Writing and Mathematical Problem-Solving: Effects of Writing Activities on Problem-Solving Skills of Elementary Students

Jacqueline Fluent
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MS in Mathematics, Science, and Technology Education

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WRITING AND MATHEMATICAL PROBLEM-SOLVING: EFFECTS OF WRITING ACTIVITIES ON PROBLEM-SOLVING SKILLS OF ELEMENTARY STUDENTS

Over the past twenty years, there has been a re-examination of the bonds among the 3Rs—reading, writing, and arithmetic (Bell & Bell, 1985). Research indicates that writing has important implications for the learning and teaching of mathematics (Bell & Bell, 1985; Miller & England, 1989; Silver, Kilpatrick, & Schlesinger, 1990; Meier & Rishel, 1998; Whitin & Whitin, 2000). According to their study, one benefit associated with writing assignments is, they provide an avenue for students to develop and present their own thoughts and perspectives on the mathematics they were studying (Miller & England, 1989). They concluded, “Writing about mathematics is a very empowering experience for students” (p. 310). By participating in writing activities, students are able to construct their own meaning and take control over their learning (Meier & Rishel, 1998). In addition, the objective of writing to learn a content area is to focus the student’s thinking toward a better understanding of the subject matter.

During my graduate work, I have adopted a more constructivist philosophy of teaching. In contrast to the traditional classroom, I believe education should be student-centered, and the teacher’s role is to establish a strong sense of community. According to the NCTM (2000),

“Teachers play an important role in the development of students’ problem-solving dispositions by creating and maintaining classroom environments...in which students are encouraged to explore, take risks, share failures and successes, and question one another. In such supportive environments, students develop confidence in their abilities and a willingness to engage in and explore problems and they will be more likely to pose problems and to persist with challenging problems” (p. 52).
Another benefit is that writing activities "enable learners to make their mathematical thinking visible" (Whitin & Whitin, 2000, p. 17). It is through writing that teachers obtain a window into their students' thinking (Albert & Antos, 2000). Teachers are able to identify error patterns and misconceptions prior to formal assessment. Early identification allows them to reteach immediately rather than waiting until after an exam when non-understanding generally surfaces (Miller & England, 1989).

Recently there has been a demand on our students to explain their mathematical processes in most of standardized testing. The New York State Department of Education recently initiated new mathematics assessments for grades 3 through 8 that include mathematics problem solving components that are set in a context of other subjects and require students to respond to problems using mathematically sound procedures, and clear and complete explanations and interpretations.

During my five years of teaching, I have found that even the most astute students have difficulty communicating their procedures in problem solving. Too often children convey the correct answer, however, they did not know how they found the solution. On many occasions, I have presented problems, both challenging and simple, that students have been able to solve, yet they cannot explain their strategies for finding the answer, or state that they "just knew" the answer. Because of the increasing academic demands being placed on students, I feel that it is necessary for children in my classroom to learn to explain their problem solving strategies and communicate their procedures clearly through writing.
The purpose of this study was to investigate the effectiveness of writing activities on students' achievement, and communication skills of urban elementary students. Two types of writing, transactional and expressive, comprise a variety of methods: questions, explanations, word problems, letters, autobiographies, and journals.

Student writing activities will be assessed using a problem solving themed writing rubric (Appendix A) and student attitudes will be assessed using informal discussions between student and teacher, and student to student, and communication skills will use a combination of assessed writing activities and informal discussions. The purpose of this study is to examine the effects of using writing activities in mathematics on student's achievement and communication skills of mathematical problem solving.

My research was designed to answer two specific research questions: Does integrating writing with mathematics affect elementary students' achievement in problem solving? and Is there a relationship between students' achievement in problem solving and their communication skills?

To insure the validity and reliability of my findings I decided to gather triangulated data for each of the research questions. As Table 1 shows, I used three data sources as a means for collecting and summarizing data for each of my research questions. Table 1 below indicates which data sources were used for each research question.
Table 1: Triangulation of Data Sources

<table>
<thead>
<tr>
<th>RESEARCH QUESTION</th>
<th>DATA SOURCE #1</th>
<th>DATA SOURCE #2</th>
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</tr>
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<tr>
<td>1. Does integrating writing with mathematics affect elementary students' achievement in problem solving?</td>
<td>PRE WRITING SAMPLE RUBRIC SCORES</td>
<td>TEACHER OBSERVATION</td>
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<tr>
<td>2. Is there a relationship between students' achievement in problem solving and their communication skills?</td>
<td>PRE WRITING SAMPLE RUBRIC SCORES</td>
<td>INFORMAL DIALOGUE</td>
<td>POST WRITING SAMPLE RUBRIC SCORES</td>
</tr>
</tbody>
</table>

“America’s schools are not producing the math excellence required for global economic leadership and homeland security in the 21st century” (U.S. Department of Education, 2005). Mathematics is a critical skill in the information age. For this reason, “We must improve achievement to maintain our economic leadership” (U.S. Department of Education, 2005). In order to do so, we must ensure that schools employ scientifically based methods with long-term records of success to teach mathematics and measure student progress.

The “No Child Left Behind” Act requires that states align K-12 assessments with their academic standards for what students should know and be able to do. According to the plan, states, school districts, and schools must be accountable for ensuring that all students, including disadvantaged students, meet high academic standards. States must
develop a system of sanctions and rewards to hold districts and schools accountable for improving academic achievement (U.S. Department of Education, 2005).

In accordance with "No Child Left Behind", New York State has adopted challenging academic achievement standards for the tests in mathematics. The statewide assessment test is geared to the New York State Learning Standards and directly measures specific benchmarks that are part of the Standards. Accountability is becoming increasingly important at the national and local level with a focus on mathematics. Writing activities foster responsibility, a sense of authority, and serve as a record of student progress over a predetermined period.

In the following chapter, I will investigate the trend of writing in problem solving and discuss the effects of infusing writing-to-learn strategies. I will explore the benefits of writing activities, especially the implications that such activities improve students' achievement. In addition, I will examine the types of writing in problem solving and the constructivist ties to writing activities.
LITERATURE REVIEW

In the past, mathematics was viewed as a subject where the teacher, as authority figure, passed on information. The primary goal was to “develop student competency with arithmetic skills” (Burns, 1995, p. 6). Instructional time in mathematics employed the use of practice exercises from textbooks and the teacher acted as answer key. Traditionally, answers were either right or wrong and the primary goal was to elicit correct responses. Recently, much focus has been placed on problem solving and the thought processes, context, and understanding behind it (Miller, 1991).

Research indicates that writing has important implications for the learning and teaching of mathematics (Bell & Bell, 1985; Borasi & Rose, 1989; Miller & England, 1989; Clarke, Waywood, & Stephens, 1993; Rudnitsky, Etheredge, Freeman, & Gilbert, 1995). This review of the literature on writing in mathematics focuses on the current trends of writing in problem solving and discussed the effects of infusing writing-to-learn strategies. The benefits of writing activities and the types of writing in problem solving, types of assessment used in problem solving and the constructivist ties to writing activities will be examined.

