathematicians to approach complex texts and organize information. Shanahan and Shanahan (2008) found that the strategies employed by mathematicians included close reading and rereading of passages among the most valuable for comprehension of proofs and other mathematical texts. The importance of these practices stems from the density of mathematical concepts that are presented, compared to narrative text, and from the high concentration of symbols, equations, graphs, charts, and other visual representations of key mathematical concepts (IRA, 2006). "Math reading requires a precision of meaning, and each word must be understood specifically in service to that particular meaning" (Shanahan & Shanahan, 2008, p. 49). Shanahan and Shanahan (2008) also found that mathematicians emphasized the importance of general and specific definitions for words that appear in most high school math textbooks. An integral segment of mathematical literacy deals with the variable nature of terms used in mathematical texts and students need to identify the difference in colloquial use of the word and its mathematical implication (Shanahan & Shanahan, 2008; IRA, 2006).

Writing

Writing with a mathematical perspective requires similar skills and strategies as reading with a mathematical perspective, since both are important aspects of mathematical literacy. The relationship between reading and writing mathematically is highlighted by placing both these functions in parentheses in Figure 1 to demonstrate their importance to the construction of mathematical literacy. The overlap between these two areas of mathematical literacy is particularly related to the variety of symbols, notation, and other visual means of communicating mathematical knowledge. "Like mathematical language, mathematical symbolism too can leave many mathematical processes implicit…" (Fang, 2012b, p. 52). As students learn to read mathematical symbolism, along with the associated mathematical vocabulary, teachers should model and encourage writing out the symbols for students to gain fluency manipulating mathematical notation (Buehl, 2017). Writing can be a powerful means by which students can begin to create their own understanding of mathematics, but first requires the student to know what to write. As Karpicke and Blunt (2011) acknowledge, "Retrieval is not merely a read-out of the knowledge stored in one's mind; the act of reconstructing knowledge itself enhances learning" (p. 744). When students write what they know about previously learned information, they are mentally preparing to add new material to that schema, thereby engaging in the act of reconstructing knowledge (Karpicke & Blunt, 2011). Writing in this manner will help to retrieve and scaffold stored knowledge to synthesize new knowledge (Anderson & Pearson, 1984; Fisher & Frey, 2009). Many students take notes, though frequently “these student-created texts are vastly inferior to written texts that might have been studied” (Buehl, 2017, p. 244). Mentoring students to become mathematically literate should include writing strategies that enhance learning, versus simply copying from a teacher presentation. Literacy research points to using two-column notes or other structured note-taking strategies which encourage students to paraphrase or elaborate on content knowledge. This is because effective use of these writing strategies involves reframing mathematical ideas into personal understanding, as well as creating questions and tracking personal comprehension (Buehl, 2017; Greenleaf, Cribb, Howlett, & Moore, 2010). When students learn to write about mathematical knowledge, beyond a basic understanding of symbols and notation, they are actively synthesizing new information for comprehension (Buehl, 2017; Fisher & Frey, 2012).

Speaking

Verbal mathematical literacy refers to the ability of an individual to use the insider “discourse” of mathematics, an established use of language that usually incorporates a fixed set of terms and vocabulary (Buehl, 2017; Gee, 1996). Use of mathematical discourse places a student within a community of learners who identify as those who can learn and understand mathematics. Since this is a mindset that math teachers wish to encourage in students, discussion of mathematical knowledge is essential to building mathematical literacy and comprehension (Buehl, 2017; Moore & Onofrey, 2007; Gee, 2001). It is not enough for teachers to simply model appropriate mathematical discourse, students themselves must practice using mathematical vocabulary and reasoning in class discussions. “True learning communities learn from one another…. As people share their understandings and reasoning with one another, they teach each other in a variety of ways” (Bransford & Darling-Hammond, 2005, p. 64). Talking about mathematics allows students to formalize their thoughts about mathematical language, visual displays, and facts to construct formal mathematical knowledge, making verbal mathematical literacy integral to the process of building mathematical thinking processes (Fang, 2012b; Johnson, Watson, Delahunty, McSwiggen, & Smith, 2011; Buehl, 2017). Strategies for achieving this goal will be explored in the support section of this report, along with their connections to motivation and culture.

Culture and Mathematical Literacy

When considering the acquisition of any form of literacy, it is important for teachers to know that individuals must learn the meanings assigned to words, phrases, and symbols that are developed by others. Bruner (1996), for example, maintains that meaning-making is achieved within the culture surrounding an individual. This is important because as the individual is socialized into a culture, meanings are attached to words and symbols in relation to those cultural contexts. This could be the cultural context of the individual student, the students’ community and family, the classroom, practices within the discipline, or a combination of these cultures. It is necessary, therefore, for teachers to bear in mind the significance of cultural impact when emphasizing literacy in the classroom. “Although meanings are ‘in the mind,’ they have their origins and their significance in the culture in which they are created. It is this cultural situatedness of meanings that assures their negotiability and, ultimately, their communicability” (Bruner, 1996, p. 3). These contentions are echoed in NCTM position statements regarding recommendation for current pedagogy, as well as in the current body of research on mathematical literacy (NCTM, 2014; Moje et al., 2004). There are many implications of these points for the classroom teacher to consider. First, to facilitate literacy, the teacher must create a classroom culture that emphasizes this cultural relevance. Second, the teacher must guide students to understand how to situate mathematical problems in the context of their lives. Third, the teacher must use proven instructional strategies and techniques that promote mathematical literacy (Bransford & Darling-Hammond, 2005; Rogoff, 2003; Lee, 1995). By addressing these implications, students in the class will gain an appreciation of the math they are learning and retain the information for longer periods of time (Bransford & Darling-Hammond, 2005).

Therefore, teachers must continually balance their classroom cultures with the culture of the wider world, including that of the students' community and the community of mathematical experts. Building mathematical literacy requires students to deeply engage with mathematical sources, knowledge, and means of communication, requiring teachers to make connections between mathematical material and students' lives. Without this connection, students are ill-equipped to develop mathematical literacy (National Mathematics Advisory Panel, 2008). Given the importance of previously learned schema in comprehending mathematical discourse, teachers must connect mathematics with students' lives in order to build new mathematical conceptual knowledge (Buehl, 2017). Researchers have observed that although mathematical texts frequently contain examples that are realistic, but many students do not see them as connected to their real-lives (Moje, Stockdill, Kim, & Kim, 2011). The NCTM offers recommendations for effectively building a classroom culture that will stimulate learning in its Access and Equity position statement:

> These practices include, but are not limited to, holding high expectations, ensuring access to high-quality mathematics curriculum and instruction,

> allowing adequate time for students to learn, placing appropriate emphasis on differentiated processes that broaden students' productive engagement with mathematics, and making strategic use of human and material resources." (NCTM, 2014, "Access and Equity in Mathematics Education," para. 2)

Researchers such as Willingham (2009) and Paulos (2001) have documented the unfortunately large number of students who enter math classrooms with poor attitudes towards the content as a consequence of how it is taught and how it is viewed in the wider culture. However, Willingham's conclusion supports the NCTM argument that these notions can be overcome by setting high expectations, using effective instructional strategies to support mathematical literacy, and establishing a classroom culture that positively utilizes relationships (Buehl, 2017; Willingham, 2009). Another important part of this classroom culture is the relationship between the students and teacher. Heron (2003) found that even struggling students participated more when teachers made them feel important to classroom discussions and activities. Heron goes on to state that in addition to maintaining positive relationships with teachers, students responded well to "teachers who made them feel welcome in their classroom, who were tough on them, and who expected them to learn" (2003, p. 568).

Motivation and Mathematical Literacy

Motivation in secondary students has been an object of interest to educational researchers, particularly because students' efforts tend to decrease over the course of adolescence, in a variety of schools and countries (Peetsma & Van der Veen, 2015; Midgley, Feldlaufer, & Eccles, 1989). The task of implementing mathematical literacy is affected by the ways in which secondary teachers utilize motivation. Posamentier and Smith (2015) observe that

“Planning motivation requires creativity and imagination. The needs and interests of students must be carefully considered. This will naturally vary with the student characteristics found in today’s schools” (p. 76). How to increase student motivation in mathematics is the central question of effective teaching (Posamentier & Smith, 2015; Hannula, 2006). Contemplating the relationship between motivation and mathematical literacy is critical if teachers wish to use motivation to teach mathematical literacy effectively, as Posamentier and Smith (2015) suggest.

Motivation is broadly understood to have three overarching structures that influence learning behaviors: affect, expectations, and values/goals (Peetsma, Hascher, Van der Veen, & Roede, 2005). The affective component of motivation refers to the emotional connection students have to a task or classroom environment; the expectations component refers to students’ belief they can accomplish learning tasks, or self-efficacy related to academic goals (Peetsma & Van der Veen, 2015). Within the values/goals component of motivation, a further distinction is made between intrinsic and extrinsic motivation based on the cause of action. Intrinsic motivation for a task implies an individual has innate interest or personal desire for completing the task whereas extrinsic motivation indicates the task is being completed for the benefit of the end result, separate from the action of completing the task (Deci & Ryan, 2000; Peetsma & Van der Veen, 2015).

Peetsma and Van der Veen’s (2015) structure of motivation provides a guide for exploring the relationship between mathematical literacy and motivation because the components of the motivation framework influence the components of mathematical literacy. The explicit nature of this motivation model gives teachers the ability to guide student behavior towards building mathematical knowledge by focusing on motivational states and processes (Hannula, 2006). During adolescence, changes in cognitive and emotional processing abilities influence the motivational states and processes described in Peetsma and Van der Veen's model (2015). Understanding development is critical to the expectation and affective components of motivation because learning tasks that are developmentally inappropriate undermine motivation and produce disruptive behavior (Bransford & Darling-Hammond, 2005). When students feel they are unable to complete a task or are not emotionally invested in the content or classroom, motivation decreases, along with the possibility of building mathematical literacy. Bransford and Darling-Hammond (2005) additionally note that "teachers can tap into developmental interests as a way of enhancing motivation in school tasks" (p. 109). Since adolescence brings about new awareness and concern with wider social circles (Feinstein, 2009), secondary teachers can highlight the aspects of mathematical literacy which emphasize applications outside the classroom and tie mathematical knowledge to a broad community to increase intrinsic motivation. Buehl (2017) states that teachers must be daily considering the intersection of literacy and motivation because students must place value in the content they are learning, especially when it is difficult. "'A powerful why' is essential to our efforts to address non-cognitive factors that matter in [mathematical] literacy" (Buehl, 2017, p. 234). When students have "a powerful why" (p. 234), they are displaying intrinsic motivation, a key feature of the values/goals component of motivation (Buehl, 2017; Peetsma & Van der Veen, 2015).

