ALGEBRA I TEACHERS' USE OF OPEN-ENDED ASSESSMENT ITEMS

by

NICOLE FOSTER ICE

(Under the direction of Thomas J. Cooney)

ABSTRACT

Research has shown that mathematics teachers' current assessment practices are not consistent with recommendations in the mathematics education reform literature. One recommended strategy is the use of open-ended assessment items. The purpose of this study was to investigate factors that facilitated or impeded teachers' use of such items.

Models of epistemological development provided insight into the teachers' beliefs about mathematics, teaching, learning, and assessment and orientation to authority. The beliefs and orientation to authority were then examined to determine their influence on the teachers' use of open-ended items. Literature on reflective thinking was used to discuss the ways the teachers were thinking about their instructional and assessment practices, as well as their actual practices. The teachers' thinking and practices were then examined to determine their influence on the teachers' use of open-ended items.

Two eighth-grade Algebra I teachers who had participated in a professional development project designed to expand their understanding of the purposes and uses of assessment, as well as to change their instructional and assessment practices, were participants in the study. Each teacher completed a survey, was interviewed, and was observed teaching. Artifacts were collected that included copies of tests, quizzes, worksheets, handouts, and graded student assessments. Inductive analysis was used to analyze the data.

Beliefs, authority, reflection, knowledge, and constraints emerged as factors that influenced the teachers' use of open-ended items. An interpretive analysis of each of these factors is provided and includes how each factor influenced the teachers' use of open-ended items. Findings include that although teachers were able to use open-ended items on tests and score student responses to those items, they did not use information about students' thinking to inform instruction.

The findings suggest that preservice education and professional development programs should help teachers move beyond simply using open-ended items and help them use student responses to such items to inform instruction. Additional implications for teacher education and research are given.

INDEX WORDS: Assessment, Open-ended items, Teacher beliefs, Reflective thinking, Preservice education, Professional development, Middle grades mathematics teaching, Secondary mathematics teaching

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DEDICATION

To Jacey

May you have big dreams and the courage to pursue them.

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CHAPTER 1

INTRODUCTION

Over the last two decades, numerous publications have pointed to the need to improve mathematics education by providing opportunities for students to develop deeper understandings of mathematics (e.g., National Council of Teachers of Mathematics [NCTM], 1980, 1989, 1991, 1995, 2000; National Research Council [NRC], 1989, 1993). More profound understandings of mathematics can be encouraged in the classroom by using instructional and assessment practices that require higher-order thinking on the part of students. Mathematics teachers are being urged, and increasingly required, to lessen their dependence on traditional assessments that focus on students' ability to recall facts and perform rote procedures, and to increase their use of assessment practices that will help foster increased student mathematical understanding.

The strong push over the last decade by the mathematics education community to implement assessment reform began with the publication of the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) and *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (NRC, 1989). The reform movement continues to be manifested in the literature to the present day. Several studies (e.g., Cooney, 1992; Hancock, 1994; Senk, Beckmann, & Thompson, 1997), however, have determined that teachers' current assessment practices are not consistent with the advocated changes. It is important to understand why teachers are not embracing the forms of assessment in the current reform literature. This study was designed to investigate the assessment practices of two Algebra I teachers who had been in a professional development project designed to acquaint them with reform-oriented assessment.

Recent Calls for Reform in Mathematics Education

NCTM (1989), in its *Curriculum and Evaluation Standards for School Mathematics*, called for mathematical experiences that require students to reason and communicate mathematically, to solve problems, and to make connections within mathematics and across other subject areas. NCTM advocated that curriculum changes should foster higher-order thinking on the part of students. In *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, the NRC (1989) stated that learning by imitation from lectures, worksheets, or routine homework is not retained for long and contributes only to good performance on standardized tests and lower-order thinking skills. This type of learning is generally ineffective for long-term learning, for higher-order thinking, and for versatile problem solving. To promote mathematical understanding, the curriculum must provide students with the chance to participate in activities in which they examine, reason, solve, and communicate mathematically; that is, students must take an active part in creating their own mathematical understanding. The message of promoting students' deeper understanding of mathematics is also emphasized in *Measuring What Counts: A Conceptual Guide for Mathematics Assessment* (NRC, 1993):

> Students of mathematics should be given opportunities to pose problems and advance hypotheses after they have examined a situation for the patterns and relationships it contains. They need to learn how to construct and use mathematical models of real phenomena. They should be taught to make and test their inferences, using estimates and the mathematics of uncertainty as well as the more familiar techniques of arithmetic, algebra, geometry, and calculus. (p. 21)

Although traditional assessments, most often multiple-choice and short-answer questions that have a single numerical answer, are good at determining whether students have learned mathematical facts and skills, "they are not appropriate in assessing the more process-centered goals of the new standards" (Moon & Schulman, 1995, p. 3). The types of assessment practices being advocated for use in the mathematics classroom include open-ended questions, projects, investigations, observations, interviews, presentations, and portfolios. An emphasis on deeper understanding in the teaching and learning of mathematics creates the need for complementary assessment practices that provide opportunities for teachers to gather in-depth information about their students'

> ability to apply their knowledge to solve problems within mathematics and in other disciplines; ability to use mathematical language to communicate ideas; ability to reason and analyze; knowledge and understanding of concepts and procedures; disposition towards mathematics; understanding of the nature of mathematics; [and] integration of these aspects of mathematical knowledge. (NCTM, 1989, p. 205)

The goal of assessment reform is to help teachers learn different ways to assess student learning, which can lead to a better understanding of what students know. Improved comprehension of students' mathematical knowledge can lead to more meaningful classroom instructional decisions.

Teachers' Assessment Practices

Recent studies of teachers' assessment practices have investigated the extent to which teachers have progressed in implementing the changes advocated in the reform literature. Stiggins and Conklin (1992) found that teachers did not understand what higher-order thinking skills were or chose not to assess them, which often led to inconsistencies between the level of thinking skills required by students during instruction and on assignments and tests. Senk et al. (1997) found that most teachers' test items were low level and required little or no reasoning on the part of students, and that open-ended items were rarely used on the tests. This observation mirrored Cooney's (1992) finding that teachers used more questions that resulted in a single number answer than open-ended ones.

Teachers tend not to use open-ended items for a variety of reasons. They have a limited knowledge of and ability to implement alternative assessment techniques (Nash, 1993; Senk et al., 1997; Stiggins & Conklin, 1992; Wilson, 1993), they believe that the questions are too difficult or inappropriate for their students (Cooney, 1992), and they are concerned about their ability and time needed to grade student responses (Cooney, 1992; Cooney, Bell, Fisher-Cauble, & Sanchez, 1996; Nash, 1993; Senk et al., 1997). However, Kulm (1993) found that teachers who participated in professional development on alternative assessment changed both their assessment and instructional practices to include approaches intended to enhance students' higher-order thinking processes. These studies, along with others discussed in the following chapter, show the importance of determining the extent to which teachers have made progress in implementing the assessment changes advocated in the reform literature in order to help determine how to best assist teachers in meeting reform movement goals.

Beliefs and Authority

Research has shown that teachers' beliefs about mathematics, teaching, learning, and assessment affect their classroom practices (Borko & Putnam, 1995; Cooney & Shealy, 1995; Shealy, 1994; Thompson, 1984; Wilson, 1993; Wilson, 1992). For example, Thompson found that a teacher who believed mathematics was "cut and dried" did not provide students opportunities for creative work and instead focused on memorization of procedures. Shealy (1994) found that a teacher who valued the contribution of student thinking allowed for investigative situations in the classroom. Teachers' beliefs about mathematics, teaching, learning, and assessment can be discussed using categories in which they fall according to their orientation to authority. These categories can be composed using three models of epistemological development developed by Perry (1999), Baxter Magolda (1992), and Belenky, Clinchy, Goldberger, and Tarule (1986). The orientations range from knowledge being absolute and given by an authority, to knowledge being situational and developed in context using evidence.

Analyzing teachers' beliefs with respect to orientation to authority can lend insight into which beliefs facilitate or impede teachers' ability to implement advocated assessment reform.

Reflection

Dewey (1933) claimed that *thought* can be equated with belief. An idea may emerge from any source, but the individual then attempts to establish a belief based upon evidence and rationality. It is this type of thought that Dewey proposed as *reflective thinking*:

> Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends constitutes reflective thought. (p. 9)

The process of reflective thinking occurs in two phases. First, a person enters "a state of doubt, hesitation, perplexity, mental difficulty, in which thinking originates" (Dewey, 1933, p. 12). The person recognizes something as problematic. What follows is "an act of searching, hunting, inquiring, to find material that will resolve the doubt, settle and dispose of the perplexity" (p. 12). The demand for a conclusion to a problem is the definitive characteristic of reflective thinking.

An analysis of teachers' instructional and assessment practices can reveal what is problematic for them and consequently elucidate areas in which teachers seek evidence in order to make decisions. It is in these areas that the teachers' beliefs are capable of being changed and thus of be impacted by professional development programs. The present study attempted to determine what issues, if any, the participant teachers found problematic in order to ascertain in what areas they engaged in reflective thinking.

Professional Development for Teachers

NCTM acknowledged that the kind of instructional and assessment practices advocated in the reform literature is "significantly different from what many teachers themselves have experienced as students in mathematics classes" (NCTM, 1991, p. 2).

Research suggests that teachers' beliefs, knowledge, and past experiences significantly affect classroom practices (e.g., Borko & Putnam, 1995; Senk et al., 1997; Thompson, 1992). Given teachers' limited experiences with reform, it is not surprising that it is difficult for many teachers to change their instructional and assessment practices.

A common thread running through calls for assessment reform is the emphasis on professional development for teachers. In discussing the obstacles and challenges of implementing their vision for mathematics assessment, the NRC (1993) described teachers as the foundation of assessment reform. Teachers' professional development will become increasingly important because they need to "become skilled in using and interpreting new forms of assessment (NRC, 1993, p. 11). Guskey and Huberman (1995) claimed that "inservice training and other forms of professional development are a crucial component in nearly every modern proposal for educational improvement" (p. 1). Their claim is supported by the view of Bryant and Driscoll (1998) that

> major shifts are under way in the world of assessment that require increased roles and responsibilities for teachers. As attention has turned to the importance of classroom assessment, a significant need has arisen to help teachers develop deeper understandings of the purposes and uses of assessment. (p. 1)

Professional development programs are designed to bring about change in such things as teachers' classroom practices, beliefs, or attitudes. NCTM (1991) recommended that teachers should be provided with opportunities to "examine and revise their assumptions about the nature of mathematics, how it should be taught, and how students learn mathematics" (p. 160). Guskey (1986) reported most teachers participate in professional development "because they want to become better teachers" and gain "specific, concrete, and practical ideas that directly relate to the day-to-day operation of their classrooms" (p. 6). Although there is strong support for teachers to participate in professional development programs and many teachers want to take part in such programs, there remains the question of whether professional development for teachers can be effective in bringing about change. Borko and Putnam (1995) reported that "there is substantial evidence that professional development programs for experienced teachers *can* make a difference—that teachers who participate in these programs can, and often do, experience significant changes in their professional knowledge base and instructional practices" (p. 60).

The teachers in the present study participated in a professional development project designed to expand their understanding of the purposes and uses of assessment, as well as to change their instructional and assessment practices, specifically with respect to open-ended items. This study explored the extent to which the teachers were willing to implement changes in their classroom assessment practices and what aspects, if any, of the professional development project facilitated those changes. The professional development project was designed for teachers of Algebra I and Geometry courses in a Georgia school district.

The Magnolia County Algebra I and Geometry Assessment Project

The Magnolia County school district is located near a large, metropolitan city in Georgia. It contains 40 elementary schools, 13 middle schools, 10 high schools, and 2 open campus high schools, with a total enrollment of approximately 67,500 students.

Beginning with the 1998-99 school year, both middle and secondary Algebra I and Geometry teachers in Magnolia County were required by the system to meet mandated student assessment requirements. The mandate was that at least 20% of the items on all classroom tests must require higher-order thinking on the part of students. The assessment requirement was intended to affect not only teachers' classroom assessment practices but also their instructional practices. County policymakers expected teachers to change their instructional methods to incorporate more reform-oriented instruction when faced with a requirement to do so with their classroom assessments. In an effort to assist teachers in meeting that requirement, Magnolia County and the University of Georgia (UGA) began an Eisenhower-supported professional development project[1] in April 1997. The main goals of the project were to train a cadre of middle and high school Algebra I and Geometry teachers to write open-ended assessment items, to create a bank of these items, and to use the item bank as a basis for training all Magnolia County teachers of Algebra I and Geometry in the methods and benefits of using assessment practices consistent with current calls for reform.

Each middle and high school in the county was invited to send its mathematics department chair and another teacher to participate in the project. In spring of 1997, approximately 30 teachers participated in 12 hours of training that included an analysis of the rationale for and the characteristics of reform-oriented assessment practices, development of strategies for writing open-ended items, and practice in scoring student responses to open-ended items. During the summer 1997, the teachers met twice for the purpose of writing and editing items. The items were written to correlate to the county curriculum, a set of behavioral objectives for specific skills which students were to be able to demonstrate at the completion of the Algebra I and Geometry courses. In June, the project teachers met for 3 days to write open-ended items. The items were then critiqued by mathematics teachers (not from Magnolia County) and mathematics education doctoral students (myself included) familiar with open-ended items. The project teachers met again in July to edit the items. The teachers had difficulty writing items that were not skill based, and thus the items were revised as needed by the UGA Mathematics Education faculty member and doctoral students involved in the project.

During the 1997-98 school year, a 19-member subgroup of the project teachers, named the Advisory Committee, were sent the revised items to field test with their students. Four times during that school year the Advisory Committee met to make recommendations about the items based on their collected student responses. Additional revisions were made as needed by the UGA faculty member and doctoral students. The

[1] This project was supported under the Eisenhower Higher Education Act under the direction of Drs. Thomas J. Cooney and Laura Grounsell.

items were subsequently sent to a research mathematician, who reviewed the items with respect to mathematical significance and correctness. Final versions of the items were placed in a searchable database for use by all Magnolia County Algebra I and Geometry teachers.

At the four meetings of the Advisory Committee, teachers were also provided with additional professional development regarding the use of open-ended items and the scoring of student responses. A strategy for introducing the use of open-ended items into their classrooms was discussed; teachers were advised to have their students respond to sample items, to score those responses, and then to discuss with and show their students characteristics of successful and unsuccessful responses. The teachers were also involved in extensive discussions that highlighted student responses with a variety of scores in an effort to refine the teachers' ability to use a scoring rubric in a consistent manner.

In the effort to meet the main goals of the project of creating the item bank and helping teachers become proficient at scoring student responses, time was not available to address other issues regarding the use of open-ended items. For example, the teachers were not provided with examples of instructional activities that focused on open-ended items. They were also not provided with information about how to use student responses to inform their instruction.

Purpose of the Study

In an attempt to understand why teachers are not embracing the forms of assessment in the current reform literature, this study was designed to determine the extent to which two Algebra I teachers implemented reform assessment practices and what factors facilitated or impeded that implementation. Specifically, this study investigated the following questions:

- What are the teachers' current assessment practices and beliefs?
- To what extent do their beliefs facilitate or impede the use of open-ended items?

- About what issues, if any, do the teachers engage in reflective thinking, and did that thinking facilitate or impede the use of open-ended items?
- What aspects, if any, of the professional development project facilitated the use of open-ended items?

This study was intended to provide insight into the factors that can help mathematics teachers implement assessment reform, as well as to highlight the potential for professional development programs and assessment resources to assist in reform efforts.

CHAPTER 2

RELEVANT LITERATURE

This literature review is organized into five sections. The first section is devoted to describing aspects of assessment. Next is a summary of recent research about teachers' assessment practices. The third section includes literature relevant to a theoretical perspective from which to view the data in order to understand the findings. Following that is a review of studies about teacher beliefs. The final section discusses characteristics of effective professional development programs.

Aspects of Assessment

Definitions and Characteristics

Assessment, as defined in the *Assessment Standards for School Mathematics* (NCTM, 1995), is the "process of gathering evidence about a student's knowledge of, ability to use, and disposition toward, mathematics and of making inferences from that evidence for a variety of purposes" (p. 3). Many of the currently advocated assessment strategies come under the umbrella term *alternative assessment*. Alternative assessment strategies are designed to "gain insight into students' broad knowledge and understandings of mathematics, not just skills and procedures" (Kulm, 1994, p. 3). These types of assessment methods focus on ways to collect evidence of student understanding, usually through questions or activities in which students must use higher-order thinking skills. Tasks that elicit this type of thinking on the part of students are those that require more than just information retrieval.

There are many assessment practices that have the potential to require higher-order thinking by students: open-ended items, projects, investigations, observations, interviews, and portfolios. Open-ended items "have more than one answer and/or can be solved in a variety of ways" (Moon & Schulman, 1995, p. 25). Students not only have to produce answers but must show their solution process and justify their answer. Open-ended items provide opportunities for students to demonstrate their mathematical thinking, their reasoning process, and their problem-solving and communication skills. Since they have a wider range of solutions and solution methods than traditional assessment questions, open-ended items are better at revealing students' understanding of mathematics.

Cooney, Badger, and Wilson (1993) suggested that in order to gain insight into students' mathematical understanding, good assessment tasks should (a) involve significant mathematics, (b) be able to be solved in a variety of ways, (c) elicit a range of responses, and (d) require communication on the part of the student (pp. 245-256). The open-ended items developed in the Magnolia County Algebra I and Geometry Assessment Project were included in the final bank only if they met the 4 criteria suggested by Cooney et al.

Purposes of Assessment

Assessment can play a variety of roles in the classroom. The primary purpose of assessment should be to improve instruction in order to better facilitate student learning. Other purposes are to evaluate student achievement, document and report student progress, inform students of strengths and weaknesses in their knowledge, communicate expectations, and to use assessment as a instructional strategy.

In its *Principles and Standards for School Mathematics*, NCTM (2000) advocated that "assessment should support the learning of important mathematics and furnish useful information to both teachers and students" (p. 22). NCTM stated:

> Assessment should be more than merely a test at the end of instruction to see how students perform under special conditions; rather, it should be an integral part of instruction that informs and guides teachers as they make instructional decisions. (p. 22)

Assessment can enhance students' learning by conveying to the student what "kinds of mathematical knowledge and performance are valued" (p. 22). For example, through the use of assessment techniques such as open-ended items, students "are likely to learn through the process of articulating their ideas and answering the teacher's questions" (p. 22). Teachers can help students understand the characteristics of appropriate and correct responses to complex questions and tasks through the use of scoring rubrics. By helping the student to assume responsibility for their own learning, teachers move them toward being more independent learners. Teachers should use assessment information to make instructional decisions as well as decisions about student attainment. NCTM (2000) recommended that

> to ensure deep, high-quality learning for all students, assessment and instruction must be integrated so that assessment becomes a routine part of the ongoing classroom activity rather than an interruption. Such assessment also provides the information teachers need to make appropriate instructional decisions. (p. 23)

Thus teachers should not just use formal, summative assessments, such as tests and quizzes, but also informal, formative assessments such as questioning during instruction. Teachers should make sure their assessment is aligned with their instruction.

The use of tasks that go beyond merely asking for correct answers helps teachers understand student mathematical thinking. This understanding can provide a base for instruction in an effort to enhance student thinking. NCTM (2000) claimed that teachers, as the collectors and users of assessment information, must

> understand their mathematical goals deeply, they must understand how their students may be thinking about mathematics, they must have a good grasp of possible means of assessing students' knowledge, and they must be skilled in interpreting assessment information from multiple sources. (p. 24)

In order for teachers to accomplish these tasks, "assessment must become a major focus in teacher education and professional development" (p. 24).

Recommendations for Classroom Assessment Practices

Chambers (1993) claimed that "the teacher's priority should be to attempt to understand how the students are thinking rather than to get the students to understand how the teacher is thinking" (p. 25). Assessment should constantly occur during instruction, such that the two activities are virtually indistinguishable. This will help teachers "optimize both the quantity and the quality of their assessment and their instruction and thereby optimize the learning of students" (p. 25).

With the introduction of any reform, it is easy to think "out with the old, in with the new." However, the use of alternative assessment strategies does not imply the exclusion of more traditional assessment methods. Traditional and nontraditional assessment tasks are just different ways to gather information about student knowledge and understanding. It is appropriate to use multiple-choice or short-answer items when assessing particular mathematical skills or procedures. However, alternative assessment tasks are better for assessing students' mathematical understanding because they provide a "deeper, richer look at students' thinking" (Moon & Schulman, 1995, p. 11).

Recent Studies of Teachers' Assessment Practices

Stiggins and Conklin (1992) described the results of numerous classroom assessment studies they conducted over a decade beginning in the early 1980s. In one survey, designed to determine teachers' concerns about different kinds of tests, the authors found that 45% of the 8th-grade and 49% of the 11th-grade mathematics teachers in their study cited the need for improvement in their teacher-constructed objective tests. Teachers indicated that they were concerned whether their tests were effective, how they could be made better, whether they were challenging enough, and whether they facilitated in learning. In another study, Stiggins and Conklin asked secondary teachers in a graduate course in educational measurement to reflect on their assessment activities. The purpose for assessment cited most frequently was grading (36%), followed by determining student mastery (30%). These teachers' assessments were mostly tests they created, which were planned in advance and whose results were recorded as a grade.

In a third study, Stiggins and Conklin (1992) collected the assessment profiles of eight high school teachers—two each in mathematics, science, social studies, and language arts. Several patterns emerged from the data. On average, high school teachers devoted nearly one quarter of their class time to assessment. They mainly used assessment for grading purposes. The teachers either did not understand what higher-order thinking skills were or chose not to assess them. Often, the level of thinking skills required of students was not consistent between instruction, assignments, and tests. Teachers were unfamiliar with appropriate methods for assessing performance and viewed instruction and assessment as distinct functions. They were unable to integrate instruction and assessment during class time. Finally, although they desired to base their assessments on student achievement, teachers often considered affective factors when grading in an effort to motivate students.

In a study of secondary mathematics teachers' evaluation practices, Cooney (1992) found that 48% of the teachers in his study used tests provided by the publishers of their textbooks, whereas 42% of the teachers created their own tests. This finding led Cooney to conclude that since the publishers' tests were unlikely to incorporate assessment strategies advocated by the NCTM (1989) *Curriculum and Evaluation Standards for School Mathematics*, at least 48% of the teachers surveyed were "testing for a narrow range of mathematical outcomes" (p. 5). Cooney also found that unit tests were the largest factor teachers used to determine student grades. When asked to generate items that would assess a deep and thorough understanding of mathematics, 57% of the teachers "created *more difficult* items, but not items that tested a deeper understanding as defined by the NCTM Standards in which communication, reasoning, problem solving, and connections are emphasized" (p. 8). The teachers in the study indicated that the most important purposes for assessing students' understanding was to certify mathematical competence, identify misconceptions in order to adjust instruction, and provide feedback on student progress. When presented with tasks that required, in varying degrees, reasoning, communicating, and problem solving, teachers said they would be more inclined to use the problems that resulted in a single number answer than the problems that were open-ended. When asked about reasons that would discourage their use of the items, teachers expressed lack of confidence in doing the items themselves or in their ability to score the item responses objectively. The teachers also commented on the items being too difficult or inappropriate for their students, and were concerned with the time needed to grade student responses to the items. Some teachers in the study said they would use the open-ended items for class discussion purposes but not to evaluate students. Cooney concluded that reform was not widespread in Georgia classrooms and was not likely to occur unless teachers are provided with significant inservice programs. Also, he suggested that since many teachers depend on evaluation items that are from external sources, teachers might be willing to use a greater variety of assessment items if given an appropriate resource or the opportunity to work with others to create an assessment resource.

Cooney et al. (1996) discussed five issues that were central to most of a group of teachers who were implementing various aspects of alternative assessment. First, the teachers were concerned that the use of alternative assessment would introduce unpredictability into the classroom. No longer would the instruction be teacher-centered and address limited mathematical objectives. Second, the teachers expressed concern over content coverage and standardized tests. The teachers of higher-level content classes were especially conservative in implementing alternative assessment because of the emphasis in these classes to prepare students for later coursework and for them to do well on standardized tests. A third concern of the teachers was making sure students understood what would be expected of them. To help students understand their expectations regarding alternative assessment, the teachers believed it was important to have students practice responding to open-ended questions, as well as allowing them to see examples of high-quality responses. The issue of time was also a concern expressed by the teachers. Cooney et al. noted that no teachers "used portfolios, journal writing, projects, and tests that were dominated by open-ended questions" (p. 486). However, the teachers responded favorably when encouraged to start simply, such as using questions of the form "What's wrong with this?" The teachers found that an item bank was very helpful since they had difficulty in creating good open-ended questions. Finally, communicating with parents about students' responses to alternative assessment tasks was a concern expressed by the teachers. The teachers found, however, that once parents were made aware of the demands of the tasks and what kind of information could be gathered about student understanding from the tasks, they were accepting and supportive of the teachers' decision to use alternative assessment in the classroom.

Cooney et al. (1996) also found that project teachers realized they have the ability to change their ways of teaching and assessing mathematics. Teachers in the project expressed "appreciation for the increased communication with their students that alternative assessment" afforded them (p. 487). When asked why teachers may be reluctant to use alternative assessment, one teacher commented that they may not be aware of what students are capable of doing. Alternative assessment strategies provide an opportunity for students to go beyond what traditionally might have been expected of them.

Kulm (1993) conducted a study to determine whether teachers' use of alternative assessment had an effect on their classroom instruction. Eighteen teachers participated in graduate coursework designed to help them plan and implement alternative assessment approaches. The teachers met twice a month during the school year. They were observed and kept journals, their classroom tests were collected, and their students were surveyed. Kulm found that when teachers used alternative assessment practices, their teaching also changed. The teachers were found to have increased their use of strategies that promote students' higher-order thinking. They reported being better able to use different forms of assessment, being more likely to have students show and explain their work, and using multiple ways to assess students' knowledge and skills. They were more likely to use open-ended problems in evaluating students' problem-solving ability and to focus more on process rather than just an answer. Kulm claimed that "this study provided evidence that inservice work on alternative assessment can pay dividends in helping mathematics teachers use approaches which enhance higher-order thinking processes" (p. 17).

Unlike the teachers in Kulm's (1993) study, the teachers in Hancock's (1994) study were provided with only a workshop and literature concerning reform assessment practices. The workshop and literature were designed to introduce the teachers to revisions in the state-mandated end-of-course test for Algebra I. Policymakers in North Carolina revised the test to include open-ended questions and real-world problems and to allow student access to graphics calculators. The goal was to have teachers change their assessment practices to mirror the test and thus ultimately change their instructional practices to be in line with current calls for reform in mathematics teaching and learning. Hancock found that the teachers' assessment practices were not influenced by the mandate and the test revisions; the teachers seldom used open-ended and real-world problems in their assessment of students. They were more likely than before to use the graphics calculator but not always in a way that was advocated. The teachers were more influenced in their assessment practices by their perceptions of their students, mathematics, mathematics assessment, time constraints, and colleagues than by the mandate. Hancock concluded that assessment items themselves are limited in their ability to communicate instructional goals to teachers, and that state-mandated tests can influence teachers' assessment practices only if the goals of the tests are aligned with teachers' beliefs about mathematics teaching.

Nash (1993) conducted a study of mathematics teachers striving to implement reforms in their assessment practices. She found that the teachers struggled with student assessment for several reasons: their lack of knowledge about appropriate assessment techniques, their lack of experience in implementing alternative assessment methods, and their lack of support in modifying alternative assessment methods to meet individual classroom needs. Nash concluded that time constraints were the single greatest impediment to the teachers' implementation of alternative methods of student assessment.

Wilson (1993) conducted a study of a single teacher striving to implement reform in her assessment practices. The teacher demonstrated an understanding of some of the notions of the current mathematics education reform movement. However, Wilson found that the teacher was ineffective in implementing reform assessment practices because she could not successfully incorporate any of the strategies into her grading scheme. The teacher actually had a limited understanding of alternative assessment and that allowed her to view her own practice as mostly aligned with current reform efforts. Thus, the teacher did not see a need for much change in her assessment practice. The teacher's assessment practices were influenced by the expectations of others, the institutionalized curriculum, the school structure, and her working conditions.

Senk et al. (1997) studied the assessment and grading practices in 19 mathematics classrooms. They found that in all classes students' performance on written tests or quizzes was the primary factor in grade determination. Most test items were low level and required little or no reasoning on the part of students. There was virtually no use of open-ended questions on tests. The teachers' choice of test items were influenced by several factors. The subject matter appeared to make a difference in the types of questions on tests. Teachers of Geometry courses had fewer skill items on their tests than did teachers of Algebra I, Algebra II, or post-Algebra II courses. The geometry teachers also more frequently used test items that required student reasoning, such as asking for explanations, justifications, or proofs. The textbook used in a class had a strong influence on teachers' tests. Four of the 14 algebra teachers rarely asked students to interpret or draw graphs or diagrams. These teachers also used textbooks that were lacking in visual representations. In contrast, teachers who tested drawing or interpreting graphs more frequently used textbooks that emphasized visual representation. All the teachers in the study reported that technology influenced their assessments. The technology allowed teachers to use situations that contained tedious calculations and "not-so-nice" numbers. Some teachers of Algebra II and post-Algebra II classes noted that technology allowed them to ask new types of questions, changed the quality of figures and graphs available to students, and helped raise issues of accuracy. Of the 11 teachers who described their main source for assessment instruments, 6 regularly used textbook publishers' tests, and 5 created their own tests but consulted a published test before writing their questions. The reasons cited for using the tests provided by the publisher included convenience and students' familiarity with the terminology since the tests reflected wording used in the textbook. The teachers reported no strong influence by standardized tests on their teaching and testing.

Senk et al. (1997) identified two factors that appeared to have the strongest impact on the teachers' assessment and grading practices: (a) teachers' knowledge and beliefs about assessment, and (b) the time teachers need to create and grade various forms of assessment. Ten of the teachers in the study had received training in assessment techniques. Virtually all the teachers reported being familiar with the NCTM curriculum standards, and three teachers said they were familiar with the assessment standards. The knowledge teachers gained as a result of training appeared to affect their assessment practices. Of the seven teachers who were asked to describe the extent to which their own assessment practices were consistent with current recommendations, six expressed making some progress toward implementing changes recommended for assessment practices. The progress they described was the increased use of multiple assessment techniques and the use of technology. However, these teachers indicated a limited knowledge of and ability to implement alternative assessment techniques, which served as a deterrent to using new forms of assessment as often as more traditional tests. Teachers' beliefs about their students affected their ability to implement some assessment techniques. For example, the belief that students are not motivated discouraged teachers from assigning research projects and computer explorations. Teachers felt that older students would not think it was "cool" to talk about mathematics, and that kept them from requiring students to explain problems orally. Finally, time constraints inhibited teachers' use of alternative assessment items. Teachers reported that the newer forms of assessment took about twice as much time to prepare and twice as much time to grade as more traditional chapter tests. Senk et al. suggested that more attention be given to teacher education and material development with respect to classroom assessment.