Problem Solving

According to the National Council of Teachers of Mathematics (NCTM, 2000) problem solving is a fundamental component of mathematics. This organization stated that problem solving standards in instructional programs from pre-kindergarten through grade 12 should enable all students to-
• build new mathematical knowledge through problem solving,
• solve problems that arise in mathematics and in other contexts,
• apply and adapt a variety of appropriate strategies to solve problems, and
• monitor and reflect on the process of mathematical problem solving (p. 51).

Kenyon (1989) defined problem solving as “the process by which a person uses previously acquired knowledge and skills to attempt to find a resolution, not immediately apparent, to a situation (problem) that confronts him or her” (p. 76). Solutions are not readily available and students encounter disequilibrium. Engaging in problem solving provides students with repeated opportunities to devise, tackle, and explain difficult problems that involve considerable effort (NCTM, 2000). “Good problems give students the chance to solidify and extend what they know and, when well chosen, can stimulate mathematics learning” (NCTM, 2000, p. 51).

According to Countryman (1992), students need to “know and to understand the advantages of different methods of obtaining answers. They need to know when to guess, when to use pencil and paper, when to use a calculator, how to recognize an answer, and whether the answer makes sense” (p. 9). In a study of 29 college mathematics students, which examined the potential benefits of journal writing for mathematics instruction, Borasi and Rose (1989) found “an increased awareness of the process of doing mathematics seems especially important for the students’ success in mathematics” (p. 356). Throughout the study period, students were asked to write three entries per week. By asking students to report in their journals, Borasi and Rose (1989) discovered how students solved a problem or approached the study of a topic. The researchers found students can “be encouraged to become introspective of how they do and learn
Writing and Mathematical Problem-Solving

mathematics, and consequently, be brought to identify more general heuristics to solve mathematics problems as well as to realize the possibility of alternative approaches to the same learning task” (p. 356).

Reflection is another key component of problem solving. Silver, Kilpatrick, & Schlesinger (1990) place much emphasis on reflection. In their text, they state:

“Our thoughts are ephemeral creatures that won’t be pinned down until we articulate them in speech or writing. It is only when we have said or written them, and then have reflected on them, that we know what we are thinking.” (p. 21)

Consequently, because we do not retain much of what we see and hear in mathematics until we have appropriated it on our own, reflection enables students to group their thoughts and “get it out into the open or pin it onto the page” (Silver et al., 1990, p. 21). Once there, students are enabled to examine, repair, or augment their thinking. Burns (1995) suggests classroom lessons should help students learn to use a variety of strategies to solve problems, to verify and interpret results, and to generalize solutions to new problem situations. Writing requires students to formulate and clarify their ideas and, therefore, can contribute to helping students develop these abilities (p. 69). Whitin and Whitin (2000) assert that writing provides students with a record of their thinking that can be analyzed and reflected upon, thus enabling students to develop a personal voice.

Clarke, Waywood, and Stephens (1993) conducted a four-year teaching experiment, which explored the implications of the regular completion of student journals in mathematics. “It was intended that journal writing would assist students progressively to engage in an internal dialogue through which they reflected on and explored the mathematics they met” (p. 237). According to their research, students initiated questions
about what they were doing, and demonstrated increasing confidence in using their own words to link ideas. They were able to make suggestions about possible ways to solve problems, even if these approaches did not prove to be successful. “Through their writing, they showed that they are actively constructing mathematics” (p. 248).

Communication

The Principles and Standards for School Mathematics (NCTM, 2000) emphasize communication as a vital component of mathematics and mathematics education. Communication Standards in instructional programs from pre-kindergarten through grade 12 should enable all students to-

- organize and consolidate their mathematical thinking through communication;
- communicate their mathematical thinking coherently and clearly to peers, teachers, and others;
- analyze and evaluate the mathematical thinking and strategies of others;
- use the language of mathematics to express mathematical ideas precisely (p. 60).

Classrooms that foster communication enable children to “generate ideas, develop a personal voice, and reflect upon their current understandings” (Whitin & Whitin, 2000, p. 6). In addition, such classrooms enable students to speak about their thinking – to discuss observations, explain procedures, and justify that their solutions are correct (Silver et al., 1990). Through this process, students find out what they know and what they do not know. “As students communicate their ideas, they learn to clarify, refine, and consolidate their thinking” (Whitin & Whitin, 2000, p.6).
It is especially important that students share their thoughts clearly and completely to their peers and teachers. By testing their ideas and sharing knowledge in the classroom, students are able to see if their thoughts are understandable. As indicated by the NCTM (2000), "when students are challenged to think and reason about mathematics and to communicate the results of their thinking to others they learn to be clear and convincing" (p.59).

Furthermore, students must have opportunities to listen to the strategies and ideas of others in order to test their own mathematical thinking. Silver et al. (1990) posit, "The only way we have of knowing what our thinking is like is by comparing it with that of others" (p. 23). By listening to others, students gain multiple perspectives, which allow them to make connections and gain better mathematical understanding (NCTM, 2000).

Finally, in order to express ideas precisely, students must use mathematical vocabulary, notation, and structure. Connolly (1989) states "language, oral or written, is an expressive instrument through which we communicate what we have previously thought. It is also a reflective instrument through which we think, alone or with others, about what we are doing" (p. 9).

In a study of 401 third-grade and fourth-grade students, Rudnitsky et al. (1995) designed and field tested instruction intended to help students construct knowledge about addition and subtraction story problems. The method of instruction that was developed and reported on in the study adhered to an important guiding element, that children, building on existing knowledge, actively construct new knowledge through their experience and interactions with the environment" (p. 468). The researchers contend, "The context in which learning is embedded is important. At least some understandings
are negotiated in a social and cultural context. Our instruction recognizes that the most powerful and productive thinking may be done with others and attempts to create a culture of collaboration and thinking aloud” (p. 468). As a result, teachers reported a significant increase in mathematical discourse among students. Through mathematical discussions, students acquired knowledge of word-problems and transferred this knowledge to problem solving.

**Benefits of Writing Activities**

Research has shown that there are many benefits associated with the mathematics writing connection (Bell & Bell, 1985; Miller & England, 1989). Writing activities provide an open, accessible avenue of communication between teachers and students; impart a window to students’ understanding; provide students with a personal voice; and promote a sense of ownership and responsibility for one’s thoughts.

Unfortunately, no classroom teacher has time to interact individually with each student for five minutes every day. However, writing activities provide an avenue of communication between teachers and students that are accessible on a daily basis. Students may convey their thoughts about class, about what they are learning, and may even write about themselves as learners. Miller (1991) declares “A timed, classroom writing session gives the teacher the opportunity to know what each student is thinking during that time and, often, the opportunity to get to know more about each student as a person and a learner” (p. 518).

