The Quantitative Literacy Connection: Is Literacy Instruction the Key to Teaching Mathematical Habits of the Mind?

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Recent research in the field of literacy has supported a shift from content-area literacy instruction to instruction focused on disciplinary literacy (Shanahan & Shanahan, 2010). The contrast indicates a change from generalizable strategies for reading and writing designed to enhance comprehension of text regardless of content area, to the development and use of instructional methods derived from strategies and approaches used for communication, thought, and comprehension by experts in correspondent disciplinary fields (Shanahan, Shanahan, & Misischia, 2011). If a goal for literacy researchers and instructors in literacy education courses is to aid in the development of teacher candidates' tools for and knowledge of literacy instruction in relation to disciplinary practice, the evolution of the concept implies a greater understanding of the ways of knowing and methods of interpretation embodied in the individual academic disciplines. In other words, literacy strategies promoted as tools for improved comprehension, especially with regard to reading and text, may need to be re-examined in relation to the ways of knowing as enacted in specific disciplinary contexts. Disciplinary literacy research suggests that educational researchers may need to take a closer look at the literacy practices present in different fields, and, as a result of their findings, identify and develop instructional practices specifically geared toward fostering literacy expectations for those fields.

In the field of mathematics, Siebert and Draper (2008) noted that the traditional focus on content-area literacy instruction in pre-service education courses presents multiple problems for mathematics educators. Characterized as a "communication problem" (p. 235) between literacy and mathematics educators, Siebert and Draper's (2008) content analysis of documents and texts commonly used in literacy education courses indicated that literacy methods identified as content area reading strategies are often contrary to the literacy practices of the discipline of mathematics. Their analysis "suggest[ed] that many literacy messages fail to resonate with mathematics educators because they neglect, deemphasize, or misrepresent the nature and content of the discipline of mathematics" (Siebert & Draper, 2008, p. 231). According to the authors, should content-area literacy instruction be a goal for teacher educators, and, ultimately for classroom teachers, literacy researchers should expand their definitions of text, reading, and writing, in order to more fully account for the ways of knowing in the disciplinary fields. They also suggested that literacy researchers work to become more familiar with the expectations and practices of the discipline, rather than prescribing generalized methods for literacy instruction. This is a suggestion with which we fully concur. Acknowledging differing expectations for literacy across fields, however, should not imply that there are no commonalities in relation to literacy across fields or disciplines, but research designed to identify those differences, as well as common practice, is necessary.

The exploratory study described in the following sections was designed to establish a foundation for future research about the disciplinary literacy practices in the field of mathematics. The purpose was to examine the instructional practices already in place in an undergraduate mathematics course designed to increase quantitative literacy for non-math majors. Using a disciplinary-literacy lens, our goal was to discover: (1) what types of instructional practices related to literacy were present, and (2) if present, could the literacy practices used be linked to students' increased quantitative literacy?

LITERACY METHODS IN MATHEMATICS INSTRUCTION

In recent years, the National Council of Teachers of Mathematics (NCTM) has called for a greater emphasis on instructional methods that support *reasoning* and *sensemaking* (NCTM, 2009), which aligns with many of the instructional practices supported by an educational focus on disciplinary literacy. Although some mathematics teacher-educators have promoted the use of literacy strategies specifically calibrated for use in mathematics classrooms (Kenney, Hancewicz, Heuer, Metsisto, & Tuttle, 2005), Siebert and Draper (2008) have noted that mathematics teachers tend to resist adopting literacy strategies because they are often presented in ways that seem unrelated or contrary to mathematical ways of knowing – especially when presented in content-area literacy coursework. Even when specific literacy strategies are observed in mathematics courses, research supporting a connection between the use of those strategies and the development of quantitative literacy is rare. Generally, such support is implied through studies focusing on other aspects of the use of literacy strategies, including performance of mathematical tasks, rather than as the result of a dedicated investigation of the use of the strategies to promote students' ability to adopt mathematical "habits of mind"(Wilkins, 2010).