Theoretical Perspectives

Beliefs and Authority

In this study, *beliefs* are referred to as Dewey (1933) described them, in that they cover

> all the matters of which we have no sure knowledge and yet which we are sufficiently confident of to act upon and also the matters that we now accept as certainly true, as knowledge, but which nevertheless may be questioned in the future. (p. 6)

Thus knowledge is a specific kind of belief: that which is accepted as true but may be revised upon new evidence.

The ability of beliefs to be changed also hinges on the individual's orientation to authority, which determines to what extent context was used in establishing the beliefs. Orientation to authority is discussed using epistemological development models. The remainder of this section discusses the three epistemological development models that were used to help describe the thinking and behaviors of the teachers in the study. The models were chosen to help characterize teachers' beliefs about the nature of mathematics, the teaching and learning of mathematics, and assessment. Although I did not attempt to determine where the teachers fit in any of the models, the models were useful in revealing the extent to which teachers' beliefs and orientation to authority facilitated or impeded the use of open-ended items.

The Perry Development Scheme

Perry (1999) created a developmental scheme that contains nine positions that indicates how persons look at aspects of their worlds. Copes (1982) collapsed Perry's nine positions into four categories: *dualism*, *multiplism*, *relativism*, and *commitment*. From the dualistic perspective, a person believes that all knowledge is known, that there an answer for every question and a solution to every problem. In this position, one would view a teacher as the source of knowledge whose role it is to dispense that knowledge. One would view students as receivers of information whose role is to demonstrate they have learned the right answers. Thus, learning is "committing to memory, through hard work, an array of discrete items—correct responses, answers, and procedures" as assigned by the teacher (Perry, 1999, p. 66). Because of the role of the teacher as the authority, students would not be considered an appropriate source for knowledge, learning, or teaching. For the dualist, assessment is the asking of questions to determine if students know the right answers.

The multiplist can view aspects of her or his world in several different ways, depending whether they are closer to dualism, or the stage after multiplism, relativism. First, a person will believe that most knowledge is known, and that which is not, is knowable. The teacher is still the source of knowledge, and knows the correct ways to find the right answers, but will now present students with diverse views and alternate possibilities so that they can learn to find the answers themselves. A person will then move to understanding that uncertainty is not concocted by teachers for instructional purposes but that uncertainty exists in the world. Finally, a multiplist no longer believes that there is a right answer to every question or problem given by an authority figure; this person has moved to the opposite extreme and believes that every person has the right to her or his own opinion and that all opinions have equal merit.

When a person realizes that not all opinions are equally good, he or she has moved toward a relativistic perspective. The relativist recognizes that some opinions are inconsistent with observed data or are not logically sound, but that there can be several equally valid viewpoints depending on context.

Commitment implies a person recognizes that several perspectives can be considered valid and that decisions must be made. The person realizes that any decisions will be made on the basis of uncertainty, and he or she takes the risk to do so.

Baxter Magolda's Epistemological Reflection Model

Baxter Magolda (1992) conducted a longitudinal study of students' perceptions of the nature of knowledge. Using data gathered from the in-depth interviews, along with a perspective gleaned in part from Perry's work, Baxter Magolda identified four distinct stages of knowing: *absolute*, *transitional*, *independent*, and *contextual*. The characteristics of each stage can be illustrated by discussing (a) the role of the learner, peers, and instructor, (b) evaluation, and (c) the nature of knowledge.

A person with the perspective of absolute knowing contends that knowledge is certain or absolute. Absolute knowers "believe that absolute answers exist in all areas of knowledge" (Baxter Magolda, 1992, p. 36). They can acknowledge that differences exist in the opinions of authorities, but these are viewed simply as variations among details or opinions or misinformed authorities rather than discrepancies in facts. Since authorities such as instructors have all the answers, it is the role of the learner is to obtain knowledge from them, and thus learning is focused on acquiring and remembering information. The instructor is the holder of knowledge, and it is her or his responsibility to transfer it to the learner in a clear, appropriate way that fosters acquisition. Because peers "do not possess knowledge other than that obtained from authorities" (p. 37), their role is limited to sharing materials and explanations in order to assist others in acquiring knowledge.

Evaluation of learning is seen as an opportunity for the learner to reproduce acquired material in order to determine whether it is correct.

Although still believing that absolute knowledge exists in some areas, persons in the category of transitional knowing have concluded that uncertain knowledge exists in other areas. Transitional knowers view discrepancies among authorities as resulting from the answers being unknown. The learner is pushed to understand knowledge rather than just remember information. Because the learner needs more than just a provider of information, the instructor’s role is to use teaching methods that would foster understanding and application of knowledge. Although they still are not seen as knowing the answers, peers can help promote understanding and learning by participating during discussions and hands-on activities. Evaluation of learning, rather than measuring acquisition of material, is used to determine the extent of student understanding.

The category of independent knowing represents a change to the outlook that knowledge is mostly uncertain and that everyone has her or his own beliefs. The focus is on the learner thinking through and expressing her or his own views, seeing her or his own opinions as valid. Thus, “authorities are no longer the only source of knowledge” (Baxter Magolda, 1992, p. 55). The different opinions that authorities hold are just a range of possible viewpoints in a given area. The instructor’s role is to promote independent thinking and allow opportunities for the exploration of knowledge and exchange of opinions. Peers are necessary; they “are a legitimate source of knowledge rather than part of the process of knowing” (p. 55). With the focus on independent thinking, the idea of judging some views as better or worse is not considered. The emphasis is on open-mindedness and allowing “everyone to believe what they will” (p. 56). Evaluation of learning rewards independent thinking but does not penalize views that are different from the instructor or authors of textbooks.

A person with the contextual knowing perspective still views knowledge as uncertain, but the “anything goes” attitude is replaced with the belief that judgments about knowledge are possible in a given context using available evidence. The learner thinks through problems, and integrates and applies knowledge depending on the context. Learners still create their own viewpoints, but they must be supported with evidence. They are open to the formation of new viewpoints given additional insights and context. The role of the instructor is to provide opportunities for learners to apply their knowledge. Peers can be valuable if they are able make worthwhile contributions to the process of learning. Evaluation of any type is appropriate if it "accurately measures competence in a particular context" (Baxter Magolda, 1992, p. 69).

<u>Belenky, Clinchy, Goldberger, and Tarule's Women's Ways of Knowing Project</u>

Using the results of their study and building on Perry's scheme, Belenky, Clinchy, Goldberger, and Tarule (1986) described five perspectives "from which women know and view the world" (p. 15): *silence*, *received knowledge*, *subjective knowledge*, *procedural knowledge*, and *constructed knowledge*. Each perspective can be described according to the different ways that women view authority.

In the position of silence, women see themselves as mindless and voiceless, and thus are blindly obedient to external authorities. They feel passive, reactive, and dependent, and view authorities as all-powerful and overpowering. They are not capable of realizing that words are powerful transmitters of knowledge. The study found that only a small number of women who could be characterized as silent.

The perspective of received knowledge describes women as capable of receiving knowledge from the authorities. They are able to reproduce that knowledge, but not create it themselves. These women learn by listening. Everything they hear is coded as right or wrong, true or false, good or bad. Every question or problem has one correct answer, dispensed from authorities, and any other answers or viewpoints are automatically assumed to be wrong. Thus, received knowers cannot tolerate ambiguity. They want predictability and clarity, and want to know what is going to happen when and what they are expected to do. Belenky et al. claimed that

> these women either "get" an idea right away or they do not get it at all. They don't really try to *understand* the idea. They have no notion, really, of understanding as a process taking place over time and demanding the exercise of reason. They do not evaluate the idea. They collect facts but do not develop opinions. Facts are true; opinions don't count. (p. 42)

Women become their own authorities when they are in the position of subjective knowing. All knowledge and truth "are conceived of as personal, private, and subjectively known or intuited" (Belenky et al., 1986, p. 15). These women begin to understand that firsthand experience is a powerful source of knowledge, and "they begin to feel that they can rely on their experience and 'what feels right' to them as an important asset in making decisions for themselves" (p. 61). For these women, there is a shift in the orientation of authority from external to internal.

A realization that intuitions and gut reactions are fallible is a characteristic of the position of procedural knowledge. Truth and knowledge are not just there for the taking, they must be obtained through careful observation and analysis. Reasoning has taken on a prominent role in determining what is true. These women are "practical, pragmatic problem solvers" (Belenky et al., 1986, p. 99). Within the category of procedural knowledge are *separate* knowers and *connected* knowers, designations that refer to "relationships between knowers and the objects (or subjects) of knowing (which may or may not be persons)" (p. 102). Separate knowers have an orientation toward impersonal rules. When "presented with a proposition, separate knowers immediately look for something wrong—a loophole, a factual error, a logical contradiction, the omission of contrary evidence" (p. 104). They are determined to examine ideas critically. Authority resides in reason, and experts are only such in light of their arguments. Connected knowers have an orientation toward relationship. They believe the only way to "understand another person's ideas is to try to share the experience that has led the person to form the idea" (p. 113). Whereas the separate knower would be interested in the steps taken while reasoning, the connected knower wants to become aware of circumstances that led to a perception. Authority resides in the commonality of experience. Separate knowers try to

> subtract the personality of the perceiver from the perception, because they see personality as slanting the perception or adding "noise" that must be filtered out. Connected knowers see personality as adding to the perception, and so the personality of each member of the group enriches the group's understanding. (p. 119)

In the final position, constructed knowledge, the answer to any question varies depending on the context in which it was asked. Thus, according to Belenky et al. (1986), all knowledge is a construction, and all truth is a matter of the context in which it is embedded. At this point, question posing becomes the dominant method of inquiry. Constructed knowers tolerate ambiguity and recognize that conflict will always be present.

Summary

The three models of epistemological development discussed all contain a set of categories in which individuals fall according to their orientation to authority. The orientations range from knowledge being absolute and given by an authority, to knowledge being situational and developed in context using evidence. The models provided insight into the teachers' beliefs about mathematics, teaching, learning, and assessment and their orientation to authority. The present study sought to determine the influence of the teachers' beliefs and orientation to authority on their assessment practices.

Reflection

This study began with the notion that teachers' beliefs about mathematics, teaching, learning, and assessment would facilitate or impede the use of open-ended items. However, during initial data analysis, the theme of reflection also emerged. The literature on reflective thinking was used to help describe the teachers' thinking about their instructional and assessment practices, as well as their actual practices.

Dewey (1933) claimed that *thought* can be described in three different ways. It can be the "uncontrolled coursing of ideas through our heads" (p. 4). The formation of these ideas is unregulated and automatic, and thus random and chaotic. A second meaning of thought would be the idea of things not actually sensed or perceived, that is, a "mental picture of something not actually present" (p. 4). This type of thought requires inventiveness on the part of the individual. Finally, thought can be equated with belief. An idea may emerge from any source, but the individual then attempts to establish a belief based upon evidence and rationality. It is this third type of thought that Dewey proposed as *reflective thinking*, the

> active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends. (p. 9)

The process of reflective thinking occurs in two phases. First, a person enters "a state of doubt, hesitation, perplexity, mental difficulty, in which thinking originates" (Dewey, 1933, p. 12). The person recognizes something as problematic. What follows is "an act of searching, hunting, inquiring, to find material that will resolve the doubt, settle and dispose of the perplexity" (p. 12). The demand for a conclusion to a problem is the definitive characteristic of reflective thinking. Dewey claimed that for a person to be genuinely thoughtful, he or she must be willing to accept being in a state of doubt for as long as necessary in order to find justification for a belief.

Why do some individuals seem more capable of entertaining reflective thought than others? Dewey (1933) proposed that individuals must possess three attitudes in order to develop the ability to think reflectively, *open-mindedness*, *whole-heartedness*, and *responsibility.* Open-mindedness is the desire the listen to multiple sides of a discussion, to consider facts from any source, to seriously entertain alternative possibilities, and to "recognize the possibility of error even in the beliefs that are dearest to us" (p. 30). An individual with an open mind is more likely meet that which is problematic, thus triggering the process of reflective thinking. Whole-heartedness is what helps motivate thinking. Someone with this attitude is immersed in the subject and is excited about it. This allows for the spontaneous occurrence of questions and the onslaught of suggestions that pop up in the mind. These questions and suggestions motivate further inquiry on the subject. Responsibility is the ability to "consider the consequences of a projected step" and the willingness to accept those consequences (p. 32). Individuals frequently profess particular beliefs yet do not commit themselves to the consequences that unfold as a result of holding the beliefs. To be responsible, an individual must decide to "carry a thing through to its end or conclusion" (p. 33) without allowing the unavoidable consequences to distract them from their intended goal.

In the present study, the teachers' instructional and assessment practices were analyzed to determine what, if anything, they found problematic. Problematic issues are open to the process of reflective thinking, which leads to the formation of evidentially held beliefs. It is with these beliefs that the opportunity for change exists. Such beliefs are the ones that professional development programs have the chance to impact, thus helping teachers make progress in implementing reform initiatives.

Research on Teacher Beliefs

Thompson (1984) investigated the conceptions of mathematics and mathematics teaching held by three junior high school teachers. The study showed that "teachers' beliefs, views, and preferences about mathematics and its teaching played a significant, albeit subtle, role in shaping their instructional behavior" (p. 105). Consistencies, and some inconsistencies, were found between teachers' professed views and their teaching practices. One teacher, Lynn, had the view that mathematics was "cut and dried" and allowed few opportunities for creative work. Her teaching was consistent with this view; she took a prescriptive approach in which her aim was to get the students to memorize specific procedures. Another teacher, Jeanne, indicated that it was important for a teacher to encourage student participation in class and to be alert to clues from the students in order to adjust lessons to meet student needs. However, observations concluded that Jeanne made no effort to encourage classroom discussions, nor did she conduct discussions between herself and her students in order to gather information about the need to adjust lessons. Thompson concluded that the teachers' instructional practices are influenced by their views, beliefs, and preferences about mathematics because of consistencies she found between teachers' professed conceptions of mathematics and the manner in which they typically presented mathematical content in the classroom.

In a study of three preservice secondary mathematics teachers' knowledge and beliefs about mathematical functions, Wilson (1992) found that course activities related to functions helped the preservice teachers construct a more meaningful understanding of functions. They generally had a relativistic view of functions, allowing them to think about functions in flexible and dynamic ways. However, they had more dualistic views of mathematics in general and of mathematics teaching. Wilson concluded that the possible conflict between the teachers' relativist view of functions and their dualistic beliefs about mathematics and mathematics teaching may have made it difficult for the teachers' increased understanding of functions to affect their teaching in a significant way.

Wilson (1993) used a case study approach to investigate a high school mathematics teacher's assessment practices and related beliefs. Ms. League's beliefs about students experiencing success and fairness matched well with her methods of assessment. Her students were given numerous opportunities to enhance their grades, and no evidence of bias was found on any assessments. Although she expressed the views that mathematics should be taught in connection with other disciplines and in the context of real-world problems, and that the primary reason for teaching mathematics is its usefulness and applicability to other disciplines, no evidence of these views was found in Ms. League's formal assessment tasks. Nor did her assessment instruments match her stated views on teaching and learning. These views included thinking of the student as a constructor of knowledge with the teacher as a facilitator of the construction process. But her assessments reflected a view of the student as a blank slate, an accumulator of pieces of knowledge and procedures. Finally, Ms. League talked of the ideals that the most valid assessments are based on personal knowledge of students and that the best assessment would be based on multiple sources of knowledge. However, she was unable to find ways to document the personal knowledge she had of students or include it in her formal assessments, and she also did not use a variety of assessment methods.

Shealy (1994) followed two teachers through their final year in a teacher education program and their first year of teaching. He found that the two teachers occupied different positions in Perry’s Development Scheme and that those differences were elaborated in the teachers’ classroom instruction. Greg’s willingness to value others’ voices yet take risks are characteristic of Perry’s commitment position. Greg said he needed to provide an appropriate learning environment for student learning, which for him involved helping students express themselves in investigative situations. Although some lessons did not go well and he lost some control in some classes, Greg was not discouraged in his efforts. He was willing to act on his beliefs even in the face of uncertainty. Todd, in contrast, was a more multiplistic teacher. Although he professed the importance of problem solving and making mathematics interesting, when open-ended investigations and problem-solving activities did not work as classroom instructional strategies, Todd quickly fell into a more traditional pattern of instructional techniques. He was able to switch easily to his less-emphasized teaching themes, which were to help students by providing the next step and to exercise more classroom control, indicating a lack of commitment to his professed ideas. Furthermore, Todd did not appear to see the contradiction in his expressed values and instructional practices.

Cooney and Shealy (1995) conducted a 3-year project in which five middle and high school teachers received support to rethink their assessment practices. The teachers met quarterly for assistance in formulating assessment plans and to share materials and experiences. Data collection activities included surveys, individual and group interviews, document collection, and classroom observations. All five teachers "professed significant changes in their understanding of assessment and four changed their teaching significantly" (p. 3). The teachers whose central beliefs about mathematics and teaching were most in line with current reform ideas were the most innovative in their assessment practices.

The empirical literature says that teachers' beliefs influence their conception of mathematics as well their instructional and assessment practices. This study was designed to investigate the extent to which teachers' beliefs about mathematics, the teaching and learning of mathematics, and assessment facilitated or impeded their use of open-ended items.

Characteristics of Effective Professional Development Programs

One way for professional development programs to be effective is to "offer teachers practical ideas that can be efficiently used to directly enhance desired learning outcomes in students" (Guskey, 1986, p. 6). Authors of professional development programs should recognize that change is a gradual and difficult process for teachers and that it requires much personal effort. Thus, if a professional development effort "is to be successful, it must clearly illustrate how the new practices can be implemented incrementally, without too much disruption or extra work" (p. 9). According to Guskey, professional development programs that have been successful in encouraging sustained change have several common characteristics. First, new programs or innovations are presented in clear and explicit ways. They are explained in concrete rather than abstract terms and are aimed at specific teaching skills. Second, teachers' concerns about how the new practices will affect them personally are addressed in a direct and sensitive manner. Teachers must first resolve any personal concerns before they can focus their attention on how the new program or innovation will benefit students. Finally, professional development programs that have been successful in encouraging sustained change must have the person introducing the new program or innovation seen as credible by the teachers. The person must be able to "stress how these new practices can be practically and efficiently used" (p. 9). Along with a professional development program with the above characteristics, teachers need continued support and follow-up activities, such as meeting with other teachers or supervisors. Even the best program will not eliminate fear and doubt when the teacher is in the process of actually implementing new ideas or innovations.

Clarke (1994) stated there is an increased recognition that without carefully planned professional development programs, there is only a small chance that the reform vision for teaching and learning mathematics will be implemented. He provided ten principles of professional development programs gleaned from the research literature that are needed to help improve teachers' classroom practice. A summary of the ten principles to be used as a guide when planning and implementing professional development programs is included in Figure 2.1. Clarke claimed that his review of the literature led to the conclusion that a professional development program that incorporates or addresses each of the ten principles would have an excellent chance of supporting the professional growth of teachers.

Loucks-Horsley, Hewson, Love, and Stiles (1998) reported a common vision of professional development programs developed through examinations of reform documents produced by a variety of different organizations, including the National Council of Teachers of Mathematics, the National Research Council, and the National Staff Development Council. They found that effective professional development experiences are focused on well-defined images for effective classroom learning and teaching; allow teachers the opportunity to build their knowledge and skills; use or model the same strategies desired for teachers to use with their students; build a learning community, promoting continuous learning as a normal part of the school culture; help

1. Issues to be addressed in the program should be identified by the teachers themselves.
2. Groups of teachers from the same school should participate in the program.
3. The program should address impediments to teachers' growth, such as teachers' inadequate knowledge and lack of ownership of proposed changes.
4. Teachers should be actively involved in the program.
5. Teachers' commitment should be fostered in many ways.
6. The professional development program should provided opportunity for teachers to validate in their classrooms the information supplied by the program.
7. Time for discussion of problems and solutions regarding new approaches should be incorporated into the program.
8. Teachers should be able to gain ownership in the program.
9. Ongoing support should be made available to teachers.
10. The program should encourage teachers to set further professional development goals.

Figure 2.1. A summary of Clarke's (1994) ten principles.

teachers to serve in leadership roles; provide links to other parts of the education system, such as with other district initiatives; and continuously assess and make improvements in order to meet the needs of teachers. The focus of professional development in the past has been on bringing in outside expertise to demonstrate a new program or approach. Currently, professional development focuses on the teacher and the environment in which the teacher belongs.

The literature about effective professional development programs supports the claim that the Magnolia County Algebra I and Geometry Assessment Project was a professional development program that included appropriate components in order to be effective. For example, the project addressed a specific need of the teachers in the present study, it provided them with a resource as well as with continued support and follow-up, and the teachers were actively involved in the program and had ownership of the resulting resource material. This study was designed to provide insight into the potential for professional development programs and assessment resources to assist mathematics teachers in implementing assessment reform.

CHAPTER 3

METHODOLOGY

The present study focused on two teachers' use of open-ended assessment items in their eighth-grade Algebra I classrooms in an attempt to understand the factors that influenced their use of those items. As the research questions were "formulated to investigate topics in all their complexity" (Bogdan & Biklen, 1992, p. 2), and not to test specific hypotheses, a qualitative design was appropriate. Thus, data were collected "through sustained contact with people in settings where subjects normally spend their time" (p. 2). Extensive teacher observation combined with a written survey, interviews, and artifact collection allowed for a large set of data from which to search for patterns and themes. This chapter describes the selection of teachers, data collection activities, data analysis procedures, limitations of the study, and researcher's background and perspectives.

Selection of Teachers

All 19 members of the Advisory Committee (previously described) were considered for possible inclusion in the study. I was allowed access to these teachers by Magnolia County because of my participation in the professional development project. The final selection of the two teachers was a mixture of circumstance and purposeful selection (Patton, 1990).

I decided to observe teachers in Algebra I classrooms for two reasons. First, during the project I worked with the Algebra I writing group when the initial item generation and revisions were done. This experience made me familiar with the Algebra I items that the teachers could use during the study. Second, because of my experience as a classroom teacher, I felt comfortable in the Algebra I classroom. I was familiar with the curriculum, the kinds of resources available to teachers of algebra, and the types of technology available and the opportunities for their use in the algebra classroom. For these reasons I focused on teachers who would be teaching Algebra I during the time of the study.

I compiled information about the class schedules of the teachers. A total of nine teachers were teaching Algebra I during the year of the study, three at the high school level and six at the middle school level. These teachers were sent the *Assessment Survey for Algebra I Teachers* (see Appendix A). On the survey the teachers were asked to indicate whether or not they would be willing to be contacted about participation in future research.

Of the high school teachers, two out of the three returned their surveys. One teacher declined to be included in future research; the other indicated a willingness to be considered. After a phone discussion with that teacher, however, I determined that the time during which the study would take place would not be convenient for her for personal reasons. The teacher who did not return the survey revealed during a follow-up phone call that she would be out of the country for the first few weeks of school and could not be a participant.

I then directed my attention to the group of middle school teachers. Four of them returned the surveys in a timely fashion, and all indicated they would be willing to be contacted for possible participation in future research. I wanted to observe each participant from the first day of school and each school day thereafter for an extended period of time. I believed not only that this procedure was the best way for me to note the obvious daily happenings, but also that by becoming a “piece of the woodwork” I would be able to observe the teachers and students in more natural states than might be the case if I were regarded as simply an occasional visitor in the classroom. In fact, one of the participants admitted later that she had a “tendency as a teacher to adjust my instruction for visitors. If you are here every day, I will be more natural” (comment made by Leah, 8/24). Thus I examined the teaching schedules of the four teachers who remained in consideration to determine the best possible option for data collection. Two of the teachers were in the north part of the school district, the other two were in the south part, and all four teachers were in different middle schools. When I looked at the teachers' schedules, the classes of the two south area teachers overlapped, and I would not have the opportunity to observe their classrooms from "bell to bell." The size of the school district prevented me from being able to observe both a south area teacher and a north area teacher; I could not possibly travel the distance required in the time I had between their classes. The two north area teachers' schedules showed that the first teacher was scheduled to teach an Algebra I class during sixth period and that the second teacher was scheduled to teach Algebra I classes during fifth and eighth periods. The schools were located close enough to each other to allow observations of the sixth-and eighth-period Algebra I classes, each from the beginning of the daily class period to the end.

I contacted the two teachers and reminded them of my research interests related to the project. Leah and Sue both allowed me to observe in their classrooms. Both teachers were serving as department heads in their respective schools (Leah later declined to continue as department head), had repeatedly shown their desire for professional growth by participating in numerous professional development opportunities, and had demonstrated leadership expertise in their field by conducting professional development courses within their school district. I was pleased to have teachers considered to be role models by the school district mathematics coordinator as participants in the study.

Data Collection Activities

Several sources of data were used in order to portray the instructional and assessment practices of the teachers in the study. Three of the data sources, the survey, interviews, and artifacts, were the data collected "in the subjects' own words so that the researcher can develop insights on how subjects interpret some piece of the world" (Bogdan & Biklen, 1992, p. 96). Data were collected from these sources in order to gather evidence of how mathematics instruction and assessment appeared to the teachers and the meanings they assigned to various factors of instruction and assessment. Classroom observations were conducted to see how the teachers' mathematics instruction and assessment appeared to me in an effort to elaborate on the teachers' stated beliefs and their descriptions of their instructional and assessment practices. Each data source is described in detail below.

Both teachers completed the survey in April 1999. It was designed to provide initial data concerning their interpretations of assessment, their assessment practices, their beliefs about the nature of mathematics and the teaching and learning of mathematics, and their perceived effectiveness of the professional development project. The survey data were used as background information for classroom observations and interviews.

Each teacher agreed to three in-depth interviews, with one to take place just before the observations began, one during the time the observations occurred, and one later in the school year. The interview protocols are contained in Appendix B. Sue's interviews took place as planned on August 18, 1999; September 20, 1999; and June 8, 2000; each was about 60 minutes in length. For personal reasons, Leah was unable to meet for an interview until September 8, 1999, which was during the time the observations occurred. When I attempted to schedule a second interview with Leah before the observations ended, she cited a lack of time to meet with me. At first, I was concerned that a problem had arisen that made Leah regret she had agreed to participate in the study. But comments she made to me during the observations revealed that she was indeed overwhelmed with commitments, so I did not attempt to pressure her for the interview. Thus, the second interview with Leah was April 19, 2000, and there was not a third. Each of Leah's interviews was approximately 60 minutes long. All interviews were audiotaped and transcribed.

The artifacts included copies of tests, quizzes, worksheets, and other handouts used in each teacher's classroom. All the students' tests and quizzes graded during the time of the study were copied and collected. The artifacts provided information concerning the type of items that the teachers used on class assignments and on formal assessments, as well as information concerning how they perceived student responses to those items.

Each teacher was observed as she taught two instructional units. A classroom observation guide was used to help focus the observations (see Appendix C). Both teachers' instructional and assessment activities related to the first two chapters of the Algebra I textbook, and included the topics of variables, expressions, properties, integers, and rational numbers. I began the observations the first day of school, August 23, 1999, and observed daily until the teachers completed both instructional units. Leah was absent from class one day for personal reasons, and both Leah and Sue were absent on August 16th because of a district meeting. I observed in Leah's classroom for a total of 28 days, and in Sue's for a total of 24 days.

During each observation I took fieldnotes. The physical aspects of the classroom were noted, such as the arrangement of student desks. Classroom procedures and routines were described, such as the taking of roll. The teachers' instructional and assessment activities were recorded, including any writing done on the overhead projector or chalkboard and verbal statements or questions made by the teacher. Student questions, responses, and behaviors were also recorded. In addition, I attempted to address specific questions with respect to each teachers' instruction and assessment:

- What amount of time is given to different aspects of instruction and assessment?
- Is the level of thinking skills required by students consistent between instruction, assessment, and assignments?
- Under what circumstances do students work alone or together?
- Do instruction and assessment occur simultaneously?
- How does the teacher use assessment information?

I also noted what did *not* happen in the classroom that I might have expected to happen. Additionally, I made notes of my feelings, reactions, hunches, speculations, insights, initial interpretations, questions, and working hypotheses in the fieldnotes with respect to specific observances.

The classroom observations provided confirming or disconfirming evidence with respect to teachers' survey responses and comments made during interviews. The classroom observations targeted the instructional and assessment practices of the teacher in order to reveal patterns and regularities of behavior. The data helped me determine the teachers' instructional and assessment practices. The observations were used to determine the extent to which teachers' responses on the survey and in interviews were manifested in the classroom.

Data Analysis Procedures

There were two phases of data analysis. The first phase consisted of a descriptive analysis in order to answer basic questions about the teachers' practices and beliefs. I initially read the written data sources and highlighted pieces that appeared significant with respect to the research questions and the theoretical orientation. Each highlighted piece was placed on an index card. I then sorted the cards using inductive analysis, which means that "the patterns, themes, and categories of analysis come from the data; they emerge out of the data rather than being imposed on them prior to data collection and analysis" (Patton, 1990, p. 390). This was done in an effort to "identify significant patterns, and construct a framework for communicating what the data reveal" (p. 371).

The first analysis resulted in the cards being sorted into four categories: mathematics, teaching, learning, and assessment. I continued to sort the cards within each of the four categories in order to identify themes that related to each category. Using these results I wrote chapters 4 and 5, which contain the descriptive data about Leah and Sue.

The second phase of data analysis consisted of analyzing the data with an emphasis toward interpretation. According to Patton (1990),

> Interpretation, by definition, involves going beyond the descriptive data. Interpretation means attaching significance to what was found, offering explanations, drawing conclusions, extrapolating lessons, making inferences, building linkages, attaching meanings, imposing order, and dealing with rival explanations, disconfirming cases, and data irregularities as part of testing the viability of an interpretation. (p. 423)

I analyzed the data again and specifically looked for significant pieces that related to authority and reflective thinking in order to interpret the data with respect to my theoretical orientation. Using the results from this interpretive analysis, along with the results from the descriptive analysis, I wrote chapter 6, which contains a theoretical interpretation of the data.