In an exploratory investigation to ascertain the influence of the use of regular writing in algebra class, Miller and England (1989) conducted an investigation, which studied the
effect of regular writing in algebra classes on students' attitudes and skills in algebra. In addition, researchers examined the influence of reading students' regular, written work on the teachers' awareness of students' problems in and attitudes toward algebra. As part of the study, the teachers were required to spend time each week reviewing students' writings and provide the faculty with their own writings, which would reflect dominant impressions drawn from the students' writings. Following a particular prompt which assessed students' understanding of the rules or "Order of Operations", teachers learned "that just because a student can quote a rule or property does not necessarily mean that they know how to apply the rule or property" (p. 304). Thus, the students' writing increased teachers' understanding.

Because of their confidential nature, writing activities take the focus away from individual students, allowing them to write without drawing attention from their peers. Miller (1991) stated, "given the opportunity to write about their understanding, or lack of understanding, of mathematics, students who will not ask questions in class may express their confusion privately in writing" (p. 518). In 1984, Bell and Bell conducted a study that investigated the effects of a program that combined expository writing with instruction in mathematical problem solving using two ninth-grade general mathematics classes. One class was used as an experimental group, which taught problem-solving skills by using a method combining traditional mathematics techniques with a structured expository writing component. The second class, the control group, was taught only the traditional mathematics methods. According to their findings "through writing, students can communicate to the teacher, either directly or indirectly when they are having difficulty understanding the material" (1985, p. 219). If students are confused, writing
will force them to try to discover what is bothering them. As a follow-up, they recommend that students write an explanation of how they overcame their confusion. Having students write explanations, or tell why they cannot do so, provide a window on their understanding of the material. In turn, information is provided on how the lesson is being received and which material needs to be reinforced (Meier & Rishel, 1998). In addition, when students begin studying a new mathematical concept, teachers often assume that students know very little about the topic. In actuality, students may have formed some rather complete, although possibly partially mistaken ideas about the topic. "One way to detect and examine the ideas students may have prior to formal instruction is to provide a writing assignment" (Silver, et al., 1990, p. 20). "Through this process, the teacher becomes aware at a deeper level of the common understandings or misunderstandings that are characteristic of their students" (Silver et al., 1990, p. 21).

Another benefit of writing in mathematics is that it instills a sense of responsibility in students. Following their study of 500 secondary students, year 7 to year 12, Clarke, Waywood, and Stephens found that articulating their own thinking empowered students. By encouraging students to convey what they have learned puts them in charge of their own thinking. Clarke et al. (1993) contend, "The key appears to be to encourage students to question themselves when they do not understand rather than be dependent upon their teacher to tell them whether to understand. This requires an internalization of authority, responsibility, and control" (p. 248). Additionally, attitudinal benefits evoke from writing activities. Through constant reflection, students develop a sense of confidence in the mathematics at hand (Albert & Antos, 2000)."Students begin to question what they are doing, and show increasing confidence using their own words to link ideas" (Clarke et
al., 1993). They are also able to relate the real world with mathematical concepts. Albert and Antos (2000) proclaim, “As mathematics becomes relevant, students become more motivated to learn and more interested in the learning process” (p. 526).

**Types of Writing**

“Writing to learn” in science or mathematics classes is most about developing students’ conceptual understanding of these subjects by developing their capacity to use the languages of these fields fluently. The writing-to-learn movement is fundamentally about using words to acquire concepts. It is about the value of writing “to enable the discovery of knowledge” (Connolly, 1989, p. 5). Within this framework are two types of writing that enhance conceptual development: transactional writing and expressive writing.

Transactional writing, most commonly found in the mathematics classroom is public in nature and intended to be read by an audience. Transactional writing takes the form of questions, explanations, and word problems. The main purpose is to inform, explain, or report concepts, processes, and applications (Rose, 1989).

The main purpose of question writing tasks is to elicit from students what they do not understand. There are many different ways to incorporate this method. Teachers may collect student-generated questions at the beginning of class and address their issues immediately. This technique provides students with an immediate response and may be used as a springboard for the day’s lesson. Teachers may also write back to the student later and provide clarification and suggestions for the student (Rose, 1989). By providing
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a written response, valuable classroom time can be saved for issues of greater concern while still addressing individual student needs (Bell & Bell, 1985).

Explanations are an effective way to evaluate student understanding (Bell & Bell, 1985; Rose, 1989). Teachers may ask students to write how they solved a particular problem or explain any challenges they may have encountered (Rose, 1989). During their study, Bell and Bell (1985) required students to formally record the problem-solving steps they experienced and to make judgments about them. The writing assignments asked students to concentrate on the process they used in solving specific problems. This process allows students to put into words what they understand and do not understand thus providing teachers with insight into students’ conceptual understanding.

Another form of transactional writing, problem creation, entails students writing their own problems or changing existing problems. This process enables students to see how problems are constructed and helps them learn to deal with situations in which appropriate mathematical ideas and techniques are not obvious (Silver et al., 1990). As part of their study, Rudnitsky et al. (1995) incorporated several lessons, which engaged students in the creation of mathematical stories and story problems. The researchers maintain, “To write a comprehensible problem, a student presumably must understand the concept underlying the problem” (p. 470). This valuable teaching technique demonstrates students’ understanding of the concept underlying the self-created problems (Rudnitsky et al., 1995).

Expressive writing places emphasis on the process of writing and thinking (Rose, 1989). The forms of expressive writing used in mathematics classrooms are letter writing, autobiographical writing, and journal writing. As stated by Rose (1989) “Letter writing
Writing and Mathematical Problem-Solving

has several advantages over other writing tasks; students are familiar with writing letters, like to have an audience for their writing, and feel comfortable including both affective and cognitive thoughts” (p. 23). Students can express thoughts and feelings about mathematics, explain procedures to an absent child, or ask advice on how to solve a particular problem. Following their study, which shared the experiences of secondary teachers who used writing to learn algebra, Miller and England (1989) indicated, “Students seem to write more if they address their comments to someone” (p. 308) like a friend or a past teacher.

Autobiographical writing is comfortable for students because it gives them permission to write about something with which they are familiar (Countryman, 1992). This form of writing encourages students to share previous experiences in addition to responding to structured questions. Through this process, students realize that writing is a “vehicle by which they can recognize feelings and experiences and that the written product can become a record for referral and reflection” (Rose, 1989, p. 24).

Furthermore, as students write about their mathematical background they “come to see themselves as central to the process of learning” (Countryman, 1992, p. 22). It is important for teachers to realize that “students' early school experiences with learning mathematics are critical for forming their basic attitudes and understandings” (Burns, 1995, p. 5).

Journals are multifaceted and address a variety of individual classroom and teacher needs. Subject matter may include summaries, explanations, and questions regarding specific content, descriptions of mathematical procedures, solution strategies, and feelings about class, mathematics, and the teacher (Rose, 1989). One benefit associated
with journal writing is that it gives students time to think at their own rate and to internalize new concepts by relating them to their own experiences” (Kenyon, 1989, p. 84).