For example, Friedland, McMillan, and del Prado Hill (2010-11) studied middle school teachers' use of literacy strategies, but no analysis of the impact of the methods on student learning or quantitative literacy was provided. Pape, Bell, and Yetkin (2003) suggested the use of metacognitive strategies in mathematics courses would aid student performance on mathematical tasks; however, the impact on students' overall quantitative literacy was not discussed. Similarly, teachers' attendance to meaning-making in algebra classes has been studied (Harel, Fuller, & Rabin, 2008), but the overall focus was on aspects of the teacher's mathematical explanations that might affect students' non-attendance to meaning in mathematical learning, and not directly on student learning.

THE QUANTITATIVE LITERACY MODEL

Grounded in the work of the literacy theorists presented in the previous section, the exploratory study described here used Wilkins' (2010) Quantitative Literacy (QL) Model as the basis for assessing the use of literacy instruction in a mathematics course designed to bolster students' quantitative literacy. The model was developed through data derived from the Second International Mathematics Study (SIMS) Student Background Questionnaire (Westbury ~~& Thalathoti, 1989)~~ 1991 and is comprised of three components: students' beliefs about mathematics, their mathematics cognition, and their mathematical dispositions (Wilkins, 2010). The intent of this study was to examine only student beliefs and dispositions about mathematics and to identify classroom events and practices consistent with disciplinary literacy instruction. Our intent was not to examine mathematical achievement or knowledge (eg., students' ability to solve problems or perform procedures), and we acknowledge that this research can make no claims about the relationship between literacy instruction and this very important domain. As a result, we leave questions about implications for mathematical reasoning and skill for future studies.

METHODS AND DATA COLLECTION

The study was conducted by two researchers, one with a background in mathematics, and the other with a background in literacy, over the course of an academic year at a regional campus of a large mid-western university system. A pre/post quantitative literacy survey based on the original SIMS survey (Westbury ~~& Thalathoti, 1989~~; Wilkins, 2010), was administered to all students in nine sections of a 100-level mathematics course designed for non-math majors (see Appendix A). The course, titled *Mathematics in the World*, was designed to convey the essence of mathematical applications across mathematical disciplines in real-world contexts. Pre- and post-survey data from a total of 103 students were analyzed. In addition, three separate sections of the course were observed twice, once by each researcher focusing on observations relating to her area of knowledge (literacy or mathematics). Following preliminary analysis of the data, invitations were sent to participant volunteers whose pre/post survey data showed positive or negative movement in relation to quantitative literacy. Questions from the semi-structured interviews were loosely based on the Burke Interview Modified for Older Readers (BIMOR; Goodman, Watson, & Burke, 2005). Four students agreed to participate in the interviews, which lasted approximately 45 minutes each. The interviews contained general questions for all participants and additional questions relating to their specific responses on the survey. (See Appendix B for the protocol and sample questions.) Quantitative data were analyzed in aggregate using McNemar's Test for Correlated Proportions for movement toward or away from QL over the course of the semester. Observational and interview data were coded for classroom events, literacy practices, and QL episodes, based on Spradley's (1980) methods for thematic analysis.

Quantitative Analysis

In order to use survey data to determine movement toward or away from QL, we first independently examined the survey statements to categorize each as positive or negative in relation to QL. Following a discussion of our individual categorizations for norming purposes, we then sent a brief query to the mathematics faculty at our university for their input on statements for which we disagreed. Based on our analysis we determined that four of the questions (18, 24, 26, and 30) were worded in a way that could not easily be interpreted as either positive or negative; thus, we did not include data from these questions in our findings.