Limitations of the Study

A customary definition of *generalization* would be that the findings of a study will transcend the specific research subjects and setting. With respect to the present study, that would mean that other Algebra I teachers would use or not use open-ended items similar to those used by Leah and Sue and for the same reasons. In that sense, the findings of this study are not generalizable. However, if a different definition of *generalization* is considered, then the findings are generalizable. With the assumption that “that human behavior is not random or idiosyncratic” (Bogdan & Biklen, 1992, p. 45), then the findings of this study point to some general ideas about the social processes of mathematics instruction and assessment that can indeed be applied to other mathematics teachers and their classrooms. Another way to approach the idea of generalization is to remove the responsibility for providing it from the present study and place it upon the users of this research. In that way, it is up to the users to decide how the findings are applicable to their given situation. The careful documentation of the present study allows such a determination of relevance to take place.

The theme of reflection did not emerge until after all data collection activities were completed. I might have asked different questions and made different observations if I had had an orientation towards reflection during the data collection. This possibility should not be considered a flaw in the study. The nature of qualitative research is such that important questions or concerns are raised as a result of the study and are not necessarily made before undertaking the research.

My main concern at the onset of the study was the extent to which my presence would change the behavior of the teachers. I did not want them to change their instructional and assessment practices because of my presence. Although no researcher can eliminate the effect of her or his presence on what is being studied, I tried to minimize the effect by being a part of the classroom from the beginning, both in terms of the school year and of each classroom period. I was specifically concerned that the teachers might see me as someone from the professional development project sent to judge them. To alleviate this concern, I constantly attempted to interact with the teachers "in a natural, inobtrusive, and nonthreatening manner" (Bogdan & Biklen, 1992, p. 47). I was a silent onlooker during classroom observations, and when I was spoken to by the teachers, I remained as neutral as possible with my responses. My concern also kept me from being aggressive during interviews. This limited how far I was willing to bring up inconsistencies and inaccuracies concerning the teachers' instructional and assessment practices. For example, during interviews, I did not bring up specific instances in which I observed the teachers making mathematical errors.

Researcher's Background and Perspectives

My interest in investigating teachers' assessment practices stemmed from my desire as a classroom teacher to enhance my teaching abilities through the pursuit of a doctoral degree. One area in which I specifically felt weak was assessment, as I did not believe I was doing a sufficient job of incorporating new assessment ideas that I had encountered into my teaching. During my doctoral program, the opportunity to help develop and coordinate a professional development project for Algebra I and Geometry teachers occurred, and I was confident I would learn a great deal from that experience. That has indeed been the case. The present study is a direct result of my participation in the development and coordination of that professional development project and my desire to determine its ability to aid teachers in their classrooms.

As a classroom teacher, I believed it was my responsibility to assist my students to gain knowledge and confidence in order for them to be successful in whatever future mathematics courses they enrolled, whether in high school or in a postsecondary institution. I endeavored to convince all my students that they did indeed possess significant mathematical abilities and that they were capable of learning mathematics at a level higher than they might have originally believed. As a result of my classroom experiences, I have certain views about the abilities of students, the responsibilities of both the teacher and students, and effective teaching practices. I believe all students are capable of learning mathematics and that I have the responsibility to search diligently for a variety of effective ways to help them learn mathematics. Although students have a responsibility to listen and participate in classroom activities, as well as to study and do homework, only when I had exhausted my teaching ideas did I consider a student’s personal habits or qualities as the reason for their lack of success in my classroom. I tend to react poorly to the teacher who teaches in a narrowly construed manner, tests for low-level abilities, and quickly places blame on students for poor performances on tests. It is in these areas that I see myself as somewhat different from the teachers in my study. As a result, I had to take care not to let frustration fill my mind to the point where I could not accurately report what I observed or appropriately interpret my findings. I had to remind myself to look at the data from all sides, not simply from the side of how I thought it should have been done.

CHAPTER 4

THE PARTICIPANT LEAH

This chapter introduces the first teacher in the study, Leah. It describes her actions and beliefs under the categories of mathematics, teaching mathematics, learning mathematics, and assessment. These categories emerged during the initial data analysis.

Introducing Leah

Leah was a white female in her tenth year of teaching middle grades. She taught seventh- and eighth-grade classes in a middle school of approximately 1250 students. The students were from a suburban, mostly upper socioeconomic, Caucasian population. Leah had been department head until the year of the study. She had requested not to have a teaching assignment of three preparations because she felt it was too much for a teacher to have to prepare lessons for Pre-algebra, Algebra I, and Geometry courses and be department head. Leah also conducted a professional development course for county geometry teachers. The year of the study she again taught those three different mathematics courses and so had declined to continue as department head.

Leah had a bachelor of science degree in mathematics and a master of education degree in middle grades education. In her first interview, she said she felt that she had “expertise in the subject” of mathematics and thought she was “a good math teacher.” She indicated why she had chosen to teach mathematics:

> I enjoy doing math. It was always my favorite subject in school. Learning math was easy for me—I had a talent for doing math. I love to teach because I get to teach math. I’m not sure if I would like teaching if there were no such thing as mathematics. (Survey)

Leah taught middle grades because she liked children of that age. As a new teacher, Leah had never wanted to teach beyond the Algebra I level because of her “lack of confidence in [her] ability to teach at a higher level” of mathematics (Survey). At the time of the study, geometry was her favorite course to teach: “It’s very hands-on, and you can do a lot of technology. And I like to do the technology and hands-on” (Interview 1).

Leah participated in the professional development project because she enjoyed learning and considered herself to be a lifelong learner. Referring to professional development opportunities, she said that “[I take] everything that comes along because I just always feel like I’m going to get something out of it” (Interview 1). Leah also said that she learned best “definitely by doing projects and maybe a little bit of group work. Most of all, projects.” Even though she considered herself a learner, Leah claimed it was difficult to change her teaching practices:

> I think it takes a long time and a lot of hard work. It cannot be done in a very short period of time. I think we have to try one or two things a year and then make a change maybe over a 10-year period. I think it takes a long time. (Interview 1)

Leah’s motivation for change in her teaching was grounded in her ability to “step outside [herself] and see some things that are not the best” (Interview 2) and resulted from her analysis of her teaching and her efforts to find better ways to help students learn mathematics. This motivation led to her participation in numerous professional development programs.

Themes Related to Mathematics

Leah described mathematics as “how we keep track of things, how we use data to look at information and make decisions” (Interview 2). According to her survey response, Leah felt that mathematics was important because it provided a basis for modeling real-world phenomena, it was basic to so many other school subjects students encountered later in high school or possibly even in college, and it helped students discover and explore possible relationships between different quantities that vary. Leah believed mathematics required people to think, communicate, and solve problems. When asked if there is an answer to every question and a solution to every problem, she replied

> I guess. I'm trying to think of a nonexample. A solution could be that there is no solution, so that's a solution. Yeah, in one way or another there's a solution to everything. It may not be exact. (Interview 2)

As previously mentioned, Leah felt that she had expertise in teaching the mathematics courses that she was assigned. She did not feel her mathematics skills were problematic, and even if they were, "you can get more math stuff from anybody" (Interview 1). During that same interview, Leah made several comments about what it meant to know mathematics. She claimed that to have a knowledge of mathematics implied "you know enough about a subject to be able to teach someone else—knowing enough to teach someone." Leah also said that to have a knowledge of mathematics meant that someone "can come back at a later time, a really long time, and still be able to use that knowledge or answer that question." She also claimed that to have a knowledge of mathematics meant that someone had the ability to "do something sort of naturally and by habit, rather than having to think about it; it becomes second nature." A knowledge of mathematics, for Leah, implies that the person knows mathematics well enough to teach someone else, that he or she is able to retain the knowledge and use it a later time, and that the knowledge is readily available to a person since it was an acquired habit.

Themes Related to Teaching Mathematics

Leah considered herself very knowledgeable about the reform movement in mathematics education. Her self-assessment was that "I think I understand it 100%" (Interview 2). On a continuum from traditional to reform, Leah considered her teaching to be three fourths of the way toward reform. She explained,

> When I'm planning my lessons, the number one thing I try to do is to work in something that's hands-on, something that's cooperative learning, some technology, and some real-life applications. I try to do that with almost every

> lesson, or I know I try to do that with every unit. I will do technology with every unit. I will do real-world application. I will do cooperative learning—I do that pretty much daily—and the fourth thing—hands-on—I don't try to do it every day. But within a unit all of those things will get done a couple of times. (Interview 2)

On her Algebra I course syllabus, Leah provided the following analysis:

> Emphasis is placed on real-life applications, coordinate geometry, problem-solving strategies, and computer and calculator technologies. Students will be required to justify solutions to problems numerically, graphically, symbolically, and verbally.

Leah felt that she helped students to understand mathematics better by her use of hands-on and cooperative learning activities, and by the inclusion of technology and real-life applications in her lessons.

Leah's main philosophy about her teaching was that students were not going to sit around and do rote work. She wanted students to be challenged and engaged during class. When asked what it meant for students to be engaged in mathematical learning, Leah replied that they should have a focus on or "complete attention to what they're doing, talking about math, using a lot of math vocabulary" (Interview 2). A strategy Leah used in her classroom to encourage students to talk about mathematics was that the student desks were arranged in groups of four. The arrangement easily allowed students to participate in group activities. When working individually, the students could whisper to a neighbor with a question or to verify an answer.

Because Leah believed it was "difficult to learn something when you don't know why you're learning it" (Observation, 9/21), she incorporated real-life applications into her teaching. A lesson on formulas included $d = rt$, that is, the distance traveled (d) equals the rate (r) multiplied by the time (t). Leah commented to the students that this formula was very useful and that it "comes up a lot in science" (Observation, 9/9). When she introduced inequalities, Leah discussed real-life situations that involved the ideas of greater than or less than in which “you put a limit on something” (Observation, 9/22). For example, she pointed out that “in real life there are things you can and cannot do, like a speed limit.” When she asked students to reply to this comment, and to the inequality $s \leq 70$ that she had written on the overhead, a student said “you can drive under 70 but not over 70,” and another student added “and you can drive 70.” Leah wrote $v \geqslant 18$ on the overhead and asked for a real-life example, to which a student volunteered “you can’t buy some stuff in the store unless you’re 18 or over.” Rounding was another opportunity for Leah to make a real-life connection with mathematics. She asked students, “When in real life situations do we round?” A student responded with “buying tubes of paint,” and Leah added “wallpaper rolls” (Observation, 8/26).

Leah used technology as an aid in her teaching in a variety of ways. She frequently used the computer for topic presentations instead of using the chalkboard or overhead. The TI-82 calculators were used for computation, such as evaluating the expression $\frac{100}{2}(4+1)$, and for changing fractions such as $\frac{2}{3}$ and $\frac{7}{11}$ to decimals in order to make numerical comparisons. Leah used the ability of the calculator to convert decimals to fractions in a lesson in which she described a rational number as a number that can be written as a fraction in which the numerator and denominator are both integers and the denominator is not equal to zero. During the fifth week of school, Leah and her students participated in an integrated lesson about hurricanes that also involved the students’ other subject teachers. For one of the mathematical activities, Leah led the students in graphing data on the TI-82 calculator, such as hurricane wind speed vs. barometric pressure. The class was observed using the personal computer lab one time (9/10). The students used a particular software, the Math Toolkit, to make rectangles and cover them using square units in order to determine area. Leah believed that those instances in which she used real-life applications and technology in her lessons were beneficial for students to help them understand mathematics better.

Leah's Teaching Style

During a typical Algebra I class, Leah lectured to the students, provided examples, and assigned classwork and homework in order for students to practice mathematical skills. Most of the time students worked on assignments individually, and Leah walked around and answered questions when students raised their hands. When she considered her classroom practices, Leah commented,

> I still do a lot of direct instruction, which I guess you have to do. You could still be completely reformed and do a lot of direct instruction, but I do think I do a lot of direct instruction. (Interview 2)

Directive also described Leah's teaching. For example, while students were taking notes, she would frequently make comments such as "I will tell you when to write," "This is the page I want you to copy," and "[This] is important; put a star by it" (Observation, 8/26). When students were doing classwork, Leah told them, "I am going to come around and make sure you are showing your work like I want you to show your work" (Observation, 8/23). She was also explicit about how the students were to do their homework. The directions that Leah gave the students for doing their homework are shown in Figure 4.1. On the same day that the directions were given, Leah had the students begin their homework assignment in class so that she could make sure they were setting up their homework assignment the way she wanted them to.

Leah's directive approach also included giving the students rules or requirements about how she wanted things done. For example, she told the students, "I don't want you to use an x any more for a times sign" (Observation, 9/1). There were several specifics Leah had concerning fractions and decimals. She requested "that we not use mixed numbers," since $\frac{5}{3}$ looks better than $1\frac{2}{3}$, and because "we like improper fractions better than mixed numbers" (Observation, 9/8). She never explained to the students why

-leave space for corrections in class

-put #1 under #2, etc.

-only right answers is unacceptable

-make corrections before next class

-get help

-grade HW during class with red pen: -0, -2, etc.

-HW collected 1-2 times a week for grade, for neatness, correctness, evidence of grading

Figure 4.1. The homework directions Leah showed on the overhead on 8/26.

improper fractions were preferred. Over the course of several days, Leah presented some rules that students were to follow. The rules are shown in Figure 4.2. She explained that "those are just some rules we are going to follow this year," but never gave any reasons or justifications for them.

If a math problem uses fractions only, then the result must be a fraction.

If a math problem uses decimals only, then the result must be a decimal.

From now on, if the question is written in fractions, you cannot switch to decimals.

If a fraction is negative, make the numerator negative and the denominator positive.

Figure 4.2. Leah's rules that she presented on 9/23, 9/24, and 9/27.

There were also rules to be followed that concerned what was acceptable mathematical work, which meant that students would not be given credit for just an answer. On the first day of class, Leah told the students, "You must be able to justify your solution, not just answer the question" (Observation, 8/23). She frequently reminded the students of this requirement. For example, when she taught a lesson on formulas, she presented a formula that would determine which day of the week a person was born given their birthdate. Some students began to say the day of the week they remembered being told they were born on, and Leah asked them, "Is that a good enough answer for a math teacher?" (Observation, 8/23). The students chorused "No." She reminded the students that they must write out the formula and show all steps in order to be given credit for any answers.

Leah believed that her explanations were important for the students even though they had been exposed to the topic in the past. For example, when discussing the distributive property, she said, “I want to make sure you understand my definition of the distributive property,” and proceeded to show students on the overhead the following:

$$2 \cdot \underline{\quad} + 2 \cdot \underline{\quad} = 12$$

Leah asked the students to fill in the blanks, which they could do. She summarized her explanation by demonstrating that

$$2 \cdot \underline{4} + 2 \cdot \underline{2} = 12 \text{ and } (4+2) \cdot 2$$

$$2 \cdot \underline{3} + 2 \cdot \underline{3} = 12 \text{ and } (3+3) \cdot 2$$

and told the students that because of the 2, the expression in the parenthesis must add to 6 (Observation, 9/2).

As she reviewed exercises in class, Leah told the students how to set up problems and how to proceed. For example, the students were shown the problem in Figure 4.3.

> Christine is saving to buy a holiday gift for her favorite aunt. She has \$6 now and adds \$2.50 per week.
>
> How much will be saved in seven weeks?
>
> How much will be saved in “*w*” weeks?

Figure 4.3. Leah’s problem presented on 9/27.

Leah then had the students copy the chart in Figure 4.4. She told the students, “Finish the chart until you can answer the question” (Observation, 9/27). In this example, Leah did not allow students sufficient time to complete the chart and answer the questions. Instead, she posed the following questions:

> What if I said, “Let’s save money for 52 weeks”? You would not like a chart with 52 numbers. How can we figure that out without using a chart? You’re going to

multiply 52 by 2.50 plus 6, right? What if *w* weeks? *w* times 2.50 times plus 6. Do you get it?

# week	$ save
now	$6
1	$8.50
2	$11.00
3	
4	
5	
6	
7	

Figure 4.4. Leah's first chart.

Several students replied that they did not understand. Leah followed with "Let me show you another way I like to do these problems," and put the chart in Figure 4.5 on the overhead. She asked, "Now do you get it?" (Observation, 9/27). Although the students did not indicate that they understood her explanation, Leah moved on to another problem.

now	$6	
1	8.50	6 + 2.50
2	11.00	6 + 2.50 + 2.50
3	12.50	6 + 2.50 + 2.50 + 2.50
4		this one would be 6 + 4(2.50)
5		6 + 5(2.50)
6		6 + 6(2.50)
.		.
.		.
.		.
w		6 + *w*(2.50)

Figure 4.5. Leah's second chart.

A lesson on simplifying expressions included such exercises as simplify $\frac{12-8b}{2}$.

Leah told the students that $\frac{3}{5}+\frac{8}{5}$ was really $\frac{3+8}{5}$. She explained that they could do it in the reverse, that is, that $\frac{17+2}{10}=\frac{17}{10}+\frac{2}{10}$. Leah said "all I care is that you can go from here, $\frac{17+2}{10}$, to here, $\frac{17}{10}+\frac{2}{10}$, and you believe me that it is true" (Observation, 9/28). She wanted the students to know that $\frac{12-8b}{2}=\frac{12}{2}-\frac{8b}{2}=6-4b$ since she had said that the expression would simplify that way.

<u>Leah's Questioning Techniques</u>

As a result of her participation in the professional development project and the county's mandate concerning 20% higher-level thinking items on tests, Leah felt that her instructional practice had changed. She believed she asked more higher-level questions during class discussions, "modeling the kinds of questions" she asked on tests (Interview 1), and that she allowed students to "create their own techniques for solving problems" (Survey). She was confident that she understood what higher-order thinking items were because, unlike teachers who think that "any problem that has words in it is a higher-order thinking question" (Interview 2), Leah knew that those types of items could be open-ended, that is, ones that had multiple solutions or a variety of ways to arrive at the solution. The open-ended items that Leah gave in class are included in Figure 4.6. The students did not appear to have difficulty responding to these items.

Create an expression, read it to another student, and have them write it as an algebraic expression.

Create five math problems with the answers 1, 2, 3, 4, and 5. Use only four 4's, sets of ( ), exponents, $+$, $-$, $\times$, $\div$.

Make a math problem with four different operations and translate it.

<u>Figure 4.6.</u> Leah's open-ended items she gave in class on 8/26, 8/27, and 9/1.

During the integrated lesson on hurricanes, the students watched a video produced by the Discovery Channel (Observation, 9/16). The assignment was for students to write 10 mathematical facts from the video, not including dates, number of hurricanes, or number of deaths. From those facts, students were to create five mathematical story problems and solve them. One student offered, “36 inches of rain fell in six hours. How many inches of rain fell per hour?” Leah stated that the students created good story problems. The students were also able to solve their problems and Leah said she was very satisfied with their work.

A small group activity that Leah used involved algebraic properties (Observation, 9/1). The groups of three or four students were to order the properties according to their importance and justify to the class why they put the properties in that particular order. Leah told the students that she would be looking for the thought and reasoning they used for their ordering. She wanted the students “to maybe not so much repeat back to me but to do something with it to where, ‘Okay, these are the properties’” (Interview 1). She had tried to create an activity in which the students had to think about the properties instead of just being able to recognize them. The students struggled with this assignment, and the order of the importance of the properties among the groups was very different. For example, most groups thought the reflexive property was not important, because “it was just repeating.” When queried about this assignment, Leah said, “I feel like they’ve been introduced to all the vocabulary, and they’ve seen it all, and now I can use it throughout the year” (Interview 1). However, Leah claimed a few moments later, “I don’t know if they got away from that like I wanted them to.” She was unsure whether the assignment had helped the students to understand the properties, but “maybe [the properties will] look a little more familiar to them” (Interview 1).

Another change that Leah felt occurred in her instruction was that she allowed students to communicate more. She said, “I listen to what the students are saying more than I used to” (Survey). Sometimes Leah appeared to listen to what the students said, and sometimes she did not. At times Leah listened to students, then used their comments with elaboration to further a point. For example, the students were told to “think about how you’re going to explain that $-\frac{4}{3}$ is greater than -2” (Observation, 9/24). A student offered, "it's closer to zero," and Leah reiterated to the class "$-\frac{4}{3}$ is closer to zero, so $-\frac{4}{3}$ is greater than -2." Another time that Leah used a student response to further the discussion was during a lesson on reciprocals. Figure 4.7 exhibits the examples and nonexamples of reciprocals Leah showed the students on the overhead. She then posed

examples	not examples
$\frac{10}{11}\cdot\frac{11}{10}=1$	$-\frac{3}{4}\cdot-\frac{3}{4}=\frac{9}{16}$
$-1\cdot-1=11$	$1\cdot-1=-1$
$1.5\cdot.\overline{6}=11$	$1.6\cdot.\overline{7}=\frac{56}{45}$
$\frac{4}{5}\cdot 10\cdot\frac{5}{4}=1\cdot 10$	

Figure 4.7. Leah's examples and nonexamples of reciprocals.

the question "Two numbers are reciprocals of each other if…?" A student responded, "If the numerator and denominator are flipped." Leah replied, "We need another definition than the flipping one." A second student offered, "If they equal one." Leah followed with, "If their product equals one specifically" (Observation, 9/29). She used the second student's comment, along with her elaboration, to present a definition for reciprocal.

Leah also accepted student answers and explanations without any elaboration on her part. For example, when she was helping the students review for the second test, she gave them a study guide that asked, "Why is $X+Y \neq XY$?" A student said, "Because XY is multiplication," and Leah accepted what the student said and went on to the next question on the study guide. She did not request or provide an example to show that $X+Y \neq XY$. Another time, when students answered "$\frac{1}{30}$ of an hour" and "2 minutes" to the question shown in Figure 4.8, Leah said, "Everybody get this? Yes?" and moved on to the next problem (Observation, 9/29). Leah did not ask for or provide an explanation to the problem even though not all the students indicated that they understood the answer.

Ashley drives 30 miles in one hour. How long does it take to travel one mile?

Figure 4.8. Leah's question given in class on 9/29.

At times when Leah appeared to not listen to the students, they had answers that seemed to fit her questions but she did not accept them or follow them up. For example, when Leah asked the students why adding two negative numbers gives a negative number, one student replied, "I had negative two dollars, adding negative six dollars is like losing six dollars, so now I lost eight dollars" (Observation, 9/21). Instead of using this idea of money, which would be familiar to the students, Leah countered with "All right guys, watch me," and proceeded to draw a model for adding -2 and -6. The model she drew is shown in Figure 4.9. The Rs represented red chips, which stood for negative numbers, and Leah commented, "All together I have eight."

-2 RR	-6 RRR RRR

Figure 4.9. Leah's model for adding -2 and -6.

Another time, after she reviewed a worksheet where students found the volume and surface area of rectangular prisms, Leah commented, "Just by the way, if we were using inches, volume is measured in cubic inches, surface area in inches squared. Why?" A student said, "We only have two dimensions." Instead of using his remark to further the concept, Leah said, "It's an area problem, so we use inches squared or centimeters squared. We are finding how many squares cover the area" (Observation, 9/13).

The question in Figure 4.10 was included on the study guide for the first chapter. No student volunteered to answer this question, so Leah prompted them with the following:

> You've got to work it out. What kind of answer am I looking for here? A numerical. So how do you answer that question to get credit for it? No, the area does not double, why? (Observation, 9/14)

The area of a circle with radius 10 cm is approximately 314 cm^2. If you double the radius to 20 cm, does the area double also? Explain why. Also, explain if you solved the problem numerically, verbally, symbolically, or graphically.

Figure 4.10. Leah's chapter 1 study guide question.

A student said, "Show both sets of numbers," but Leah did not acknowledge her answer and went on without ever answering the study guide question (Observation, 9/14). In these situations in which Leah either did not accept or follow up student responses, the students had offered an appropriate way to think about the question or a method to determine the solution to the question. However, Leah did not appear to value the student's thinking; instead, she chose to convey her own thinking and her preferred methods.

Frequently, while Leah was reviewing homework or classwork, if a student's answer was not correct, she simply called on other students until someone said the correct answer. No effort was made to probe incorrect responses. Many times Leah would also answer the questions herself. For example, when she asked, "What good does the distributive property do for us?" she immediately followed with "The distributive property lets us combine like terms" (Observation, 9/2). Sometimes Leah would answer the question herself after an incorrect student response. When asked to simplify the expression $\frac{5}{8}+-\frac{3}{4}+\frac{15}{16}$, a student said he did not know what to do. Leah tried to encourage him by saying, "Common denominators," and the student replied, "8." Leah said, "That won't work" and proceeded to simplify the expression (Observation, 9/24).

When Leah ran into difficulty with respect to answers and explanations, she would move on to something else. When teaching a lesson on simplifying expressions, she posed the problem $\frac{5}{6}m + \frac{m}{6}$. She wrote on the overhead $\frac{m}{6}$(5+1), and immediately the students commented that they were lost. Leah tried to explain that the terms in the expression had a $\frac{m}{6}$ in common and asked “Does that make sense?” No student said yes, and Leah said, “Let’s move on” (Observation, 9/2).

The students were assigned the following problem for homework on page 43 of their textbook:

> Lorena can paint the house in 25 hours. Mia can paint the same house in 30 hours. If Lorena and Mia work together, how many hours will it take to paint the house?

The students were confused about this problem. Prior to class, Leah had put the computations in Figure 4.11 on the board. The students were lost as they attempted to follow what Leah had written; she became flustered when she tried to explain what she had done. Finally, Leah quit working with this problem and told the students to hand in their homework papers (Observation, 9/27).

x = # hours to paint the house

$$\frac{x}{25} + \frac{x}{30} = 1$$

$$\frac{30x + 25x}{750} = 1$$

$$55x = 750$$

$$x = \frac{750}{55} = \frac{150}{11} = 13\frac{7}{11} = 13.\overline{63}$$

Figure 4.11. Leah’s computations shown on 9/27.

Another homework problem that Leah assigned was from page 69 of the textbook, the critical thinking problem shown in Figure 4.12. Leah began to review this problem by saying,

> How do we prove that something always works? You have to explain this to me and you can't use numerical examples because that would take all day. How are you going to explain this to me? (Observation, 9/24)

To find a number between $\frac{3}{4}$ and $\frac{6}{7}$, John added as follows: $\frac{3+6}{4+7}=\frac{9}{11}$. He claimed his method will always work. Do you agree?

Figure 4.12. Leah's critical thinking homework problem discussed on 9/24.

A student replied, "Verbal." Leah said that the answer was yes, the method would always work. Another student asked, "How could you guess the answer without ever knowing; that is, if there is no example?" Leah replied, "How do we say—prove something works? We have a theory, and we haven't disproven our theory. Let's move on" (Observation, 9/24). Leah was not prepared to explain this homework problem to the students. She was also unprepared to discuss different ways of constructing proofs.

Leah never sufficiently explained these and other problems for the students, and she never revisited these problems in later class periods.

Leah's Instructional Decisions

Leah sometimes used the curriculum guide as a resource when planning lessons. She said, "[I] look at the curriculum guide every now and then. I'm not one of those people that never look at that. But I look at it maybe once or twice while I'm teaching the unit" (Interview 1). Leah also used the textbook as a resource, but she decided on the content of her lessons and the order in which they occurred. For example, Leah incorporated the last section of chapter 1, problem solving, into the lesson for section 1 because they both contained algebraic and verbal expressions.

Leah was confident of her decision to spend more time on chapters 1 and 2, which were review material from the previous year's Pre-Algebra course. During the first interview Leah commented,

> We're teaching a different child and may have to approach it differently. I know at the high school, they don't have to spend as much time like I did on chapter 1 and chapter 2 going over integers and fractions and decimals, that type of thing. They cover material much more quickly than we do, but I felt like as a teacher that it was important because I taught seventh-grade Pre-Algebra, and I just didn't think that that was enough practice on the fractions and the positives and the negatives.

During the second interview, Leah again defended her decision to take more time than the high school teachers with respect to covering basic skills: "I felt like it needed to be done, and I did it." Most of the homework and classwork assigned in Leah's class emphasized the basic skills of algebra. In the text, she always assigned the practice exercises for each section, and approximately one third of the time assigned the critical thinking and applications problems. The worksheets she gave in class were procedural exercises to practice the skills.

Leah believed that her ability in mathematics as well as knowledge about her students helped her to make good decisions regarding lesson content and ordering. However, mathematical content problems occurred with her explanations. Students appeared not to understand her explanations of some exercises and problems. But Leah often had good explanations of why something worked. For example, when she explained why a positive number multiplied by a negative number equals a negative number, Leah reminded the students that multiplication is just repeated addition. She wrote the following on the overhead:

$$-5+-5+-5+-5+-5+-5=-30$$

$$6(-5)=-30$$

and said, “Six times negative five is really saying add six sets of negative five, and if you do that addition you get a negative” (Observation, 9/28).

Leah focused on her own thoughts and experiences when she made decisions regarding instruction.

Themes Related to Learning Mathematics

When asked in the survey about how she thought students learned mathematics, Leah focused on two ideas: problem situations and repetition. Her first emphasis was that students learned best when given problem situations to explore in order to learn mathematical concepts and procedures. She also noted that students needed new situations and challenges in order to further their current knowledge through the process of applying that knowledge. Second, Leah emphasized that students needed to see lots of examples of concepts and procedures broken down into small steps in order to master material. Additionally, students needed to spend a great deal of time practicing mathematical skills so that they become automatic.

Leah frequently reminded students that two ways in which they could demonstrate that they had learned mathematics were to find and correct mistakes and to show their work. It was important for students, if they had an incorrect answer on the homework, a quiz, or a test, to write down the correct answer. Leah often made comments such as, “If ya’ll didn’t get this right, you need to have this on your paper” (Observation, 9/30), and “You should have the correct answer written down to the problem if you missed it” (Observation, 9/29). Students were to use the correct answers to go back through their work and find their mistakes. Once the mistakes were found, the students were supposed to correct their work by “doing the problem over again and showing the teacher you know how to do the problem” (Observation, 9/21). The ability to find and correct their mistakes showed Leah that the students had learned mathematics. That was why she told the students it was important for them to “be neat, organized, and show your work so that you can find your mistakes” (Observation, 8/23, written on an overhead transparency). Their ability to find mistakes in their or in another student's work meant that they understood a topic. The importance of this ability was confirmed when Leah asked the students a couple of days before the chapter 1 test if they knew volume and surface area "[well] enough to find another student's mistakes" (Observation, 9/13).