Pedagogy that Supports Mathematical Literacy

Research indicates that certain instructional strategies are more effective at building mathematical literacy than others (Buehl, 2017; Shanahan & Shanahan, 2008), and those which demonstrate the most relevance to this study will be examined. In particular, the use of gradual release lesson planning, zone of proximal development, questioning, group discussion, feedback, and technology will be considered in relation to mathematical literacy, and the cultural and motivational factors which underpin it. These instructional strategies reflect a constructivist perspective because they reflect the mechanisms for how mathematical literacy is acquired and, hence, how it can be taught, while also taking into account the cultural and motivational factors which drive the functional value of mathematical knowledge (Glaserfeld, 2002). Although constructivism is a theory of learning and not of pedagogy, literacy research and constructivist theory both argue that knowledge is produced and meanings are ascribed to new ideas through bridging new and old experiences, so teachers must take account of students' prior conceptions of math (Buehl, 2017; Teachnology, 2018; Bransford & Darling-Hammond, 2005). Constructivist research has also influenced research into mathematical literacy, particularly the focus on problem solving skills and decisive thinking, which are indicative of mathematical literacy (Bhutto & Chhapra, 2013). Consequently, the pedagogy that supports mathematical literacy described in this section focuses on students constructing mathematical knowledge holistically, and does not recommend teachers explicitly giving students information.

Gradual Release and Zone of Proximal Development

The seminal work of Soviet psychologist Vygotsky (1978), which focuses on social-cognitive learning and development, expounded upon by Pearson and Gallagher (1983), and adapted for a literacy model by Schoenbach, Greenleaf, and Murphy (2012), highlights the importance of using classroom culture and developmentally appropriate motivation strategies to implement mathematical literacy. Teachers may begin using Pearson's and Gallagher's (1983) gradual release of responsibility model by thinking aloud while reading and deconstructing sentences of a math textbook, by modeling examples, or by explicitly building on previously learned concepts. This is the teacher-regulated phase of the model, when students are first introduced to new topics (Buehl, 2017). Vygotsky's zone of proximal development (1978) is the intermediate phase during which teachers can use scaffolds such as spiral questioning, guided practice, or collaboration activities for students to build confidence with new ideas. Deliberate collaborative learning activities are key to building mathematical literacy, as they encourage students to use the language of the discipline in their questions, reasoning, conclusions, and comprehension (Wilkinson & Son, 2011). The zone of proximal development is predicated on a positive classroom environment, where students are confident they can complete tasks and comfortable seeking knowledge that will enable them to continue to the student-regulated section of the Pearson and Gallagher model with skills indicative of mathematical literacy (1983). When scaffolds are used appropriately within the zone of proximal development, students are motivated to interact with the mathematical texts and concepts independently (Buehl, 2017).

Questioning

Building mathematical literacy requires students to take ownership of the content they are studying and learn to think according to mathematical concepts, which both require that students know what they need to know. This step to becoming mathematically literate can be initiated with appropriate questioning techniques (Buehl, 2017). Rothstein and Santana (2014) developed the Questioning Formulation Technique based on research focused on acquiring proficiency in a wide range of subjects. The protocol asks students to produce their own questions based on the teacher's question focus, work with open- and close-ended questions, prioritize and discuss how to use the questions, and reflect on the process and the information gained. Rothstein and Santana (2014) found that "... students who traditionally have not participated at all seem to be the most readily activated by this invitation…. They can use it to analyze math problems and demonstrate new problem-solving abilities" (para. 34). An important aspect of questioning and using student-driven question formulation is the diversity in types of thinking which are fostered, including divergent, convergent, metacognitive, and critical thinking. This in turn will contribute to improved mathematical literacy because “this is the kind of intellectual heavy lifting that scholars in any field must do” (Rothstein & Santana, 2014, para. 21). Furthermore, as Elves (2013) suggests, “the development of these questioning skills and behaviors empowers the learners to conceptualize and express their thinking without having to depend primarily on teacher questioning” (Elves, 2013, p. 2).

Feedback

Questioning through a mathematical lens and building lessons which follow a gradual release model both require good teacher feedback to be effective strategies for implementing mathematical literacy. Teachers need to use feedback to make sure that the appropriate connections to existing schema are made and the student is remembering the new information correctly (Pearson, 2011; Alexander & Jetton, 2000). Effective feedback is timely and should also include some positive reinforcement along with suggestions of how to improve or expand on an idea. Additionally, positive feedback helps the student calmly continue with learning instead of stressing about whether the answer is right or wrong (Feinstein, 2009; Buehl, 2017).

Technology

Finally, the role of technology in the 21st century classroom is undoubtedly connected to any discussion of mathematical literacy, culture, or motivation, because the advent of new technological research in the wider culture is undeniable. Singh (2017) notes that due to the increased presence of technology in business, “Companies today are strategizing about future investments and technologies such as artificial intelligence, the internet of things, or growth around new business models” (para. 1). Since teachers of mathematics must be mindful of exterior cultural influences when setting a tone for classroom culture, effective technological tools are essential. The NCTM (2015) maintains that content-specific and content-neutral technological tools can support students' understanding of mathematics,

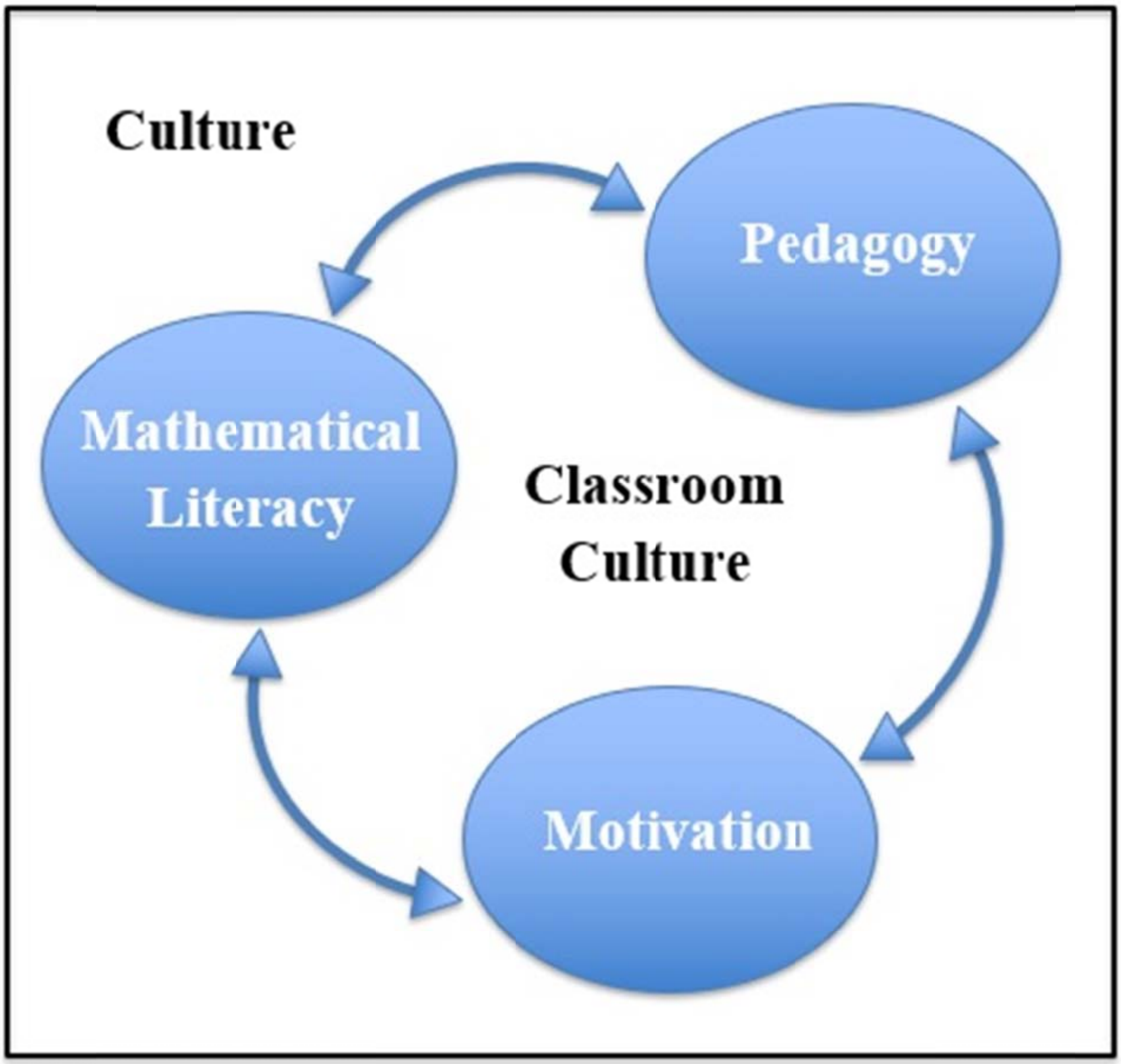
> In mathematics education, content-specific technologies include computer algebra systems; dynamic geometry environments; interactive applets; handheld computation, data collection, and analysis devices; and computer-based applications. These technologies support students in exploring and identifying mathematical concepts and relationships. Content-neutral technologies include communication and collaboration tools and Web-based digital media, and these technologies increase students' access to information, ideas, and interactions that can support and enhance sense making, which is central to the process of taking ownership of knowledge." (NCTM, 2015, "Strategic Use of Technology in Teaching and Learning Mathematics," para. 2)

Significant research points to the progress made with strategic use of technological tools to develop mathematical literacy skills such as problem solving, justifying, and reasoning (Gadanidis & Geiger, 2010; Nelson, Christopher, & Mims, 2009; Pierce & Stacey, 2010). Further research points to the variety of technological activities that can spark many different levels of thinking depending on the needs of the teacher's lesson (Papanastasiou & Ferdig, 2006). With the plethora of content-specific technological tools, such as computer algebra systems or manipulative geometric software, teachers can motivate students to take ownership of their mathematical literacy by discovering knowledge independently or collaboratively (NCTM, 2015).

Conclusion

The relationships between mathematical literacy, motivation, culture, and pedagogy are complex, with a great deal of overlap. In attempting to analyze these relationships, a conceptual framework began to take shape, according to the current research on the topics and their mutual influences. Figure 2 represents the result of this research.