Assessment

Assessment is a valuable way to monitor student progress and clarify teacher expectations (Charles, Lester, & O’Daffer, 1988; Danielson & Hansen, 1999). These measurements provide feedback to students regarding their progress; offer parents evidence of their children’s level of functioning; and enable teachers to determine whether the activities accomplished their intended goal (Danielson & Hansen, 1999).

According to Danielson and Hansen (1999) “Performance assessment is any assessment of student learning that requires the evaluation of student writing, products, or behavior” (p.1). Assessments take many forms and accomplish a variety of purposes. Written products include essays, journal entries, and reports. Additionally, behavior assessments provide students with opportunities to demonstrate their knowledge or skill through their behavior (Danielson & Hansen, 1999).

Danielson and Hansen (1999) emphasize the importance of performance task rubrics to evaluate student learning and student work. They suggest educators can save time and effort by adapting existing tasks and rubrics to their own use. Through this approach, teachers benefit from the work of others while using a task that reflects their own needs. Charles et al. (1988) contend that your plan for evaluating progress in problem solving should build on the goals you select. In their research, Charles et al. (1988) discuss several important goals for teaching problem solving and provide effective evaluation
techniques to assess these goals. Furthermore, great importance is placed on the
evaluation of students’ progress in problem solving in two major areas: performance in
using a variety of problem-solving skills and strategies, and attitudes and beliefs
regarding problem solving. Several techniques for evaluating these outcomes include
observing and questioning students, using assessment data from students, and using
analytic scoring techniques.

Informal observation and questioning allows the evaluator to observe individuals,
small groups, or whole classes solving problems while asking evaluative questions and
recording observations (Charles et al., 1988). This method can be used to assess both
performance and attitudes and beliefs and is associated with many benefits:

- It allows for evaluation in a natural classroom problem-solving setting.
- It is flexible, allowing for evaluation of only a few students at a time.
- It allows for evaluation focused on limited, specific aspects of student behavior.
- It allows for evaluation of aspects of performance and attitude that are difficult, if
  not impossible, to evaluate using other techniques.
- It provides a record of observed growth in the development of specific problem-
  solving skills and attitudes and a check on evaluations using other methods
  (p. 19).

Structured interviews also involve observation and questioning, however the
interview is usually limited to one student. Although structured interviews take a great
deal of time, this method allows the evaluator the opportunity to ask probing questions
and allows for responses more elaborate in nature. This technique permits students to
give detailed responses regarding what they are thinking and doing and provides “insight
into a student's thinking processes that are not usually apparent from written work” (Charles et al., 1988, p. 22).

Another technique for evaluating problem-solving performance and attitude goals incorporates self-assessment data from students. One method, student report, instructs students to write about a problem-solving experience. Students reflect on a situation and describe how they solved the problem. A general prompt, such as “Tell about your thinking as you describe how you solved the problem,” may help the student get started (Charles et al., 1988, p. 24).

Inventories are another type of self-assessment in which students check from a list of items to provide a self-appraisal of performance or attitudes. Charles et al. (1988) maintain, “ Inventories are especially useful for measuring student attitudes and beliefs related to problem solving” (p. 29). Using inventories allow students input into the evaluation process and require little of the teacher’s time for collecting data.

Finally, Charles et al. (1988) consider how a student’s written work on a problem can be used to assess development in problem solving. Analytic scoring incorporates an assigned scale of points to certain phases of the process. This scoring method allows the teacher to pinpoint specific areas of strength and weakness and provides specific information about the effectiveness of various instructional activities.

A Constructivist Approach

Often, we encounter objects, ideas, and problems that are unfamiliar to us. Brooks and Brooks (1993) maintain when such a discrepancy occurs “we either interpret what we see to conform to our present set of rules for explaining and ordering our world, or we
generate a new set of rules that better accounts for what we perceive to be occurring” (p. 4). This process of equilibration is how people come to know about their world (Brooks & Brooks, 1993).

Jean Piaget was a genetic epistemologist concerned primarily with cognitive development and the formation of knowledge. “His research led him to conclude that the growth of knowledge is the result of individual constructions made by the learner” (Brooks & Brooks, 1993, p. 25). Piaget (1971) wrote:

The current state of knowledge is a moment in history, changing just as rapidly as knowledge in the past has changed, and, in many instances, more rapidly. Scientific thought, then, is not momentary; it is not a static instance; it is a process. More specifically, it is a process of continual construction and reorganization (p. 2).

In his discussion on constructivism, a theory of knowledge that explains how we know what we know, Zahorik (1997) posits, “knowledge changes as we engage in new experiences that test what we know. These new experiences may cause us to alter or add to our understanding, sometimes in subtle ways and sometimes dramatically” (p. 30). Learning in mathematics also involves a sense-making process. Connolly (1989) asserts, “Learning involves manipulating, not just memorizing, inert information” (p. 3). “It involves listening to the mathematics teacher, but it also involves ‘making sense’ for oneself: producing, applying, and extending knowledge in the way a mathematician or scientist does” (p. 3). All of us are constantly engaged in this process in our everyday lives, but this is also the process that scholars in every discipline follow. “They seek new
experiences to test, and they subsequently construct knowledge through inquiry and scholarly dialogue” (Zahorik, 1997, p. 30).

“In contrast to traditional instruction, current practices for effective mathematics teaching call for actively engaging children with mathematical experiences that help them make sense of mathematical ideas” (Burns, 1995, p. 9). It is the teacher’s role to create a learning environment that fosters the construction of knowledge and this sense-making process (Brooks & Brooks, 1993). In order to do so, teachers must provide a wealth of opportunities for students to work together collaboratively (Brooks & Brooks, 1993). By working in small groups, students benefit from hearing other perspectives and seeing the way that others learn. In turn, “teachers create a classroom culture within which cooperative learning will flourish, and where students feel able to take intellectual risks without fear of punishment, embarrassment, or reprisal” (Alkove & McCarty, 1992, p. 18).

NCTM (2000) contend “teachers play an important role in the development of students’ problem-solving dispositions by creating and maintaining classroom environments in which students are encouraged to explore, take risks, share failures and successes, and question one another” (p. 52). “In such supportive environments, students develop confidence in their abilities and a willingness to engage in and explore problems and they will be more likely to pose problems and to persist with challenging problems” (NCTM, 2000, p. 52). Teachers must also inquire about students’ understandings of concepts and allow their responses to “drive lessons, shift instructional strategies, and alter content” (Brooks & Brooks, 1993, p. 105).
Students come to mathematics class having a variety of real-world experiences on which to continue the construction of their knowledge of mathematics (Miller, 1991). Miller (1991) asserts, “The construction of knowledge requires active engagement in thought-provoking activities. Because writing leads people to think, improved mastery of mathematics concepts and skills is possible if students are asked to write about their understanding” (p. 517). In contention with constructivist views, Borasi and Rose (1989) claim that writing activities “can also positively influence the student-teacher interaction and classroom atmosphere; when students and teachers freely communicate and see each other as caring human beings, the classroom can turn into a more pleasant environment where all members become partners in learning” (Borasi & Rose, 1989, p. 363).