After the surveys were administered, data were examined only from students who participated in both the pre- and post-assessments. Analysis looked for movement toward or away from QL over the course of the semester during which the students were enrolled in the mathematics course. For example, Statement 2 "I think mathematics is fun" was categorized as a positive statement, thus responses of agree or strongly agree on the survey were interpreted as positive in relation to QL. Statements of disagree or strongly disagree were interpreted as negative in relation to QL. Alternatively, Statement 5 "If I had my choice, I would not learn any more mathematics" was determined to be a negative statement, and responses of disagree or strongly disagree were interpreted as positive evidence in relation to the Dispositions/ Motivation domain of the QL model, while agree or strongly agree would have indicated negative QL. As a result of the analysis significant ($p = .05$) movement was seen in a positive direction on some survey questions in the Motivation area of the Mathematical Dispositions Domain. Movement toward or away from QL in the Beliefs Domain did not appear to be significant.

Table 1: Analysis of Pre-/Post- Survey Data

Question	Significance of change between 1st & 2nd Administrations
I think mathematics is fun.	Agreement rose significantly (p-value = .008); Disagreement fell significantly (p-value = .0262)
If I had my choice, I would not learn any more mathematics.	Disagreement rose significantly (p-value = .0353)
I refuse to spend a lot of my own time doing mathematics.	Disagreement rose significantly (p-value = .0447)
I would like to work at a job that lets me use mathematics.	Agreement rose significantly (p-value = .015)
I could never be a good mathematician.	Agreement fell significantly (p-value = .010); Disagreement rose significantly (p-value = .0004)
Mathematics is useful in solving everyday problems.	Agreement rose significantly (p-value = .021); Disagreement fell significantly (p-value = .0245)

Only 6 questions in table 2

As is shown in Table 1, movement toward QL was statistically significant on questions 2, 5, 6, 11, 15, and 19. In this case positive movement was determined when agreement with a positive statement rose between survey administrations, and/or disagreement decreased; conversely, for statements identified as negative, movement toward QL was determined if agreement with the statement decreased and/or disagreement increased between administrations.

Additionally, the aggregate movement toward QL that was statistically significant in the questions analyzed was not consistent across individual students. In other words, a student showing movement toward QL in the area of dispositions toward mathematics may have shown no movement or movement away from QL in one or more of the other facets of the model.

Qualitative Analysis

Analysis of the observational data indicates that some constructivist literacy strategies, including metacognitive practices, questioning, teacher modeling, and think-aloud, were present in the classes, but most interactions were limited to traditional lecture or question-and-answer recitation (Nystrand, Wu, Gamoran, Zeiser, & Long, 2003). During interviews, students indicated a preference for "step-by-step" instruction that, upon further analysis of the classroom observational data, seemed to coincide with teacher modeling and think-aloud (TA). TA episodes were subsequently analyzed based on Boaler and Greeno's (2000) learner stance and Ciardiello's (1998) question levels.

The Observations. Data from the observations and field notes were coded thematically, following Spradley's (1980) model. Initially, events were coded based on classroom instructional events, including specific literacy practices observed. For example, the following excerpt from observation of Mr. Blane's class (all names are pseudonyms) was coded as an example of *guided practice*. During the event, Mr. Blane demonstrated the process for graphing linear equations, presenting the steps using a transparent overhead that contained graphing lines.

Mr. Blane: If x and y were both 0, would this be true?" [Indicates shaded area]

Student: Yeah

Mr. Blane: All of that would be shaded in and that would be the graph of the linear equality. [Explains that shading indicates all of the parts where 2x+y < 20] (Observation 1, November 21, 2011)

Coded data were then examined for instructional practices that were seen across all four classrooms and in observations by both researchers. Literacy practices that were observed included references to metacognition or how students know what they know, or in some cases do not know; explicit vocabulary instruction; the use of questioning strategies; and teacher modeling through thinking aloud.

The Interviews. Interviews from each student were also transcribed and coded, specifically looking for evidence of or references to QL, based on Wilkins' (2010) model. For example, the following excerpt from Taylor, a sophomore majoring in education, was coded under *mathematical dispositions/attitudes toward math and self.*

Taylor: I love math

HSD: And what do you enjoy about it?