Figure 2



Culture plays two roles in this framework; exterior culture is a prerequisite to mathematical literacy, as cultural norms and practices in the discipline influence the meanings assigned to mathematical words, symbols, and situations. Positive classroom culture is similarly integral to mathematical literacy, motivation, and the effective instructional practices outlined above. Within these cultures is placed a cycle of using mathematical literacy to design strategies to increase motivation to learn the mathematical skills included under mathematical literacy. Effective instructional strategies such as gradual release lessons, questioning, and successful use of technological tools are guided by the reading, writing, speaking, and thinking skills that are indicative of mathematical literacy. In turn, appropriate implementation of these pedagogies will also increase motivation to become mathematically literate. A complementary dynamic is evidenced by the double-ended arrows. Motivational theories influence pedagogy much the same way as theories of mathematical literacy. Effective implementation of the pedagogy described above will help students improve their mathematical literacy skills, leading to increased motivation. Examining each piece of the puzzle in relation to the other offers teachers the best chance to help students reach their full potential in mathematics.

RESEARCH METHODOLOGY

Introduction

Mathematical literacy in the secondary class is an intricate process reliant on teacher and student interactions with others and, therefore, cannot be easily reduced to a simple score on an objective test. Thus, it was necessary to observe the practices that build mathematical literacy skills outlined in the literature review, and discuss these practices and their justifications with teachers. This section describes important details related to the methodology of this qualitative research study, including the procedures undertaken, the participants of the study, the instruments associated with these procedures, the data analysis, and the limitations and strengths of this methodology. Each section also includes a rationale for the methodology decisions made, based on the purpose of the research study and the central question: **What is the relationship between mathematical literacy, motivation, and culture?**

Study Procedures

The first data collected was a set of interviews conducted with five current classroom teachers. Interviews lasted no more than one hour, were recorded, and later transcribed for in-depth analysis. Transcripts were supplemented by journal entries and contemporaneous notes taken by the co-investigator. A predetermined set of questions was created prior to the interviews; however, each interview resulted in a unique variant on this set of questions based on the active dialogue between the teacher and interviewer. Despite slight variations in wording and follow-up questions, data collected from the interviews was consistent. Interview data provided a broad range of teachers' perspectives on mathematical literacy, motivation, culture, and classroom practices. All records of transcripts, journals, and notes related to teacher interviews have been securely stored and will be destroyed following presentation of the research study. The interview question framework is included in Appendix D.

The second method of data collection was classroom observations, lasting no more than two hours in the classroom of each interview participant. An observation guide to identify classroom literacy strategies is included in Appendix E. This served as a guide for observation notes for later analysis, though this was also adjusted to meet the needs of the diverse classroom environments observed. Classroom observations allowed for verification and documentation of instructional practices discussed during interviews. In three cases, the observation was conducted before the interview, which provided the opportunity to discuss classroom literacy strategies observed during the interview. In one case, the observation was conducted after the interview, which yielded slightly less concise interview data, but overall did not adversely affect the quality of data gathered. In the case of one participant, an interview was conducted but no observation due to time constraints. Observation notes have similarly been stored securely and will be destroyed following presentation of the research study.

Participants

Teachers selected to participate in this study had to have the following criteria:

1. Currently teaching math at the secondary level (6-12 grades)
2. At least five years of teaching experience
3. Knowledge of mathematical literacy

These criteria were chosen to identify secondary math teachers who have been teaching long enough to develop effective teaching strategies through experience and education. Knowledge of mathematical literacy means familiarity with the term as it relates to mathematical concepts taught in secondary classrooms and built through reading, writing, and speaking. Since the study seeks to explore how different teachers define mathematical literacy, this criterion was the most flexible of the three, although participating teachers needed to demonstrate at least a basic understanding of the term. This determination was made by reviewing participant pre-surveys.

To identify a teacher as a potential participant, an introductory letter and pre-survey were included when initial contact was made via email. The introductory letter and participant pre-survey are included in Appendices A and B, respectively. The letter provides solicited teachers with a brief overview of the purpose and procedures of the study and information regarding their informed consent to participate in the research study. The enclosed pre-survey includes a few basic questions which allowed teachers to see what the interview questions would be like before they decided to participate. The survey also afforded the opportunity to tailor interview questions according to the teacher's responses and verify that the teacher demonstrated appropriate knowledge of the topics under consideration. Eight teachers were solicited to participate via email at the recommendation of professors or colleagues. Of the eight, six indicated interest and five completed the participant pre-survey; one teacher who completed the pre-survey later withdrew from consideration. The five teachers who participated were ultimately selected based on their responses to the participant pre-survey and the recommendations of other teachers. Participating teachers, identified by pseudonyms, are profiled in Table 1.

Table 1

Teacher pseudonym	School type (public, private, etc.)	Parish	Pre-survey	Years of teaching experience	Grade level observed	Subject observed
Stan	Private	Jefferson	No	39	10th	Geometry
Esteban	Public	Orleans	Yes	25	n/a	n/a
Polly	Catholic	Orleans	Yes	10	12th & 8th	Trigonometry & Pre-Algebra
Helene	Catholic	Orleans	Yes	25	8th	Honors Algebra
Janelle	Public	Orleans	Yes	5	9th	Algebra I

As mentioned above, the framework for interview questions, the observation guide, the introductory letter, and the participant pre-survey are included in the appendices. In addition to these instruments of data collection, a comprehensive document of informed consent was used to describe the purpose and procedures of the study to participating teachers. The document of informed consent is included in Appendix C. It outlines the purpose and procedures of the study and informs participants of the exploratory nature of the study, lack of procedures experimental in nature, and steps taken to protect sensitive information. This document was presented to each participant and reviewed at the first meeting and signed by the participant and co-investigator.

Data Analysis

Once interview and observation data were gathered, a protocol was developed to analyze the qualitative data. Each teacher and school were assigned pseudonyms to guard sensitive information. All interviews were transcribed, and transcript data was coded into four main categories and related subcategories as follows:

1. Mathematical Literacy (ML)
    - A) Definition of ML
    - B) Relation to other forms of literacy/disciplinary literacy
    - C) First encounter with the concept of ML
2. Culture
    - A) Exterior culture of student body
    - B) Classroom culture
3. Motivation
    - A) Motivating resistant students
    - B) Motivating students in general
4. Pedagogy
    - A) General instructional strategies to support ML
    - B) Questioning
    - C) Assessment
    - D) Sources

These categories were chosen to align the original interview framework with the themes that emerged throughout the study. Using this coding structure, four tables were created to organize teacher's responses to each topic. Teacher responses were condensed for display in the interview tables; however, these entries do not represent the word choices of the researcher, but the exact words and phrases used by each participating teacher. A fifth table was created to organize observation data, with codes corresponding to the questions listed on the observation guide. These five tables visually display common themes that emerged throughout the research, and are summarized and explained in the fourth section.

Methodology Strengths and Limitations

In general, qualitative research studies such as this one share a number of strengths and limitations in common. A strength of using qualitative data is the large amount of information generated by procedures such as interviews and observations. Other strengths specific to this study are discussed later in this section. Golafshanni (2003) recognizes that a drawback to this type of study is the difficulty of establishing reliability and validity, while these terms are used distinctly in quantitative research, "terminology that encompasses both, such as credibility, transferability, and trustworthiness is used" (p. 600). Additionally, the researcher and participants are primary instruments of data collection in qualitative research, introducing the possibility of bias (Atieno, 2009). Researcher bias was curtailed by sticking to participants' exact words in organization of data and by identifying specific actions during classroom observations. Participant bias was curtailed by supplementing interview data with classroom observations to validate teachers' responses. Transferability to larger populations was somewhat mitigated by the use of diverse pool of participants, although the small sample size was also a limitation.

Additionally, the study results cannot be exactly repeated, which is a normal part of qualitative research study.

The methodologies described in this section were developed to provide the clearest possible picture of the qualitative data gathered and aligned with the study's statement of purpose. While the procedures were very useful in contributing to the purpose of the research study, there were limitations to the methodologies employed as well. The use of a pre-survey with the letter was a strength of the data gathering procedure, as it allowed the researcher to tailor interview questions according to the teacher's responses. Unfortunately, not every teacher completed the pre-survey, which frequently happens when soliciting responses from participants in qualitative studies. The interviews with teachers who did not respond to the survey generally took longer to conduct and yielded somewhat less detailed data, though this did not adversely affect the quality of data or present identifiable data bias, as evidenced by the consistency across participant responses.

A flexible interview question framework allowed the researcher to adequately prepare for the interview based on responses to the pre-survey and gather the appropriate data, but also adjust the questions during the conversations with each teacher as the narrative warranted. Another strength of the data gathering procedure was the combined use of interviews and observations, with observations providing validity for the responses supplied during interviews. This strength was observed when the interview was conducted prior to the observation and after the observation.

A challenge to this study was time, due to the necessity to conduct data gathering during the late spring and early fall. These challenges resulted in minor changes to the procedures and restricted the possibility of follow-up meetings in person to clarify points in the interview.

Ultimately, changes made due to time restraints did not have an adverse effect on the quality of data gathered because teacher responses and classroom practices observed remained consistent.

Conclusion

This section outlined the methodology of the research study, including the procedures, participants, instruments of data collection, and the organization of data analysis, as well as a description of the limitations and strengths of this methodology. All methodologies of this study were designed to generate authentic qualitative data to answer the central research question. In the next sections, the key findings of the study will be explored and the implications of these findings will be reviewed.

RESEARCH FINDINGS

Introduction

In this section, the key findings of the research study are presented according to the framework described above. The first four subsections present the data gathered from teacher interviews, led by tables displaying teachers' responses to the four main categories of the study: Mathematical Literacy, Culture, Motivation, and Pedagogy. Teachers' pseudonyms are listed in the first row of each table, and subcategories are listed in the first column. Table entries contain condensed statements made by each teacher but use the participating teachers' own word choices to restrict researcher bias. Following each table is a summary of the data which also establishes connections to the research question. Some direct quotes are cited below the tables to support the findings. The fifth subsection includes a table with data gathered from classroom observations, with teachers' pseudonyms listed in the first row and categories aligned with the observation guide listed in the first column. Following the fifth table is a summary of the observation findings and their connection to the research question. The section concludes with an overview of the findings prior to discussion of the implications of the study in the final section.