Summary

Research indicates writing activities enhance students’ understanding in problem solving. The review of literature illustrates writing in mathematic genres promotes students’ self-worth, provides daily opportunities for communication between teachers and students, and provides an avenue for teachers to evaluate students’ conceptual development. In addition, rubric assessments and performance tasks are valuable techniques for measuring student progress. Assessments assume many forms and achieve a range of purposes. Furthermore, writing activities foster constructivist ideology and create learning that is more meaningful. Students are enabled to reflect upon previous knowledge and prior experiences in order to revise and rework these ideas to form new knowledge in problem solving.
METHODOLOGY

Using an action research model, I conducted a study to determine the effects of writing activities on students' achievement and communication skills in mathematical problem solving. A goal of the study was to discover improvements in students' performance and communication of problem solving activities. The study stretched over an eight-week period, beginning in January 2006 and ending in March 2006. I wanted to examine my belief that writing activities contribute to higher performance and better communication skills of problem solving activities.

According to Mills (2000), action research is defined as "any systematic inquiry conducted by teacher researchers...in the teaching/learning environment to gather information about how their particular schools operate, how they teach, and how well their students learn" (p. 5). The purpose of action research is to gain insight, employ reflective practice, promote positive changes in the school environment, and improve student outcomes and the lives of those involved.

The study data will be collected from a group of 20 urban elementary students in the fifth and sixth grades from various urban elementary schools located throughout the City of Rochester, New York. None of the students have been identified learning disabled, receive special education services, or have Individual Education Plans (IEP). The assessment tools used to determine any changes in problem solving ability and communication skills, either positive or negative will be collected from student journals, teacher observations, classroom teacher surveys, and informal dialogue. Changes will be determined by comparing writing samples from the first and last sample of the study period (labeled pre- and post-writing sample), as well as weekly assessments conducted by myself and a survey completed by the student’s classroom teacher.
Procedures

Prior to beginning the study, consent was requested from the parents of each of the students (Appendix D). After obtaining permission from their parents, I asked each of the students classroom teacher’s for their assent to do this study (Appendix E). I explained my requirements and provided an opportunity for them to ask any questions they may have. Once I received permission from the parents and students, and teachers gave their assent I preceded with the study.

Throughout the research period, participants and researcher met at a predetermined location. Students were split into two equal groups of 10 participants per group. Participants responded to a variety of writing assignments. Within the writing to learn framework, two types of writing were used: transactional writing and expressive writing. Students wrote their own word problems and used their journals to ask questions they had regarding assignments. In addition, students were asked to write a mathematical autobiography in which they shared previous experiences and their feelings about mathematics. Finally, the journals were utilized to elicit solution strategies and steps for assigned problems.

Each student was given and kept a spiral notebook to solve a variety of problems (Appendix B). Each day, students were presented with a problem and were encouraged to design a plan and document their findings. Students solved problems both independently and as part of small groups. At the start of each session, students were given 15 – 20 minutes to solve their problems and record their strategies. Students then took turns sharing their solution strategies through discussion sessions, which generally lasted about 15 minutes. Journal’s were collected at the end of each session and entries were scored using a problem solving themed rubric then returned to
students at the next meeting time. Students were provided opportunities to respond to their scores, communicate their thoughts to the researcher, and revise their solution strategies.

The quality of problem solving writing was documented by tracking the writing assignments. Solution strategies were scored by using a Problem Solving Rubric found in Arter and McTighe (2001) Scoring rubrics in the classroom: Using performance criteria for assessing and improving student performance. Permission was sought and obtained to use the analytic rubric (Appendix A). Students’ responses to problems were graded in each of three categories: mathematical knowledge, strategic knowledge, and explanation. The three category scores were averaged to get a combined rubric score for the journal entry. Adding the three scores together and dividing by three provided an average rubric score. Early writing sample scores were compared to post writing sample scores to determine if there was a difference in the level of student performance.
RESULTS

The purpose of this study was to determine if writing activities had an effect on student achievement in mathematical problem solving. I have recently gained interest in this topic because of my graduate coursework at St. John Fisher College and because of the importance being placed on written explanations in mathematics on New York State assessments as well as other standardized tests. The study focused on two main principles:

1. Does integrating writing with mathematics affect elementary students' achievement in problem solving?
2. Is there a relationship between student achievement in problem solving and communication skills?

Data for student communication skills for this study were collected using anecdotal records of informal dialogue between students and teacher, student journals, observations, and performance assessments. These assessment tools were used to gauge effects of student communication skills that are discussed throughout the study. While assessing student's attitudes and performance in problem solving, additional themes were identified from anecdotal records, student journals, observations, informal dialogue, and performance assessment. Other themes identified included increase in students' understanding of problem solving and an improved attitude towards problem-solving solutions.

Writing and student achievement in problem solving

This study focused on how integrating writing with mathematics affected student performance in problem solving. Data was collected from three main sources in order to
triangulate the findings. The first two sources involved analysis of student journal entries through use of a problem solving themed rubric. Early writing rubric scores were compared to recent writing rubric scores to determine whether an increase in performance occurred.

Each student kept a spiral notebook to solve a variety of problems. Each day, students were presented with a problem and were encouraged to design a plan and document their findings. Many problems were intended to be solved independently, while others were meant to be worked on in cooperative groups. At the start of each session, students were given 15 – 20 minutes to solve their problems and record their strategies. Upon collection of the journals, students took turns sharing their solution strategies with the class. Discussion sessions generally lasted about 15 minutes.

The quality of problem solving writing was documented by tracking the writing assignments. Solution strategies were scored by using a Problem Solving Rubric (Appendix A) found in Arter and McTighe (2001) *Scoring rubrics in the classroom*. Using performance criteria for assessing and improving student performance. Students received a score from zero to four in each of three categories: mathematical knowledge, strategic knowledge, and explanation. The three category scores were averaged to get a combined rubric score for the journal entry. An average rubric score was calculated by adding the three scores together and dividing by three. Early writing sample scores were compared to post writing sample scores to determine if there was a difference in the level of student performance. These data, along with anecdotal records were used to show the effects of journal writing on students' achievement in problem solving.
Mathematical Knowledge

The Problem Solving Rubric assessed students' mathematical knowledge, strategic knowledge and explanation. In the category of mathematical knowledge, students were evaluated on their knowledge of mathematical principles and concepts, which result in a correct solution to a problem. These data were separated into one-week increments and analyzed. For each week, student's scores in the category of mathematical knowledge were calculated to determine a mean score. These data were used to categorize students in one of three performance ranges: above average, average, and below average. Mean scores ranging from 3.75 to 4.0 were considered above average, scores ranging from 3.0 to 3.5 were considered average, and scores of 2.75 and lower were considered below average. To determine the ranges in score, each possible score was divided by 4 to come up with a percentage. 3.75 to 4.0, the equivalent of 93% to 100% was considered above average. 3.0 to 3.5, the equivalent of 75% to 87% was considered average. 2.75 and below, the equivalent of 68% and lower was considered below average. Table 2 represents the average rubrics scores in the category of mathematical knowledge for the eight-week research period.
Table 2: Summary of Results for Mathematical Knowledge

<table>
<thead>
<tr>
<th>Week #</th>
<th>Above Average Scores</th>
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<th>Percent of Group</th>
<th>Below Average Scores</th>
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% Increase/Decrease | -3 | -15% | +2 | +10% | +1 | +5% |

Analysis of rubric scores indicated very little growth in students' achievement in the category of mathematical knowledge. The number of students with above average scores decreased by 15% over the eight-week study, while the number of students with below average scores increased by 5%. Furthermore, the amount of students with average scores stayed relatively the same with only a 10% increase.