Taylor: I love that it is black and white, typically. Um, there's always an, there's always an answer, you know, and there might be 7,000 different ways to get to that answer, but, typically, it's black and white. You know, it's not like with English where "well, in my opinion" you know. It's very logical and I like that. And that it's universal, that's a big thing too. You know, it's pretty much the same everywhere in the world that you go, you know, dependent; it's not dependent on language or anything like that. I really like it. (Interview, March 27, 2012)

During coding of the interview data, a theme that emerged was the students' preference for what they identified as "step-by-step" instruction. In fact all four of the students participating in the interviews used the exact phrase "step-by-step" spontaneously during the discussions. Upon further examination of the data, it became possible to note fine distinctions between how the students understood or interpreted "step-by-step." For example in Table 2 we display statements made by Taylor, Kim, and Ronnie, each discussing "step-by-step" as a method for solving mathematical problems that provided consistency and security. Provided one follows the appropriate steps, one will end with the correct result.

In another instance Ronnie again used the term "step-by-step" however the meaning of the phrase changed this time to indicate an effective method of instruction used by teachers to explicitly guide students through mathematical tasks.

Table 2: Sample Participant Interview Responses Indicating Preference for Step-by-Step Problem Solving

Participant	Interview Statement
Taylor	If you can, if you can analyze something, a formula, then you can pick out directions and then you can follow it step, by step, by step, by step. And it helps you feel like you have kind of a guide of getting through the mathematical equation as opposed to just looking at it and trying to have a bunch of guesswork. Which I feel like a lot of the other disciplines you end up doing is a lot of guesswork because there is no foundation set down. With math, for the most part, unless you're going to get into the discovery of dark matter and all that kind of stuff, there's pretty much, you know, there's foundation already laid for you.
Kim	I have to go step-by-step [to solve a math problem]. . . I follow, like, [a] certain path to get there. . .I'm good at math because, like, I like to follow directions, and that's what math is to me. You know, you have to follow this, like, certain steps. You can't just do it however you want, 'cause then [you're] not going to get the right answer . . .[In math] you have to follow rules. Like, you have to follow the steps to find the answer.
Ronnie	In order to solve a problem correctly there are certain steps you gotta take. You have to do everything in a certain order. It's usually always do things in the right order to get the right answers.

> Ronnie: I like being taught, step-by-step. I know that's. . .the way everybody does it, but some teachers do it more than others. (Laughs). (Interview, April 4, 2012)

Similarly, Chris, referred to the importance of "step-by-step" in relation to instruction.

> Chris: I like it when the math teacher goes step-by-step to make sure that everybody's on the same page . . . Just working through the problem with you helps, and then giving you homework to work on your own to make sure you get the concept . . . I would ask [the instructor] how to do [a difficult problem], and, when he'd go step-by-step, he didn't just write the answer, he would ask, like me or someone else in the class, if they could figure out what the answer was for each step. (Interview, April 9, 2012)

Following preliminary analysis of the interviews, noting the students' references to step-by-step in both problem solving and instruction, we re-examined the observational data for events during which processes seemed to be taught in a step-by-step fashion. Commonly throughout the observational data, we saw this through teacher *think alouds*.

Thinking Aloud. *Thinking Aloud* is an instructional process supported by literacy researchers as a method that allows teachers to explicitly demonstrate ways of knowing and thinking within their academic disciplines (Zwiers, 2008). The technique involves the verbalization of the thoughts and processes that are typical of the teachers' internal processing of discipline-related material in a way that allows students to observe the methods of thinking and knowing within a particular field.

During our site visits we noted that instructors in each of the three classes we observed often talked through the methods for solving mathematical tasks in a manner similar to Thinking Aloud. Often these visual and verbal demonstrations highlighted procedures which generally, though not always, included specific steps.