Mathematical Literacy

Table 2

Topic	Stan	Esteban	Polly	Helene	Janelle
Definition of mathematical literacy (ML)	Big picture, quantitative lens for organization and interpretation of the world, math applications in real life, interests, understand 'why,' the talk of math, writing	Conceptual knowledge, math vocabulary, numeracy, understand literal text, real world problems, representing data, building on concepts from factual knowledge, essential questions, 'why' does it work this way, writing and rewriting, discuss, communicate	Understand math as a whole, fluid with math facts, number sense, build understanding from basic facts, understanding the 'why,' build on prior knowledge, critical thinking skills, real world connections, problem solving, multiple perspectives to solve a problem	Real world applications communicate mathematical ideas, math terms, read and explain math, problem solving, deep comprehension, asking 'why'	Problem solving, critical thinking, recognize what to do and explain the concepts and procedures, read, think, analyze, use math terms, real world applications, building knowledge through Bloom's taxonomy, error correction, the 'why'
Relation to other forms of literacy/ disciplinary literacy	One facet of skills to view the universe, interaction with varying texts	Cross-curricular content helps enhance ML	Basis is critical thinking skills, understand the 'why' of each subject, cross-curricular content	Depth of comprehension, it's acceptable to be mathematically illiterate, but not in English	Reading to learn in every class, relate math to other subjects
First encounter with the concept of ML	Observed vicariously through math professors, teaching elementary teachers to explain the 'why'	Around 2000, district wide emphasis on math vocab, numeracy, Word Walls	Teaching students with learning differences, explaining 'why' it works	Gradually evolved through research/PD, explaining to parents and students	Studying at UNO and Xavier University

Table 2 Summary

Most teachers had several responses in common when asked to define what mathematical literacy means to them. All five said that mathematical literacy means knowing ‘why’ something works or ‘why’ math concepts are organized the way that they are. All teachers interviewed described mathematical literacy as the ability to communicate mathematical ideas and concepts, although the specifics of the modes of communication were slightly different for each teacher’s response. These differences were not significant, but simply reflected each teacher’s personal word choices and interpretations of the concept of mathematical literacy. The reading, writing, and speaking framework established in Figure 1 offers a guide for comparing these responses because teachers tended to mention reading, writing, and spoken literacy skills during interviews. Four teachers referenced the discourse of mathematics in some fashion, with Stan defining mathematical discourse as the “talk” of mathematics, and Esteban, Helene, and Janelle referring to math vocabulary or terminology. Esteban, Helene, and Janelle said that mathematical literacy includes the ability to read math texts, while only Stan and Esteban included writing in their definition of mathematical literacy. Four teachers referenced mathematical ideas, concepts, or ways of thinking in their definitions of mathematical literacy, with Esteban, Polly, and Janelle stating that the ability to build knowledge from smaller concepts is an important skill of mathematical literacy.

Janelle also included the ability to recognize and detect errors in mathematical reasoning as part of mathematical literacy, and as a mathematical method of thinking that is directly related to the world outside the classroom. Demonstrating error detection is a significant part of mathematical literacy because it indicates that a student knows the content thoroughly and can examine procedures precisely to identify flawed logic. Shanahan and Shanahan (2008), for example, reported this mathematical literacy skill after consulting with experts specializing in proof reading.

All teachers referred to the application of math in the world and the exterior culture in some way. Stan stated, “Everybody has ways to interpret the world that they’re in, and one of those lenses that you can use to interpret the world has this sort of quantitative aspect to it” (Stan interview, p. 3). He also went on to state that mathematical literacy includes the ability to relate mathematics to one’s personal interests and real life. Other teachers maintained this assertion in different ways, stating that mathematical literacy is the ability to apply math to real world problems, represent, explain, and critically analyze information using mathematical means of thinking. Polly contended that multiple perspectives from diverse life experiences help to enhance mathematical literacy due to this connection to the real world. “We have a very diverse school in general, socioeconomically, ethnically, et cetera. I feel that that actually helps mathematical literacy in that, somebody might see it in a different light than somebody else” (Polly interview, p. 13). These responses reflect characteristics of mathematical literacy presented in the literature review, namely, that mathematical literacy is built by connecting to prior knowledge and applying concepts to everyday contexts (Buehl, 2017; Jablonka, 2003).

Each teacher had a slightly different understanding of mathematical literacy in relation to other forms of disciplinary literacy. Three emphasized cross-curricular connections in their responses to this question, which is more closely related to reading-in-the-content-area in current research literature on mathematical and disciplinary literacy (Buehl, 2017; Shanahan & Shanahan, 2008). Stan described disciplinary literacy as a set of skills used to view the universe, and Polly echoed this idea by stating that students must understand the ‘why’ of each discipline but went on to state that all forms of disciplinary literacy share a basis of critical thinking skills.

Helene made a particularly insightful comparison between mathematical literacy and other forms of literacy, stating, "… if somebody couldn't read, people would be appalled that they couldn't read, and we think of literacy that way. But it's more than acceptable to say… 'I'm not a math person'" (Helene interview, p. 3). Her comment encapsulates research findings that show the prevalence of math antipathy and its acceptance in the exterior culture (Willingham, 2009; Paulos, 2001). Helene considers mathematical literacy to be representative of deep comprehension of mathematical conceptual knowledge and each discipline affords the opportunity to be literate in comparable deep conceptual knowledge, which is consistent with current research on mathematical literacy and disciplinary literacy as presented in the literature review (Buehl, 2017; Shanahan & Shanahan, 2008).

The diversity of the interview participants' education and previous teaching experience is evidenced by the diversity in responses to the question of when each was first introduced to the concept of mathematical literacy. Janelle, the most recently certified teacher, stated that mathematical literacy was discussed in teacher education courses taken at local New Orleans universities, demonstrating the increased focus on mathematical literacy and disciplinary literacy in recent years as highlighted in the literature review. Other teachers stated that mathematical literacy was a concept that they learned about while teaching, either through professional development or through experience.

Culture

Table 3

Topic	Stan	Esteban	Polly	Helene	Janelle
Exterior culture of student body	Homogeneous, well-to-do socially and socioeconomically, sometimes brings apathy/lack of motivation, the idea that school may be irrelevant to success or outdated	Fear of math more than dislike, feeling unprepared, desire for success, some extenuating circumstances which prevent success, diverse student body, the norm is ok with mediocrity, students don’t want to be seen as a nerd or better than peers	Many students have had bad experiences in math classrooms before, varying ability levels, socioeconomic and ethnic diversity, different family viewpoints on math influence students’ attitudes	Parents’ attitudes towards math dictate how students view math, students come from diverse math backgrounds and ability levels	Parents with education, some one-parent homes, some students raised by other family members, some dislike math due to a lack of eighth grade math teacher
Classroom culture	Students encouraged to work independently, follow their own paths for learning without an instructor, lots of tools and physical objects around the classroom, connections to other cultures and religions through geometry, teaching math history from a multicultural perspective, some students view resources as opportunity to thrive, students are challenged to dig deeper into ML regardless of motivation or ability level, many students arrive far ahead of other high school students	Working to build confidence, students motivating one another, students are encouraged to collaborate and arrive at solutions without fear of failure, everyone is afforded the right to learn and ask questions without fear of harassment or teasing, use peers as support system and resources to learn from one another’s strengths, accountable math talk, constructive conversation and discussion of math problems, competition drives success, real world connections, using math and everyday language	Diverse perspectives help with problem solving and building ML, finding more than one way to approach a situation, have fun in the classroom, talk about life, dating, etc. allow students to be a little crazy because by the end of the class period they are more productive and focused, educate the whole person, honesty and respect, hard work, finding solutions even if it doesn’t come overnight	Getting out of students’ way to do the work of learning, pacing, organization, friendly competition, honors students tend to enjoy the math, pushing students to excel, convincing other students’ that math is OK and they can succeed, opportunities for success with little things, students recognized outside of classroom, supporting one another, students’ personality affects the way the teacher drives the class	Established when they walk in the building and the classroom, positive energy and vibes in the classroom, clean, orderly, disciplined, teachers care about students’ success, purposeful classes, collaborative, regular procedures and expectations for learning and problem solving, exploring knowledge as a group, skills for success in the real world in the learning environment

Table 3 Summary and Connection to Mathematical Literacy

Like Table 2, which displays teachers' responses to questions related to mathematical literacy, Table 3 reveals many similarities in the way mathematical literacy is situated in cultural contexts, despite some differences in exterior culture. The first row of the table displays teachers' descriptions of the exterior culture of their student body. Exterior culture refers to the immediate community with which students come in contact, such as parents, other family members, and friends. The teachers interviewed represent a diverse cross-section of schools in the New Orleans area, as outlined in Table 1. Consequently, a wide variety of exterior cultures were represented in the interview data. The second row of the table displays teachers' descriptions of their classroom cultures, which tended to include more similarities than the responses regarding exterior culture. The similarities observed in these teachers' classroom cultures represent traits of a classroom culture which supports and enhances mathematical literacy.

One of the most striking similarities across the data was the report that many students feared or disliked math before they entered the teacher's classroom. Esteban, Polly, and Janelle explicitly stated this in their responses. Esteban considered there to be a desire for success, but fear of failure and lack of preparation produces dislike of math and decreased confidence. Both Polly and Helene teach in Catholic schools and stated that parents' attitudes towards math significantly affected students' attitudes, regardless of socioeconomic or ethnic background, and could encourage or discourage students to succeed in math class. Stan, Esteban, and Janelle also referred to familial influences, though in different ways. Stan reported that students may exhibit apathy towards math as a result of their families' higher socioeconomic status. Esteban mentioned that students who lack a strong support system at home also lack the confidence to succeed in math. Janelle shared similar sentiments and went on to state that many students come from single-parent homes or live with extended family members, but typically grow up in a home with educated caregivers. Esteban also provided insight on peer influences on students' attitude towards math, stating that students do not want to be seen as smarter than their peers, and "the norm is ok with mediocrity" (Esteban interview, p. 15). As cited in the literature review, intrinsic motivation heavily influences students' mathematical literacy development, and students' motivation and attitudes are influenced by family and peer influences from the exterior culture. Teachers' discussion of the impacts of exterior culture on mathematical literacy related to current researchers' findings that value and meaning are ascribed to mathematics by the members of an individual's community and family, not just by mathematical experts. As such, value and meaning can vary widely among different groups, though the data showed that many groups tended to have some people who disliked or feared math and some who did not.

The data displayed in the second row of Table 3 reveal several common attributes of classroom cultures that support acquisition of mathematical literacy. Stan, Esteban, Polly, and Janelle referred in some way to real world connections when describing their classroom culture, highlighting mathematical literacy as a bridge between the classroom culture and exterior culture. In addition to connecting mathematical content to real world applications, all teachers interviewed stated that their classroom culture is built on the assumption that all students are capable of succeeding with math and are challenged and encouraged to do so. Polly, Helene, and Janelle stressed the importance of personally connecting with students outside of an academic context. Janelle mentioned the importance of "[making] class purposeful, using positive vibes, positive energy" (Janelle interview, p.7). Polly emphasized the importance of being honest and connecting with students, adding, "You have to educate the whole person…. I think that honesty helps build those positive relationships and even builds respect because they know that I'm not going to lie to them" (Polly interview, p. 14). Helene stated the significance of recognizing students outside of class at sporting events or other nonacademic activities. These teachers' contention that establishing a positive rapport with students is supported by Heron's (2003) research mentioned in the literature review that found that student participation is increased when teachers make students feel valued and capable of success. In turn, mathematical literacy will be fostered because students will be more likely to participate and persevere when completing the activities that are designed to build mathematical literacy.