Leah believed her instruction provided all the necessary components for each of her students to learn mathematics. She believed her instruction and assessment matched, and thus any student mistakes were careless and meant the students did not learn what they should have learned because of their lack of effort. When the students did poorly on the first chapter test, Leah commented, "Do you think that now you might be more careful next time?" (Observation, 9/21). A couple of days later, she told the students that no one had an A average and that they needed to improve their grades. Leah reminded the students that Algebra I was going to get more difficult and that they were still reviewing material from last year. She spoke to them about meeting their parents at open house the night before:

> I told them that your grades could be better. They need to spend time going over your work with you. You need to do algebra with someone—I mean an adult or someone from high school who knows algebra. (Observation, 9/23)

Leah tried to make it clear how much responsibility she wanted the students to take for their own learning.

Themes Related to Assessment

Leah admitted, "Assessment has never been my strength" (Interview 1). She noted that the courses in her masters program along with professional development opportunities had furthered her understanding of the need for her assessment to be aligned with her instruction. Leah referred to reformed assessment practices when she said,

> [Because] I want them to be engaged and be busy doing something other than rote work, then my assessment needs to match my instruction, and that type of assessment goes along with that type of instruction. (Interview 2)

When asked for examples of her reformed assessment practices, other than the use of the project items on tests, Leah replied,

> Well, some things I have done are like doing a group quiz and letting two students discuss their quiz before they turn it in, but they do it independently. I think that's pretty good reformed [practice]. I find that the students are real engaged and learn a lot from doing that, but I don't usually count it as a very heavily weighted grade, because it's a group thing. It's not an individual activity, it's a collaboration, and it may not reflect accurately what the child knows because they're getting a lot from the people they're working with. (Interview 2)

Leah believed assessment was "using a test or activity to determine if a student has acquired knowledge" (Survey). According to her, "good assessments allow the instructor to quickly evaluate learning," and they "contain questions that necessitate the use of higher-order thinking" (Survey). Those types of questions are ones that required taking something already known, the facts, and "being able to do something that you haven't done before but you know enough about other little things to put it all together and figure it out" (Interview 1). Justification is also required with those types of questions, that is, "it's not just a numerical answer and move on" (Interview 2). Once she had evaluated a student's learning, Leah could assign the student a grade or evaluate instruction. She used the evaluations to give herself information, to say, "Oh, well, that was a valuable way to spend my time. I really got the point across" (Interview 1), or to decide that it had not been a valuable way to spend class time. Leah also felt there was great value in the student responses to the higher-order thinking questions because she could determine whether a student's thinking was limited or more mature. She felt that “seeing how they think” enabled her to “communicate on their terms a whole lot better” (Interview 1). It helped her because, she said,

> [If] I know if Johnny is a little bit slower, I know that I need to show him an example that I can go over with—thinking a little bit better and challenge them a little bit more and try to plan activities along the line of their thinking. (Interview 1)

During the first interview, Leah said she wished she could do more types of assessment but that she did not feel that she had the time and did not “feel [that she was] together enough to do journals and portfolios and tests and quizzes and homework.” During the second interview, Leah said, “[I don’t] do as much alternative assessment as I could with projects and portfolios. I just don’t do that.” When prompted to elaborate on that comment, Leah replied,

> They’re too difficult to grade. I find that when I’ve tried it in the past that I do not spend time giving them a good going over to give the grade. I feel like, well, if it’s good, and I give it a real general A, B, C, D kind of grade rather than a numerical percentage. And maybe I would rather have something that was a little more mathematical to assess by.

Leah believed that open-ended items, such as those from the bank, were more mathematical. She said that with projects “it seems like a lot of things that go into the rubric end up being non-content related things like organization, appearance, and all of that seems to work its way into the grade” (Interview 2). Leah thought that the most emphasis should be on the mathematical content.

<u>Item Use</u>

Leah believed the county mandate of 20% higher-order thinking items “definitely increased the amount of higher-order thinking” questions she used in the classroom, and it “definitely affected the assessments because I don’t know that I necessarily would have used 20% higher-order thinking—maybe I would have done 10%” (Interview 1). If she had not used the items from the bank on her tests, Leah said she would have used the items in some way: “I might have used them just as part of instruction. I thought they were really good questions” (Interview 2). Because the items were organized in a notebook (and later in the searchable database), they were very accessible. She believed the main benefits of her project participation were related to the scoring of student responses and the writing of test items. Leah said,

> I thought it was effective when we sat down and looked at some different samples of how some people answered questions and how we could score those. That was really helpful to talk about the way to score them. (Interview 2)

She furthered explained,

> The thing I got most out of this [was] I learned how to write the questions, and when I sit down to do assessment now I’m much better at writing my own items myself. I usually just used the textbooks—I did not used to spend a whole lot of time writing my own questions, but since I got that practice I do that a whole lot more. (Interview 1)

She reiterated in her second interview how valuable the project was with respect to helping her write her own test items.

> I think I really learned to write those questions, and I don’t think I could have learned that just from practicing on my own and reflecting on my own. I think that really needs to be done with other math teachers. I really learned how to write good questions and think about it.

When Leah used the items from the bank, she used them on tests. When selecting items to use, she looked at what objective the item covered so that she “chose the ones that cover what I have covered in the unit” (Interview 2). She went on to say that she also looked at the wording of the items and selected an item that she “thought was worded better or maybe easier to grade.” Leah did not grade student responses with the suggested rubric developed during the project (see Appendix D). Instead, she did it another way.

> I would say if all the questions—if there were 20 questions on the test, every question was a five-point question, and most of the time I'd give them half credit or full credit or just take off a point. That's the way I graded mine. (Interview 2)

Leah felt that the 3, 2, 1, 0 rubric did not work into her grading scheme. In the past, she had been reluctant to use open-ended items because the student responses were too lengthy to grade. As a result of her participation in the project, she said,

> I'm getting better at grading [responses]. I think I've gotten to where I can sort of categorize the responses a little bit faster, and I've gotten better at breaking down the points and saying whether somebody is going to get half credit or is this going to be a credit question—get full credit or half credit if that's an option. Or this is going to be a question I'm going to divide into thirds and give them one third, two thirds, or full credit. Or if this question—I know what a one third answer looks like and a two third. I've gotten little bit better at seeing that. (Interview 1)

Leah believed, "[I know] what to expect as answers even before I even get the test" (Interview 1). When asked about scoring of student responses, she said,

> Well, I think I grade them easier because I think I expect—compared to my expectations on the response—I think I give them a lot. It's not how I would have answered it, but I guess that's acceptable. I think I grade them easier. Or maybe easier to medium—about the same. Not harder. I just want them to get a good grade. (Interview 1)

Leah was also encouraged to use open-ended items because the student responses "really give me a clear understanding of what they do and do not know" (Interview 2). She got that understanding because "you just see more of what the child is thinking when you ask them to explain something rather than just what their solution is, but you see more how they got it" (Interview 1).

The assistant principal at the school was supportive of Leah and her use of open-ended items. They had met, Leah said, because

> [I] had told the assistant principal these kids are just not doing very well, and so she wanted to help me sit down and reflect on that statement. We came to the consensus that the kids were having a really hard time with the critical thinking—that it was very new for them. There were several reasons why we had that conversation. One, because I thought they weren't doing too well, and two, because of the math meeting where I had been trying to talk about this and give examples because this is the direction we're supposed to go as a whole in the middle schools. I was real concerned at that point that the kids weren't doing well, but she made me feel better that they hadn't had a lot of practice in the previous grades and that it was very challenging, she thought. We thought with time and practice they would do better. (Interview 2)

Leah agreed with the vice principal's opinion that the students should stay in the Algebra I class if they had the basic skills. Leah's strategy to help the students be more successful on open-ended items was to cut down on the number of items on the tests (she was beyond the 20% requirement), and to let the students get better as time passed since they would see more items and would have more opportunities to practice writing responses.

Leah said she was always surprised "when [the students] can't answer [an item] and [she felt] they should be able to" (Interview 2). She was surprised that students were not prepared very well to respond to open-ended items: "I guess that's just kind of in the life of a teacher. I just think it's mostly based on the content, not based on the wording of the question" (Interview 2). Leah believed that the items themselves were appropriate and that if the students had learned the content as well as they should have they would not have responded poorly to an open-ended item.

Leah said her assessment practices were improved because open-ended items were a way to assess the students better. She felt that her improved assessment practices "encouraged [her] to keep doing more of what [she] was doing" during instruction because open-ended items matched her instructional practices (Interview 1).

Informal Assessment

Leah used several methods to informally assess her students. As she walked among the students as they worked, she looked to see if they were producing correct answers. She also determined the extent to which students had correct answers on their homework or classwork when they volunteered answers, and also when she called on nonvolunteers for answers. For example, when students chorused answers to homework problems numbers 28 to 33 on page 69, many of them were incorrect. Leah told them, "Ya'll didn't do a very good job with these" (Observation, 9/24). Generally during class Leah would direct questions to all the students, such as the questions shown in Figure 4.13. Typically some students would say yes, some would say no, or there would be no response from the students. Leah said she looked for students' nodding and facial expressions as a means to determine whether they understood the material. She felt that such questions gave "an idea of how the student is feeling about how ready they are. I think I get a feeling of what they know" (Interview 2).

How was this assignment? Easy?

How many missed less than 3 questions?

Do ya'll think you understood all that?

Are ya'll gonna be able to do that?

Are ya'll ready for a quiz tomorrow on adding and subtracting integers?

Figure 4.13. Examples of Leah's classroom questions.

Leah used the county readiness test to "set off any kind of alarms that this child really needs to be in pre-algebra and not in algebra" (Interview 1). She discovered from the responses that the students confused the circumference of a circle with its area and that, as she expected, the students needed work with fractions. Leah said she had learned to spend more time on those topics, especially since later she told the students that "fractions are the difference between good grades and bad grades in algebra" (Observation, 9/20). The readiness test was not used for a grade, and when asked if it was used as an assessment, Leah replied, “No, [I] just used it to get to know the students really” (Interview 1). Leah did not make a distinction between assessment and grading.

Formal Assessment

Leah told the students to remember that the grade they made in her class stayed with them through high school. In order to determine their class grade, Leah used tests (50%), quizzes (25%), and homework (25%). In her course syllabus, Leah wrote the following:

> Homework is assigned daily. At least 30 minutes should be spent on Algebra homework. Students will get full credit for homework if the question is written, work is shown, the assignment is complete, and most of it is correct. Students must correct their work in colored ink before turning it in.

Previously, Leah had assigned a grade to homework based on whether or not the student did the assignment. Now, she said,

> Working with the project and getting it down to where you can analyze a test question has helped me analyze their homework a little bit better. And I think I’m better at grading homework [than] I used to be and better at assigning a grade. I mean, it used to be when I would assign a grade to homework, it was, “Yeah, you did it or you didn’t.” And now I can sort of say, “Yeah, you did it, you did a good quality job. Yeah, you did it, you did a poor quality job.” (Interview 1)

She used the homework to find out “what kind of worker they are” and “about their study habits” (Interview 1).

When she created her quizzes and tests, Leah used a variety of sources, including the textbook publisher’s assessment materials, the textbook, the item bank, and her own knowledge. She matched the quiz or test to the material covered in class and the amount of time spent on the material. She said, “If I spend 25% of my class time on a certain topic, I’m probably going to have about 25% of my test on that topic” (Interview 1).

Leah gave two quizzes during the study. The first quiz consisted of 10 items and was procedural. Student answers were either correct or incorrect and the students' grades were varied. The second quiz was from the textbook publisher's materials and was also procedural. Again, the items were graded either correct or incorrect. The students' grades were very high, with 19 of 21 students making As and Bs.

Leah's Use of Open-ended Items

The first test consisted of 20 items worth 5 points each. Ten students passed the test, 11 failed, and there were no As. The mean and median of the test scores were 68 out of a possible 100. The first set of 14 items were short answer and were graded correct or incorrect. The second set of 6 items consisted of 5 open-ended items from the bank and 1 item that Leah had created. The students were allowed to use their calculators on the last 6 items. Leah scored the student responses to these items using a point system she developed.

The students did well on the first two open-ended items. The responses appeared easy to score because they were clearly either correct or incorrect. Leah scored the responses to these items consistently. The next three open-ended items caused significantly more trouble for the students. On the item shown in Figure 4.14, either students were able to give a correct answer with an appropriate justification and received full credit, or they were unable to do either and received no credit. The scoring was

> Students were asked to write an expression for "the sum of the square of *x* and *a*." Donnel wrote $(x + a)^2$. Chandra wrote $x^2 + a$. Who is correct and why?

Figure 4.14. The third open-ended item on Leah's chapter 1 test.

consistent for this item in that similar responses earned the same scores. The next item, shown in Figure 4.15, gave students the most trouble. Three students responded with correct responses, which earned full credit. Two responses earned one point because their expressions added to 36 when *x* equaled 4 instead of when the expressions were multiplied. No credit was earned by the remaining 16 students. On these test papers Leah

Create two different expressions, each containing the variable x, such that the product of the two expressions equals 36 when $x = 4$. Show that your answer is correct.

Figure 4.15. The fourth open-ended item on Leah's chapter 1 test.

wrote, "You didn't understand the question." Most students had created two expressions, each of which equaled 36 when x equaled 4, instead of multiplying the two expressions together. Again, Leah scored the responses consistently.

The last item used from the bank on the chapter 1 test is shown in Figure 4.16.

Create a numerical expression with six different numbers and the operations of addition, subtraction, and multiplication that when simplified results in 10. Show that your expression simplifies to 10.

Figure 4.16. The fifth open-ended item on Leah's chapter 1 test.

Twelve students earned less than full credit on the problem, with eight earning no credit. However, Leah admitted to the students, "I wasn't carefully grading no. 5. Some of you got credit [who] didn't use six different numbers" (Observation, 9/21). As Figure 4.17 shows, Leah graded the student responses to this item inconsistently. Only 2 of the 9 students who earned full credit for their responses actually met all the criteria. Another student who wrote "$5 \cdot 4 + 10 + 30 + 40 - 90$" was given 2 points. This response was similar to the last one in Figure 4.17, but did not include an extra 1 at the end. Thus, the student responses were similar, but one earned 5 points and the other 2 points. Another instance of inconsistent scoring occurred with these two responses:

$$1 + 2 \cdot 3 + 4 + 6 - 9 = 10 \qquad\qquad 48 \div 4 \cdot 3 + 2(8 - 5)$$

Both students used six different numbers but used the order of operations incorrectly and showed no work. The response on the left earned no credit, but the response on the right, which also included the operation of division not asked for in the directions, earned 3 points.

Number of Students	Sample Response	Researcher's Comment
2	$11 \cdot 3 + 10 - 5 \cdot 4 - 13$ $33 + 10 - 20 - 13$ $43 - 20 - 13$ $23 - 13 = 10$	Used 6 different numbers Used all 3 operations correctly Showed work
1	$[(4 \cdot 2 + 1 - 4) \cdot 2] \cdot 1$ $8 + 1$ $9 - 4$ $5 \cdot 2$ $10 \cdot 1 = 10$	Used less than 6 different numbers Used all 3 operations correctly Showed work
4	$10 \div 2 \cdot 2 + 10 - 10$ $5 \cdot 2 + 10 - 10$ $10 + 10 - 10$ $20 - 10 = 10$	Used less than 6 different numbers Used all 3 operations correctly Also used division Showed work
1	$4 \times 3 + 1 + 11 - 4 - 10 = 10$	Used less than 6 different numbers Used all 3 operations incorrectly Did not show work
1	$3 + 5 - 2 + 0 \cdot 1 + 4 \cdot 1$	Used 6 different numbers Included an extra number Used all 3 operations incorrectly Did not show work

Figure 4.17. Student responses to the fifth open-ended item that received full credit.

The students did much better on the test item that Leah had created. Only a few students earned less than full credit. The students were given a rectangular solid and asked whether the surface area doubled if the length was doubled. They also had to explain their answer. The students had worked on similar exercises in class, so most of them were able to determine that the surface area did not double. Leah scored the student responses to this item consistently.

After Leah returned the graded tests, there was an atmosphere of slight shock among the students. One student even grumbled loudly, "Did everybody do bad on this test?" (Observation, 9/20). Leah reassured the students, "It's the first test taken, and people usually do lower on the first test. You will do better on the next test." The next day she asked the students, "Did you notice on your test you needed to explain your answers?" She tried to help them understand that she required explanations and that good explanations would help them do better on the next test. But the students did not do better on the second test. Three students were absent, and of the 18 students who took the test, 10 passed and 8 failed. No student made an A on the test. The mean was essentially the same as on the first test (67 vs. 68). The test consisted of 25 items, each worth a maximum of 4 points. The first 16 were short answer and were graded correct or incorrect. The next 8 were from the bank, and the last item Leah had created. The students were allowed to use calculators on the last 9 items.

The students fared much better on the eight open-ended items than they had on the open-ended items on the first test. On the second test, the students did better on the open-ended items than on the short answer items. The students did well on the open-ended items specifically addressed in class. During the review for the second chapter test, Leah gave the students open-ended items similar to four that appeared on the test. The scoring of the student responses to those items was consistent; they were clearly right or wrong. The second open-ended item from the chapter 2 test is shown in Figure 4.18.

Jose notices the following pattern:

$$\frac{1}{2}-\frac{1}{3}=\frac{1}{6}$$
$$\frac{1}{3}-\frac{1}{4}=\frac{1}{12}$$
$$\frac{1}{4}-\frac{1}{5}=\frac{1}{20}$$
$$\frac{1}{5}-\frac{1}{6}=\frac{1}{30}$$

Generate two additional equations that follow this same pattern and explain why your equations demonstrate the pattern.

Figure 4.18. The second open-ended item on Leah's chapter 2 test.

Leah graded the responses inconsistently. Nine students generated the equations, showed how they generated them, and earned full credit, whereas one student only generated the equations and also earned full credit. Three students only generated the equations and earned 2 points. Two students wrote that the denominators were multiplied but did not notice that the numbers were consecutive and thus generated incorrect equations. These students earned no credit. The remaining three students earned no credit because their responses did not contain any correct information.

The fifth open-ended item on the chapter 2 test is shown in Figure 4.19. There

> Using the four numbers below, write an expression with at least two different operations whose value is negative. Evaluate your expression and show that the answer is negative.
>
> 6 -2 4 1/2 $-.5$

Figure 4.19. The fifth open-ended item on Leah's chapter 2 test.

were some inconsistencies in how Leah scored responses to this item. Four responses were correct and earned full credit; one student made a mathematical error yet earned full credit. Two students used all five numbers and earned full credit, whereas another student used all five numbers and earned only 2 points.

The students fared the worst on the seventh open-ended item, shown in Figure 4.20. However, overall the students did better on this question than they did on seven of

> Find two different expressions involving negative numbers that equal $12x + 72$ when the distributive property is applied.

Figure 4.20. The seventh open-ended item on Leah's chapter 2 test.

the short-answer items. Six students answered correctly and were given full credit, whereas seven students could not set up an expression that involved the distributive property and were given no credit. The remaining students, who made a variety of errors, were each given 2 points; Leah scored their responses consistently.

The last item on the test, which Leah had created, is shown in Figure 4.21. More students missed this item than missed any other item in the second set. Only four students gave the correct answer, gave the work to support the answer, and earned full credit. One student had a correct answer but the work did not support the answer, and yet the student earned full credit.

Steven bought 7/8 pounds of candy corn for $1.00. How much does one pound cost? Explain how you got your answer.

Figure 4.21. The item on the chapter 2 test that Leah created.

Leah claimed that the students did not do well on the second test (Interview 2). She felt that the students struggled with the open-ended items:

> [They] did not understand the direction of some of these alternative assessment items, or it seemed like it was too much for them to put all into one question to have lots of little different details to pay attention to. (Interview 2)

Leah felt that there were too many details to which the students had to attend on the fifth and seventh open-ended items (Figures 4.19 and 4.20).

As noted above, Leah had created the last item on the test, and the student responses were poor. She said, “I made up number twenty-five on my own and, and they just didn’t get it very well” (Interview 2). Not only was the item not open-ended, but it seemed to more appropriately address a curriculum objective for the next instructional unit, solving problems involving ratios, proportions, and percents. Leah was disappointed that the students did poorly on the question, because she had given examples in class that related to it. The related examples that she gave are shown in Figure 4.22. Leah felt the fraction 7/8 made the question too difficult for the students.

Chapter 2 test, Item 25:

Steven bought 7/8 pounds of candy corn for $1.00. How much does one pound cost? Explain how you got your answer.

Examples shown in class that related to the test item:

4 cookies for $1.00, thus 25¢ per cookie is a unit cost
5 hotwings for $2.10, so the unit cost of hotwings 42¢

Figure 4.22. Leah’s chapter 2 test Item 25 and examples shown in class related to it.

The students were not given a final examination at the end of the semester. Leah met with a group of the school's algebra teachers, and together they decided not to give a final examination. As a group, the teachers "felt like developmentally that they're not necessarily ready for that—we thought that would be overwhelming to assimilate a lot of topics" (Interview 2). Leah said the high school algebra teachers "were real surprised that we weren't doing that" (Interview 2).

When Leah thought about her assessment practices, she commented, "[I feel] like I emphasized the test too much. I felt like I was saying "test" all the time—it felt like it was taking away something from the classroom. So I feel like I probably won't say it as much" (Interview 2).

Summary

Leah viewed mathematics as a tool to examine data and make decisions. She thought that mathematics required people to think, communicate, and solve problems. Leah did not believe her mathematics skills were problematic, because, to her, for someone to have a knowledge of mathematics meant that the person could teach someone else, could retain the knowledge for later use, and that the knowledge became an acquired habit. Leah was confident of her expertise in the subject areas she taught, and specifically in Algebra I. She viewed herself as the authority regarding decisions about her teaching. Leah claimed to understand completely the reform movement in mathematics education and as a result of that understanding, felt that hands-on and cooperative lessons, as well as the use of technology and real-life applications, were important in order to teach for understanding. However, her teaching was mainly authoritarian, with an emphasis on demonstration. According to Leah, learning occurred through the use of problem situations as well as repetitive work, but her instructional focus was on repetition. She believed that her teaching provided all the necessary components for students to learn and that if they did not learn the material it was due to their careless mistakes or lack of effort. Leah used open-ended items on chapter tests and scored student responses both consistently and inconsistently. She mainly used assessment to assign grades as opposed to informing her instruction.

CHAPTER 5

THE PARTICIPANT SUE

This chapter introduces the second teacher in the study, Sue. It describes her actions and beliefs under the categories of mathematics, teaching mathematics, learning mathematics, and assessment. These categories emerged during the initial data analysis.

Introducing Sue

Sue was a white female in her 17th year of teaching and her 13th year of teaching mathematics. She taught seventh-and eighth-grade mathematics classes in a middle school of approximately 1000 students. The students were from a suburban, mostly upper socioeconomic, Caucasian population. At the time of the study, Sue served as department head, as she had for the previous 4 years, and taught Pre-Algebra, Algebra I, and Geometry courses. She also conducted numerous professional development courses for county teachers during the school year and summer.

Sue held a bachelor of arts degree in history and had previously taught history at the secondary level. After some years as a full-time mother, she had gone back to teaching history but began taking mathematics classes. She earned her grades 7-12 mathematics certification and said, “It was the best thing I ever did as far as a career decision” (Survey). Sue had intended to teach mathematics at the secondary level, but no positions were available. She accepted a position as an eighth-grade algebra and history teacher. She found that she enjoyed working with the middle grades students, and she decided it was a personal goal to “make sure they are ready for high school” (Survey).

Sue participated in the professional development project because she thought it would be interesting. Also, since one of her duties as department head was to assist other mathematics teachers in her school to meet the county mandates, Sue believed that her participation in the project would assist her “to teach others how to do it” (Interview 1).

She believed that the project experience would improve her ability to use the items, and that in turn would improve her to ability to teach other teachers about the using the items. She felt that participation in professional development allowed teachers to gain a better comprehension of reform issues and aided in understanding the "steps and what procedure they're going to go through with each of the different concepts and how…they [are] going to show students" (Interview 3).

Sue believed the main benefit of her project participation was related to using the 4-point rubric developed during the professional development project. She believed that the group discussions about the scoring of student responses was the most important part of the project. She liked "getting different viewpoints of what [I should be] looking for" in student responses (Interview 3) and thought that those different viewpoints helped her to determine whether her scoring was accurate, too harsh, or too lenient.

When asked how she learned best, Sue replied, "Gee, it's been so long. Probably by doing. By doing, I think" (Interview 1). Specifically, she wanted to be in professional development courses in which she did not have to sit and listen, but in which the teachers enrolled in the course participated and did things to help "you kind of perk up."

Themes Related to Mathematics

Sue believed that mathematics was "understanding with logic. It's organizational skills. Yes, you're working with numbers—it's a tool more than anything. It helps you think, and of course you have to use a set of numbers" (Interview 3). According to one of her survey responses, Sue felt that mathematics was important because it enabled students to learn how to think logically and develop other mental capacities. She thought that "thinking skills are the most important thing that math helps you with" (Interview 3). Sue reiterated her belief that mathematics was a tool when she told the students, "Why do you do math? To learn to solve problems" (Observation, 8/25).

Her comments to students revealed other beliefs that Sue held about mathematics. One was that "math is something you have to do day after day after day" (Observation, 8/23). To Sue, mathematics was a set of skills that required daily practice in order to become proficient. Another aspect was that "unfortunately math is subject to careless mistakes—you have to be careful" (Observation, 9/9). Further, mathematics is "not tricky if you know the rules" (Observation 8/31). During a lesson on simplifying expressions, Sue wrote the expression $\frac{b^2 - 5}{a^3 + 6}$ and substituted the values $a = 3$ and $b = 2$ so that when the expression was evaluated, the result was $-\frac{1}{33}$. She then commented, "I end up getting weird answers when I make up problems" (Observation, 8/24). Sue emphasized "nice" mathematics; that is, she mostly demonstrated mathematics in which the answers were integers which resulted from following set procedures. As a result, her students were shown a limited view of mathematics. By her instructional methods, Sue implied that mathematics was simply a collection of procedures that would be used in the next level of courses.

In her first interview, Sue conveyed what it meant for students to have a knowledge of mathematics:

> Material that they have learned through the material that has been presented to them. Of course, they have to have a certain knowledge coming into it, too, and then to evaluate what they have learned from what they brought coming into that particular concept and what they've learned from it, coming out of it, I guess.

To have learned material meant that students could "turn around and explain it to someone else" (Interview 1). Sue did not make a distinction between learning and understanding. She believed,

> If he can go back and explain it to somebody else, then he has an understanding of it, unless he's completely wrong. But let's say he is right, that he is capable of conveying that same idea and concept and so forth and explaining it to someone else. Then he has really learned it. He understands it enough that he can tell somebody else it. (Interview 1)

Sue felt that to fully understand a concept, students also needed to know

> where it's coming from—the past that they've had, how it built up—into this particular concept or idea and a little bit of where it's going. Let's say that they're multiplying or distributing a term. We will go ahead and talk about it and where it came from and so forth, and what they've had previous to that, and then where you are right now. And every once in a while I might just show them where it's going—that they're going to have it in Algebra II, they're going to have it in Trig, they're going to have it in Calculus, and so forth. So it's not something that they're just learning for here and for this test and goodbye—that it's going to be built upon. (Interview 1)

Sue always referred to past or previous mathematics courses when she discussed any aspect of mathematics. She never mentioned mathematical applications.

Sue decided not to teach any mathematics below the pre-algebra level because basic arithmetic was not exciting to her. She needed "to be challenged to a certain extent," and said, "When it becomes routine, that is, you're doing the same thing over and over again, it's not as exciting" (Interview 1). Sue complained about the first chapters covered in the textbook during the Algebra I course: "I'll be glad when we get out of this stuff that is really easy—it's boring" (Comment to me, Observation, 9/17).
She liked to teach Algebra I the most:

> [That course is] more or less the beginning. I mean, Pre-Algebra leads into it, but it's the first of that really higher-level course, and it's kind of good to see those light bulbs and the challenge going on and so forth, and seeing how much you can get out of the kids and to challenge them. (Interview 1)

Sue considered Algebra I the first of the upper-level courses. She told students, "Algebra I is the most difficult class you'll take. It is the first time you see that higher-level thinking, and it is a big jump" (Observation, 9/9). In her third interview, Sue explained why she thought Algebra I was such a big jump for students:

> I think the accountability, having the students more accountable for their abilities, and so forth. I think the difficulty of the material. Some of the material—to me Algebra I is probably the hardest of the upper-level courses and that's because you see that all of a sudden at the same time, that you don't have time enough to just do well on it. You have to keep on going and going and going, and you have to understand it for other courses.

The year of the study was the first year that Sue had taught Algebra I to students who were not considered honor students. Previously at her school only seventh graders with As and high Bs in Pre-Algebra had been allowed to take Algebra I in the 8th grade. Now students with those grades took Honors Algebra I, and students with low Bs as well as Cs took regular Algebra I. This was Sue's first experience with a regular Algebra I course. Prior to the year of the study, students who were enrolled in a regular Algebra I course would have taken another year of Pre-Algebra in the eighth grade.

Themes Related to Teaching Mathematics

Sue claimed that her level of understanding of the reform movement in mathematics education was "probably a little more than 50%. I don't think I understand it completely, but I'm not completely in the closet of not understanding any of it" (Interview 3). She was aware of the differences in the newer geometry books: "You can see where the infiltration of algebra is coming in and the integration between the two more so than the books we used to use" (Interview 1). In the same interview, Sue also pointed out that the older geometry books were heavier on proofs and the newer ones were not, "which is the way we want to go." She claimed that her teaching in the Geometry class was more reform based because she was able to "explain things but put them in their lap to keep on going" (Interview 3). In her other classes, Sue felt that she had to explain content more explicitly, which reduced the amount of reformed teaching methods she could include in those classes.