As I analyzed anecdotal records, I looked for behaviors and comments regarding students' performance during the problem solving process. Specifically, notes regarding application of students' mathematical knowledge in multiplication and fractions. Regular observations highlighted students by number, with my notes about their abilities in these areas.

Anecdotal records and analysis of student journal entries provided opposing information. Prior to the study, a majority of students demonstrated weak computational
skills, particularly multiplication. Over the course of the study, new multiplication algorithms were introduced. Journal entries and field notes indicated that most of the students were able to incorporate these new concepts into their solutions. Student 10 communicated, "I like multiplication because I'm getting to learn more multiplication." Student 12 expressed, "I like logic and addition and division and also multiplication because all of that stuff is easy to me." Finally, Student 11 indicated, "I think that problem solving is great because it help with my math like time tables, fractions and other math things."

Consequently, students were better able to execute multiplication algorithms. The classroom teacher of Student 14 had little prior knowledge of multiplication concepts, and as a result, he struggled throughout the first semester. As he learned new skills, he incorporated them into his solution strategies. Later journal entries supported his newfound knowledge evidenced by his use of the lattice method and partial products method of multiplication.

Furthermore, as a culminating activity, I introduced a fairy tale story problem (Appendix C) that integrated fraction mathematical knowledge. Upon completion, students were asked to create their own story problems. Seven of the 20 students, or 35%, composed story problems with a fraction theme. The following are several examples:

Student A wrote:

"There once was a boy, that for Christmas got a velveteen rabbit. Out of all the toys he got that day, the rabbit was the best. For at least two hours the little boy loved him. How long is 1/6 of two hours?"

Student B wrote:

"It was a bright sunny day at the Daytona 500. Jeff Gordon was in the lead when
he realized he had a flat tire. While they were changing the flat tire, they realize that 2/4 of the bolts on his tires had fallen off. If there are six bolts on each wheel, how many bolts fell off.”

Student C wrote:

“Once upon a time, there was a poor villager, who only had 18 worthless beans. One day when he was walking to the market he met a wise elderly man who sold his gold laying hen for one-sixth of the beans. So then the next day he met the same man who said, “I’ll give you 3 gold bars for one third of your beans.” So they made a trade. Then the next day he stumbled upon the wise man and said, “I’ll give you this lovely golden harp for one half of your beans.” How many beans did the villager have left?”

Student D composed a Cinderella themed story. The fourth problem in her story reads:

“Finally, she was at the ball.
Wanting to dance with the finest of all.
There stood 12 men fine and tall.
She took 2/6 of the men and danced
While she danced, she had a ball.
How many men did she dance with in all?”

Although some problems are integral parts of the story, and many are more extensive than others are, I believe the students demonstrated growth in their mathematical knowledge of fractions.

The remainder of the class implemented other types of problems similar to their daily journal problems. Students addressed time concepts, multi-step problems, and logic problems. Review of the assignment indicated that students demonstrated mathematical knowledge on many different types of problems.
Finally, anecdotal records suggested that students exhibited broader mathematics vocabulary as a result of writing about mathematics. Students frequently assisted each other during problem solving activities and discussed the mathematics at hand. Students were generally on task and were noticed communicating to each other through explaining and clarifying ideas.

**Strategic Knowledge**

In the category of strategic knowledge, students were evaluated on their identification of important elements of the problem and the use of models, diagrams, symbols, and/or algorithms to systematically represent and integrate concepts. These data were separated into one-week increments and analyzed. For each week, student’s scores were calculated to determine a mean score. These data were used to categorize students in one of three performance ranges: above average, average, and below average. Mean scores ranging from 3.75 to 4.0 were considered above average, scores ranging from 3.0 to 3.5 were considered average, and scores of 2.75 and lower were considered below average. To determine the ranges in score, I divided each possible score by 4 to come up with a percentage. 3.75 to 4.0, the equivalent of 93% to 100% was considered above average according to our school grading scale. 3.0 to 3.5, the equivalent of 75% to 87% was considered average according to our school grading scale. 2.75 and below, the equivalent of 68% and lower was considered below average according to our school grading scale. Table 3 represents the average rubrics scores in strategic knowledge for the eight-week research period.
Table 3: Summary of Results for Strategic Knowledge

<table>
<thead>
<tr>
<th>Week #</th>
<th>Above Average Scores</th>
<th>Percent of Group</th>
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<th>Below Average Scores</th>
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% Increase/Decrease: -10, -50%, -2, +10%, +8, +40%

Analysis of rubric scores indicated little growth in students’ achievement in the category of strategic knowledge. The number of students with above average scores decreased significantly over the eight-week study. In addition, there was an increase in the number of students with below average scores. Moreover, the amount of students with average scores stayed relatively the same.

Due to limited exposure to problem solving, students had little prior knowledge of solution strategies prior to beginning the study. Multi-step problems and problems involving several solutions proved to be challenging for many students. One indicator was that students did not identify all the important elements of the problem. Many identified some important elements, even most of the important elements, yet failed to demonstrate understanding of the relationships among elements.

In contrast to the rubric, anecdotal records and analysis of students’ response journals provided a window to students’ thinking and strategic knowledge. Teacher field notes
revealed numerous occasions where students utilized manipulatives to assist in their solution strategy.

During our sharing sessions, students provided a variety of strategies for finding solutions. One problem in particular elicited a number of ideas:

“A farmer has 15 animals, some pigs and some chickens. Together, they have a total of 40 legs. How many pigs and how many chickens does the farmer have?“

Of the 20 participants, four students, or 20% executed a guess, check, revise strategy. Two students or 10% accomplished the problem by writing a number sentence. Ten students or 50% constructed a chart or a diagram. One student, 5%, carried out their strategy through a combination of number sentences and charts. While three students, 15%, chose to work backwards. An interesting strategy emerged during the share time following the problem solving activity.

Student E conveyed,

“I counted by twos until I got to 40. Then I put them (twos) into groups of five, and came up with three groups. I multiplied 3 x 5 = 15, so I knew I had 15 animals. Then I circled two groups of twos, five times for the pigs because 4 x 5 = 20. That left me with ten twos. And 2 x 10 equals 20. Twenty pigs’ legs plus twenty chickens’ legs equals forty legs.”