Besides applications and the personal touch, the teachers interviewed also unanimously reported that their classroom cultures incorporate some form of collaborative learning. Esteban stated that "the culture is set up in the mindset that everybody in this classroom has, and is afforded the right to learn…. If you are unsure, do not be afraid to ask the question without fear that someone will harass, tease, or harm you because you don't know" (Esteban interview, p. 13). He also added that the classroom culture encourages constructive discussion of math problems and invites students to utilize one another as resources for help and motivation. Janelle also spoke on the benefits of a collaborative classroom culture where students encourage each other to problem solve and celebrate in their classmates' success. Helene supported these statements and added that there is also an element of friendly competition in the classroom culture to push students to excel.

The emphasis on connections between math and life outside the classroom, and collaborative learning to build mathematical knowledge are two of the key aspects of classroom culture that serve to build mathematical literacy (Buehl, 2017). Collaborative learning strategies such as group discussion increase students' fluency with mathematical discourse in their questions, conclusions, and comprehension (Wilkinson & Son, 2011). Connecting math to the real world enhances mathematical literacy by tapping into students' prior schema (Buehl, 2017). The interview data shows that these features of classroom culture help to support mathematical literacy, regardless of peripheral differences in external culture.

Motivation

Table 4

Topic	Stan	Esteban	Polly	Helene	Janelle
Motivating resistant students	Trying to see the students perspectives, personalized learning/projects, connecting math to other interests, individual attention	Showing results of practice and repetition that lead to success, encouraging other students, building intrinsic motivation	One-on-one meetings, getting to know students and their interests, relating content to the real world	Individual tutoring, formation center slips, positive relationships can bring results even if student does not like math	Encouragement, one-on-one math tutoring, working at the board to boost confidence, peer tutoring
Motivating students in general	Student-regulated learning, showing them they can be successful on their own, inspire them to learn more, finding connections to personal interests, offering engaging activities, challenging students to think more deeply, find creative ways to teach math	External motivation: Class Dojo: rewards good behavior and adds points to weekly assessment but does not deduct points, visible to students and parents, similar to a game/social media, helping prepare students and build up energy to work well at math, lunch time tutoring, building confidence and that mindset, teamwork, competitiveness for success	Tangible rewards (stickers), taking ownership of and responsibility for their learning, see improvements as they complete activities, knowing what to do and what to expect, confidence in applying knowledge and making connections to what they know, short videos for flipped classroom, life lessons/realness/ honesty	Engaging questions that are not so difficult that they are frustrating, seeing grades improve as they move through online assignments, friendly competition, positive and negative motivation, recognizing students outside of class	Know what to do to be confident, hands-on activities, teachers who are caring and positive influences, group work, clear expectations and routines, knowing they can succeed, teamwork

Table 4 Summary and Connection to Mathematical Literacy

Table 4 displays data collected from interview questions related to motivation and several teachers refer to their statements regarding mathematical literacy skills when describing their motivational strategies. The first row contains responses to the topic of motivating students who are resistant to learn math on a level that is indicative of mathematical literacy. All five teachers mentioned the value of individual attention when working with unmotivated students. Stan and Polly referred to student interests to create natural motivation to learn new mathematical concepts, as this not only builds connection between mathematics and the real world, but also builds a positive rapport with the student. Stan recommended trying to see the student’s perspective and personalize the concept in some way. Polly recounted the story of a student who was failing. She arranged a one-on-one meeting with the student to pinpoint the problem and provide some constructive feedback. After that meeting, “there’s a complete turnaround” and the student started to be more successful in the class (Polly interview, p. 11). Helene expounded on this idea by stating that “a lot of the students who dislike math will still work if they like the teacher” (Helene interview, p. 9). This finding was supported by Heron’s (2003) research which stated that students will work diligently in class if the teacher maintains a positive relationship with the student.

Esteban and Janelle focused on the need to provide struggling students with encouragement to build confidence and show them the results of their hard work. Esteban told a story of challenging a student to race on a math problem. The student responded that he didn’t want to because he thought Esteban was smarter than him. Esteban pointed out that by working the same problem three times a day as he does, the student would be able to see the improvement on those problems. “Now… he’s working harder at getting the three than he had before when he was doing none. So… resistance sometimes in turn will bring success if they understand that… practice makes better, but perfect practice makes perfect" (Esteban interview, p. 10). Esteban's anecdote relates back to the expectations component of Peetsma's and Van der Veen's (2015) motivational research which argues that students' motivation is increased when they believe they can succeed at an academic task.

The second row of Table 4 contains responses to the question of how to motivate students in general. Here, all five teachers' responses overlapped around the ideas of increasing students' confidence and success in math, but the details of achieving this end varied by teacher according to their instructional style. For example, Polly utilizes a flipped classroom approach where students are assigned video lectures to view before class. She observed that this instructional technique encourages students to take responsibility for their own learning and allows them to see improvements as they watch the videos, take notes, and make improvements on assessments.

> They need to get it on their own, which is very difficult as a teacher, to sit back for a little bit, but for them to really see that motivation. They are more engaged because they are more active, because they know what they're doing. When they walk into class, they already know how to do the lesson because they've watched the videos." (Polly interview, p. 10)

Her flipped classroom approach is different from Janelle's direct instruction approach, but both discussed the importance of setting clear expectations so that students know what to do to be successful. Stan also relies on a flipped classroom and student-regulated learning to show students that they can be successful on their own and challenge them to think deeply about the mathematical connections to their own lives. He commented, “I think people, when they see somebody who knows something that they know, like… basketball, but then see somebody who knows basketball and knows how to use math in it, I think that motivates [them] to at least know what that person knows. So I think that little hook is powerful” (Stan interview, p. 8). Esteban and Helene both recommended a mix of positive and negative motivation, either of which can be intrinsic or extrinsic. Helene stated that it is important to structure questions so that students are required to think but do not become frustrated. Both use friendly competition in their classrooms to motivate students as a group, noting classroom technology can provide the basis of this type of motivation, as students compete to earn the most points, similar to online games. They utilize two separate programs: Helene’s focuses on academic points and Esteban’s awards or deducts points according to behavior.

The data demonstrates that motivational strategies for all types of students, regardless of ability level or attitude towards math, connect to mathematical literacy in several important ways. Making math connections to students’ personal interests beyond the classroom, maintaining a positive attitude when problem solving, and emphasizing the gradual building mathematical skills through repetition are all hallmarks of mathematical literacy (CCSSI, 2018; Hynd-Shanahan, 2013). These practices can also be used to increase motivation for the content, allowing teachers to effectively make use of the relationship between mathematical literacy and motivation (Buehl, 2017).

Pedagogy

Table 5

Topic	Stan	Esteban	Polly	Helene	Janelle
General instructional strategies to support ML	Big picture, student-driven by the end of school year, interest-based, flexibility, collaborative learning, real world applications, kinesthetic tools to build understanding, discovery method	Lecturing, modeling, building understanding in layers, spiraling, discovery method, introducing inquiry-based problem then teaching concept, ‘Think about a plan’ framework, collaboration, TAPPS	Original flipped classroom lecture videos, modeling, direct instruction building on previously learned content, discovery method	Organizational structure and pacing for learning: binders with guided notes and vocabulary/ formula sections, online homework with supports, direct instruction, discovery method	Teacher explanations, group activities, hands-on math activities, writing out sentences to explain steps, verbally explaining steps using math vocabulary
Questioning	Ask what’s going on vs. telling what’s going on, ‘why’ something works in addition to ‘what’ and ‘how,’ guiding questions of math/Geometry	Essential questions to guide lesson/unit planning, ‘why is this this way?’ open-ended questions, justification of answers	Leading questions, scaffolded questions, student-generated questions	Socratic questioning, asking for proof of an answer, balance of questions and instruction, rote methods for problem solving	Bloom’s Taxonomy, using underlining and highlighting to solve word problems, identifying questions
Assessment	Project-based, Genius Week: personal interest in Geometry, research, journaling	Balance of technology- and paper-based, data-driven instruction, writing to see reasoning	Original written tests with application/ word problems, projects to visually represent concepts, Homework Selfies	Group-graded homework, online practice quizzes with supports (form), in-class quizzes (performance), Four Corners	Exit Tickets, quizzes, tests (based on Eureka math) verbalizing and summarizing learning for the day to carry over for next lesson, Thumbs Up/Thumbs Down

Table 5 continued

Topic	Stan	Esteban	Polly	Helene	Janelle
Sources	OneNote text and activities, Geogebra and Processing for visualization, physical objects, instructional videos of discussion	Math textbook, technological supports: calculators, Photomath	Google Classroom for everything except tests and quizzes, Doceri app for flipped classroom videos	Desmos graphing & calculator software, MyMathLab, online texts with real-world/cross-curricular links	Eureka Math, original Power Points, Think-Through math interventions to build confidence

Table 5 Summary and Connection to Mathematical Literacy

Table 5 displays teachers' responses to interview questions related to the specific instructional strategies which connect the mathematical literacy, culture, and motivation. Each teacher describes a few of his/her general instructional strategies in the first row of the table, followed by each teacher's use of questioning, assessment, and sources within their overall pedagogy. Although there is diversity in the instructional approaches described, there are a number of similarities in the ways these approaches relate to mathematical literacy. In interview responses, teachers tended to blend general instructional strategies with literacy strategies, with some variations made based on their personal styles and student needs. Since many responded with similar definitions of mathematical literacy, the supportive instructional strategies also had common attributes, such as the applications of questioning or collaborative learning. Naturally, teachers also adjusted instructional strategies to suit the needs of the students or the school's math curriculum. These variations are most notable in the types of sources and assessments discussed.

Stan, Esteban, and Janelle explicitly mentioned collaborative or group learning activities in the description of their general instructional strategies. Esteban explained a particular strategy called Think Aloud Paired Problem Solving (TAPPS). He considers TAPPS to be an application of accountable talk or constructive use of mathematical discourse, stating,

> It helps them socially and it helps them to communicate. Many people are afraid to discuss math problems, but what has to happen is, in order for you to have that constructive conversation with one another you have to be able to talk out your problem, and then it becomes checks and balances with the people that [are] right there by you and they're supporting you." (Esteban interview, p. 14)

His rationale for using a discussion-based collaborative learning strategy aligns with the other teachers' responses regarding the use of collaborative learning to increase mathematical literacy. Similarly, Stan, Esteban, Polly, and Helene stated they use discovery-learning in some form with their students to promote the skills associated with mathematical literacy, such as making conjectures and using mathematical discourse to solve application problems. Everyone except Stan reported using direct instruction, modeling, or lecturing as a regular instructional strategy and Polly stated that she alternates between using direct instruction through modeling and with questioning. All five teachers discussed the importance of building larger mathematical concepts from previous content, a hallmark of mathematical knowledge construction and mathematical literacy.