Table 3: Field Note Excerpt: Mr. Blane, Teacher Think Aloud

Speaker	Notes
Mr. Blane	Remember, we spent some time [previously] graphing linear equations. [Reminds students of the steps for graphing linear equations.]This time, it's just a little bit more difficult. I'm going to do [a] problem on the board and really break it down" [Writes an inequality on board] How do you say that symbol? [Symbol is ≥]
Students	Greater than or equal to [Multiple Responses]
Mr. Blane	First I'm going to look at the equal part. . .We know that. . .if x is 0, y would be 20. [Writes where 20 would be on the y axis of the grid.] If x is 0, y would be?
Student	10
Mr. Blane	10. Then we would connect [20 and 10] with a line [on the grid] [Draws connection between two points]

For example in the excerpt from the field notes displayed in Table 3, Mr. Blane shows the students how to graph a linear inequality. During this instructional event, the instructor uses what appears to be a Think Aloud process to walk students through the process for graphing a linear equation in a step-by-step manner reflective of the descriptions made by the interview participants; thus, this event was coded as a Think-Aloud.

In a second example, displayed in Table 4, Mr. Giles shows the students how to use an algorithm to schedule multiple concurrent events. During this event Mr. Giles also provides step-by-step instruction for completing the mathematical task, but this variation includes examples of mistakes and misdirection during the process. Students participating in the exchange supply responses (both correct and incorrect) when directed to do so, but also volunteer questions as they arise, indicating participation in construction of their own knowledge for completion of the task.

Question Levels. Analysis of the classroom episodes coded as Think Aloud and the variations among those episodes, as indicated in Tables 3 and 4, led us to consider both levels and quality of student participation during the Think Aloud events. In the example from Mr. Blane, though seemingly engaged in the demonstration based on the responses supplied by some of the students, the interaction is reflective of recitation (Nystrand et al., 2003), in which the teacher is the authority and the students are asked to provide responses to questions for which there is an expected answer. In the example from Mr. Giles, however, students initiated questions and attempted to provide

Table 4: Field Note Excerpt: Mr. Giles, Teacher Think Aloud

Speaker	Notes
Mr. Giles	[Responds to student question about a homework problem by noting that the language in the textbook is confusing. Explains the problem in his own words]. Apply this processing algorithm . . . which basically means [explains meaning of the word algorithm, draws diagram on board; uses ELMO to show diagram from book. Writes on board. Uses fingers to trace "Critical Path" in problem. Task is to create a list of tasks in order, to be completed in the shortest amount of time using an algorithm.] There's a lot of ways to do this. . . just make it neat so that you can understand or keep track of what you're doing. [Thinks aloud as he is working through the problem. Uses statements like "I'll tell you the biggest trouble I have" "This is where I have trouble sometimes. . . I do this,. . .then I have to do this" Shows process of elimination to determine which steps to take next.] "Whoops! This can happen sometimes" [Indicating consequence of an incorrect selection of paths. Demonstrates trying another approach.] What does this task tell me? . . Can I do this? That's what I want to do. Yes, I can . . .[Asks class] "Who's gonna get it?" [Which processer will be assigned to the next task on the chart?]
Student X	Processor 1 [Incorrect]
Mr. Giles	Task 3? [A different student supplies the correct response]. What happens to this guy? [Indicates a different processor on the chart]
Student X	Idle [Meaning that that processor has no task during that period of time]
Mr. Giles	Yes
Student X	Idle time, is that where you say you mess up?
Mr. Giles	Yes. [Explains how mistakes can be made, and provides example.] The key to doing well [with this mathematical task] is taking your time.

responses, even if they were not sure they were correct. Some of these questions also demonstrated curiosity about approaches to mathematical tasks by mathematics experts, or the ways of knowing in the field. As a result, we determined more analysis was needed to explain the variations in student-teacher interaction during the Think Aloud events.

Drawing from Ciardiello's (1998) levels of questions, the observations were again re-visited, this time with coding questions asked by both instructors and students during Think Aloud episodes. The question levels used were *memory*, based on basic recall of content-based information; *convergent*, questions that required students to use mathematical knowledge to construct responses;

divergent, questions that required students to use their knowledge of mathematics content, structures, and ways of thinking to predict or infer; and *evaluating*, questions that required students to use their mathematical knowledge to judge, defend, or evaluate.