Sue's main concern about reform was the pushing of the curriculum down into the earlier grades. Although she understood "that students can learn maybe a little bit more than what we traditionally felt they could" (Interview 3), she believed that it was not in the best interest of students to have Geometry as an on-grade-level course for eighth graders. At the time of the study, Sue believed that too many students were taking Algebra I in the seventh grade and Geometry in the eighth grade. She claimed that timeline rushed the students and that they would not be able to gain the "understanding that they're going to need to be successful in high school" (Interview 3). As department head, Sue had decided that the school was going to "beef-up" its honors program so that teachers could "start weeding them out more" (Interview 3) in an effort to reduce the number of seventh grade students taking Algebra I. She was afraid of the level of difficulty that the students would encounter when they reached high school mathematics courses. Sue admitted that the teachers in the school had been getting positive results as far as students taking Pre-Algebra in seventh grade and Algebra I in eighth grade, but she felt that it was putting "a lot more frustration or demand on students based on—everything's been easy for them all the way through, and all of a sudden they hit this wall a little bit earlier" (Interview 3). That is why, Sue claimed, "Before [the school system] didn't put algebra in the eighth grade because [the school system] didn't think [the students] were mature enough to handle it" (Interview 3).

On a continuum from traditional to reform, Sue considered her teaching as a whole to be "more towards the traditional, not quite halfway in the middle, but close" (Interview 3). What Sue considered traditional was having control over the class, that is, having a very structured classroom. She not only strictly controlled the behavior of the students but also controlled the intellectual atmosphere of the classroom. Sue had an agenda for each classroom period and did not allow student discussion or questions to distract her from that agenda. For example, if the students asked too many questions about a specific example, she would move on to the next example. Sue presented topics, answered a few questions, then had students begin practice exercises. She believed this structured way of conducting lessons was needed by students. In particular, she believed the students in the regular algebra class needed more structure because “it is all really kind of new to them. Even though they’ve had the pre-algebra, it’s not anywhere like algebra, and they need to have the more structured” classroom (Interview 3). Sue felt that the Honors Algebra students “didn’t need as much structure to go from each one of the steps. Now with the regular algebra, they need more hand holding. They basically needed more of the structure to go from A to B to C” (Interview 3).

The number of students in a class also contributed to the need for structure. At the time of the present study, Sue’s geometry class contained only 11 students, and she felt that she was able to “introduce things and make them work harder trying to develop their own thoughts in their own ways” (Interview 3). However, looking forward to the next school year, Sue predicted there would be two geometry classes containing 20 students each, and she said, “I’ll probably have to have more structure because of the size of the class” (Interview 3).

Sue’s Teaching Style

Sue’s belief about the necessity of structure was reflected in her teaching. Each day the class was conducted in the routine outlined in her course syllabus:

> Students are expected to have good attendance and be seated and ready to work at the bell. Class generally begins with a brief math warm-up, followed by homework check, lesson or activity, with a few minutes to begin the homework assignment before dismissal, if time allows.

On many days, the students picked up a photocopied warm-up activity as they entered the classroom and sat down and began working on it while Sue took attendance or spoke with a teacher who needed a few minutes of her time. An example of a warm-up activity is given in Figure 5.1.

WARM-UP 2

1. 15 · ______ + 1 = 91
2. 17 · (10 + 8) = ______
3. (17 · 10) + (17 · 8) = ______
4. Which formula(s) can be used to find the perimeter of a rectangle? Circle your answer(s).
   $p = l + w + l + w$
   $p = lw$
   $p = 2(l + w)$
   $p = 2l + 2w$
5. Find the perimeter of a rectangle if $l = 10.5$ cm and $w = 8.5$ cm. ______

Figure 5.1. An example of Sue's warm-up activities.

On other days, Sue would write an exercise on the overhead that related to the previous nights' homework or to what the lesson was to be that day. For example, Sue told the students, "Why don't you get out a piece of paper and see if you can do this one: $\left(-\frac{2}{3}\right)\left(-\frac{1}{8}\right)\left(\frac{9}{5}\right)\left(-\frac{1}{2}\right)$." This was a warm-up problem that related to the day's lesson, which used the area formula for a rectangular solid (Observation, 9/20).

Sue claimed that the issue she struggled with most in her teaching was student attendance. She said,

> I think that's one of the big problems that we have here because if they're not at school there's a blank or an area that they're not going to understand. Some will come in for help, but a lot of them don't. (Interview 3)

Sue's concern about student attendance existed in part because of the way she taught. She went through the book page by page, section by section, chapter by chapter. She told the students, "The most important thing you are going to learn is in this textbook" (Observation, 9/7). To Sue, missing a day of class meant a student missed a section of the book, thus an important piece of mathematics. Since the lessons were sequential and each contained requisite material for the next day's lesson, missing class meant students were behind. She told the students that a good reason not to miss class was that the book itself was "not something you can go home and read," and that "sometimes your book does not provide an explanation, and you will need to get that in class" (Observation, 8/23). Sue's dependence on the textbook for the structure and content of her teaching was obvious when she questioned the sequencing of topics in the textbook but followed the given order anyway. The textbook included the topic of the mean of a set of numbers in the section of chapter 2 about dividing rational numbers. Sue said that it was "a weird place to put mean" (Comment to me, Observation, 9/21), but she still taught the lesson according to the order and examples given in the textbook.

Sue structured her requirements for students with respect to mathematics. For example, the students were assigned for homework to simplify the expression $\frac{3}{4}+\frac{2}{3}(x+2y)+x$. Sue simplified the expression, and the answer she wrote was $\frac{3}{4}+\frac{5}{3}x+\frac{4}{3}y$. A student asked if the expression $\frac{3}{4}+1\frac{2}{3}x+\frac{4}{3}y$ was okay. Sue replied that she would count the student's answer correct but said she hoped that he would either do all mixed numbers or all improper fractions. A few minutes later, Sue said that as a rule, "If you start with fractions, you should end up with fractions. If you start with decimals, you should end up with decimals" (Observation, 9/1). She reiterated this requirement for student work a couple of days later, but at no time did she give the students any reason or justification.

Sue tried to motivate students by telling them that the content was easy and that it was review material. On the first day of class, she told the students that the first three or four chapters should be a review of what they did in their Pre-Algebra course. When she referred to a quiz that contained questions about inequalities, sets, integers, and absolute value, Sue commented that "the material is pretty basic" (Observation, 9/17). During a review of a worksheet exercise, $12-(-63)$, Sue said that all she had to write was 12 + 63, and claimed, "That's not hard, is it?" (Observation, 9/9). It was Sue's habit to offer an explanation or to show the steps of a procedure, and then follow with a phrase such as "This is not hard" or "This is really pretty easy." On several occasions, her insistence that the material was easy did not help to alleviate student confusion. For example, when beginning a section in the first chapter about formulas, Sue claimed, "Formulas are easy. It is easier to work with formulas than to do things other ways. Basically all you're doing is substituting in" (Observation, 9/1). However, a student commented that he did not understand formulas, and specifically where they came from. Sue replied, "They are just given to you. Eventually you're just going to have to memorize formulas."

On another day, Sue introduced the formula for the *n*th term of a sequence, $a_n = a + (n - 1)d$. She said "You need to know this formula. Formulas are easy to work with as long as you understand" (Observation, 9/20). Sue proceeded to define what each variable was in the formula and showed the students an example from the textbook. Figure 5.2 shows what she wrote on the overhead. Sue then assigned the students

ex. 8, 5, 2, -1, . . . Find the 25th term.
$a = 8$
$d = -3$
$n = 25$
$a_n = a + (n - 1)d$
$= 8 + (25 - 1)(-3)$
$= 8 + (24)(-3)$
$= 8 + -72$
$= -64$

Figure 5.2. A textbook example shown in class on 9/20.

homework that contained four exercises using the sequence formula. At the beginning of the next class period, a student asked Sue, "Will you go over one more time how to find the terms, like the 19th term?" Several other students then commented that they also needed help with the formula. Sue replied, "They're not as hard as they seem—you just need to figure out how the formula works and how to plug in"(Observation, 9/21). She then proceeded to illustrate the four homework exercises in Figure 5.3. On the overhead, Sue wrote the values for *a*, *n*, and *d* for each exercise and then substituted the values into the sequence formula. Twice students indicated they had trouble determining the *d* values. For Exercise 26, Sue asked, "What's the difference between the numbers?" Many

24. Find the 19th term of the sequence for which $a = 11$ and $d = -2$.

25. Find the 16th term of the sequence for which $a = 1.5$ and $d = 0.5$.

26. Find the 43rd term of the sequence -19, -15, -11, ...

27. Find the 58th term of the sequence 10, 4, -2, ...

Figure 5.3. Textbook exercises 24 to 27, p. 77.

students replied "negative 4." When Sue inquired if the difference was indeed negative, a student said, "No, 4, because you are increasing" (Observation, 9/21). On the following exercise, No. 27, Sue explained that $d = -6$, "because we're subtracting 6, aren't we?" One student immediately said, "Where did you get negative 6?" Sue followed with "You have 10, 4, -2. You are subtracting 6 each time." A second student commented, "This is totally confusing," and a third student said, "I'm lost." Sue responded, "You're just plugging in." Sue had focused on the formula itself during the lesson. She did not discuss what a sequence was nor how the terms in a sequence were generated. During the discussion, Sue referred to the sequence as series; for example, when referring to Exercise 26, she told the students, "This time they're just giving you a series." Although the students did not seem to find problematic the formula itself, which Sue continued to focus on, determining the values a, n, and d to substitute into the formula appeared to be a stumbling block.

Sue envisioned the use of technology and manipulatives as a way to motivate students. At the end of the class period on a Friday, Sue took the students to the computer lab. It contained 30 Power MacIntosh 5500/225 computers. The students worked on a tutorial program similar to using the manipulatives AlgeBlocks to help them learn how to multiply and divide integers (Observation, 9/17). Sue believed it was a nice activity for ending the week and that she could motivate the students to learn the rules for multiplying and dividing integers when they returned to class the next Monday.

I did not observe Sue using manipulatives, but she discussed how she had used them in the past. Specifically, she talked about how the use of AlgeBlocks had helped the students understand the multiplication of binomials. First, the students were shown how to use the manipulatives to multiply binomials, and then they used the AlgeBlocks program on the computer to multiply binomials. Sue said,

> [The students] found that interesting, and then leading them into the FOIL, it clicked a little bit better, and it was faster. They needed less repetition than they did just memorizing FOIL. It seems like they grasp it better. They can understand there was a middle term better. (Interview 1)

Sue recognized that manipulatives helped students learn. She said that manipulatives were the hands-on things that could be used to help students "kind of perk up," and said, "[I am] not always the one that does hands-on things, but I do use more than I used to" (Interview 1).

Sue's Questioning Techniques

During class, Sue used questions directed toward individual students as well as questions aimed at the students as a group. She said, with respect to students answering questions, "Sometimes I want them just to answer to get done and go on, and the other times if I want to reach a specific student then I will ask [her or him] specifically" (Interview 2).

Sue addressed students specifically when she wanted answers to homework or classwork exercises. If the answer was incorrect, she called on other students until the correct answer was given. For example, Sue wrote on the overhead "Evaluate $-2x^3$ when $x = 3$," and then asked the students for the solution. One student offered "-216," and Sue replied, "Nope." A second student said "-18," and again Sue replied, "Nope." Finally a third student gave the correct answer, -54. Sue replied, "Yep" and then wrote out the steps to evaluate the expression (Observation, 8/27). Sometimes, if a student gave an incorrect answer or several students gave incorrect answers, Sue would state the correct answer. She never probed students' incorrect responses in an effort to identify misconceptions. When students asked questions concerning a homework exercise, Sue usually provided the steps on the overhead. Sometimes she sent the student who asked for the help to the board. For example, a student asked for help to evaluate $-\frac{4}{3}+\frac{5}{6}+\left(-\frac{7}{3}\right)$. Sue asked the student, "So what do you have to do first?" The student replied, "Get a common denominator," and then wrote $-\frac{8}{6}+\frac{5}{6}+-\frac{14}{6}$ on the board. Instead of allowing the student to continue, Sue immediately said that the answer would be $-\frac{17}{6}$ and then asked the class if there were any more homework questions (Observation, 9/15).

Sue claimed that her use of open-ended items on quizzes and tests affected her instructional practice. She said, "I have students explain why a step in the calculation of a problem can be completed or why it can't. Usually, I would tell them why" (Survey). During the first week of class, Sue asked students for more than just their correct answer. On several occasions she asked for explanations. For example, she asked the class for the answer to the warm-up exercise shown in Figure 5.4. A student volunteered the correct

The perimeter of a rectangle is 78. The length is twice the width. What is the width?

Figure 5.4. A warm-up exercise from 8/27.

answer, and Sue asked him to explain how he figured that out. The student said he had used trial and error to find the correct answer. After the first week of class, she seldom asked for explanations of the answers to specific homework and classwork questions.

Sue claimed that her participation in the professional development project had affected her instructional practices. She wrote that since the time of the project, she questioned students as she explained procedures in class (Survey). Often Sue demonstrated examples from the textbook on the overhead and then asked the class a question such as, "Any questions on that so far?" Usually only a few students nodded their heads, and Sue continued with the lesson or made an assignment. Other times the questions aimed at the class as a whole related to specific examples shown in class. For example, Sue demonstrated how to find the volume of a rectangular prism using the textbook example shown in Figure 5.5. After writing on the overhead the formula for the

Find the volume of a rectangular prism 4 inches long, $3\frac{1}{2}$ inches wide, and $\frac{1}{2}$ inch high.

Figure 5.5. Textbook example.

volume of a rectangular prism, $v = lwh$, Sue asked the students, “Does it make any difference what order I multiply them in?” Several students chorused no, and Sue proceeded to show the steps to evaluate the formula with the given values.

Frequently questions to the students as a group resulted in situations in which Sue either disagreed with a student’s correct answer or offered an incorrect or incomplete answer. For example, when she solicited words and phrases to describe the operations of addition, subtraction, multiplication, or division, a student said “separate” for division. Sue said she did not agree with the student’s response and asked for other suggestions (Observation, 8/23). During a lesson on simplifying expressions, Sue wrote the expression shown in Figure 5.6 on the overhead. She asked the students what to do, and

Simplify. $\left(-\frac{1}{4}\right)\left(\frac{8}{3}\right)-\left(\frac{5}{6}\right)\left(\frac{2}{5}\right)$

Figure 5.6. Sue’s example.

a student said to “multiply.” Sue said that she had to cancel first, and then proceeded to simplify the expression (Observation, 9/21). When Sue asked students how to simplify the expression $7x(-3y) + 3x(-4y)$, a student offered, “You do multiplication first.” Sue replied, “Well, I distribute first, then I add” (Observation, 9/21). The expression shown does not demonstrate the distributive property. After she showed examples of Venn diagrams and discussed intersection and union of sets, a student asked Sue, "Can you have $A \cup B = \varnothing$?" Sue thought for a moment and said, "No, because you would have all the numbers in both sets if a union." The student then asked, "What about if both sets had no numbers?" Sue again thought for a moment, and finally replied, "Yeah, I think you could" (Observation, 9/7). She then started to discuss graphing integers on a number line. The homework assignment contained four exercises related to drawing Venn diagrams; they are shown in Figure 5.7.

Draw a Venn diagram to find each of the following.

50. the intersection of {vowels} and {first seven letters of the alphabet}

51. the intersection of {1, 3, 5} and {4, 6, 8, 10}

52. the union of {*a*, *b*, *c*, *d*} and {14, 15}

53. the union of {letters in the word *dictionary*} and {letters in the word *nation*} and {letters in the word *tidal*}

Figure 5.7. Textbook exercises 50 to 53, page 53.

During the next class period, Sue had students draw Venn diagrams for the exercises on the board. Two students correctly answered Exercises 50 and 51. Two other students drew incorrect Venn diagrams for Exercises 52 and 53. For Exercise 52, Sue asked the student to write the answer in set notation, and the student wrote $A \cup B = \{a, b, c, d, 14, 15\}$ and then sat down. When she looked at what the student drew for Exercise 53, she said, "This would be very difficult to draw as a Venn diagram. It's hard to do a Venn diagram" (Observation, 9/8). She then proceeded to demonstrate examples of adding and subtracting integers. The correct Venn diagrams for Exercises 52 and 53 were never drawn.

Sometimes Sue asked questions to the students as a group and then answered them herself. For example, during a lesson on verbal expressions, Sue asked, "What would the 'difference between *r* and *s*' look like?" She immediately wrote on the overhead "*r* – *s*" and was about to proceed to another exercise. But a student asked, "What if *s* has a bigger number than the *r*?" Sue looked at what she had written on the overhead, said something about absolute value to herself, and then began to discuss bases and exponents (Observation, 8/23). When she reviewed the identity and equality properties, Sue wrote on the overhead that $10 \cdot 1 = 10 \cdot 1$ and then asked if that represented the reflexive property. She answered the question immediately with "No, $a = a$, any number equals itself is what the reflexive property states" (Observation, 8/27). A short time later, Sue had the students answer textbook exercises aloud as a group. One exercise was to state the property illustrated by $7 + 6 = 7 + 6$. The students were unable to give a correct answer, and Sue said the answer was "reflexive because nothing changed." This contradicted what she had previously said regarding the reflexive property.

Sue's Instructional Decisions

Sue considered the county curriculum as the guide for her teaching. She knew which chapters and sections in the textbook she was required to cover during the semester and paced herself accordingly. She covered the first two chapters quickly because she considered them a review of Pre-Algebra material. She planned to slow down beginning with chapter 3, which covered solving equations. Sue used the textbook almost exclusively for her lessons. She followed the order of the textbook and presented its examples in class during instruction. Only if there were student questions did she make up and present additional examples.

Themes Related to Learning Mathematics

Sue claimed that students learn through a "combination of ways. Not just by doing, but sometimes they just need it really quiet so that they can concentrate—doing the old-fashioned ways" (Interview 1). Although she believed that "there's something to be said about the doing situation, the hands-on things, the manipulative things," Sue emphasized in her teaching the learning philosophy that students are "going to have to do some things by themselves, and some of it is just going to have to come" (Interview 1).

She believed that students needed a quiet, controlled classroom where the teacher presented many examples of concepts and procedures, and the students had as much time as possible to practice skills.

Sue felt that repetition was the key to understanding mathematics. In class, she would do more examples and explain procedures slower when the students expressed confusion. For example, after showing a procedure to compare and order rational numbers, a student still had questions. Sue replied, “Let me do a few more,” and she proceeded to explain very slowly a few more examples similar to the first one. After the first test, when the students had not done as well as she would have liked, Sue said, “I think I’m probably going to start doing more repetition in the class because I haven’t done a lot of repetition, because it was review” material in the first chapter. When asked what she meant by *repetition*, Sue replied, “Like dittos and stuff like that. They have had some dittos, but they haven’t had as many as they probably need to have” (Interview 2). Throughout the time of the study, the students were given in addition to homework from the textbook, dittoed sheets of paper which mostly were copies of worksheets provided by the textbook publisher. Sue told the students that “to study math, you go back over the problems” (Observation, 9/23). She confirmed a student’s comment that, to study for a test, do the problems “over, and over, and over again” (Observation, 9/2).

Sue believed students demonstrated mathematical understanding by showing the steps of procedures. She often reminded the students to “show steps” (Observation, 8/24), that they needed to “write it out, not just your answers” (Observation, 9/21), and that she wanted “not just answers, I want to see operations” (Observation, 8/23). The reason she required students to write down their steps was so that “they could find any mistakes” (Observation, 8/24). Finding and correcting mistakes helped students learn correct procedures, and correct procedures led students to obtain correct answers, which affirmed their mathematical understanding. She told the students, “If you do the steps correctly, you will get the right answer. If you make a mistake, you will get the wrong answer" (Observation, 8/24).

Sue believed that the main factor that contributed to a lack of student learning was immaturity. When asked why some students seemed to be doing well in the class and others not, Sue replied, "The maturity of some of them in here is not as high as you would like them to be, but they have just gotten out of seventh grade" (Interview 2). On the second quiz, Sue said the class did worse than her other Algebra I class because there was a maturity factor: "In my opinion there are more immature students in this class" (Comment to me, Observation, 9/20). She repeatedly noted that the first two chapters of the Algebra I book were review material. When asked why not all the students were making high grades, because the material being covered was a review, Sue claimed that the students "don't want to spend the time interpreting the questions correctly," that "they don't have the patience" to read the questions thoroughly, and that they "need to take [the class] a little more seriously" (Interview 2).

Other factors that Sue felt contributed to a lack of student learning were lack of motivation, uninformed parents, and inadequate prior instruction. When the students were not satisfied with their chapter 1 test grades, Sue said, "You need to spend more time than you realize studying algebra" (Observation, 9/7). After she had graded the first chapter test, Sue commented to me that she wanted to see more As and Bs on future tests. She said, "They have to settle down and take it a bit more seriously, and maybe there are things that I need to do with them, but in this particular group none of them have come in before or after school" to receive extra help with mathematics (Interview 2). When asked how the students could be helped to do better as a group in eighth-grade algebra, Sue said that the parents needed to be made more aware of what was expected in that course. She said, "I think the parents didn't quite understand. Some parents pushed their kids into being in a course that they were not ready for, and then other parents did not understand that the students would have to put as much effort into it as required and needed"

(Interview 3). Finally, Sue said that in the Pre-Algebra course, the teachers needed to make sure that the students knew how to do operations with integers, knew how to solve simple equations, and understood the order of operations. That way, Sue could skim over those topics and "get into the meat" of Algebra I, so that she "[would] then have time to do as much factoring as possible or as much graphing or equations, then rush and do everything" (Interview 3).

Several instances that Sue referred to as lack of student maturity or motivation were actually due to a lack of clarity or communication on her part. For instance, she reprimanded students for not having a sample test finished and ready to review during a particular class period (Observation, 9/1). In actuality, she had never told the students to have it finished by a certain date and had given the impression that they were going to work on it during class. Another day, a Friday, Sue instructed the students to get ready for a quiz. Sue did not give "pop" quizzes and had told students they would know in advance the dates for quizzes. When the students complained that they were not prepared to take the quiz, Sue replied, "This is a high school course—you need to come in for help" (Observation, 9/17). In fact, that prior Monday the students had been told they would have a quiz on Wednesday or Thursday, which they did not, and Sue was absent from class on Thursday. She had not communicated to the students that the quiz would be on Friday. When she returned the graded quizzes the following Monday, she told the students, "[Some of you] must decide if [you] are going to stay in Algebra I or move back to Pre-Algebra [and that you] need to take this class seriously or [you] will not do well" (Observation, 9/20). Sue explained that she knew that this class was not taking Algebra I seriously because in her other algebra class many students had made the effort to take the first chapter test over again, but no one in this class had. The students said they did not know they had the option to take the test over again, but Sue said she had announced it several times. In fact, she had never announced that students had the opportunity to retake the first chapter test in an effort to improve their grades.

Themes Related to Assessment

Sue defined assessment as “evaluation. To see if students understand concepts” (Survey). When asked to elaborate on her view by giving the characteristics of good assessment, Sue replied that good assessment was a “tool to test or evaluate students’ knowledge either formally or informally” (Survey). She claimed that many students memorized mathematics and how to do procedures. Thus, she felt that mathematics assessment should provide students an opportunity to “show they understand the concepts through explanations and examples. They need to stretch their mind” (Survey). Sue believed that when the students stretched their minds, they were thinking. Evidence of student thinking was collected from what students wrote:

> [If] it’s written, of course, obviously you know. If they’re trying to work a problem out, and they’re not successful, and they write down what they’ve been doing, obviously it shows you that there had to be some thought process versus just putting an answer down which is incorrect, because you can’t see the thought process. (Interview 3)

Sue believed that her use of questions that required higher-level thinking skills provided students with opportunities to show their thought processes. She stated that higher-level thinking questions required students to “use what they know and think about it to come up with a solution to something or to come up with ideas for something” (Interview 1). Further, she believed that such questions could be word problems or open-ended items from the bank. But she also believed that higher-level thinking could be elicited from students through the use of more difficult problems, that is, those problems that required more steps to arrive at an answer. For example, during a lesson on evaluating expressions, Sue presented the example shown in Figure 5.8. She told the students that she liked “problems like this because you have to think a little bit more” (Observation, 8/24).

Evaluate $\frac{2}{3}\left[8(a-b)^2+3b\right]$ if a = 5 and b = 2.

Figure 5.8. Sue's example on evaluating expressions.

Item Use

On the first day of class, when she previewed the course, Sue told students that they would be required to respond to open-ended items. She said that for those types of items the students would not provide just an answer but would have to tell her "why." She also said that the responses to those types of items were "not always right or wrong." "How you support your answer" was how credit was gained for the response, because the items might have more than one answer (Observation, 8/23). Two class periods later, Sue showed the students two examples of open-ended items. The items, which were from another county assessment project involving pre-algebra teachers, are shown in Figure 5.9.

Place parentheses in each expression below so that when the expressions are evaluated you get two different numbers. Show how you got the two numbers.

$2\times 6\div 2\times 6$ $\qquad$ $2\times 6\div 2\times 6$

Kendall and Serena both evaluated the following expression: $8\div 4\times 2$.
Kendall says the answer is 4. Serena says the answer is 1.
Explain how each person found their answer. Who is correct and why?

Figure 5.9. Sue's examples of open-ended items.

Sue solicited responses, and several students gave correct responses to both items. Sue then asked rhetorically, "Is responding to an open-ended question hard?" She told the students that it was not hard and said "[You] are just using your knowledge to explain something" (Observation, 8/25). Later, Sue explained to the students that their responses to open-ended items would be graded according to a rubric. They would receive 3 points for correct answers, 2 points for answers that are mostly correct but "don't really have everything there I want you to have" (Observation, 9/7), 1 point for answers that contained some correct parts, and 0 points for incorrect answers.

During the observation period, the students asked several questions about open-ended items. Right before the first chapter test, a student asked if there was "any way to prepare for the higher-level questions" (Observation, 8/30). Sue replied, "Those questions are like bonus problems, bonus questions—they are a step more difficult, a little more harder." She tried to reassure and motivate the students by then saying, "If you really know your facts and procedures, you should be able to figure those out" (Observation, 8/30). This statement to the students demonstrated Sue's belief that using open-ended items on assessments did not necessitate changing her instructional activities. When asked if she would make any changes in her teaching as a result of using open-ended items, Sue replied no (Interview 3).

Sue believed there were numerous benefits in using open-ended items, both for the students and for herself. She felt the students benefited because they could obtain credit without having a completely correct response; the other questions on the test were graded either correct or incorrect. She said that the students liked knowing that they could earn credit because their responses were "not going to be completely right or not going to be completely wrong" (Interview 1). Sue believed that open-ended items provided opportunities for the students to practice giving extended responses, so that the students could "start thinking that way" (Interview 1). She believed that the students would encounter those types of items in their future mathematics courses.

The main benefit Sue attributed to her use of open-ended items in Algebra I was the rigor she perceived they added to the course. She claimed,

> The rigor is not necessarily the math part. Some of the math part is not that difficult, but the thinking is adding the rigor. In fact, they're going from something that they have learned by memorization, by doing just on paper and so

> forth, and coming up with their own ideas and supporting their ideas. They're not used to that. (Interview 1)

Sue said that using open-ended items also allowed her to "see if [students] can express their reasoning" (Survey). When asked to elaborate, Sue replied that the student responses allowed her to determine

> whether they're thinking correctly or not. They say, well, that's the answer. Or if they can explain the answer, they know the procedures usually. Of course, sometimes the procedures are a little different than the way we would have liked to have seen them, but if they can understand. They may not have the steps I would want to see all the time, but they had the thinking there. (Interview 1)

To Sue, the student responses to open-ended items allowed her to "see if they understand the concepts completely," since a student may have made a mistake in her or his computation but otherwise answered the question correctly. Sue enjoyed the surprise of seeing student thinking that was different from her own: "[The] different things they were looking at that I hadn't thought of and responses that I had to think about" (Interview 3). She thought that reading those responses was a learning experience for her.

A factor that Sue believed discouraged her use of open-ended items was the difficulty the students had responding to them. Sue claimed, "[The students] didn't understand things that I thought were crystal clear" (Interview 3). She attributed their misconceptions to their lack of maturity and preparation for a test, as well as to how they viewed the items. She said, "They don't like to read things. They don't like to read instructions. They just wanted to go ahead and do it. It's math. You're working with numbers, not reading" (Interview 3). She believed, "[The students made an item] more difficult than it actually is, and I had to explain to them that these questions are not as difficult as they're trying to make it to be and that it's just to see if they could understand and relay their information back to the teacher that they understand the concepts" (Interview 3).

Other factors that Sue thought impeded her use of open-ended items included lack of time and the amount of material on a test. Sue said that she used items from the bank as long as they coincided with the material she had covered in class and if she had room on the test. She said, “If it got to the point that the test was pretty meaty to begin with, I didn’t include them, because [the students would run] into a time problem of getting through everything” on the test (Interview 3).

Sue had several ideas about how to help students successfully respond to open-ended items. She claimed,

> [It is difficult to find] time to explain how to do the problems. Of course, what you’re doing can lead into that type of a problem that you can explain how to do it, but I think I need to do a better job in explaining what type of problems these open-ended questions are. And then as to when [the students] have it on a test, of course it won’t be the same question. Because the idea is that they haven’t had this type of question before, but they won’t feel quite as panicky. Maybe we can get a more successful response on it. Time’s always a problem. (Interview 1)

Sue also felt that increased student exposure to open-ended items would help students to create appropriate responses:

> [I specifically do not] want a parent coming in and saying, “Well, my child didn’t understand how to answer this type of question.” Well, if Johnny has seen a lot of these questions or if they have had some of them to do as homework and have other children correct them, and explain them, and why they were given this, and why they were given that, and so forth, and myself just discussing in class, well, they will understand. Because you don’t want the parents coming back and saying, “Well, this isn’t fair,” or whatever. (Interview 1)

Thus, Sue claimed that if students had an opportunity to respond to open-ended items, to have other students and her offer feedback on their responses, and to have her explain to them why they earned a particular score, they would have a better chance to create appropriate responses to open-ended items. Finally, Sue felt that students would be better prepared to respond to open-ended items in her Algebra I class if similar items were to be used by Pre-Algebra teachers in their classes.

Informal Assessment

Sue used several methods to informally assess her students. She would frequently walk among the students' desks as they worked. Not only did that help her keep the students on task, but she also looked to see whether students were producing correct answers. Occasionally, Sue collected worksheets completed during class to assess student understanding. Once, after she had reviewed the students' work, she decided to revisit the rules for adding and subtracting integers. She told the students, "We need to do some more repetition on this" (Observation, 9/9). Another time, when Sue determined that the students were having difficulties with properties, she offered extra worksheets before the test to those students who wanted them.