Questioning strategies that support mathematical literacy were an area of interest in the interviews due to the role that differing levels of questions play in the construction of mathematical knowledge. Most teachers described questioning strategies that employ essential, leading, or open-ended questions to guide mathematical instruction. Polly and Janelle noted the importance of student-generated questions to give students the opportunity to practice the metacognition skills associated with mathematical literacy. Additionally, Stan, Esteban, and Polly referred to the original overarching ‘why’ questions that form the basis of mathematical concepts, which are used to structure and organize curriculum materials. Four teachers also reported the use of scaffolding questions to help students gain confidence as they acquire mathematical literacy. Janelle specifically cited Bloom’s Taxonomy as a framework for her questioning strategy and Helene expressed that she typically uses lower-level questions to move through the rote methods for problem solving, particularly when pressed for time.

Several common features were discovered in the assessment strategies teachers described to support mathematical literacy. Esteban, Polly, Helene, and Janelle reported using formative assessments such as homework, exit tickets, or practice quizzes. Of these teachers, there were several ideas regarding the implementation and style, with Polly, Helene, and Janelle using strictly paper-and-pencil homework and Esteban using online homework. Helene described her use of technology to support written assessment, “I’ll assign that prior to a quiz in class on paper so that they have the opportunity to get the online help… they can click, ‘Show Me a Different Problem,’ they can talk to their neighbor, they can talk to me” (Helene interview, p. 5). This approach allows students to build metacognition skills and mathematical literacy while also checking for understanding of procedural knowledge.

Polly contends that homework can be used to stimulate critical thinking by asking students to check their own work. “I just do Homework Selfies because I grade for completion… I actually give them the answer key. Their job is to do the homework, check it, and that way they’re able to see, ‘I did this wrong, well, what did I do wrong? How do I get to this answer?’ And then if they’re still struggling, then they can bring those to me” (Polly interview, p. 8). This approach to assessment requires students to think about the justification and reasoning behind mathematical procedures, an important aspect of mathematical literacy.

Stan and Esteban mentioned the importance of having students write about concepts to show their reasoning, and to serve as a reflection, or closure of students' thoughts about the topic at hand. Both teachers also included writing as an important skill associated with mathematical literacy in Table 2. Esteban maintains that written homework is more helpful for the teacher, stating, "It has to be written in order for you to dissect whether or not the kids are performing the algorithms correctly…. The beautiful thing about paper-generated assessments is that you get to see quality of work, based on students. You get to see whether or not they know how to reason, model, apply to solve" (Esteban interview, p. 5, p. 7). Stan and Polly recommended using projects to visually represent a concept, or to connect to students' interests outside of class. Both writing and making connections to mathematical applications in the world are necessary for students to develop mathematical literacy.

The teachers who were interviewed incorporate a variety of sources in their classrooms, most of which are online. Stan stated that students do not like to read the textbook, so he organized the information from the textbook into a OneNote document where students can read through examples if they need a source to reference besides their own notes. He also models mathematical concepts with software such as Processing and Geogebra, and students are encouraged to use these tools to "construct, manipulate, hypothesize about, and make conjectures that they might have about different configurations. They'll see me play with it, then I get them to play with it, they're asked to produce some things with it" (Stan interview, p. 8). These technological sources allow students to practice mathematical literacy skills.

Other teachers discussed the use of math sources in lesson planning, but responses tended to favor technological sources or teacher-created materials based on other sources in their instructional strategies. Polly stated that her flipped classroom videos are all original, and Janelle stated that her PowerPoints are original, but based on Eureka Math. Helene reported that many of the note packets she distributes to students are based on the materials of a mentor teacher, with adjustments made to suit her needs. Stan, Esteban, Polly, and Helene responded that they use technological tools to support students and build confidence. By using a variety of sources to implement their instructional strategies, the teachers are fostering mathematical literacy because students are given multiple representations of mathematical concepts, information, and procedures for solving problems.

Observations

Table 6

Topic	Stan	Polly	Helene	Janelle
Types of interaction	Almost equal split between student-led and teacher-led, most classes are student-led by the end of school year, lots of student-student interactions, some teacher-student(s)	Teacher-small group and student-student for the duration of both periods, more student-student observed with 12th grade than 8th grade	Started strictly student-student for group activities, moved to teacher-whole class after approximately 15 minutes	Interactions evenly split between teacher-whole class, teacher-individual/group, and student-student
Language and comprehension indicators, motivation for content	Math vocabulary words used throughout class period, students were on-task throughout class period, many began working unprompted, online practice quizzes and varying levels of verbal questioning used to indicate comprehension	Math vocabulary used in teacher's scaffolded questions and student-student interactions, some girls in both sections took a while to settle into work, by end of period, all were working quietly and efficiently, 12th graders used notes to answer questions in group discussions	Math vocabulary used during 4 Corners activity: students wrote and verbally explained their groups' terms, most students on task for the duration of period, went right into homework grading procedure (clear expectations)	Math vocabulary used in teacher questioning and student explanations of work on whiteboards, teacher monitoring room to keep students on-task, some took longer to settle into Algebra I mode than others, students provide written and spoken justification for answers

Table 6 continued

Topic	Stan	Polly	Helene	Janelle
Materials and sources, physical environment	OneNote documents on laptops, Geogebra modeling software used by teacher first, students follow along on laptops, demonstration of volume with blocks, 2-D drawings on blackboard, lots of physical objects and visual displays of geometry around the room, warm and inviting, cozy	8th grade: laptops for warm up, teacher-created test review, sticky notes 12th grade: online software: MyMathLab, teacher-created notes, sticky notes to annotate student work Physical environment: (same) lots of motivational quotes/posters displayed, personal effects such as pictures, posters with math concepts, clean, warm, welcoming, objectives clearly posted	Teacher-created guided notes with math vocabulary, whiteboards, mathematical posters displayed, online software: MyMathLab, very little displayed because teacher changes rooms for each period	Mathematical posters, quotes, vocabulary displayed, personal effects such as pictures and letters displayed, word problem sheet aligned to target vocabulary for lesson standard, whiteboards, clean and bright feeling, different from entrance to school, objectives and rules clearly posted
Cultural and social makeup of class	10 girls, 5 boys, 11 white, 4 non-white	8th grade: 16 girls, 7 white, 9 non-white 12th grade: 26 girls, 22 white, 4 non-white	27 boys, 25 white, 2 non-white	13 boys, 6 girls, 19 non-white
Literacy strategies and regular classroom practices	Questioning, modeling	Questioning utilized in both periods	Group-graded homework, 4 Corners activity, questioning	Word problems, collaborative learning activity with discussion and explanation of work, questioning

Table 6 Summary and Connection to Mathematical Literacy

Observation data is displayed in Table 6, organized according to the observation guide included in Appendix F. Observation data is used to provide support for the data gathered from teacher interviews. Mathematical literacy is evidenced by the interactions observed, language and comprehension indicators used, and instructional strategies employed by the teachers.

Interactions. All teachers observed dedicated some time to activities that stimulated student-student interaction in addition to teacher-student group or teacher-whole class interactions, as peer discussions help boost the speaking skills of mathematical literacy. For example, several students asked classmates clarification questions before going to the teacher, and frequently did not need to ask the teacher for additional help. As cited in the literature review, student-student interactions like this improve mathematical literacy by giving one student the opportunity to refine their knowledge by explaining the problem to a classmate and by giving the other student a different perspective on the same problem. Additionally, teacher-student interactions supported mathematical literacy through the language and strategies used.

Language and Comprehension. Mathematical discourse was observed in all types of interactions, including math vocabulary, procedural terms, and symbolic representation. Language was used by teachers to model appropriate use of terms and by students to demonstrate comprehension of the content by explaining a problem or concept using mathematical language. Students also demonstrated comprehension through written or typed assessments which required them to understand mathematical discourse and apply it to specific examples. Since fluency with mathematical discourse is essential to achieving mathematical literacy, teachers incorporated discourse into questioning, modeling, and collaboration activities, three of the most frequently observed instructional strategies and supported by research cited in the literature review.

Strategies. The three strategies listed above were observed at some point during each teacher's lesson. Helene's lesson is one example which seamlessly merges questioning, modeling, and collaborative learning strategies. Helene opened her lesson with an activity where students would gather in groups according to their knowledge of a vocabulary word or phrase related to combining like terms. Once in groups, the students discussed what their word or phrase meant and reached a consensus to report to the whole class. This group activity helped foster mathematical literacy by requiring students to talk about their prior knowledge with their peers and explain the word or phrase using mathematical language. One of the questioning strategies used to increase mathematical literacy was to scaffold questions starting with prior knowledge, then guiding students to the desired concept. For example, notes were structured to help students recall previously learned vocabulary such as coefficient, and questions expounded on previous terms to help students make connection to new concepts such as combining like terms. Helene modeled how to combine like terms with examples while connecting what she was doing to the opening activity and asking students guiding questions to complete each example. Modeling allowed students to see how previously learned mathematical procedures were applied to new concepts, an integral skill associated with mathematical literacy.

Janelle's lesson was similarly structured. She began with an independent opening activity followed by a group activity where students were given a set of word problems, matched equations to each word problem, and solved them. Students demonstrated mathematical reasoning in their group discussions by pointing out that certain equations did not contain the correct numbers or variables used in a word problem, helping them choose the appropriate equation. Translating word problems into equations is an essential skill of mathematical literacy, as noted in the literature review. Janelle integrated questioning throughout this activity by circulating the room and asking students to explain their work or reasoning, addressing multiple levels on Bloom's Taxonomy, which she cited as her main questioning guides in the interview. Modeling was used in the lesson to show students the steps of solving a linear equation, and students used modeling strategies as well to explain their work to the whole class.

In his interview, Stan reported that by the end of the school year he has almost completely incorporated the flipped classroom approach using student-driven lessons. Once a week he has a longer class period with students and on those days he does some direct instruction and modeling before allowing the students to work at their own pace for the rest of the lesson. I observed on one of these days in late spring. Stan began the lesson by modeling the concept of volume in a variety of ways, such as using a manipulative kit, sketching on the board, and modeling with the Geogebra software, which students could access on their own laptops. He interspersed the modeling of this concept with a number of open-ended questions and more specific questions about how each model represented volume. Following this portion of the lesson, students continued their work on the laptops, occasionally discussing their work with other students at their table. During the student-driven part of the lesson, Stan circulated the room to help individual students and used scaffolded questions to guide students to build on previously learned knowledge.