For example, during the session on critical path scheduling shown in Table 4, Mr. Giles asked students to indicate which processor should receive the next task according to the algorithm used. The event was coded as a *convergent question* as students were required to demonstrate mathematical understanding through their responses.

> Mr. Giles: I didn't hear the right number yet. [Two separate students provide incorrect answers]. Two shots and 0 for 2. Who do I give it to? (Observation 2, November 17, 2011)

In a separate example, also from Mr. Giles' critical path scheduling lesson, the instructor himself models asking and responding to *evaluating* questions commensurate with expectations from the field:

> Mr. Giles: [Continues explanation of Number 11. Thinks aloud. Asks himself about the consequences of his choices.] Will this [option] work? No. This one? No. . .I finally get to this one [Processor Number 4, and that one is correct]. Use your head here. I did not use mine. [Points out an error he made during his example, using the diagram on board] (Observation 2, November 17, 2011)

FINDINGS AND DISCUSSION

The student preference for "step-by-step" methods in mathematical teaching and learning contexts that emerged during interviews, and the variations we noted in the classroom events coded as Think Alouds, seemed reflective of the four types of *learner stance* defined by Boaler and Greeno (2000). For our study, we interpreted these types of knowledge in the following ways: *Received knowing* views knowledge as something to be provided by an external authority, typically the teacher, believing that the responsibility for evaluating one's current knowledge and for creating new knowledge lies mainly with the teacher rather than the student. *Separate knowing* sees the aim of learning as primarily to align one's content knowledge to the parameters set by the discipline. Separate knowers are cognizant of the rules of the discipline and seek to refine their knowledge to meet disciplinary standards. *Connected knowing* views learning as being constructed socially through texts, conversations, and other representations of disciplinary content. Connected knowers seek others' perspectives on the content in order to enrich their understandings, and they attempt to reconcile those perspectives with their own. Finally, *constructed knowing* combines both separate and connected knowing in constructing, refining, and validating the learner's own knowledge.

The goal to improve instruction for quantitative literacy, which includes students' beliefs about and dispositions toward math (Wilkins, 2010), seems consonant with moving learners toward more empowered stances. The participants' preference for step-by-step instruction in mathematics classes, as well as their references to the step-by-step nature of mathematics initially seemed to connect to *received knowledge*, but evidence from Think Alouds similar to and including the Mr. Giles' excerpts in the previous sections, seems to indicate that this method may provide a tool for more fully apprenticing students into the ways of thinking and knowing in mathematics, especially when particular attention is paid to *convergent, divergent,* and *evaluating* questions (Ciardiello, 1998) during the exchange. Furthermore, because variations of Thinking Aloud may already be common in mathematics instruction and because Thinking Aloud is supported by disciplinary literacy researchers, this instructional technique may provide a link between mathematics and literacy instruction that can be further explored for the development of students' quantitative literacy.

WHAT TYPES OF INSTRUCTIONAL PRACTICES RELATED TO LITERACY WERE PRESENT?

Through analysis of the observations and interviews, we found evidence of the following strategies consistent with methods discussed in content-area literacy and disciplinary literacy coursework: metacognition and self-regulation of learning, vocabulary acquisition, classroom discussion, the use of questioning strategies, and teacher think-alouds. Metacognition was especially prevalent during student interviews when students shared how they independently recognized or navigated difficult or confusing material, often taking a step-by-step approach for solving. During classroom observations, metacognitive efforts were noted most often when students asked instructors clarifying questions about material presented in class or in class-based texts. Vocabulary was explicitly taught by instructors as they introduced new terms during think aloud demonstrations. Classroom discussion, though present, most often occurred between students just before class regarding homework or impending test material. Some classroom discussion occurred during teacher think alouds/demonstration, but the amount of participation by students tended to correspond with the levels and types of questions asked by the instructor and their peers. Finally, the most prevalent of all of the literacy activities observed was modeling through teacher Think Aloud.