The main method that Sue used to informally assess her students was with respect to the homework. She relied on students' questions about their homework to monitor their understanding. The students were assigned homework almost every day. The assignments covered only the practice exercises and not the critical thinking or application exercises. After the warm-up activity, the students would be told to get out their homework papers, and Sue would ask a question such as, "Are there any problems on this that you need to see worked out?" (Observation, 8/25). The students would quietly watch Sue as she provided the necessary steps to reach the correct answer. If there were no questions about the homework assignment, she would make a comment such as, "I am going to assume everybody got everything all right" (Observation, 8/31). When asked why the students generally did not ask many questions in class, Sue replied, "No, they don't, but we're still working with pre-algebra, and maybe that's why they don't" (Interview 2). Sue was not observed asking general questions such as "Does everyone understand?" or "Does anyone have any questions?"

Formal Assessment

Sue relied heavily on tests to assess students and determine grades. Approximately two thirds of the students' semester grade depended on their test grades. The majority of the remaining portion of the semester grade was determined by their grades on quizzes and the final exam. Sue believed that the semester grades should be determined in this manner because tests, quizzes, and the final exam are "math related, not just cutesy things, but something that has some meat in it" (Interview 1).

Sue gave two quizzes during the study. She considered quizzes not as important as tests, just "kind of an indication of 'Okay, you better know this'" for the test (Interview 2). Quizzes were opportunities for students to see where they were making mistakes in order to get them corrected before taking the test. The first quiz contained 20 items on adding and subtracting integers; it was entirely procedural in nature. The students did well on the quiz. For the second quiz, Sue said,"[I] was wondering if I needed to have them [open-ended items] on the quizzes, and I did put two of them on the quiz" (Interview 2). Sue used open-ended items beginning with her second quiz.

Sue's Use of Open-ended Items

The second quiz had 23 items, 21 of which were procedural, and 2 of which were open-ended items from the bank. The open-ended items included on the second quiz are shown in Figure 5.10.

1. Carlos claims that $5-x$ is always the same as $x-5$. Is his claim correct? Why or why not?

2. Vanessa said that 4 is a rational number while Neville claimed that 4 is an integer. Who is correct and why?

Figure 5.10. The open-ended items on Sue's second quiz.

Sue had a specific answer in mind that she wanted to see in the responses to the first open-ended item. She wanted the students to show that when $x = 5$, the two expressions would be equal, otherwise they would not. Sue said,

> I always interpret it different with the word *always* because I always wanted to put the 5. I wanted them to tell me everything really for three points. I want them to realize that if x is 5, that would work. However, x is not always going to be 5. (Interview 2)

Sue used the 4-point rubric developed during the professional development project to score the student responses. The majority of students received a score of 2 on the first open-ended item. She said, "I think I gave 2s instead of 3s because I was looking for the idea of the value of x being 5 as well as others. In other words, I wanted them to think" (Interview 2). A sample of student responses receiving a score of 2 is shown in Figure 5.11. Based on the scoring rubric, it is possible to justify a score of 3 for all but one of

Yes, because if x was 5 in the first one it would [the answer] is 0 but in the second one if x is 5 then the answer would be 0. (One student made this response)

No it is not the same because $5 - x$ the x could be negative and the answer would be positive. In $x - 5$ if x was negative the answer would be negative.

No. Because if $x = 7$ then $5 - 7 = -2$ but if you do $7 - 5$ is equals 2 so it is not always the same.
(The remainder of the students who earned a score of 2 had responses similar to the last two shown above.)

Figure 5.11. Sample student responses receiving 2 points out of 4.

the student responses that earned a score of 2. On those students' papers, Sue had written comments such as "If $x = 5$ the result is 0," "If x was 5, it would work," and "x could be 5." Sue reviewed the quiz in class, and she told the students that this open-ended item had a yes and a no answer. She said, "If $x = 5$, then yes. If $x = 3$, then no" (Observation, 9/20). A student raised a question about her answer and noted that the question used the word *always*, which meant a no answer only. Sue replied, "I'll have to reconsider the question" and continued with the quiz review. When asked to talk about what occurred in class with respect to the quiz, Sue said that she thought it was best to go ahead and give the students an additional point for those responses because those students were not wrong even though they did not include everything that she was looking for.

The second open-ended item on the quiz (Figure 5.10) elicited a range of responses. Responses given full credit said that both Vanessa and Neville were correct because 4 is both a rational number and an integer. Students who selected either Vanessa or Neville as correct and gave a similar reason received a score of 1 or 2 depending on the clarity and correctness of their response. The responses that did not contain information pertinent to the question received no credit. No responses mentioned any information about the characteristics of rational numbers and integers, and thus did not discuss why 4 met the criteria for each. This scoring was consistent with Sue's lesson on rational numbers. She listed the rational numbers as being made up of the natural (counting) numbers 1, 2, 3, …, and the whole numbers 0,1, 2, 3, …, and she listed the integers …, -3, -2, -1, 0, 1, 2, 3, …. She did not mention that the rational numbers are those that can be put in the form $\frac{a}{b}$, with $a, b \in \mathrm{Z}$, and $b \neq 0$.

Sue's chapter one test contained 25 items, 22 of which were short answer, graded correct or incorrect, and 3 of which were open-ended items from the bank. The students were not allowed to use calculators on the test. The open-ended items that were on this test are shown in Figure 5.12. Most students were able to respond to the first item correctly and earned full credit (3 points). Several students did not use six different numbers and earned 2 points. The remaining student responses had a variety of mathematical errors and garnered either no credit or 1 point if their response contained some accurate information related to the question. Sue scored the responses consistently, with the same scores for similar student responses. When asked about the responses to this item, she said that she encountered no surprises.

The students had the most difficulty responding to the second open-ended item. Four students earned full credit for their responses. Examples of student responses that earned full credit are shown in Figure 5.13. Five students earned 2 points for their

1. Create a numerical expression with six different numbers and the operations of addition, subtraction, and multiplication that when simplified results in 10. Show that your expression simplifies to 10.

2. Students were asked to write an expression for "the sum of the square of *x* and *a*." Donnell wrote $(x+a)^2$. Chandra wrote x^2+a. Who is correct and why?

3. The following responses were given when students were asked to evaluate 2^9.
   Joe responded $2^9 = 2 \rightarrow 4 \rightarrow 6 \rightarrow 8 \rightarrow 10 \rightarrow 12 \rightarrow 14 \rightarrow 16 \rightarrow 18 = 18$
   Sally responded $2^9 = 2 \times 9 = 18$
   David responded $2^9 = 2^3 \cdot 2^3 \cdot 2^3 = 8 \cdot 8 \cdot 8 = 512$
   Kim responded $2^9 = 2^3 \cdot 2^3 \cdot 2^3 = 6 \cdot 6 \cdot 6 = 216$
   Which student is correct? Explain why that student is correct.

Figure 5.12. The open-ended items on Sue's chapter 1 test.

responses. Most of these students did not clearly convey what needed to be squared, or they added something about the distributive property. Seven of the eight responses that earned 1 point were similar in nature. An example of a response that earned 1 point is

Chandra is correct because it says "the square of, (x^2) and the sum of that and "a."

Chandra is right cause it didn't say the sum of x and a squared it said the sum of the square of x and a $x^2 + a$

Figure 5.13. Examples of student responses that earned full credit.

shown in Figure 5.14. All seven student responses were similar and were given the same credit; thus Sue's scoring was consistent. The remaining response that earned one point

Donnell is right because you would first add x & a – (x + a), then you would square the sum of x and a, so the final expression would be $(x + a)^2$

Figure 5.14. An example of a response that earned 1 point.

is shown in Figure 5.15. In this response, the student demonstrated no appropriate mathematical reasoning. According to the rubric developed during the project, it would be easy to justify that the response should not be given any credit. However, Sue scored the response with a 1 because the student correctly indicated that Chandra said the correct expression. During the project, the rubric was revised to specifically address open-ended items that contained a correct and incorrect choice, such as Chandra and Donnell, so that teachers would focus on the mathematical reasoning and not give credit to students who were able only to make the correct choice. The last response to this question contained no appropriate or correct information related to the question and was given a score of zero.

Chandra is right because Donnell has to distribute.

Figure 5.15. Student response which also earned 1 point.

When asked to comment about the students' difficulty with this item, Sue said, "I didn't expect everybody would get them, but I didn't expect as many to miss it that did. It was interpretation" (Interview 2). She continued,

> I think it goes back to reading. I think if they read it as the sum of the square of *x* and *a*, and they realized you're looking for a sum, I think it's carelessness. And that was a little more challenging. I wanted it to be a little bit more challenging.

At the beginning of the class period in which Sue reviewed the test, she said to me, "The students had a rough time with one of the open-ended questions. It was an interpretation issue. Students don't know at this point that $(a + b)^2$ means two things multiplied together" (Comment to me, Observation, 9/7). However, during the review, Sue asked the students what $(a + b)^2$ meant, and a student promptly responded with "*a* plus *b* times *a* plus *b*." Sue did not attempt to determine the number of students who did or did not know what $(a + b)^2$ meant. Instead, she moved on to review the next item. When asked later what she would do with the information gained from the student responses to this question, Sue replied, "Working with various phrases might be in the future. Let's read it and see what does it mean. Of course they were working with expressions, but they haven't really gotten into it as much" (Interview 2).

The last open-ended item on the first test dealt with the evaluation of 2^9. The six responses that were scored a 3 clearly indicated how 2^9 equaled 512. The seven responses that were scored a 2 followed the rubric requirement of demonstrating substantial and appropriate mathematical reasoning, and yet were lacking in some minor way. An example of a response that earned a score of 2 is shown in Figure 5.16. The remaining

David because when you work with powers it is telling you to multiply that number by that number and so on. Example: $2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2$

Figure 5.16. An example of a response that was scored a 2.

five responses earned no credit. Four of them conveyed incorrect information. However, one response was given no credit even though some correct mathematical reasoning was demonstrated. The response is shown in Figure 5.17. The student did not

None of them are correct. The equation would be two multiplied by itself nine times and the answer would be 512.

Figure 5.17. Student response that showed correct reasoning but received no credit.

make the connection between $2^3 \cdot 2^3 \cdot 2^3$ and $2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2$, but the response demonstrated some appropriate mathematical reasoning related to the question. The rubric suggests that such a response should earn some credit. Sue was not surprised by the student responses to this item. She concluded, “I could understand why they would pick Kim and then just added. And of course that’s a careless mistake of multiplying the 2 and the 3 together, and we see that all the time. Or even multiplying 2 times 9 and getting 18” (Interview 2). Overall, Sue was pleased with the student responses to this item.

When a student commented about the difficulty of the chapter 1 test material, Sue stated,

> Chapter 1 in some aspects is a difficult chapter. Some people have trouble working with properties, and some people get confused with the orders of operations. Also, students make mistakes simplifying expressions. Chapter 2 will be easier—working with integers. (Observation, 9/7)

The second test contained 30 items, 26 of which were short answer and were graded as correct or incorrect. The last 4 items on the test were open-ended items from the project item bank. The open-ended items included on the second test are shown in Figure 5.18.

1. Movie Rental Prices:
   $2.95 for the first 2 days
   $1.95 for each day past due
   a) If x represents the number of days past due, write an expression showing the total cost of movie rental.
   b) If Gaston spent at least $9.00 but no more than $11.00, describe two ways he could have spent his money on movie rentals. Justify your answer.

2. Using four of the numbers below, write an expression with at least two different operations whose value is negative. Evaluate your expression to show that your answer is negative.
   6   -2 4   ½ $-.5$

3. Find two different expressions that equal $12x - 72$ when the distributive property is applied.

4. On a particular homework problem, Alea and Natasha have the following solutions:
   Alea: $x < -3$
   Natasha: $-3 > x$
   Are these two expressions equivalent? Why or why not?

Figure 5.18. The open-ended items on Sue's second chapter test.

Most students earned 2 or 3 points for their responses to the first open-ended item. Students who scored 2 points either neglected to answer Part (a) of the item or were able to correctly describe only one way to spend the money on movie rentals. One student was able to answer Part (a) correctly and earned 1 point, whereas another student who earned 1 point was able to indicate one way to spend the money on movie rentals. Two students were unable to give a correct response and earned no credit. Sue was consistent in her scoring of the responses.

Sue's scoring of the responses to the second open-ended item was less consistent than it was for the first item. Twelve of the 22 responses earned full credit, but half of them were not completely correct. Three of the responses had incorrect calculations, but they were negative numbers. The other three did not meet the criteria of using four of the given numbers and at least two different operations. One student whose response met the criteria yet contained an incorrect calculation that resulted in a negative answer earned 2 points and not 3 points, as had a similar response. Two responses that met the criteria but had incorrect calculations that resulted in positive answers earned 1 point. However, three similar responses to those two earned no credit. Three additional responses that earned no credit did not meet the criteria of the question. The final response that earned no credit is shown in Figure 5.19. The response met the requirements of the question to use four of

$$(-2)6+\frac{1}{2}(-.5)=-12\,\frac{5}{20}$$

Figure 5.19. A student response to the second open-ended item that earned no credit.

the indicated numbers with at least two different operations. The expression was also correctly evaluated, although the answer is a mixed number with an unsimplified fraction. Using the scoring rubric, one could justify giving this response at least 2 points, and most likely it could be scored a 3.

Seven responses to the third open-ended item were completely correct and earned full credit. One student provided only one correct expression and earned 2 points. However, two other students provided only one correct expression and received only 1 point. Twelve responses earned no credit. Nine of those responses either were blank or contained an expression that used only multiplication. The remaining three responses that earned no credit actually contained expressions in which the distributive property could have been applied. The expressions are shown in Figure 5.20. The three responses met the requirement of the rubric for 1 point in that they indicate some appropriate mathematical reasoning.

The final open-ended item on the second test elicited responses that were easy for Sue to score. Either students were able to clearly explain why the two expressions were

Student A: $2(2x+4x)-2(20+16)$

Student B: $12(2x-x)-72$ and $3(8x-4x)+(-72)$

Student C: $2\times(-6x+12)-9(-8)$

Figure 5.20. Student responses to the third open-ended item that earned no credit.

equivalent and earned full credit, or they were unable to provide an appropriate response and earned no credit. No inconsistencies in Sue's scoring of these responses was found.

The final class grades were as Sue expected. The class average was 78, and she said, "There were only a couple of As, more Bs. Bs and Cs were about equal. So, you would have liked to see more Bs, but that's the way it ended up. I wasn't really easy on them" (Interview 3).

Summary

Sue believed that mathematics was important to help students develop logical thinking as well as a tool with which to solve problems. She also saw mathematics as a set of skills that would be acquired with practice and hard work. To her, a knowledge of mathematics implied that the person could teach someone else. Sue believed that she was a good teacher, one who prepared students for high school mathematics courses. Thus, she felt she had the appropriate mathematical knowledge for the classes that she taught. Sue viewed the textbook as the authority for her instructional decisions and followed it during her teaching with respect to its content and order of topics. Sue's concern about reform issues in mathematics education was focused on what she believed was an inappropriate pushing down of the high school curriculum into the middle schools. She believed that most middle school students lacked the maturity necessary to learn well and be successful in Geometry, and, to a lessor extent, Algebra I. She believed that to assist students in learning she had to provide a structured classroom environment. She had a transmission style of teaching and emphasized repetition of skills. She believed that her instruction provided all the necessary components for student learning and that if learning did not take place it was due to the students' lack of maturity or patience. Sue used the open-ended items from the project bank on a quiz and on two chapter tests. Her scoring of student responses was in some cases consistent but in others inconsistent. She used assessment to assign grades but not for any other purpose such as to inform her instruction.

CHAPTER 6

AN ANALYSIS OF LEAH AND SUE

Beliefs, authority, reflection, knowledge, and constraints emerged as factors that influenced the teachers' use of open-ended assessment items. This chapter contains an interpretive analysis of each of those factors. It also relates the findings to the literature discussed in chapter 2.

Beliefs

About Mathematics

Both Leah and Sue conveyed a limited view of mathematics to students in their Algebra I courses. Their instruction demonstrated problems that had a single correct answer and showed mathematics, specifically algebra, as a set of skills and procedures. Both teachers used the word *problem* to refer to exercises that students did to practice skills and procedures. The emphasis in both teachers' classrooms was on finding the correct answers to such problems. This meant that students were given ample opportunity to practice algebraic skills and that the production of correct answers was of great importance. To both Leah and Sue, correct answers meant that students understood mathematics. Their manner of instruction transmitted the belief about the importance of correct answers in algebra and that those answers should be arrived at quickly without much effort. If significant effort was required to answer a question or find an answer, then the teachers believed that the student had not learned the mathematics to a sufficient degree. Similar to the conclusion reached by Wilson (1992), the limited view of mathematics conveyed by Leah and Sue appeared to impede their use of open-ended items. Because of their nature, open-ended items do not provide opportunities for students to practice skills, step-by-step, in order to find a single correct answer. Thus, Leah and Sue did not view open-ended items as beneficial to the learning of algebraic skills. Since the emphasis of both teachers' instruction was on the learning of skills, open-ended items did not fit into their instructional routine. Neither teacher used open-ended items as part of her instructional approach.

About Teaching

Both Leah and Sue exhibited an authoritative, transmission style of teaching. They routinely presented material and examples to students who were to learn through observation. The teachers seemed dualistic (Perry, 1999) and absolute (Baxter Magolda, 1992) in their approach to teaching since they viewed themselves as the source of knowledge and the students as the receivers of that knowledge. Neither teacher conducted her classroom in an investigative manner. There were no opportunities for students to solve significant problems, make conjectures, find evidence, or draw conclusions. There were also no opportunities for cooperative learning as defined by Antil, Jenkins, Wayne, and Vadasy (1998). Leah did have her desks arranged in groups, which allowed students to assist each other with exercises during class. Again, similar to the conclusion reached by Wilson (1992), the limited view of teaching demonstrated by Leah and Sue appeared to impede their use of open-ended items. Since both teachers' instruction centered on the transmission of knowledge, neither viewed open-ended items as instructional but rather as evaluative. Consequently, they used them only on a quiz or test to determine whether students had acquired knowledge.

Both Leah and Sue reported changes in their instructional practices as a result of using open-ended items on tests. Leah believed that she asked more higher-level questions during class instruction. Sue said she questioned students as she explained procedures in class. Both teachers believed that their questioning techniques fostered higher-level thinking in their classrooms. However, the questions the teachers asked focused on obtaining the correct answers or the next step of a procedure in order to find an answer. Thus, due to the nature of the questions asked in both teachers' classrooms, the use of open-ended items would not have been consistent with the classroom routine.

Both teachers encountered difficulty when they or their students asked questions that did not focus on basic algebraic skills. Leah asked some questions during class that required more critical thinking and assigned a few such questions for homework. But if students asked for an explanation, she did not provide one that seemed to make sense to the students; rather, she would move on to the next item on her agenda. Sue did not ask or assign higher-level questions. If her students asked questions such as, "Can you have $A \cup B = \varnothing$?" she was not prepared to answer. Sue became uncomfortable, attempted to answer the question, and usually moved quickly to the next item on her agenda. Neither teacher appeared prepared mathematically to answer questions that went beyond the basic skills covered in each chapter. They appeared to be uncomfortable in the presence of the unpredictability that higher-level questions created in their classrooms, a finding also reported by Cooney et al. (1996). The use of open-ended items during instruction would remove the focus on the teacher as a distributor of knowledge. It would also cause the teachers' instructional routine to be disrupted and changed from a set path that focused on the acquisition of basic algebraic skills. The teachers demonstrated a belief that algebra was limited to a set of skills, and so they preferred to remain close to a predictable path while teaching. The use of open-ended items during instruction could have taken them from that path into an unpredictable area.

The teachers' instruction followed the textbook with respect to content. Sue also followed the textbook exactly with respect to examples and order. Both teachers made sure that their instruction was aligned with the assignment that they would make from the textbook. Since most of the text's items were procedural, that is what their instruction reflected. Only two textbook items in chapter 1 and one in chapter 2 were similar to the items in the open-ended item bank. Leah and Sue did not spend time on open-ended items in class, and the assignments that they made did not contain similar items.

About Learning

The learning philosophies of both Leah and Sue centered on students seeing examples that showed steps of procedures and on students practicing skills. Both teachers believed that the students' abilities to retain and demonstrate correctly the steps of a procedure indicated learning. Both teachers had students focus on writing down steps and on finding and correcting mistakes. They believed that if students could see where they went wrong during a procedure, then they would be less likely to make that same error later on quizzes and tests. The ability to produce correct answers indicated that students had mastered material. The teachers' view of learning was dualistic (Perry, 1999) and absolutist (Baxter Magolda, 1992) in the sense that they believed learning was mostly a matter of memorizing answers and procedures. Both Leah and Sue believed that students learned through repetition, and so they required students to extensively practice algebraic skills and procedures. For both teachers, open-ended items did not promote student learning, because they did not provide the opportunity for students to practice skills using repetition as did the large number of exercises contained in the textbook.

Both Leah and Sue believed their teaching provided all the necessary components for all their students to learn mathematics. They believed that if students made mistakes the mistakes were due to carelessness; if students did poorly on quizzes or tests it was due to lack of effort or motivation or to overall student immaturity. These explanations of poor student performance appeared to prevent the teachers from changing their instructional methods. Changes in their instructional methods did not appear as needed to benefit student learning, and the inclusion of open-ended items during instruction was also not seen as beneficial for student learning.

About Assessment

Leah and Sue shared the view that assessment was a quiz or test to determine whether students had acquired knowledge. Their purpose for assessment was to determine whether students knew the correct answers; thus, both teachers exhibited the dualistic (Perry, 1999) and absolutist (Baxter Magolda, 1992) perspectives about assessment. Each teacher gave two quizzes and two chapter tests during the observation period and mainly used the results for grading purposes, a finding also reported by Stiggins and Conklin (1992). Rarely did either teacher use the results to inform their instruction. Sue once used the results of a worksheet to determine that she needed to revisit the rules for adding and subtracting integers. Other than that one occasion, Sue did not vary her instructional routine and so it did not appear that she used results to inform her instruction. Leah said she used the results of assessment to evaluate her instruction. Using the results, she would determine if her instruction was valuable in terms of whether it "really got the point across" (Interview 1). However, Leah said that even when she determined if her instruction was valuable or not, she did not take action. If the grades on the quiz or test were what she expected, then she believed her instruction was valuable. When she reviewed a graded quiz or test, she stated the correct procedures and answers, but never provided additional instruction on the topics assessed.

Both teachers used test grades mainly to determine course grades; Leah's tests accounted for 50% of a student's grade, and Sue's tests for 66%. This is similar to the finding of Cooney (1992) and Senk et al. (1997) that student performance on written tests or quizzes was the factor teachers weighed heaviest in determining student grades. Both Leah and Sue indicated that the tests had to account for a significant amount of the student's grade because tests emphasized mathematical content and neither teacher wanted such non-content factors such as organization or appearance to be a significant factor in determining grades.

Leah graded students' homework frequently. When asked about what action she took based on the results of her homework assessment, Leah said, "I'm finding out what kind of worker they are. If they are doing what they're told. Finding out if they have good study habits as far as do they do homework on a daily basis" (Interview 1). Leah used the homework papers to collect information not on students' understanding but only on the their ability to complete the assignments. Her assessment of students' homework did not translate into any instructional activities.

Leah gave an algebra readiness test at the beginning of the semester. When asked about her actions based on the results of that test, she said that she would spend more time on fractions. Leah pointed out that she did not use that readiness test as an assessment, only "just used it to get to know the students really" (Interview 1). Leah did not seem to recognize that a purpose of assessment could be to inform instructional decisions, such as spending additional time on a topic.

Leah claimed that the student responses to open-ended items were valuable because she could determine the level of maturity of her students' thinking. She said this information enabled her to "try to plan activities along the line of their thinking" (Interview 1). Leah also said that the student responses to open-ended items gave her a "clear understanding of what they do and do not know" (Interview 2). Sue claimed that the student responses to open-ended items allowed her to determine "whether they're thinking correctly or not" (Interview 1). The information about the students' thinking and understanding the teachers gained from open-ended item responses did not appear to affect their instruction. After the Chapter 1 test, which contained open-ended items, Leah told her students to notice that she required explanations on some items. She did not alter her instruction for chapter 2 to include opportunities for the students to offer explanations until the day before the chapter 2 test. On that day, she reviewed how to answer four open-ended items that were similar to ones on the chapter 2 test. Although both teachers reviewed the graded chapter 1 test with their students, neither provided additional instruction on the topics assessed.

Despite the fact that Leah and Sue focused on basic algebraic skills during instruction, open-ended items constituted a significant portion of their chapter tests. Thus, the level of thinking required by the teachers during class was seldom aligned with that required on their tests. This type of inconsistency was also found by Stiggins and Conklin

(1992). Stiggins and Conklin found that teachers viewed instruction and assessment as distinct functions and did not integrate them during class time. The teaching practices of both Leah and Sue also represented such a distinction. They believed that assessment was a test used to determine whether students had acquired knowledge, and thus it was to be used at the end of a chapter to document student learning. The teachers gave students quizzes, but quizzes were just “kind of an indication of, ‘Okay, you better know this’” for the test (Sue, Interview 2).

Leah and Sue did not hold beliefs about mathematics and teaching that were in line with current reform ideas. Both teachers used open-ended items on their tests; otherwise, their assessment practices can not be described as innovative. Other than the use of the open-ended items, both teachers relied on traditional quizzes and tests to determine students’ understanding of mathematics. Neither teacher used assessment techniques such as projects, portfolios, journals, observations, or interviews. This finding echoes that of Cooney and Shealy (1995) who found that those teachers whose central beliefs about mathematics and teaching were most in line with current reform ideas were the most innovative in their assessment practices.

The teachers’ central beliefs about mathematics, teaching, learning and assessment appeared to have a significant effect on their use of open-ended items. Figure 6.1 summarizes those beliefs and their effect on the use of open-ended items.

Authority

Sue used the textbook almost exclusively during instruction and presented the material and examples in the order they appeared in the textbook. To Sue, the textbook contained everything that was important for students to learn. Homework was assigned from the textbook, and any worksheets she gave the students for additional practice came from other published resource materials and were similar to material in the textbook. She did create her own quizzes and tests, which contained tasks she had collected from various sources, including textbooks, publishers’ assessment materials, the open-ended

	Teachers' Central Belief	Effect on the Use of Open-ended Items
Mathematics (specifically algebra)	Is a set of acquired skills and procedures	Impeded use because items do not represent a set of skills and procedures
Teaching	Is accomplished by transmission Focus should be on student acquisition of basic skills	Impeded use because items were not compatible with instructional routine
Learning	Is accomplished through repetition	Impeded use because items did not provide opportunity for students to practice skills and procedures
Assessment	Purpose is to determine whether students know correct answers and have mastered basic skills	Facilitated use because teachers viewed items as another way to determine whether students have mastered skills

Figure 6.1. Teachers' central beliefs and their effect on the use open-ended items.

item bank, professional development experiences, and other teachers. She used open-ended items on her tests to meet the county mandate and did use two on her second quiz because she believed that the more students had practice in writing responses to those type of items the better their responses would become. Sue chose items from the bank that matched the emphasis of her instruction. Thus, for Sue, a main authority regarding her instructional decisions was the textbook. Since the textbook had an emphasis on algebraic skills, it did not encourage her to use open-ended items during instruction.

For Sue, the high school mathematics teachers and courses that her students would encounter in the future also represented an authority. She focused on the learning of basic algebraic skills because that is what high school teachers would expect her students to know and what she believed her students would need to be able to do in order to succeed in courses such as Algebra II, Trigonometry, and Calculus. Her students would also need to know the skills in order to do well on the course test given by the county at the end of the school year. She believed that since she was teaching according to the textbook, this constituted evidence that she was teaching the mandated curriculum.

However, Sue's concern for what the high school teachers would expect her students to know and be able to do also encouraged her to include open-ended items on her tests. She believed that they added rigor to the tests and encouraged the students to think at a level that they would need in future mathematics courses. She also believed her students would be required to respond to open-ended items in future mathematics courses. This contradicts the finding by Cooney et al. (1996) that teachers are less likely to use alternative assessment strategies when courses were more academic because of their concern for making sure students were prepared for future mathematics courses.

Leah appeared to be something of a subjective knower (Belenky et al., 1986) because she made instructional decisions based on her teaching experience and what felt appropriate to her. She had confidence in her expertise as a teacher and relied on that expertise to make decisions. She decided on her own explanations and examples to use during instruction and sometimes did not present material in the same order as the textbook. She used the textbook for student homework assignments. When she felt it was best for her students to spend additional time covering basic skills, she did so. As a result, she spent more time than Sue covering the topics in chapters 1 and 2. She followed the county curriculum guide, but went slower than the suggested time schedule.

Leah also used tasks collected from a variety of sources to create her quizzes and tests. On her tests, Leah used open-ended items in order to meet the county mandate. She said that if the county mandate had not been 20% she would probably have used fewer of the open-ended items from the bank on tests and might have used the items in different ways, such as during instruction. Leah seemed to think that the county mandate said she had to use those particular open-ended items on her tests, which was not true. The mandate said that at least 20% of the questions on all classroom tests must require higher-order thinking on the part of students; the open-ended item bank was intended to be only one resource to help teachers meet the requirement. Thus, Leah was not obligated to use open-ended items only on tests, nor did she have to limit the higher-level thinking items on her tests to the ones contained in the bank.

Leah demonstrated her belief that she regarded herself as an authority with respect to writing her own assessment items. On both of her tests, she included an open-ended item that she had written. She believed that during the professional development project she “really learned how to write those questions” (Interview 2). She said that in the past she had usually used textbook questions, but since she had practiced writing open-ended items during the project, she felt she was much better at writing her own items.

Leah’s belief in herself as an authority was obvious from the decisions she made regarding her teaching. She chose not to use the rubric developed during the professional development project because it did not fit into her grading scheme. Instead, she developed her own way of scoring student responses that was more appropriate for her situation. Leah also decided at the end of the semester not to give her students a final exam. She felt that her students were not developmentally ready for a final exam and that they would be overwhelmed if asked to assimilate numerous topics. Leah, along with the other algebra teachers in her school, made this decision even though it was not well received by the high school Algebra I teachers. She felt not having the final exam was in the best interest of her students.

Leah considered the NCTM an appropriate authority with respect to teaching mathematics and was familiar with its goals for instruction and assessment. She frequently recited orally and in writing aspects of NCTM’s standards, including the need for activities that were hands-on, were cooperative, were connected to real-world situations, and incorporated problem solving and technology. However, in practice Leah’s instructional and assessment activities did not contain the types of activities that she claimed were important to students’ understanding of mathematics. Although she felt that her beliefs were aligned with those of the Standards, in practice she did not incorporate the ideals into her teaching. Leah did not integrate open-ended items into her instructional routine even though she considered herself an authority for instructional decisions.