Similar findings were verified through Student F’s journal entries. After demonstrating great difficulty on four fraction problems, he successfully solved the following problem:
“Shirley has 18 coins. One sixth of the coins are quarters, one third of the coins are dimes, and one-half of the coins are nickels. What is the value of Shirley’s coins?”

Student F requested counters to execute the problem and drew a diagram to demonstrate the results. Although the student responded, “I was very confused on this one,” he was able to execute the problem and develop a strategy for problem solution.

Student Explanations of Problem Solving

In the category of explanation, students were evaluated on their written explanation and rationales that translated into words the steps of the solution process and provided justification for each step. Though important, length of the response, grammar, and syntax were not the critical elements of this dimension. These data were separated into one-week increments and analyzed. For each week, student’s scores were calculated to determine a mean score. These data were used to categorize students in one of three performance ranges: above average, average, and below average. Mean scores ranging from 3.75 to 4.0 were considered above average, scores ranging from 3.0 to 3.5 were considered average, and scores of 2.75 and lower were considered below average. To determine the ranges in score, I divided each possible score by 4 to come up with a percentage. 3.75 to 4.0, the equivalent of 93% to 100% was considered above average according to our school grading scale. 3.0 to 3.5, the equivalent of 75% to 87% was considered average according to our school grading scale. 2.75 and below, the equivalent of 68% and lower was considered below average according to our school grading scale.
Table 4 represents the average rubrics scores in explanation for the eight-week research period.

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<th>Week #</th>
<th>Above Average Scores</th>
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% Increase/Decrease: -4 -20% -1 -5% +5 -25%

Analysis of rubric scores indicated a decrease in students’ explanations. The number of students with above average scores and average scores decreased over the eight-week study. In addition, there was a substantial increase in the number of students with below average scores.

One of the provisions required students to explain what was done and address why it was done. In addition, if a diagram was appropriate to the solution strategy, a complete explanation of all the elements in the diagram was required. Many students gave minimal explanation of the solution process, and often explained either what was done or why it was done. In reference to diagrams, many students incorporated diagrams into their solution strategies, yet failed to explain the elements of their diagrams. This information was found to be contradictory to teacher notes taken during informal discussions with the
whole group and with individual students. Analysis of these notes and observations indicated higher development of communication skills as well as use of mathematical terms when spoken.

Overall student growth was monitored and analyzed on a weekly basis. Students’ responses to problems were graded in each of three categories: mathematical knowledge, strategic knowledge, and explanation. The three category scores were combined and each problem-solving exercise was given a holistic score. For each week, the student’s holistic scores were added together and a mean score was calculated.

Analysis of the rubric scores indicated a general decline in student performance. The number of students with above average scores decreased over the eight-week study. In addition, there was an increase in the number of students with below average scores. Moreover, the amount of students with average scores stayed relatively the same. Further, there were only 3 students whose score increased, and 1 whose score made no change either positive or negative over the eight-week study period.

Summary

Based on the triangulation of the sources of data, I found that, although minimal, the overall increase in students’ mathematical knowledge was demonstrated through mathematical discourse during problem solving activities and strategy share sessions. Students also demonstrated that they were able to incorporate and apply new concepts into their solution strategies and student authored story problems.

My analysis of the data from all three instruments also revealed that strategic knowledge was demonstrated through the variety of strategies exhibited in student
journals and shared in discussions. Students often utilized manipulatives to aid in their solution strategies and frequently drew diagrams and charts. Students also employed strategies they learned from share sessions into problems of similar nature.

Finally, examination of the data indicated an overall decrease in students’ explanations. Although students were able to share their solution steps and strategies verbally, their written explanations were often minimal and excluded many important elements. Frequently, students neglected to address both what was done and why. In addition, they often forgot to explain all of the elements in their diagrams.
DISCUSSION AND CONCLUSION

This study was conducted to determine the effects of writing activities on students' achievement in problem solving. A goal of the study was to discover improvements in student performance and student communication skills on problem solving. The driving force of this study is the recent demand on our students to explain their mathematical processes in most of standardized testing, as well as New York State assessments in mathematics in grades 3-8 that require students to respond to problems using reliable methods and provide clear and complete justifications of their problem solving procedures. This chapter will elaborate on my conclusions as they relate to current research and offer recommendations for future research in the area of writing activities and mathematics in an elementary classroom.

In this study, students demonstrated an overall increase in mathematical performance, measured in the analysis of early and recent writing samples and teacher field notes. In addition, all three data collection instruments showed an overall increase in students' communication skills toward problem solving. Furthermore, analysis of the data revealed an existing relationship between students' performance and communication skills, both verbal and written, as they relate to problem solving.

Based on the patterns found within the data, I concluded that students demonstrated an overall increase in mathematical performance when writing activities were integrated into the mathematics curriculum. Positive results in student performance resulted from integrating writing activities into my mathematics teaching practices.

The results of this study and the literature review led me to conclude that writing activities positively affected students' general mathematics performance. However, the
research on the effect of writing on the affective learning outcomes of mathematics is limited at the elementary level.

Analysis of rubric scores indicated little growth in students' achievement in the category of mathematical knowledge. A possible cause is that as the study went on, problems became increasingly difficult. Problems addressed new concepts in which students had little background knowledge. Problems involving fractions and algebraic thinking were especially complex. In addition, multi-step problems proved to be challenging for many students.

Anecdotal records and analysis of student journal entries provided opposing information. Prior to the study, a majority of students demonstrated weak multiplication skills. Over the course of the study, new multiplication algorithms were introduced. Journal entries and field notes indicated that most of the students were able to incorporate these new concepts into their solutions.

Over the course of the study, students used appropriate mathematical terminology in their journal entries and share sessions. Field notes revealed an increase in mathematical discourse among students. Through discussion, students acquired knowledge of word-problems and transferred this knowledge to problem solving. "Through writing, students can experience the role of language in the production of knowledge as well as the presentation of knowledge, and they can themselves become the producers of that knowledge. This corresponds to a constructivist view whereby the most meaningful and memorable learning is that constructed and "owned" by learners themselves" (Rudnitsky et al. 1995 p. 469).
In addition, students were able to correctly execute algorithms during the problem solving process. Through student-authored problems, participants were able to demonstrate knowledge of mathematical principles and concepts. Accordingly, students demonstrated mathematical knowledge on many different types of problems.

As part of this study, several lessons were incorporated to engage students in the creation of mathematical stories and story problems. This method was similar to the study conducted by Rudnitsky et al. (1995) in which the researchers maintain, “To write a comprehensible problem, a student presumably must understand the concept underlying the problem” (p. 470). In both studies this valuable method enabled students to demonstrate understanding of the concept underlying the self-created problems.