Could the Literacy Practices Identified be Linked to Students' Increased Quantitative Literacy?

As the study was not developed to determine causality, this research question remains unanswered; however, based on the quantitative literacy (QL) survey administered at the beginning and end of the semester, it does appear that some students enrolled in the course did show improved QL in the dispositions domain, meaning that, in aggregate, the students ended the semester with more positive feelings toward mathematics than when they began. There are a variety of factors that may have contributed to this, including the real-world content of the course, the specific group of students who were enrolled during the semester when the study was conducted, or the instructional methods used, and further research with larger sets of participants over several semesters would be necessary to confirm these findings.

IMPLICATIONS AND FUTURE DIRECTIONS

An important point brought up by some educational researchers, especially with regard to literacy instruction in mathematics, is that often instructional recommendations for literacy appear to be divided from the ways of thinking and knowing in the discipline (Siebert & Draper, 2008). Research in disciplinary literacy supports disconnection as the emerging literature has begun to focus on specific differences between the ways that experts in disciplinary fields participate in and interact with various types of texts prevalent within their academic contexts (Shanahan, Shanahan,

& Misischia, 2011). The purpose of this exploratory study was to examine students' movement in relation to the mathematical beliefs and dispositions domains of quantitative literacy as they were enrolled in an undergraduate mathematics course for non-math majors and to observe instructional practices and student preferences for instruction within that context in order to better understand where literacy methods and mathematics content instruction converge. Based on the findings from this study, we believe that it may be possible to build on what is already present in mathematics instruction to create more opportunities for QL development within the context of the curriculum. Further investigation of the strategies already in place in mathematics classrooms and connections to students' development of quantitative literacy, especially in relation to the opportunities provided through teacher Think Alouds, is necessary. We also believe that it may be beneficial to work specifically with pre-service mathematics teachers to increase their awareness of QL and to expose them to different types of Think Aloud structures, formats, and levels of questions during their literacy-based coursework, for use in their future classrooms.

LIMITATIONS

This study was conducted on a single campus, with a relatively small number of student and faculty participants. As such, the data and findings are not generalizable to any larger contexts. Furthermore, during the interview portion of data collection, we became aware that the survey instrument, initially designed for secondary-level, and not university-level students, did not sufficiently account for the experiences and dispositions of older learners. The tool provided a useful starting place for our investigation of QL, but modification to address the needs and interests of adult learners for future research may prove beneficial. Finally, only two domains of Wilkin's (2010) model (mathematical beliefs and dispositions) were addressed in this study. The third domain, mathematical knowledge, was not studied. Conclusions about a connection between the data from this study and student mathematical performance or achievement are not possible.

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Appendix A: Quantitative Literacy Survey (based on Wilkins, 2010 and Westbury, 1991)