The sources for authority that Leah and Sue used were different. Leah relied on her past experiences and expertise in teaching, whereas Sue depended on the textbook. Thus, whereas Sue used the text's examples during instruction, Leah used different ones that she believed, from her experience, promoted student understanding. High school mathematics teachers and courses represented an authority for Sue, and the NCTM was viewed by Leah as an authority. Both teachers considered the county an authority, as they used open-ended items on their tests to meet the county assessment mandate. Sue also used the items on her second quiz. However, neither teacher's main source of authority for instructional decisions promoted the use of open-ended items as an instructional technique, and they did not use such items during instruction.

Neither teacher appeared to perceive that their main source for authority for instructional decisions emphasized the use of open-ended items during instruction, and thus neither teacher used open-ended items as part of her instructional approach. Figure 6.2 summarizes the teachers' sources for authority and their effect on the use of open-ended items.

Leah	*Sue*	*Effect on the Use of Open-ended Items*
Herself	Textbook	Impeded use during instruction because source did not promote use of items as an instructional technique
NCTM		Facilitated use on tests because Leah believed she met NCTM goals which encourages the use of alternative assessment techniques
	High school mathematics teachers and courses	Facilitated use because Sue believed her students would encounter those types of items in high school
County school system	County school system	Facilitated use because the teachers used items to meet the county assessment mandate

Figure 6.2. Teachers' sources for authority and their effect on the use of open-ended items.

Reflection

The process of reflective thinking begins with the recognition that something is problematic. If something is problematic, it causes a person to enter a state of doubt and to be perplexed. The problematic situation can then propel the person to search for a solution. The demand for a conclusion to a problem is the definitive characteristic of reflective thinking. Both teachers raised issues in their teaching that they considered problematic. For these issues, the teachers found resolution. However, there were also issues in their teaching that the teachers did not seem to consider problematic. Consideration of those issues as problematic could have initiated reflective thinking that might have influenced the teachers' instructional and assessment practices.

Problematic Issues

Leah

Changes in teaching practice. Leah's ability to change her teaching practice was a problematic issue for her. She believed that change was difficult, could only be done over a long period of time, and required a great deal of hard work. Leah said her motivation for change came mostly from a self-analysis of her teaching and her desire to find better ways to help students learn mathematics. This motivation for change led her to participate in numerous professional development programs. The kind of changes that Leah referred to were the incorporation of additional types of activities into her established instructional and assessment practices. For example, at the time of the study Leah was attempting to incorporate cooperative learning into her classroom daily because she believed that students could help answer each others' questions and thus reduce the time she spent answering them. Although Leah never referred to any of her teaching practices as problematic, she seemed to be searching for something to help improve her teaching. She kept adding discrete items to her repertoire of instructional and assessment techniques. She seemed open-minded (Dewey, 1933) in that she considered alternative ideas about instruction and assessment and thus was in a position to engage in reflective thinking.

However, Leah did not appear to think reflectively about her instructional and assessment practices, because those practices were not problematic for her. Although she believed that her instructional and assessment practices were good, she was willing to participate in professional development programs and consider ideas that could help make her practices even better.

Low student test grades. Leah considered it problematic that, in general, her students made low grades on her tests. She searched for reasons to determine why the grades were low on both open-ended and traditional assessment items. She concluded that there were several actions that she and the students could take to help them improve their grades. With respect to open-ended items, Leah maintained that the items were new to the students and that they had not had enough practice in making those types of responses. She believed that as time passed and as the students had more exposure to them, they would become better at responding to open-ended items. She decided to reduce the number of open-ended items on her tests because she was going beyond the 20% mandate. Also, the day before the chapter 2 test, she reviewed with her students how to answer four open-ended items similar to ones that were on the test. She decided that the students did not know their mathematics well enough to correctly answer open-ended and traditional items. In order to learn their mathematics better, Leah suggested to the students that they acquire better study habits as well as habits that would improve their ability to learn from her instruction (such as taking notes better, less talking in class), that they put forth more effort to learn, and that they stop being so careless and making mistakes in their work. These suggestions, along with encouraging the students to find someone outside of class (a parent, sibling, friend, or tutor) to help them learn their algebra, were ways in which Leah believed the students could improve their grades.

Student responses to open-ended items. Leah was surprised, and thus found it problematic, that students could not respond to open-ended items as well as she thought they should be able to. One reason for their poor performance was that, as mentioned above, she felt that the students did not know their mathematics well enough to appropriately respond to the items. Further, Leah believed that the students struggled with the details of open-ended items and that they did not have the ability to pay attention to so many details in one item. The last reason that she believed caused the students to respond poorly to open-ended items was that they were not clear about the directions, wording, or intent of some of the items, and thus interpreted them incorrectly. Along with the suggestions to help students improve their grades, Leah tried to help students respond better to open-ended items by sometimes giving hints, and she made an effort to select open-ended items that she believed were worded more clearly. She also reviewed in class four open-ended items that were similar to ones on the chapter 2 test in an effort to help improve student responses.

Sue

Student attendance. The most problematic issue for Sue was student attendance. She believed that absences caused students to miss a large amount of mathematical content and that they were unwilling to make the effort to come in for extra instruction. To Sue, students' absences accounted for much of their misunderstanding, especially since she believed that the textbook was not something that the students could read and understand by themselves. Sue determined that the students needed to be more diligent in their efforts to attend class.

Student course level. Sue believed that it was problematic that too many students were taking Algebra I in the seventh grade and Geometry in the eighth grade. In addition, she thought too many students were taking Algebra I in eighth grade. She believed that the students' level of maturity was not sufficient for them to be successful in those classes at those grade levels. She believed that even though those students could pass Algebra I and Geometry in the middle grades, their lack of maturity would keep them from learning the material as well as they should, and thus the students would encounter considerable difficulty in the mathematics classes in high school. As a result of her belief and her position as department head, Sue decided to make an effort to reduce the number of seventh- and eighth-graders taking Algebra I and Geometry.

Lack of student learning. Lack of student learning, as evidenced by low grades on quizzes and tests, was also problematic for Sue. She thought that maturity was the main factor that contributed to a lack of student learning. She believed that the students were just not ready to make the kind of effort that was required to be successful in Algebra I. Also, she believed that they did not want to spend time interpreting both traditional and open-ended items correctly, did not have the patience to read them thoroughly, and did not take the class seriously. Sue also believed that the students were not motivated, that their parents pushed them into Algebra I when they were not really ready to handle the course, and that the students' prior instruction in Pre-Algebra did not sufficiently instill the basic skills such as operations with integers and solving simple equations. Sue said she would continue not being easy on the students and demanding that they raise their level of effort in her class.

The Teachers' Reflective Thinking

The teachers' problematic issues had the ability to trigger reflective thinking that could have affected their instructional and assessment practices. If Leah had considered that her instruction and assessment were not aligned, perhaps she would have incorporated open-ended items into her instruction. Leah's ability to explain her students' low grades and lack of appropriate responses to open-ended items in terms of student shortcomings, thus not taking any responsibility herself, inhibited her reflection about how to improve student performance in those areas. Similarly, Sue's ability to explain her students' lack of learning in terms of student shortcomings inhibited her reflection.

Dewey (1933) stated that there are occasions in which something is considered problematic and a suggestion for resolution emerges, and yet reflective thinking does not occur. In these instances the person is not "sufficiently *critical* about the ideas that occur to him" (p. 16). The person takes the first answer or solution that occurs to her or him, and thus does not become completely immersed in the careful search for a resolution. Although Leah and Sue raised issues that were problematic to them, their solutions seemed to indicate a lack of depth of thought. Leah's action of adding discrete items to her instructional and assessment techniques seemed to indicate she did not consider her teaching as a whole. Both teachers' abilities to explain poor student performance in terms of student shortcomings implied that the teachers did not have to consider the effects of their instructional and assessment practices. Since the teachers did not appear ready or willing to engage in reflective thinking about their problematic issues, they did not reach the stage of carefully searching for a resolution. Thus, open-ended items were not considered helpful to the resolution process.

The issues that Leah considered problematic were about factors that had the potential to impact her instructional and assessment practices. Leah could make changes in her teaching and could find ways to affect students' grades and abilities to respond to open-ended items. In contrast, Sue's most problematic issues were students' attendance and level of coursework. These factors were not under her control and thus did not appear to have the ability to impact her instructional and assessment practices in any significant way. The issue of lack of student learning did have the ability to impact Sue's instructional and assessment practices. Leah appeared closer than Sue to using reflective thought to direct her teaching, as the issues she recognized as problematic had the ability to affect her teaching. Sue, however, still needed to develop a greater ability to recognize the types of problematic issues that could have an impact on her teaching.

For Leah, the resolutions to her problematic issues did affect her use of open-ended items, although in a superficial way. In contrast, Sue's resolutions did not appear to affect her use of open-ended items. Figure 6.3 summarizes the teachers' problematic issues and their effect on the use of open-ended items.

	Problematic Issues	Effect on the Use of Open-ended Items
Leah	Ability to make changes in her teaching practice Low student test grades Poor student responses to open-ended items	Added item use to her repertoire of assessment techniques Reduced the number of items on her tests Reviewed similar items with students before chapter 2 test
Sue	Student attendance Student course levels Lack of student learning	These issues were not found to have an effect on item use

Figure 6.3. Teachers' problematic issues and their effect on the use of open-ended items.

Issues That Did Not Seem Problematic

Perhaps more interesting than what the teachers found problematic was what they did not find problematic. There are numerous issues regarding their teaching practice that, if they had thought reflectively about them, might have affected the teachers' instructional and assessment practices.

Knowledge of Mathematics

Neither Leah nor Sue appeared to consider her knowledge of mathematics to be problematic. Leah stated that she had expertise in mathematics, especially in the Algebra I and Geometry courses that she taught. Sue was confident of her mathematical knowledge and as department head had assigned herself the Honors Algebra I and Geometry courses as well as the Algebra I course observed during this study. However, as described in chapters 4 and 5, both Leah and Sue were observed on numerous occasions to have difficulty with the mathematics contained in the first two chapters of their Algebra I textbook. A realization that their mathematical knowledge was lacking might have promoted additional study and an increased comfort with using open-ended items and the unpredictable situations that such use might stimulate.

Course Content

Leah and Sue also did not appear to believe that the mathematics contained in chapters 1 and 2 of the textbook was problematic for students. They frequently reminded their students that the material in those chapters was review material from the Pre-Algebra course and should be easy. When asked why students were not doing well on quizzes and tests that covered review material, Leah and Sue both responded that the students were careless. Because they believed the mathematics was easy, neither teacher seemed to consider that the students had a real lack of mathematical understanding. Recognition that the mathematics contained in the first two textbook chapters was indeed problematic for their students might have encouraged the teachers to find ways to help students create better understandings, which open-ended items could have assisted in doing.

Teaching Practice

In general, Leah and Sue did not believe any aspects of their teaching were problematic. But there were numerous aspects of their teaching that were problematic from my perspective. Neither teacher aligned her instruction and assessment. Open-ended items were on their tests but were not used during instruction. Leah used the TI-82s during two lessons but would not allow them to be used on tests in those instances that specifically matched the lesson. When Sue was told that her students asked very few questions in class, she agreed and said it was probably because the material was easy. Both teachers' instruction focused on basic algebraic skills. The times when Leah did not follow up on students' comments suggested that she did not value the students' thinking. Leah's belief that her students were not developmentally ready for a cumulative final exam seemed to indicate she had low expectations of her students' abilities, especially since the students were receiving high school credit for her Algebra I course. When the teachers sensed a lack of student understanding, they both blamed the students; at no time did either Leah or Sue indicate that her instructional techniques could be responsible. If the teachers had recognized their teaching as problematic, they might have been encouraged to find alternative instructional methods, which could have included using open-ended items.

Students' Poor Responses

Both Leah and Sue were able to offer explanations why students responded poorly to open-ended items. Their ability to explain the poor responses completely in terms of student failings was not problematic for them. Both teachers indicated that if their students knew the mathematical content, they would not have difficulty responding to open-ended items. Other reasons the teachers cited for poor responses included students' lack of maturity, not reading and interpreting directions correctly, carelessness, and the failure of Pre-Algebra teachers to use open-ended items the previous school year. Their explanations for students' poor responses hindered both teachers' capabilities to consider additional ways to promote better student responses, one of which might be to use open-ended items during instruction.

Scoring of Student Responses

Both teachers scored student responses to open-ended items inconsistently and yet their scoring was not problematic for them. This inconsistency indicated a lack of time and effort to attend to the students' thinking. Both teachers appeared to lack the attentiveness required to score uniformly on a consistent basis. More attention to students' responses might have encouraged the teachers to consider alternative ways to approach mathematical topics in an effort to increase student understanding.

Purpose of Assessment

The fact that the teachers mainly used assessment for grading purposes was not problematic for them. Both teachers indicated that they were familiar with reform literature in mathematics education, but neither seemed to grasp that a primary purpose for assessment should be to adjust instruction to improve student understanding. Both teachers used questioning during instruction, but since the teachers appeared preoccupied with their set agendas or had difficulty responding to student questions, they did not use the information their questioning techniques yielded to revise instruction. Thus, Leah and Sue used summative assessment, not formative assessment, and were not observed to integrate their instruction and assessment. If the teachers had considered other ways about how assessment could be used to foster student mathematical understanding, they might have been encouraged to use open-ended items during instruction and not just on quizzes and tests.

Leah's Conceptions of Reform

The discrepancies between Leah's conceptions of reform and her teaching actions were not problematic for her. Leah stated that with almost every lesson, or at least every unit, she tried to do activities that were hands-on, incorporated cooperative learning, used technology, and contained real-world applications. She pointed out that she helped students understand mathematics better by her use of hands-on and cooperative learning activities, and by the inclusion of technology and real-life applications in her lessons. However, her activities did not appear to provide a context for the development of deeper mathematical understanding. Also, the frequency of those types of activities did not seem to match the emphasis she expressed in her course syllabus and statements to me. Similar to a finding by Shealy (1994), Leah did not appear to see the contradiction in her expressed values and instructional practices. Thus, although Leah claimed that her understanding of reform issues in mathematics education was 100%, her actions did not provide evidence that she was able to translate that knowledge into activities that were investigative or cooperative or that were designed to increase student mathematical understanding. Leah's teaching more accurately correlated with her statement that her teaching was mostly direct instruction. If Leah had realized that her conceptions of reform and her actions were not aligned, perhaps she would have searched for ways to correlate her statements and actions, including the use of open-ended items during instruction.

Knowledge

Subject Matter Content Knowledge

Shulman (1986) described three categories of knowledge: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. Subject matter content knowledge refers to the amount and organization of knowledge a teacher possess about her or his subject area. Shulman specified that this knowledge must go beyond merely knowing facts and concepts and include “why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice” (Shulman, 1986, p. 9).

Leah and Sue did not demonstrate a rich mathematical content knowledge. Both teachers focused on a discrete set of skills and procedures that they wanted the students to be able to perform. They did not develop mathematical topics, but instead presented them in isolated contexts. The teachers did not connect topics within and outside the body of mathematics. For example, both teachers emphasized a rule that if students were given a problem that contained fractions, the answer must be in fractional form, and if a problem contained decimals, the students’ answer must be in decimal form. Neither teacher gave any rationale for her rule. During her lesson on simplifying expressions, Leah posed the problem $\frac{5}{6}m + \frac{m}{6}$. She wrote on the overhead $\frac{m}{6}$(5+1), and immediately the students commented that they were lost. Leah tried to explain that the terms in the expression had a $\frac{m}{6}$ in common and asked “Does that make sense?” No student said yes, and Leah said, “Let’s move on” (Observation, 9/2). Leah did not demonstrate the ability to explain simplifying the expression in another way or to connect it to a simpler expression and then make a progression to the given expression.

Sue began a lesson on formulas by commenting that formulas were easy. After demonstrating how to substitute numbers in such formulas as $A = \frac{1}{2}bh$ and

$SA = 2wh + 2lh + 2lw$, a student said that he did not understand formulas, specifically where they came from. Sue replied, “They are just given to you. Eventually you’re just going to have to memorize formulas” (Observation, 9/1). Sue did not demonstrate the ability to develop the formulas nor did she connect the formulas to any real-life situation.

Leah and Sue did not demonstrate a rich subject matter content knowledge as defined by Shulman. Both teachers focused their instruction on discrete mathematical skills, avoiding the use of open-ended items. As discussed previously, both teachers became uncomfortable when questions about mathematics veered from a predictable path, a potential result of using open-ended items.

Pedagogical Content Knowledge

Shulman (1986) described pedagogical content knowledge as

> for the most regularly taught topics in one’s subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that makes it comprehensible to others. (p. 9)

Sue presented the examples from the textbook during her instruction. If a student indicated a lack of understanding, sometimes Sue would attempt to create a similar example, or she would revisit the same example and go through it more slowly. For example, when she demonstrated a technique for comparing the value of two fractions, a student indicated she was unclear about how to determine the larger of the two fractions. Sue replied, “Let me do a few more,” and proceeded to work similar examples more slowly (Observation, 9/13). Sue did not attempt to use decimals, nor did she attempt to use fractions that were more familiar to students, such as $\frac{1}{4}$ or $\frac{2}{3}$ in an effort to make the technique more comprehensible to students. She only demonstrated one way to compare the fractions. Sue consistently was unable, or perhaps unwilling, to approach mathematical topics in different ways that could address the variety of ways that students learn and thus promote greater student understanding.

In contrast, Leah attempted to use a variety of activities during her lessons even though, as previously described, they did not appear to be sufficient to further students' mathematical understanding. As Leah indicated, her teaching style was direct, meaning that she provided examples to students during lessons and then made assignments that were similar to what she had presented during instruction. Leah also routinely approached mathematical topics in a single way. For example, during her lesson on formulas, Leah presented two formulas on rate, time, and distance: $R \cdot T = D$ and $D/T = R$ (she said $D/R = T$ but forgot to write it for the students). She told the students that they would "have to analyze the facts and determine if it's a rate, time or distance so you can choose the correct formula" (Observation, 9/9). Leah did not recognize that another approach could have been to introduce one formula and then focus on how to manipulate the formula to obtain the unknown value.

Curricular Knowledge

The category of curricular knowledge has three aspects. First, the curriculum, along with associated materials, is a storehouse from which a teacher can draw teaching aids to help present or exemplify content. It includes different texts, visual materials, software, demonstrations, and other alternative ways of dealing with content. Shulman (1986) states that a teacher should have the "ability to relate the content of a given course or lesson to topics or issues being discussed simultaneously in other classes" (p. 10), that is, what he calls lateral curriculum knowledge. The last aspect of curricular knowledge includes vertical curriculum knowledge, which is a "familiarity with the topics and issues that have been and will be taught in the same subject area during the preceding and later years in school" (p. 10).

Neither teacher demonstrated the use of curricular knowledge in her teaching. Neither one used a variety of curriculum materials to help frame and present mathematical content. Both focused on stating content and showing examples. Leah did participate in the integrated lesson on hurricanes with the other subject teachers in her section of eighth-grade students, but otherwise the teachers did not connect mathematics to other disciplines. The teachers also did not use the content of prior and future mathematics courses in an attempt to make connections within the body of mathematics or to motivate students. For example, they did not make comments to the students such as "Remember when you did…" or "In Algebra II you will further this concept when you do…."

Neither teacher demonstrated a rich mathematical content knowledge or curricular knowledge. Both demonstrated a limited pedagogical content knowledge. The teachers' knowledge had an effect on their instruction as well as on their use of open-ended items. Figure 6.4 summarizes those effects.

Type of Knowledge	*Effect on Instruction*	*Effect on the Use of Open-ended Items*
Teachers did not demonstrate a rich mathematical content knowledge	Both teachers became uncomfortable when mathematical questions veered from a predictable path	Impeded use because a potential result of using items is unpredictability in the classroom
Teachers demonstrated limited pedagogical content knowledge	Neither teacher used a variety of instructional techniques to address the different ways students learn	Impeded use because items could have been used as an instructional technique
Teachers did not demonstrate curricular knowledge	Neither teacher used a variety of curriculum materials to frame and present mathematical content Neither teacher connected mathematics to other disciplines Neither teacher made connections within the body of mathematics	Impeded use because items could have been used to present or connect mathematics

Figure 6.4. Teachers' types of knowledge and their effect on the use of open-ended items.

Constraints

Both Leah and Sue considered lack of time to be a factor in their teaching. They were concerned about their lack of time to score student responses to open-ended items. Also, Leah said she wished she could do more but said, “I just don’t feel like I have time” (Interview 1). She wanted to do different types of assessment, such as journals and portfolios, but lack of time was a factor in her decision not to do those types of assessment. This finding concurs with that of Cooney (1992), Nash (1993), and Senk et al. (1997), who all reported that time constraints inhibited teachers’ use of alternative assessment items. Having three class preparations for each school day also meant that Leah was limited in the time she had to prepare lessons because there was “too much to do” (Interview 1). Sue also described lack of time as a factor in her instructional decisions. It was hard to cover the curriculum because she had to spend time reviewing material from the students’ Pre-Algebra course. Sue believed that the time she spent on review material reduced the time she could spend on solving equations and other topics that she believed were more important in the Algebra I curriculum. This lack of time for instruction meant that open-ended items, which by their nature would necessitate additional class time, were not able to be used during instruction.

Sue considered the number of students in a class to be a constraint. With smaller class sizes, she believed she could introduce topics and then allow students to “develop their own thoughts in their own ways” (Interview 3). However, because she had larger classes she felt the need to be more structured; thus she presented procedures and then provided time for students to practice those procedures. The structured lesson approach Sue felt she needed because of the large class size did not allow for the use of open-ended items.

It seemed that Leah and Sue considered the students themselves to be a constraining factor. Both teachers frequently cited the students’ lack of ability and the various reasons for their deficiencies. This view of students seemed to encourage Leah and Sue to maintain their focus on getting students to master basic skills. Both teachers appeared to think that since the students had difficulty mastering basic skills, there was no need to attempt instructional activities that would require more advanced thinking skills other than memorization. Such activities included the use of open-ended items.

Several factors that have been found to be constraints in the literature did not appear as constraints to Leah and Sue. Neither teacher considered the grading of student responses to open-ended items as a constraining factor in their use. Both teachers felt comfortable grading responses, Leah with her grading scheme and Sue with the rubric developed during the project. Also, both teachers had an open-ended item bank, and they did not cite a lack of resources as a reason not to use open-ended items. Because the open-ended items contained in the bank were written to correlate with the county curriculum, neither teacher cited the curriculum as a constraint on the use of open-ended items.

Nash (1993) and Senk et al. (1997) reported that teachers struggle with student assessment because of a lack of knowledge about alternative assessment techniques. Such a struggle was not found in the present study. Leah and Sue had participated in a professional development project designed to increase their knowledge about alternative assessment, especially about the use of open-ended assessment items. Although Leah claimed that assessment was not a strength of hers, neither teacher indicated a concern about her knowledge of assessment, her ability to use open-ended items, or her ability to score responses to such items.

Both Leah and Sue used open-ended assessment items on their tests without hesitation. These results are different from those found by Cooney (1992) and Senk et al. (1997). Senk et al. found that teachers' limited knowledge of and ability to implement alternative assessment techniques served as a deterrent to using new forms of assessment as often as more traditional tests. Nash (1993) found that teachers struggled with student assessment because they lacked knowledge about appropriate assessment techniques, experience in implementing alternative assessment methods, and support in modifying assessment methods to meet individual student's needs. These issues were addressed in the professional development project. Leah and Sue's participation in the project meant that they had received training in assessment techniques and a teacher-developed assessment resource. They also were provided with training in the scoring of student responses. During the first school year after the training, they were provided with the opportunity to field test the items with their students that provided them with experience in using open-ended items.

Although the constraints did not appear to prevent the teachers from using open-ended items on tests, they may have limited the teachers' ability to use them during instruction. Figure 6.5 summarizes the constraint factors and their effect on Leah and Sue's teaching and use of open-ended items.

Constraints	*Effect on Teaching*	*Effect on the Use of Open-ended Items*
Time	Leah was concerned about the lack of time to prepare lessons; Sue was concerned about the lack of time to cover the curriculum	Impeded use because item use would require additional preparation time and use additional class time
Number of students in class (Sue)	More structured classroom where Sue presented material and students practiced skills independently	Impeded use because item use did not fit into that instructional routine
Students themselves	Teachers' view of students having numerous deficiencies that prevented them from mastering basic skills prevented the attempt of instructional activities that would require more advanced thinking	Impeded use because items did not provide an opportunity for students to practice skills and procedures

Figure 6.5. Constraint factors and their effect on the use of open-ended items.

The teaches' participation in the professional development project appeared to remove some of the constraining factors found in previous studies. Figure 6.6

summarizes the factors which were not found to be constraints to the teachers' use of open-ended items.

Non-Constraint	*How Facilitated the Use of Open-ended Items*
Grading of student responses	Both teachers used items on tests and felt comfortable grading student responses
Curriculum	The availability of items which were correlated with the county curriculum meant items were easily incorporated into the teachers' tests
Lack of knowledge about alternative assessment	Neither teacher indicated a concern about her knowledge of assessment nor her ability to use items or to score student responses

Figure 6.6. Non-constraining factors and their effect on the use of open-ended items.

CHAPTER 7

SUMMARY AND IMPLICATIONS

Purpose of the Study

Several studies, e.g., Cooney, (1992), Hancock (1994), and Senk et al. (1997), have determined that mathematics teachers' current assessment practices are not consistent with advocated changes in the current reform literature. It is important to understand why teachers are not embracing the forms of assessment in the current reform literature. This study was designed to investigate the assessment practices of two Algebra I teachers who had been in a professional development project designed to acquaint them with reform-oriented assessment. The study focused on the use of open-ended assessment items and the factors that influenced teachers' use of those items. The participants were selected from a group of teachers who had participated in a professional development project designed to increase their knowledge of reform-oriented assessment practices. The project provided opportunities for the teachers to write open-ended assessment items and also to practice scoring student responses to those items. Given their involvement in the project, some factors that constrained teachers' use of open-ended items in previous studies were removed. The participants were comfortable using such items on tests, and expressed no concern about grading student responses. Therefore, the participants provided an opportunity to investigate other factors that facilitated or impeded the use of those type of items.

The teachers in the study were required by their school system to meet mandated student assessment requirements; specifically, at least 20% of the items on all classroom tests had to require higher-order thinking on the part of students. This assessment requirement was intended to affect not only the teachers' classroom assessment practices but also their instructional practices. County policymakers expected teachers to change their instructional methods to incorporate more reform-oriented instruction when faced with a requirement to do so with their classroom assessments. The professional development project was an effort to help the teachers meet the requirement. Specifically, this study investigated the following questions:

- What are the teachers' current assessment practices and beliefs?
- To what extent do their beliefs facilitate or impede the use of open-ended items?
- About what issues, if any, do the teachers engage in reflective thinking, and did that thinking facilitate or impede the use of open-ended items?
- What aspects, if any, of the professional development program facilitated the use of open-ended items?

This study was intended to provide insight into the factors that can help mathematics teachers implement assessment reform, as well as to highlight the potential for professional development programs and assessment resources to assist in reform efforts.

Theoretical Perspectives

Senk et al. (1997) identified teachers' knowledge and beliefs as a significant factor that affected teachers' assessment and grading practices. This study began with the notion that teachers' beliefs about mathematics, the teaching and learning of mathematics, and assessment would influence their use of open-ended items. Three epistemological development models (Baxter Magolda, 1992; Belenky et al., 1986; Perry, 1999) suggest that an individual's knowledge and beliefs can be described using categories in which he or she falls according to his or her orientation to authority. The orientations range from knowledge being absolute and given by an authority to knowledge being situational and developed in context using evidence. The models provided insight into the teachers' beliefs and orientation to authority in an effort to understand the effect that those beliefs and orientations had on teachers' assessment practices.

During the initial data analysis, the theme of reflection emerged. The literature on reflective thinking (e.g., Dewey, 1933) was used to discuss the ways the teachers were thinking about their instructional and assessment practices, as well as their actual practices. To engage in reflective thinking, an individual must first recognize something as problematic and enter a state of doubt. What follows is an active search to find material that will resolve the doubt. The demand for a conclusion to a problem is the definitive characteristic of reflective thinking. There are occasions where something is considered problematic and a suggestion for resolution emerges, and yet reflective thinking does not occur. In these instances, Dewey claimed that the person is not sufficiently critical about ideas that occur about the problem and thus takes the first answer or solution that occurs and does not become immersed in the careful search for a resolution.

The present study attempted to determine what issues, if any, the participant teachers found problematic in order to ascertain in what areas they engaged in reflective thinking.

Methodology

Two eighth-grade Algebra I teachers who had participated in a professional development project designed to expand their understanding of the purposes and uses of assessment, as well as to change their instructional and assessment practices, were participants in the study. Algebra I teachers were chosen because of my previous teaching experience and because I worked with the Algebra I writing group during the initial item generation and revision period of the project. Each teacher completed a survey, was interviewed, and was observed teaching. Artifacts were collected that included copies of tests, quizzes, worksheets, handouts, and graded student assessments.

There were two phases of data analysis. The first phase used inductive analysis and identified categories that described the teachers' beliefs and practices. The results of this phase were used to write chapters 4 and 5 which contain the descriptive data about the participants. The second phase of analysis consisted of analyzing the data with an emphasis toward interpretation using my theoretical perspectives. These results were used to write chapter 6, which contains an analysis of the participants.

Findings

The Teachers' Current Assessment Practices and Beliefs

Both teachers conveyed a limited view of mathematics to students in their Algebra I courses because their instruction demonstrated only problems that had a single correct answer. They communicated that mathematics, specifically algebra, was a set of skills acquired through repetition. They both believed that to know mathematics meant that a person had a repertoire of skills that could be done quickly and easily, and that the person could teach those skills to someone else.

Both Leah and Sue used a transmission style of teaching that focused on procedural understanding. Both teachers emphasized student attainment of basic skills through repetition and memorization. Leah valued the ability of peers to assist in the acquisition of knowledge, and thus allowed her students to work in groups. Both teachers believed that the production of correct answers to procedural exercises indicated learning. and placed the responsibility for learning on the students. Leah believed that lack of learning was caused by student carelessness or lack of effort; in contrast Sue maintained it was due to student immaturity, lack of motivation, uninformed parents, or inadequate prior instruction.