Polly stated that her Honors Algebra is the only class that regularly uses the flipped classroom videos, unless she is absent from the classroom. Although I did not observe this class, there were some aspects of her flipped classroom approach incorporated into the twelfth and eighth grade lessons I observed. Both groups were reviewing material for tests, and Polly had students arranged in groups to discuss their questions with one another before asking her for help. Since students were reviewing material they had already seen before, group discussions mostly functioned to clarify certain concepts, much like the use of a flipped classroom where students have already watched video lectures. I observed several conversations between students who were asking each other for a verification about specific mathematical vocabulary used in the review questions. These conversations helped build mathematical literacy through the use of mathematical discourse, as described in the literature review, and benefited the student asking the question and the student answering the question. Like Stan, Polly used a scaffolded questioning strategy to help struggling students build on previously learned knowledge and guide them to the answer to the question that stumped them.

Motivation. Common themes arose in the motivation for the content as evidenced by student behavior during classroom observations. Some student behavior resulted from established classroom routines such as starting work unprompted shortly after arriving to class and working without the teacher's direction at various points in the lesson. Motivation for the content was evidenced in other ways, particularly during collaborative learning activities. For example, in Janelle's classroom, two students dapped each other off after solving a difficult problem together, and another student kept his group on-task without teacher intervention. This behavior indicates that the students were personally committed to learning the material in front of them and wanted to understand it thoroughly. In Polly's classroom, two students worked together to help another student answer a question. Their teamwork in clarifying the answer not only showed motivation to help their classmate, but also to ensure the answer was complete and mathematically sound. In these examples, students demonstrated that they felt they could complete each respective task and were emotionally invested in the content and the classroom. This student behavior reflected the attributes of intrinsic motivation detailed in the literature review.

Culture. Some of the richest data gathered from observation was in reference to classroom culture and its influence on mathematical literacy and motivation. Being in each classroom allowed me to observe the physical space, gauge the social and emotional tone, and explore how these aspects of the classroom environment impacted motivation and mathematical literacy development. The most noticeable commonality among the classrooms' physical environments was the evidence of each teachers' personality reflected in the decoration of each classroom. This was strongest in the classrooms where teachers did not rotate for each period. Helene changed classrooms every period, limiting her ability to decorate and personalize the space. Even with that limitation, she had some posters of mathematical concepts and inspirational quotes displayed around the area where class materials were stored. The other three teachers were able to show more of their own personalities in their classroom decorations, such as personal pictures, other inspirational quotes, and visual representations of mathematical concepts. Teachers used visual displays to communicate formulas and vocabulary, rules and expectations, objectives, due dates, and applications of math. These displays helped reinforce mathematical literacy skills by offering students visual representation of important concepts, emphasizing key terms and mathematical thinking processes, and demonstrating the real world applications of mathematical ideas. In Stan's lesson, he used one of the visual displays to help explain and model volume of a solid figure, which reflected his classroom culture by showing students that math is an important part of the physical world and that his classroom is a place to use a variety of tools to understand this connection.

Teachers' expectations supported this classroom culture and informed the strategies used to implement it such as student-led transitions, the use of mathematical discourse and reasoning, and effective management of time and materials. These observations also supported teachers' claims that building a positive relationship and trust with students helps to increase participation and adds to a positive classroom culture. Many aspects of classroom culture to support mathematical literacy were observed across the wide range of diverse student populations included in this study.

Overview of Findings

The findings of the interviews and observations of this study revealed that many teachers share similar definitions of mathematical literacy, such as the ability to read, write, and discuss mathematical concepts and ideas, apply these concepts to real world applications or interests, and build upon previously learned mathematical concepts. These skills all play different roles in the complex process of developing literacy in mathematics, as described in the literature review, and were supported by the instructional practices reported and observed. Additionally, data shows that classroom culture heavily influences student's motivation to become mathematically literate. Teachers stated the importance of initiating positive relationships with students, using collaborative learning strategies to build fluency with mathematical discourse, and encouraging students to work together and motivate one another to improve their mathematical literacy skills. The implications of these findings will be discussed in the fifth and final section of this report.

IMPLICATIONS

Introduction

In the process of completing a comprehensive analysis of the qualitative data gathered from interviews and observations, several important conclusions were identified. Prior to the analysis, adjustments to the research focus were made to achieve a better understanding of the question: **What is the relationship between mathematical literacy, motivation, and culture?** These adjustments are outlined in the first subsection, followed by the implications for teachers and future research, and the conclusions of the study.

Adjustments to Research Focus

As teacher interviews and classroom observations got underway, it became apparent that to fully answer the research question, some adjustments would need to be made to the focus of interview questions. First, interview questions were restructured to provide information on classroom culture in addition to exterior culture. This change was made because it became clear that classroom culture has an equal, and arguably greater, impact on the development of mathematical literacy. This contention is supported by the findings, which indicate similarities in classroom culture across a diverse data pool from many different schools in the New Orleans area, and the positive impact of these aspects of classroom culture on the development of mathematical literacy. Second, emphasis was also placed on the use of specific instructional strategies, such as questioning and use of technology. This change was made due to the ubiquitous nature of technology in the twenty-first century mathematics classroom, and its role in supporting and shaping mathematical literacy skills. These changes served to enhance the quality of data gathered and helped to clarify the practical implications of the relationship between mathematical literacy, culture, and motivation.

Implications

For Classroom Teachers

The main practical implications for classroom teachers are summarized in the following list, and will be explored in corresponding order.

1. Establish a positive relationship with students.
2. Create a classroom culture where students feel confident while studying math.
3. Connect mathematical ideas to students’ lives.

4. Use modeling, questioning, and collaborative learning strategies.
5. Require students to read, write, and discuss mathematical content.

When teachers build positive relationships based on trust, respect, and high expectations, students are more likely to engage in activities designed to build mathematical literacy. This conclusion was supported by research cited in the literature review and by data gathered from interviews and observations. Polly described the positive impact of these types of teacher-student relationships, specifically the academic improvements she saw with a student after she sat down and had a personal conversation about how to help. Esteban and Janelle both emphasized the role of high expectations when encouraging and motivating students to succeed in math classes, even if the student is struggling. Helene added that students frequently will work hard for a teacher they like, even if they do not like math. These are just a few examples from the data that show that positive teacher-student relationships are instrumental in building mathematical literacy.

This relationship is an important ingredient when creating a positive classroom culture in which every student feels valued and capable of success. Once this groundwork is laid, teachers are more likely to be successful when motivating students to improve mathematical literacy skills because students know that they are all working together to explore new concepts and ideas. Data from this study and research from the literature review point to the importance of positive classroom culture when implementing literacy strategies. Esteban described his classroom culture as a place where everyone is afforded the right to learn without fear of failure, where students encourage each other to do well, and where students use their strengths to help each other. Helene cited the role of healthy competition in a classroom culture, stating that students will work hard to improve their online scores. Polly explained the necessity of educating the whole person and not focusing on just math. She also stated that the diversity of students’ life experiences helps them to learn from each other and builds mathematical literacy by showing them that there are many ways to approach a problem.

Aspects of classroom culture must be balanced with the exterior culture of the student body because mathematical knowledge is built upon students' prior knowledge. Teachers must also showcase the relevance of the mathematical ideas to increase motivation for students to practice their skills because mathematical literacy includes the ability to apply mathematical concepts to situations outside of the classroom. This conclusion is supported by teachers' claims that real world applications and student interests are both integral to building mathematical literacy and motivation, along with research cited in the literature review which states that intrinsic motivation is increased when students feel content is relevant to their own lives. Stan emphasized the need to connect student learning in the classroom to their own lives because math is involved in many applications and this connection helps to motivate students. He also added that his classroom culture is driven by students and includes the physical tools they need to succeed and visualize mathematical concepts.

Once this classroom culture is established, teachers can further motivate students to continue building mathematical literacy through modeling, questioning, and collaborative learning strategies that integrate mathematical discourse and modes of thinking. Teachers interviewed stated that these instructional strategies were effective in building mathematical literacy because they show students how to apply mathematical ideas, think like mathematical experts, and formalize new knowledge through peer discussions. Data supports this because during classroom observations, students were highly engaged when these strategies were used. In Stan's classroom, students demonstrated this by independently exploring the concepts which Stan modeled for the class using the chalkboard, manipulatives, and the Geogebra software.

Following the modeling activities, Stan circulated the room and the students remained on-task and engaged with the questioning strategies that he used to help individuals with specific problems. In Polly's classroom, students were placed in groups to review for an upcoming test and discussed their questions about mathematical vocabulary. This collaboration helped all students improve their mathematical literacy by clarifying previously learned knowledge and providing the opportunity to explain their reasoning.

The skills required of these instructional strategies include reading, writing, and speaking, which help students construct new mathematical knowledge. Consistency was noted between the teachers stating that these skills were part of mathematical literacy and student engagement in reading, writing, and speaking activities during the class period. Contemporary research on mathematical literacy supports this interpretation of mathematical literacy and the use of modeling, questioning, and collaborative learning strategies, as discussed in the literature review.