SA: Strongly Agree; A: Agree; N: Neutral; D:Disagree; SD: Strongly Disagree

1	Working with numbers makes me happy.	*SA*	*A*	*N*	*D*	*SD*
2	I think mathematics is fun.	*SA*	*A*	*N*	*D*	*SD*
3	I am looking forward to taking more mathematics classes.	SA	A	*N*	*D*	*SD*
4	I like to help others with mathematics problems.	*SA*	*A*	*N*	*D*	*SD*
5	If I had my choice, I would not learn any more mathematics.	*SA*	*A*	*N*	*D*	*SD*
6	I refuse to spend a lot of my own time doing mathematics.	SA	*A*	*N*	*D*	*SD*
7	I will work a long time in order to understand a new idea in mathematics.	*SA*	*A*	*N*	*D*	*SD*
8	I really want to do well in mathematics.	*SA*	*A*	*N*	*D*	*SD*
9	I feel good when I solve a mathematics problem by myself.	*SA*	*A*	*N*	*D*	*SD*
10	I feel challenged when I am given a difficult mathematics problem to solve.	*SA*	*A*	*N*	*D*	*SD*
11	I would like to work at a job that lets me use mathematics.	*SA*	*A*	*N*	*D*	*SD*
12	I usually understand what we are talking about in mathematics class.	*SA*	*A*	*N*	*D*	*SD*
13	I am not very good at mathematics.	*SA*	*A*	*N*	*D*	*SD*
14	Mathematics is harder for me than for most people.	SA	A	N	D	SD
15	I could never be a good mathematician.	*SA*	*A*	*N*	*D*	*SD*
16	No matter how hard I try, I still do not do well in mathematics.	*SA*	*A*	*N*	*D*	*SD*
17	It is important to know mathematics to get a good job.	SA	A	N	D	*SD*
18	Most people do not use mathematics in their jobs.	*SA*	*A*	*N*	*D*	*SD*
19	Mathematics is useful in solving everyday problems.	*SA*	*A*	*N*	*D*	*SD*
20	I can get along well in everyday life without using mathematics.	SA	A	N	D	SD
21	Most applications of mathematics have practical use on the job.	*SA*	*A*	*N*	*D*	*SD*
22	Mathematics is not needed in everyday living.	*SA*	*A*	*N*	*D*	*SD*
23	A knowledge of mathematics is not necessary in most occupations.	SA	A	*N*	*D*	*SD*
24	Mathematics helps one think according to strict rules.	*SA*	*A*	*N*	*D*	*SD*
25	Learning mathematics involves mostly memorization.	*SA*	*A*	*N*	*D*	*SD*
26	There is always a rule to follow in solving a mathematics problem.	SA	A	*N*	*D*	*SD*
27	Mathematics is a set of rules.	*SA*	*A*	*N*	*D*	*SD*
28	There is little place for originality in solving mathematics problems.	*SA*	*A*	*N*	*D*	*SD*
29	There are many different ways to solve most mathematic problems.	*SA*	*A*	*N*	*D*	*SD*
30	A mathematics problem can always be solved in different ways.	*SA*	*A*	*N*	*D*	*SD*
31	Mathematics will change rapidly in the future.	*SA*	*A*	*N*	*D*	*SD*
32	New discoveries in mathematics are constantly being made.	*SA*	*A*	*N*	*D*	*SD*
33	There have probably not been any new discoveries in mathematics for a long time.	SA	A	N	D	SD

Appendix B: Semi-Structured Interview Protocol

Questions asked of all participants:

1. What was the purpose of this math course?
2. Do you believe this class was necessary for your education?
   a. How do you see yourself using mathematics in your future?
3. What concepts in the class interested you most, and why?
4. Describe the most effective math teacher you've ever had, and explain why this teacher was effective.
5. What do you do when you don't "get" a mathematical task?
6. What does it take to be good at math?
7. Who is a person that you know who is good at mathematics?
   i. What makes ________ good at mathematics?
   ii. Do you think ________ ever comes to something that gives him/her trouble when he/she is working on math?
   iii. When _________does come to something that gives him/her trouble, what do you think he/she does about it?
8. How would you help someone who was having difficulty with mathematics?
   a. What would a teacher do to help that person?
9. Do you enjoy mathematics?
   a. If yes - what do you enjoy about it?
   b. If no - what do you not enjoy about it?
   c. Can you give an example of when this type of thinking might be beneficial outside of mathematics?

Sample questions for individual participants, based on individual survey responses:

1. At the beginning of the semester you said you neither agreed nor disagreed with the statement "There is little place for originality in solving mathematics problems," but at the end, you said you strongly disagreed. Can you please explain how you see originality in approaches for solving mathematics problems?
2. We noticed that you agreed with the statement "Mathematics helps one think according to strict rules" on the written survey.
   a. What does that statement mean to you?
3. We noticed that your opinion on the statements "I will work a long time in order to understand a new idea in mathematics" and "I really want to do well in mathematics" both moved from Agree/Strongly Agree at the beginning of the semester to disagree at the end of the semester. Can you tell me a little about this change?