Leah and Sue used assessment for the purpose of assigning grades and to determine whether their students had acquired knowledge. Rarely did either teacher use the results of assessment to make instructional decisions. Both teachers used open-ended items on their tests (and Sue did on a quiz), but neither teacher used such items as a part of her instructional practice.

Effect of the Teachers' Beliefs on the Use of Open-ended Items

The teachers' beliefs appeared to affect their use of open-ended items. Their belief that mathematics is a set of skills and that learning of mathematics is done through repetition meant that the items were not seen as beneficial to learning mathematics. Both teachers' belief that the role of the teacher was to transmit knowledge also meant that the items were not useful during instruction. Leah and Sue believed that open-ended items were another way to determine whether students had mastered basic skills, and thus both used the items on tests.

Leah relied on her past teaching experiences to make decisions regarding instruction and viewed proclamations from the NCTM and the county school system as representing authority figures. Sue depended on the textbook during instruction and viewed high school mathematics teachers and courses and the county school system as authority figures. Neither teacher perceived that their main source of authority for instructional decisions emphasized the use of open-ended items during instruction.

The Teachers' Reflective Thinking

Leah was concerned about the difficulty of making changes in her teaching practices, low student test grades, and poor student responses to open-ended items. Sue was concerned about student attendance, what she felt was too many middle grades students taking Algebra I and Geometry courses, and lack of student understanding. However, the teachers' problematic issues did not appear to trigger reflective thinking. Neither teacher appeared sufficiently critical in the Deweyian sense about her problematic issues and thus seemed to reach rather shallow solutions. The teachers' lack of reflective thinking about these problematic issues could have hindered the way they used open-ended items and the potential of item use to inform their instruction.

There were several issues that the teachers did not seem to find problematic. Neither considered her knowledge of mathematics to be problematic, nor did either teacher consider the course content problematic for their students. In general, Leah and Sue did not consider their teaching problematic. They also did not consider problematic the explanations they proposed for students' poor responses to open-ended items nor their scoring of those responses. Neither teacher found problematic that her main purpose for assessment was to assign grades as opposed to informing instruction. Leah did not appear to recognize that discrepancies existed between her conceptions of reform and her teaching actions, and thus she did not consider them problematic. Since these issues were not considered problematic, they were impotent for triggering reflective thinking.

Other Findings

The teachers' subject matter content knowledge also appeared to hinder their use of open-ended items during instruction. Both teachers became uncomfortable when questions about mathematics veered from a predictable path grounded in basic algebraic skills. Also, both Leah and Sue's focus on a transmission style of teaching meant they both relied on a pedagogical style that did not include open-ended items.

Time was a constraint for both teachers. Leah said lack of time affected the preparation of her lessons, and Sue said it was hard for her to cover the curriculum. Both teachers also felt that lack of time impeded their use of open-ended items. Leah said that in the past the time to grade student responses had made her reluctant to use the items but now she believed that she was more efficient in grading the responses. Sue claimed that she did not include items on a test if it was already of such length that the students would have difficulty finishing. Sue also considered class size a constraint; more students in a class increased the need for a more structured classroom with students either listening to her present material or practicing skills independently. Both teachers considered the students' lack of mathematical ability a constraint and thus focused instruction on basic algebraic skills. During the time of the study, the constraints did not prevent the teachers from using open-ended items on tests but may have limited the teachers' ability to use them during instruction.

Effect of the Professional Development Project on the Use of Open-ended Items

Several aspects of the Magnolia County Algebra I and Geometry Assessment Project appeared to facilitate the teachers' use of open-ended items. The ease with which the teachers used the items from the bank was aided by the availability and correlation of the items with the county curriculum. The items were able to be easily incorporated into teacher-constructed quizzes and tests via a searchable database. Also, since the items were correlated with the county curriculum, which was matched with specific sections of the textbook, it was easy to determine which items could be used to address a given objective. According to Guskey (1986), one component of a successful professional development program is its ability to illustrate how a new practice can be implemented by teachers "without too much disruption or extra work" (p. 9). The item bank developed during the project was specifically designed to be used easily by teachers.

Both teachers indicated that the extensive discussions during the project about scoring student responses using a rubric were very beneficial. Clarke (1994) claimed that a professional development program should include time for discussion of problems and solutions regarding new approaches. This was done in the Magnolia County project with respect to using a rubric and both teachers indicated it aided their ability to score student responses, although their scoring remained somewhat inconsistent.

Leah believed that teachers should consider changing only 1 or 2 practices in a school year. That same belief was held by the developers of the professional development project. The project focused on a specific assessment practice, the use of open-ended items, in an attempt to help teachers become comfortable using such items and scoring student responses to those items. Thus, the professional development project was aligned with Guskey's (1986) suggestion that professional development programs should focus on a specific teaching skill. Both teachers in the study appeared comfortable using open-ended items and scoring student responses.

Although several aspects of the project appeared to facilitate the teachers' use of open-ended items, some aspects may have contributed to the teachers' rather narrow and limited use of the items. The focus of the discussions concerning rubric use was to help teachers assign points to a response based on what it did and did not contain. There was no emphasis on interpreting information gained from the response in order to make instructional decisions. If such an emphasis had been made, the teachers may have become better at distinguishing among responses by looking at the overall quality of the information contained in a response versus the parts of it that were aligned with a rubric. The project placed an emphasis on the ease of incorporation of open-ended items into teachers' tests and the comfort in their ability to use the items. But the project did not address teaching strategies in which the use of such items could have been embedded. Perhaps Guskey's suggestion is too restrictive in that although a program can focus on a single teaching behavior, if that behavior is not connected with teaching as a whole, the overall goal of the project is unlikely to be realized.

Implications for Teacher Education

The teachers in the present study participated in a professional development program designed to expand their understanding of the purposes and uses of assessment, as well as to change their instructional and assessment practices, specifically with respect to open-ended items. The study has shown that it is possible for teachers to use open-ended items on assessments and yet that usage can have little impact on their instructional decisions. The findings from this study suggest several implications for teacher education.

First, preservice education and professional development programs should help teachers move beyond just using alternative assessment strategies, such as using open-ended items, and help them use student responses to make instructional decisions that will promote students' deeper understanding of mathematics. Programs should provide teachers with opportunities to develop specific strategies for using information gained from alternative assessment techniques to inform their teaching. For example, preservice and inservice teachers could be given a set of student responses to an open-ended item and asked to provide specific instructional activities based on the information contained in those responses. Opportunities to experience models of alternative assessment should be provided to students in both preservice education and mathematics courses, as well as to inservice teachers. Preservice teachers should experience being assessed using alternative techniques in both their education and mathematics courses and be shown how instruction is adjusted for them based on their responses to those types of assessments. Evaluation methods for inservice teachers should include opportunities to respond to alternative assessment techniques and should demonstrate how the knowledge gained about a teacher's strengths and weaknesses can contribute to a professional development plan to improve her or his teaching practice.

A second implication for teacher education is to find ways to help teachers use alternative assessment techniques within the time and curriculum constraints imposed upon them by their school system. Teachers are given limited preparation time and must have ways to incorporate such assessment techniques within that time frame, both with regard to time in class and time outside of class. For example, the teachers in the Magnolia County Algebra I and Geometry Assessment Project were given the open-ended items in their final form in a searchable database so that the items could be easily incorporated into a teacher-constructed test. By virtue of their employment, most teachers are obligated to follow established curriculum goals mandated by their school system. Efforts need to be made to help teachers find ways to use alternative assessment techniques that fit within their curriculum constraints. For example, the open-ended assessment items developed in the Magnolia County project linked the items to the specific behavioral objectives of the county curriculum in an effort to ease the teachers' use of the items. Similar attempts could be made for other types of alternative assessment techniques.

Third, preservice education and professional development programs should find ways to increase teachers' knowledge of school mathematics, that is, the mathematics contained in the courses that they teach, so that they can move beyond focusing on basic skills during instruction and be more willing to tolerate unpredictability in the classroom. Programs should provide opportunities for teachers to experience and practice lessons that are not conducted in a direct, transmission style, thus giving them opportunities to investigate and collaborate with others during their learning of mathematics.

A fourth implication for teacher education is that preservice education and professional development programs should challenge teachers' beliefs about mathematics, the teaching and learning of mathematics, and assessment, as well as about the abilities of elementary, middle, and secondary students. This challenge process could be done in an effort to help teachers notice discrepancies between their espoused beliefs and their actual practices and to enable them to see teaching as problematic. Viewing teaching as problematic is the precursor to engaging in reflective thinking about teaching. Teachers need to be provided with opportunities to frame teaching as a problematic activity as well as to engage in the process of searching for resolution.

Implications for Research

According to Borko and Putnam (1995), "There is substantial evidence that professional development programs for experienced teachers *can* make a difference—that teachers who participate in these programs can, and often do, experience significant changes in their professional knowledge base and instructional practices" (p. 60). But the findings from this study suggest that although teachers were able to use open-ended items on tests and score student responses to those items, they did not change their instructional practices to incorporate more reformed-oriented methods. Thus, subsequent studies of professional development programs need to investigate how to help teachers include more reform-oriented instructional methods in their teaching practice. The following discussion on the successful and unsuccessful aspects of the professional development project described in this study will illuminate specific areas that could be considered for future research.

The professional development project provided training to assist the teachers in writing open-ended items to be included in the bank. However, that training was also manifested in Leah’s ability to create her own open-ended items. Leah claimed that what she learned most from the project was that she learned how to write open-ended items. Leah’s confidence in her expertise as a teacher appeared to enable her to write and use her own items, items that had not been through the field-testing and revision process. In contrast, Sue did not attempt to write any open-ended items herself and said, “I would be a little uncomfortable with [my own item] because it’s not field-tested” (Interview 3). Although a main goal of the project in this study was not for teachers to write their own open-ended items, future research could investigate what elements of professional development programs could encourage that activity.

During the project, teachers were advised not to begin using open-ended items with their students without an introduction to open-ended items. A strategy for introducing the use of open-ended items into their classrooms was discussed; the suggestion was made for teachers to have their students respond to sample items, to score those responses, and then to discuss what constituted successful and unsuccessful responses. Although both Leah and Sue showed examples of open-ended items to their students at the beginning of the school year, neither teacher implemented the introduction strategy that was suggested. The teachers believed that if their students knew their facts and procedures, they would not experience difficulty when responding to open-ended items. This belief seemed to impede the teachers from providing additional preparatory activities designed to assist students in responding to open-ended items. Also, since both teachers claimed time was a constraint on their instructional and assessment activities, neither teacher seemed willing to use class time to sufficiently introduce open-ended items. Future research could investigate what elements of professional development programs could encourage teachers to be more efficient and thorough when using open-ended items.

Both teachers found the extensive discussions during the project on teachers' differential scoring of student responses helpful in their learning how to score responses using a rubric. Despite these discussions, however, this study showed that both teachers were not scoring responses in a consistent manner. Future research could investigate the cause for such inconsistency in an effort to help teachers score responses to open-ended items more appropriately.

Because of time constraints, the professional development project described in the present study did not address certain issues regarding the use of open-ended items. Specifically, the teachers in the project were not provided examples of instructional activities that focused on open-ended items. They were also not provided with information about how to use student responses to inform their instruction. Future research could investigate what types of activities could promote these kinds of actions and how those activities influence teachers' subsequent instructional practices.

The Magnolia County Algebra I and Geometry Assessment Project met its main goals to train a cadre of middle and high school Algebra I and Geometry teachers to write open-ended assessment items, to create a bank of those items, and to use the item bank to train all Magnolia County teachers of Algebra I and Geometry in the methods and benefits of using assessment practices consistent with current calls for reform. Future professional development programs should build on its success to help teachers learn to use the information gathered from alternative assessment techniques, such as the use of open-ended items, to inform their instruction to promote students' deeper understanding of mathematics.

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APPENDICES

APPENDIX A

Assessment Survey

For

Algebra I Teachers

Thank you for participating in this survey. Your thoughtful answers to the following questions will be appreciated. Data from all surveys may be presented in a public way, but individual responses will be kept confidential.

(Note: The surveys sent to the teachers contained space for their responses.)

Demographic Information

1. Name:____
2. School:____
3. Number of years teaching experience:__________________________
4. Number of years teaching mathematics:_________________________
5. Degree(s) held and major(s):_____________________________
6. Why did you participate in the *Developing Alternative Assessments for Algebra I and Geometry* professional development project?
7. Why did you become/why are you a teacher?
8. Why did you choose to teach mathematics?
9. Why did you choose to teach middle grades?

Definition and Characteristics of Assessment

10. How would you define assessment?
11. In your opinion, what are the characteristics of good assessments?

Assessment Purposes

12. Describe your view of the purpose(s) of mathematics assessment.

Assessment Practices

Please respond to each of the following ONLY with respect to Algebra I courses.

13. Indicate (**by percent**) how much of each of the following factors contribute to the grade you assign students at the end of the semester grading period[2].

________% final examination
________% unit/chapter tests
________% quizzes
________% homework
________% notebooks
________% classwork
________% class participation
________% other (describe:____)
Percents should sum to 100%

14. Indicate (**by percent**) how you use the items contained in the bank. If you do not use the items contained in the bank, please check here: ________

________% final exam
________% unit/chapter test
________% quiz
________% homework
________% classwork
________% class discussion
________% warm-up exercise
________% extra-credit exercise
________% other (describe:____)
Percents should sum to 100%

15. Describe factors, if any, that have encouraged your use of the items.

16. Describe factors, if any, that have discouraged your use of the items.

17. Describe any benefits you have derived in your classroom through the use of the items.

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[2] Questions 13 and 14 were adapted from the Evaluation Practices Survey for Mathematics Teachers—an Eisenhower Program for the Improvement of Mathematics and Science Education funded project under the direction of Thomas J. Cooney.

Instructional Practices

18. Indicate the strength with which you believe the following statement to be true:
The use of the items contained in the bank has affected my instructional practices.

Strongly agree	Agree	Undecided	Disagree	Strongly disagree
1	2	3	4	5

19. If you agree/strongly agree with the statement above, describe how your instruction has been affected.

20. If you disagree/strongly disagree with the statement above, explain why the item bank has had no impact on your instruction.

21. Indicate (**by percent**) how you use the student responses to the items[3].

________ to assign grades (tests, quizzes, homework, etc.)

________ to adjust whole class instruction

________ to adjust individual student instruction

________ to inform students of errors

________ to report what mathematics students know and can do

________ to evaluate instruction

________ to communicate achievement expectations

________ other (describe:____)
Percents should sum to 100%

Teacher Beliefs

22. Describe an experience, activity, a way of thinking or feeling, or another discipline that is as different from mathematics as you can possibly imagine[4].

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[3] Question 21 was adapted from the Evaluation Practices Survey for Mathematics Teachers—an Eisenhower Program for the Improvement of Mathematics and Science Education funded project under the direction of Thomas J. Cooney.
[4] Question 22 was adapted from episodes used by Brown and Cooney in a National Science Foundation project.

23. Five teachers were discussing their purposes for teaching mathematics. You have a total of 100 points. Allocate the points to the position(s) below according to the strength of agreement with your own position on the purpose for teaching mathematics. You may distribute the points in any size increments. For example, you may assign all 100 points to a single position and 0 points to the remaining positions[5].

PATRICIA: Mathematics is important because it provides a context for developing basic skills that are needed in life.

RICHARD: Mathematics is important because it enables students to learn how to think logically and develop other mental capabilities.

OCIE: Mathematics is important because is provides a basis for modeling real world phenomena.

FRANCES: Mathematics is important because it is basic to so many other school subjects students encounter later in high school or possibly even in college.

EDWARD: Mathematics is important because it helps students discover and explore possible relationships between different quantities that vary.

__________ points PATRICIA

__________ points RICHARD

__________ points OCIE

__________ points FRANCES

__________ points EDWARD

Points should sum to 100

[5] Question 23 was adapted from episodes used by Brown and Cooney in a National Science Foundation project.

24. Six teachers were discussing the way they believe students learn mathematics. You have a total of 100 points. Allocate the points to the position(s) below according to the strength of agreement with your own position on how students learn mathematics. You may distribute the points in any size increments. For example, you may assign all 100 points to a single position and 0 points to the remaining positions[6].

DIANE:	Students need to have mathematics broken down into small steps. They master each step beginning with basic material before proceeding to the more complex ideas.
ALICE:	Students need to explore problem situations. Through such explorations they can learn underlying mathematical concepts and principles.
VANN:	Students need to see the logical structure of mathematics and the logical relationships among topics. Understanding this structure facilitates learning.
INGRID:	Students need to be given new situations and challenges which encourage them to adapt and apply their current knowledge to succeed and meet the challenge. They learn mathematics through this process of adaptation.
PAM:	Students need to spend a great deal of time practicing necessary skills. Important skills should be automatic before proceeding to other mathematical ideas.
FRAN:	Students need to consider lots of examples of concepts and procedures. This allows them to generalize and to discover relationships.

__________ points DIANE

__________ points ALICE

__________ points VANN

__________ points INGRID

__________ points PAM

__________ points FRAN

Points should sum to 100

[6] Question 24 was adapted from the Evaluation Practices Survey for Mathematics Teachers—an Eisenhower Program for the Improvement of Mathematics and Science Education funded project under the direction of Thomas J. Cooney.

25. Indicate the strength with which you believe the following statement to be true:

    My participation in the professional development project *Developing Alternative Assessments in Algebra I and Geometry* has affected my classroom instructional and/or assessment practices.

Strongly agree	Agree	Undecided	Disagree	Strongly disagree
1	2	3	4	5

26. If you agree/strongly agree with the statement above, describe how the professional development project has affected your instructional and/or assessment practices.

27. If you disagree/strongly disagree with the statement above, explain why the professional development project has had no impact on your instructional and/or assessment practices.

Future Research

Thank you completing this survey.

In some instances it may be helpful to speak to you about your survey responses.

Please indicate your willingness to be contacted for survey clarification or elaboration purposes.

________ You **MAY** contact me to discuss possible participation in future research.

________ You **MAY NOT** contact me to discuss possible participation in future research.

APPENDIX B

INTERVIEW PROTOCOLS

Interview 1, Leah

[numbers in brackets refer to specific survey questions]

Demographic Information

1) What states and school districts have you taught in?
2) How long have you taught in Magnolia County?
3) What mathematics courses do you like most to teach? Why?
4) What mathematics courses do you like least to teach? Why?
5) How is your teaching assignment determined?
6) [#6] Describe your expertise in alternative assessment.
7) [#6] How do you learn best? In what other ways can people learn?

Definition and Characteristics of Assessment / Assessment Purposes

8) [#7] How do you define knowledge?
9) [#8] What does higher order thinking mean to you?
10) [#8,#9] What does it mean to you for a student to have learned something?

Assessment Purposes

11) [#10] How are the percents you use for assigning grades determined?
12) What external guidelines are placed on your grade determinations?
13) [#11] Does the 10% mean that on each final exam, test, and quiz, 10% of those assessments are made up of questions from the item bank?
14) Where do your assessment questions come from (teacher made, item bank, textbook materials, published materials, etc.)?
15) [#12] In what ways has the information about students' knowledge been valuable?
16) [#13] What was your reaction to students' complaints that the questions are difficult?

17) [#14] Do you grade student responses to the items easier, harder, or the same as responses to other types of questions on quizzes, tests. etc.?

Instructional Practices

18) [#18] What actions have you taken after evaluating instruction using student responses to the items?

Teacher Beliefs

19) [#23] You strongly agreed that your participation in the professional development project has affected your classroom instructional and/or assessment practices. How has your project participation affected those practices?

Other

20) Has the 20% higher-order thinking questions mandate affected your instructional or assessment practices? If so, how? If not, why not?
21) In considering your assessment practices, is there anything you would like most to change? What? Why?
22) In considering your assessment practices, is there anything you will probably not be changing? What? Why?

Additional Questions

23) Why did you decline to continue as department head?
24) What was the purpose of the algebra readiness test given last week? What kind of information did you gain from the results? What action, if any, did you or will you take, given the information? Will the test count as some form of credit? If so, what type?
25) Why did the Asian student take a different test, one for pre-algebra students?
26) You walk frequently among the groups of desks. Why do you do that? What type of assessment, if any, are you making at those times?

27) What do the √, √+, etc., mean on the homework papers? What kind of information have you gathered from assessing homework papers? What action, if any, will you take as a result of the information you have gathered from students' homework?
28) How do you decide what questions are included on the quizzes? Where do the questions come from?
29) How do you use the numerous resource materials contained on your shelves?
30) What did you learn about your students as a result of the "monopoly" game using the properties? What action will you take as a result?

Interview 2, Leah

1) If you consider your teaching as a whole, where would you place yourself on a continuum from traditional to reformed? Why?
2) You ask many general questions in class such as "How are we doing on properties for the test?" What information do you gather from student responses? What decisions do you make or what actions do you take as a result of student responses?
3) Overall, do you think it is difficult to change your teaching practices? What seems to be the initiative for any changes you make?
4) How would you say the use of the items has gone over in your classroom?
5) What would be the extent of your item use if no mandate existed?
6) Regarding the staff development contained in the project, for you what were the most beneficial aspects? Why? What were the least beneficial aspects? Why?
7) What is the most important aspect that drives you to use the items?
8) How do you select which items to use?
9) In general, to what degree would you say you have made progress in implementing reform assessment practices? Reform instructional practices?
10) Give your opinion of your understanding of current reform with respect to teaching, learning, and assessment.

11) Would you say there is an answer for every question and/or a solution to every problem? Elaborate.
12) How would you describe what mathematics is?
13) What does it mean for a student to be actively engaged in learning mathematics?
14) Is the rubric developed during the project helpful? Why or why not?
15) What kind of encouragement, if any, have you been given regarding the use of the items? Did it make a difference?
16) Have you received any pressure to not use the items? What kind, if any?
17) What has surprised you reading the student responses to the items? Why?
18) What changes, if any, would you make regarding item use? Why?
19) What problems, if any, do your students have responding to the items? Do you feel the students are prepared to respond to the items? If not, how could they become more prepared?
20) What personal philosophies regarding your teaching as a whole, if any, encourage your use of the items? Why? Which, if any, discourage your use of the items? Why?
21) Is there anything that might have been more helpful for you that could have been included in the staff development project?
22) What does it mean for a student to think?

Interview 1, Sue

[numbers in brackets refer to specific survey questions]

Demographic Information

1) What states and school districts have you taught in?
2) How long have you taught in Magnolia County?
3) What mathematics courses do you like most to teach? Why?
4) What mathematics courses do you like least to teach? Why?
5) How is your teaching assignment determined?

6) [#6] Why is it important for students to think about why things occur in mathematics and how?
7) How do you learn best? In what other ways can people learn?

Definition and Characteristics of Assessment

8) [#7] What does it mean to you for someone to understand concepts?
9) [#8] How do you define knowledge?
10) What does higher order thinking mean to you?
11) What does it mean to you for a student to have learned something?

Assessment Practices

12) [#10] How are the percents you use for assigning grades determined?
13) What external guidelines are placed on your grade determinations?
14) Where do your assessment questions come from (teacher made, item bank, textbook materials, published materials, etc.)?
15) [#11] Do the percents shown indicate that each of those assessments contain that percentage of questions from the item bank?
16) [#12] What makes the item bank questions more rigorous than others you use?
17) [#12] Why is it important to gain insight to students' reasoning?
18) [#14] In what ways do you use the general feedback you get from students?

Instructional Practices

19) [#16] How did using the items help you change to allowing students to offer explanations instead of you telling them why?

Other

20) Has the 20% higher-order thinking questions mandate affected your instructional or assessment practices? If so, how? If not, why not?
21) In considering your assessment practices, is there anything you would like most to change? What? Why?

22) In considering your assessment practices, is there anything you will probably not be changing? What? Why?

Interview 2, Sue

1) When students are working and you walk among the desks, what kind of information do you gather? What do you do with that information?
2) Have you gathered the students' homework? How was that assessed?
3) Progress reports will be sent out next week. How will you determine the students' grades?
4) The parents will attend Curriculum Night this week. What kinds of things will you do when you meet the parents?
5) You returned the first quizzes. How do you think the students feel about them?
6) Your chapter 1 test contained three open-ended items. How did you pick them? How were they scored? How did the students perform? Any surprises?
7) How were the second quizzes? How did you choose the open-ended items on the quiz? How were the student responses? How did you differentiate between 0-1-2-3 responses?
8) This class does not seem to ask many questions. Do you think that is true, and if so, why do you think that is so?
9) Since the material is review, why aren't all the students making an A?

Interview 3, Sue

1) We discussed how teaching assignments were made. If someone were not successful with their algebra group, they might not get to teach algebra again. What does it mean to be successful with an algebra group?
2) We talked about ways for students to be able to give more successful responses to the open-ended items. What characteristics does a successful response have?

3) Several times you have used the phrase “I wanted them to think.” What evidence must a student show to indicated that he or she has been thinking?
4) If you consider your teaching as a whole, where would you place yourself on a continuum from traditional to reformed? Why?
5) Overall, do you think it is difficult to change your teaching practices? What seems to be the initiative for any changes you make?
6) How would you say the use of the items has gone over in your classroom?
7) What would be the extent of your item use if no mandate existed?
8) Regarding the staff development contained in the project, for you what were the most beneficial aspects? Why? What were the least beneficial aspects? Why?
9) What is the most important aspect that drives you to use the items?
10) In general, to what degree would you say you have made progress in implementing reform assessment practices? Reform instructional practices?
11) Give your opinion of your understanding of current reform with respect to teaching, learning, and assessment.
12) Would you say there is an answer for every question and/or a solution to every problem? Elaborate.
13) How would you describe what mathematics is?
14) What does it mean for a student to be actively engaged in learning mathematics?
15) Is the rubric developed during the project helpful? Why or why not?
16) What kind of encouragement, if any, have you been given regarding the use of the items? Did it make a difference?
17) Have you received any pressure to not use the items? What kind, if any?
18) What has surprised you reading the student responses to the items? Why?
19) What changes, if any, would you make regarding item use? Why?

20) What problems, if any, do your students have responding to the items? Do you feel the students are prepared to respond to the items? If not, how could they become more prepared?
21) What personal philosophies regarding your teaching as a whole, if any, encourage your use of the items? Why? Which, if any, discourage your use of the items? Why?
22) Is there anything that might have been more helpful for you that could have been included in the staff development project?
23) What types of issues do you struggle with the most in your teaching?
24) Several times you spoke of Algebra I being challenging. What is it that makes the course challenging?

APPENDIX C

Classroom Observation Guide

(from the *Professional Standards for Teaching Mathematics,* NCTM, 1991, pp. 25-63)

<u>Worthwhile Mathematical Tasks</u>

The teacher of mathematics should pose tasks that are based on—

- ♦ sound and significant mathematics;
- ♦ knowledge of students' understandings, interests, and experiences;
- ♦ knowledge of the range of ways that diverse students learn mathematics;

and that

- ♦ engage students' intellect;
- ♦ develop students' mathematical understandings and skills;
- ♦ stimulate students to make connections and develop a coherent framework for mathematical ideas;
- ♦ call for problem formation, problem solving, and mathematical reasoning;
- ♦ promote communication about mathematics;
- ♦ represent mathematics as an ongoing human activity;
- ♦ display sensitivity to, and draw on, students' diverse background experiences and dispositions;
- ♦ promote the development of all students' dispositions to do mathematics.

<u>The Teacher's Role in Discourse</u>

The teacher of mathematics should orchestrate discourse by—

- ♦ posing questions and tasks that elicit, engage, and challenge each student's thinking;
- ♦ listening carefully to students' ideas;

- ♦ asking students to clarify and justify their ideas orally and in writing;
- ♦ deciding what to pursue in depth from among the ideas that students bring up during a discussion;
- ♦ deciding when and how to attach mathematical notation and language to students' ideas;
- ♦ deciding when to provide information, when to clarify an issue, when to model, when to lead, and when to let a student struggle with a difficulty;
- ♦ monitoring students' participation in discussions and deciding when and how to encourage each student to participate

Students' Role in Discourse

The teacher of mathematics should promote classroom discourse in which students—

- ♦ listen to, respond to, and question the teacher and one another;
- ♦ use a variety of tools to reason, make connections, solve problems, and communicate;
- ♦ initiate problems and questions;
- ♦ make conjectures and present solutions;
- ♦ explore examples and counterexamples to investigate a conjecture;
- ♦ try to convince themselves and one another of the validity of particular representations, solutions, conjectures, and answers;
- ♦ rely on mathematical evidence and argument to determine validity.

Tools for Enhancing Discourse

The teacher of mathematics, in order to enhance discourse, should encourage and accept the use of—

- ♦ computers, calculators, and other technology;
- ♦ concrete materials used as models;
- ♦ pictures, diagrams, tables, and graphs;

- ♦ invented and conventional terms and symbols;
- ♦ metaphors, analogies, and stories;
- ♦ written hypotheses, explanations, and arguments;
- ♦ oral presentations and dramatizations.

Learning Environment

The teacher of mathematics should create a learning environment that fosters the development of each student's mathematical power by—

- ♦ providing and structuring the time necessary to explore sound mathematics and grapple with significant ideas and problems;
- ♦ using the physical space and materials in ways that facilitate students' learning of mathematics;
- ♦ providing a context that encourages the development of mathematical skill and proficiency;
- ♦ respecting and valuing students' ideas, ways of thinking, and mathematical dispositions;

and by consistently expecting and encouraging students to—

- ♦ work independently or collaboratively to make sense of mathematics;
- ♦ take intellectual risks by raising questions and formulating conjectures;
- ♦ display a sense of mathematical competence by validating and supporting ideas with mathematical argument.

Analysis of Teaching and Learning

The teacher of mathematics should engage in ongoing analysis of teaching and learning by—

- ♦ observing, listening to, and gathering other information about students to assess what they are learning;
- ♦ examining effects of the tasks, discourse, and learning environment on students'

mathematical knowledge, skills, and dispositions;

in order to—

- ensure that every student is learning sound and significant mathematics and is developing a positive disposition toward mathematics;
- challenge and extend students' ideas;
- adapt or change activities while teaching;
- make plans, both short- and long-range;
- describe and comment on each student's learning to parents and administrators, as well as to the students themselves.

APPENDIX D

Magnolia County Open-ended Item Scoring Rubric

0	Response indicates no appropriate mathematical reasoning
1	Response indicates some appropriate mathematical reasoning, but fails to address the item's main mathematical ideas
2	Response indicates substantial and appropriate mathematical reasoning, but is lacking in some minor way(s)
3	Response is correct and the underlying reasoning process is appropriate and clearly communicated