For Future Research

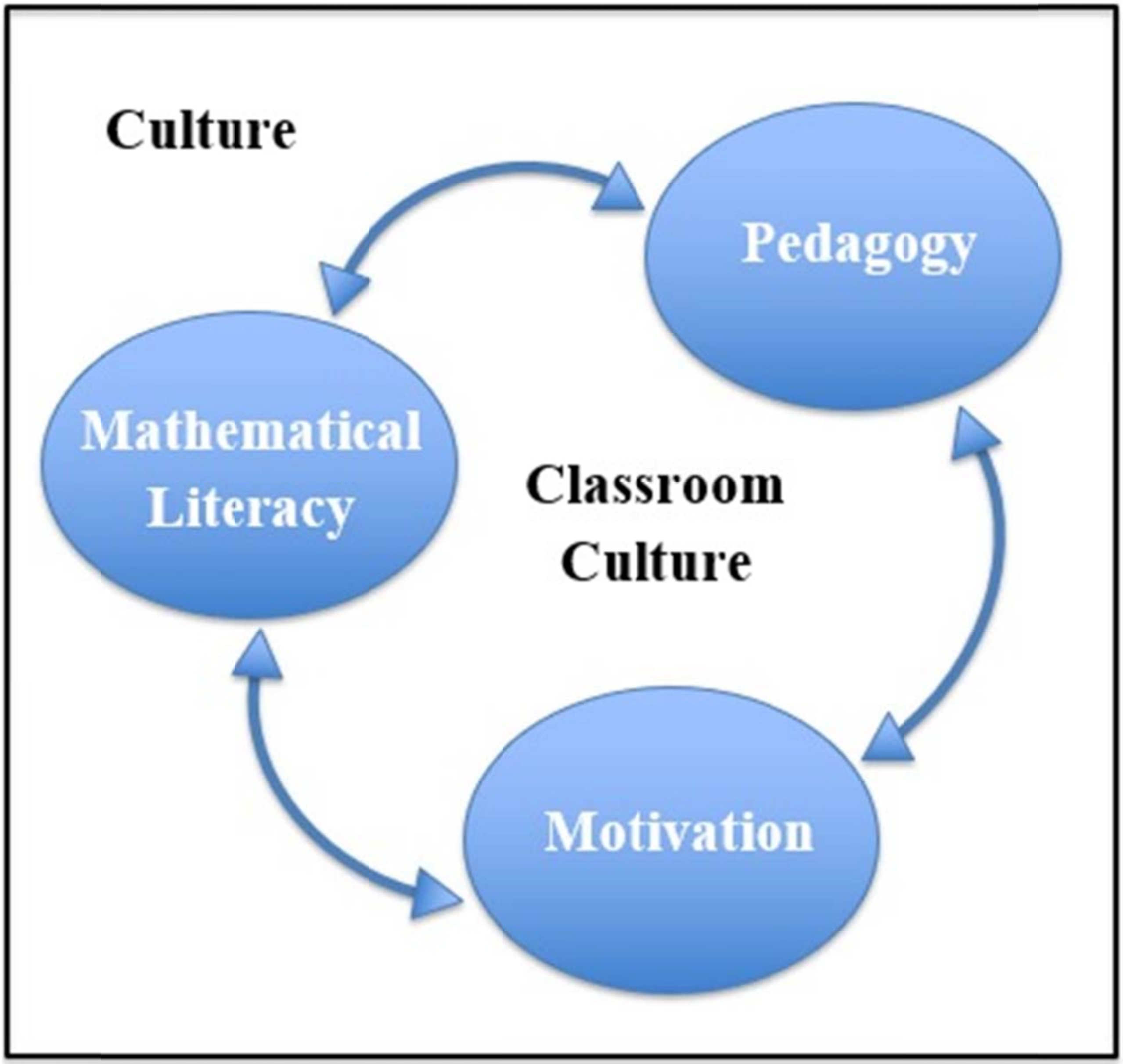
This study yielded a great deal of data on mathematical literacy, culture, motivation, and related classroom practices, but there is still much more research to be done. A narrowed focus on the relationship between culture and mathematical literacy would provide more detailed data to answer the questions raised by this study. Although it is evident that classroom culture has a huge impact on student motivation to acquire mathematical literacy, what role does the school culture play in this relationship? How do Kozol's enduring "savage inequalities" (1991, p. 83) affect teachers' ability to successfully implement mathematical literacy strategies, especially those related to the use of technology? Further qualitative and quantitative research that would directly compare the acquisition of disciplinary literacies in schools that serve low-income, middle-class, and wealthy student populations would certainly yield beneficial data for teachers and policymakers hoping to apply literacy research to narrowing the achievement gap.

Of equal interest are the effects of standardized testing on motivation and mathematical literacy. Organizations such as the NCTM and the CCSSI both support the implementation of mathematical literacy skills in the secondary classroom, but how do these skills translate to a high-stakes standardized test? Are tests culturally relevant to the students required to take them? How do these tests affect student populations in private and parochial schools that are exempt from required testing? What is the relationship between standardized tests and the acquisition of mathematical literacy skills? Research to explore these questions would undoubtedly offer teachers and policymakers a clearer path forward in the era of accountability in education.

Conclusions

The research question: **What is the relationship between mathematical literacy, culture, and motivation?** can best be answered using the theoretical framework outlined in the literature review because data from the interviews and observations contained the same elements and interact in similar ways.

Figure 2



Mathematical literacy influences the types of instructional strategies that teachers use, such as modeling, questioning, and collaborative learning. In turn, these practices help students acquire the skills included under mathematical literacy. Classroom culture is crucial to implementing the pedagogy that boosts student motivation for mathematical literacy as shown in Figure 2. Aspects of classroom culture such as positive teacher-student relationships, high expectations, and respect for all students’ experiences and abilities contribute to the effectiveness of the instructional practices that boost mathematical literacy and motivation. Within this classroom culture, these instructional strategies encourage students to read, write, and discuss mathematical concepts related to their own lives because interactions incorporating mathematical discourse are increased. Findings from teacher interviews and observations support these conclusions, and offer teachers the motivation to create a learning environment that motivates all students to become mathematically literate.

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APPENDIX A: INTRODUCTION LETTER

THE UNIVERSITY of NEW ORLEANS
DEPARTMENT OF CURRICULUM, INSTRUCTION AND SPECIAL EDUCATION

Date

Mr. Adam Poyner, Co-Investigator
(608) 843-4716
alpoyner@uno.edu

To Whom it Concerns:

I am writing to ask for your assistance in a research project that I am completing in accordance with the requirements to graduate with University High Honors from the University of New Orleans.

The topic of the thesis is Mathematical Literacy and the Secondary Student: What Effective Teachers Need to Know to Increase Motivation. In this study, I will be interviewing teachers to learn what literacy strategies are currently being used in classrooms. This study is exploratory in nature only, and no procedures of this study are experimental.

Participation will include an interview of approximately one hour to be conducted in person with you, and one classroom observation. Interviews and observations will be conducted between April 2, 2018 and May 11, 2018 at the school in which you teach. Further details will be communicated via email or telephone.

2000 Lakeshore Drive | New Orleans, Louisiana 70148
phone 504.280.6605 | *fax* 504.280.1120

THE UNIVERSITY of NEW ORLEANS

DEPARTMENT OF
CURRICULUM, INSTRUCTION
AND SPECIAL EDUCATION

If you are interested in participating in this study, please complete and return the enclosed survey. I truly hope you consider participation in this study, as I believe that your educational expertise will provide invaluable data to this thesis research. Please forward any questions, comments, or concerns to the above listed contact information.

Kindly,

Mr. Adam Poyner, Co-Investigator

2000 Lakeshore Drive | New Orleans, Louisiana 70148
phone 504.280.6605 | *fax* 504.280.1120

APPENDIX B: PARTICIPANT PRE-SURVEY

Participant Pre-Survey Name: ______________________

Email: ___________________________ Phone: ______________________

1. How many years have you been teaching? Please state certification/degrees held (if applicable) and other previous professional experience. What grade level/course(s) do you currently teach?

2. Briefly describe your general instructional strategies.

3. What does mathematical literacy mean to you?

4. How would you describe the cultural and social makeup of the students in your classroom?

APPENDIX C: DOCUMENT OF INFORMED CONSENT

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Research Contacts:

Dr. Cynthia Ybos, Principal Investigator
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New Orleans, LA 70148
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clybos@uno.edu

Mr. Adam Poyner, Co-Investigator
2000 Lakeshore Drive
PO Box 4007
New Orleans, LA 70148
alpoyner@uno.edu

Terms of Informed Consent:

I. Purpose of research: To collect qualitative data regarding the intersection of motivation and mathematical literacy in classroom practices as perceived by current classroom teachers.

II. Expected duration of subject's participation: Interviews will not exceed one hour. Classroom observations will not exceed 5 hours. Both interviews and observations will be scheduled at the participant's discretion between April 2, 2018 and May 11, 2018. Further details will be communicated via email or telephone. Overall contact with study participant should not exceed two weeks, no more than 8 nonconsecutive hours.

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III. Procedures of study: The co-investigator will review the terms of informed consent with the participant, then schedule interviews and subsequent observations subject to participant's availability. The co-investigator will conduct each interview in person with each participant. Interviews will be recorded and transcribed for later analysis.

All survey, interview, and observation data, digital and otherwise, will be securely stored by the co-investigator for the duration of the holding period of three years. No teachers' names will appear on any artifacts, pseudonyms for schools and teachers will be used in all reports. No data will be collected via interview or observation that has direct information about the participants. Neither the teachers' names nor the schools' names will be included in any artifacts, including audio recordings of interviews. Some data may appear in research reports, but will not include sensitive information. Following the end of the holding period, the co-investigator will shred documents and notes containing sensitive information, erase tapes of interviews, and permanently delete electronic files containing sensitive information.

IV. Experimental nature of study: No procedures of this study are experimental, and this study is exploratory in nature only.

V. Foreseeable risks: This study poses at most minimal risk to participants. Should participation of interviews or observations result in fatigue or discomfort, the participant may opt of the study at any time without penalty.

VI. Expected benefits: Although there may be no direct benefit to you, the participant, the possible benefit of your participation is further understanding for the co-investigator of the intersection of mathematical literacy and motivation in New Orleans classroom practices.

If you have any questions regarding this research study, please contact one of the investigators listed above via email or telephone. You may also contact Dr. Ann O'Hanlon (504-280-7386) at the University of New Orleans for answers to questions about this research, your rights as a human subject, and your concerns regarding a research-related injury.

2000 Lakeshore Drive | New Orleans, Louisiana 70148
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Participation in this study is voluntary, refusal to participate will not result in penalty, and the subject may discontinue participation at any time without penalty. By signing below, you are giving consent to participate in the above study. By signing below, you give permission for the co-investigator to record audio of interviews as described above.

I have been fully informed of the procedure described above along with its benefits and risks and hereby give my permission to participate in this study.

____________________	____________________	__________
Signature of Subject	Name of Subject (print)	Date
____________________	____________________	__________
Signature of Person Obtaining Consent	Name of Person Obtaining Consent (print)	Date

2000 Lakeshore Drive I New Orleans, Louisiana 70148
phone 504.280.6605 I *fax* 504.280.1120

APPENDIX D: INTERVIEW QUESTION FRAMEWORK

1. What is mathematical literacy? How would you describe it? How does it relate to other forms of literacy? Tell me more about the relationship between mathematical literacy and other forms of literacy. When did you first become acquainted with the concept of mathematical literacy? Tell me about how you began to use the idea of math literacy in your teaching.
2. Describe your strategies for teaching students how to read/write/speak like mathematicians. How do you handle students who seem resistant to engage with the material on a level indicative of math literacy?
3. What impact do you think these strategies have on how students learn math? How do you think these strategies impact students' attitudes towards math? Tell me about how you motivate your students to become confident with their abilities in math. What is the relationship between motivation and mathematical literacy?
4. What kinds of sources do you use in your classroom? Why did you choose these specifically? How do they reinforce the lesson of mathematical literacy? Describe how you found these sources or the process of selecting sources for your students to use.
5. How do student characteristics influence how these strategies work in the classroom? What differentiation techniques do you use in conjunction with the literacy strategies?

APENDIX E: OBSERVATION GUIDE

1. Who in the classroom is performing most of the work? What types of interactions are observed?
2. What kind of language do students use to discuss the content? Which comprehension indicators are being used? Describe students' motivation for content.
3. What materials and sources do students use in the classroom? How does the classroom's physical environment contribute to student motivation and math literacy?
4. Describe the cultural and social makeup of the classroom.
5. How are literacy strategies integrated into regular classroom practices?