Although rubric scores indicated minimal growth in strategic knowledge, students provided a variety of strategies for finding solutions during sharing sessions. I think the length of the study influenced students’ limited growth. In addition, there was no direct instruction provided for problem solving strategies. Through a constructivist framework, I hoped that students would construct their own knowledge and develop their own solutions for solving problems. I had also hoped that they would learn from each other through collaborative experiences and shared discussions.

Emphasis was taken away from formal correctness and finished products, and placed on the processes used toward finding solutions. Students realized that there were several ways to solve problems and demonstrated this knowledge by applying various strategies in their solution steps. Similarly, Borasi and Rose (1989) discovered how students solved a problem or approached the study of a topic. The researchers found students can ‘be encouraged to become introspective of how they do and learn mathematics, and
consequently, be brought to identify more general heuristics to solve mathematics problems as well as to realize the possibility of alternative approaches to the same learning task” (p. 356). The same sense of realization as well as a general feeling of independence was found among the students of this study. During discussions, students reported that they felt more at ease when they could use different methods to solve problems. “An increased awareness of the process of doing mathematics seems especially important for the students’ success in mathematics” (Borasi & Rose, 1989, p. 356).

The examination of integrating writing activities with problem solving upheld the constructivist principles of building on existing knowledge to actively construct new knowledge through experiences and interactions. “Students come to mathematics class having a variety of real-world experiences on which to continue the construction of their knowledge of mathematics. The construction of knowledge requires active engagement in thought-provoking activities. Because writing leads people to think, improved mastery of mathematics concepts and skills is possible if students are asked to write about their understanding” (Miller, 1991, p. 517).

As with Clarke, Waywood, & Stephens study, students were observed initiating questions about what they were doing, and demonstrating increasing confidence in using their own words to link ideas. They were able to make suggestions about possible ways to solve problems, even if these approaches did not prove to be successful. Through their writing, they showed they were actively constructing mathematics (1993).

Analysis of rubric scores indicated a decrease in students’ explanations. One of the provisions required students to explain what was done and address why it was done. In
addition, if a diagram was appropriate to the solution strategy, a complete explanation of all the elements in the diagram was required. Many students gave minimal explanation of the solution process, and often explained either what was done or why it was done. In reference to diagrams, many students incorporated diagrams into their solution strategies, yet failed to explain the elements of their diagrams.

Triangulation of the data sources illustrated a relationship between students’ performance and communication. A comparison of the post writing inventory and an average of rubric scores indicated 68% percent of the participants had corresponding scores on the overall averages of their performance. As well, journal entries provided an avenue of communication for students to express their thoughts and feelings about the problem solving process. In addition to their visible reactions during the problem solving process and share sessions, attitudes were measured through journal responses. Writing activities allowed students to convey enthusiasm for their successful procedures, as well as frustration for the problems they found challenging and difficult.

Recommendations

Writing activities play an important role in the teaching and learning of problem solving. Incorporating writing into the mathematics classroom provides daily opportunities for communication between teachers and students, and provides an avenue for teachers to evaluate students’ conceptual development. Borasi and Rose (1989) hypothesize,

“When students write entries and the teacher reads and responds to them, a new mode of communication is created in the classroom – a private dialogue between
the teacher and each student. Not only can teachers and students learn more
about each other and interact more personally in this way, but a different rapport
between them can be established, with positive benefits for both parties” (p. 360).

Furthermore, as students began to take risks and share their ideas with peers, a
collaborative culture emerged in the classroom. Consequently, children sought the advice
of their classmates and learned from one another. The National Council of Teachers of
Mathematics (NCTM, 2000) indicate, “Student who have opportunities, encouragement,
and support for speaking, writing, reading, and listening in mathematics classes reap dual
benefits: they communicate to learn mathematics, and the learn to communicate
mathematically” (p. 59).

While integrating writing and problem solving is an effective teaching practice, it is
by no means a solution. It is an alternative instructional vehicle with many associated
benefits. Journal entries impart a window to students’ thinking, yet integrating writing
into the mathematics classroom is an arduous task. Assessing and responding to student
journal entries is very time consuming. However, it is time well spent. Teachers
interested in engaging in an action research of this nature must be willing to allocate
extensive amounts of time for evaluation and communication.

Because findings in one group of twenty elementary students cannot be generalized to
all elementary students, a larger population is recommended for further research. Another
recommendation I have pertaining to this action research is to extend the study over a
longer period. Extending the study period over a longer time might address some of the
study’s limitations. Journal entries could be written everyday, instead of twice a week,
which would permit the observer more opportunities to evaluate, and reflect upon students’ responses.

I would also recommend that the researcher join the students in writing activities. Modeling writing and sharing it with students will make the expectations clear. As they share their perspectives as learners, the teacher can impart the point of view as an educator of mathematics. Sharing solutions, thoughts and feelings about the mathematics will foster a caring environment in which everyone learns.

Another suggestion I have is to conduct focus groups and interviews with the participants. Although structured interviews take a great deal of time, this method allows the evaluator the opportunity to ask probing questions and allows for responses more elaborate in nature. This technique permits students to give detailed responses regarding what they are thinking and doing and provides “insight into a student’s thinking processes that are not usually apparent from written work” (Charles et al., 1988).

Last of all, I would adapt the rubric to make it more understandable for students. In turn, I would incorporate self-evaluation as part of the study. By assessing their responses, and those of their peers, students would gain a working knowledge of the rubric. Focus would be taken away from the researcher’s evaluations, and students would gain a sense of ownership and responsibility.

As a result of this study, I have witnessed the benefits of integrating writing activities and problem solving. As a teacher of mathematics, I will continue to support a collaborative culture in the classroom and provide opportunities for students to communicate their thoughts and understandings in all areas of the mathematics curriculum. Communicating ideas and connecting them to what is already known are key
features of students' writings. Through written communication, students provide a window to their understanding of mathematical concepts. Furthermore, writing activities assist students in seeing themselves as active agents in the construction of mathematical knowledge and foster a sense of ownership and responsibility for one's own thoughts. Once written, their thoughts and ideas become reflective tools that can be analyzed, corrected, and expanded upon.
## APPENDIX A: PROBLEM SOLVING RUBRIC

<table>
<thead>
<tr>
<th>SCORE LEVEL</th>
<th>MATHEMATICAL KNOWLEDGE:</th>
<th>STRATEGIC KNOWLEDGE:</th>
<th>EXPLANATION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Shows complete understanding of mathematical concepts and principles; Appropriate terminology; Algorithms complete and correct</td>
<td>Identifies important elements; shows complete understanding of relationships among elements; Reflects appropriate strategy for solving problem. Solution process is nearly complete.</td>
<td>Complete written explanation; explains what is done and why. If a diagram, a complete explanation of all the elements is evident.</td>
</tr>
<tr>
<td>3</td>
<td>Nearly complete understanding of concepts and principles; nearly correct terminology; Executes algorithms completely; computations generally correct but may contain errors</td>
<td>Identifies most important elements; general understanding of relationship among elements; appropriate strategy for solving the problem; solution process nearly complete</td>
<td>Nearly complete explanation of solution process, or explains what was done and begins to address why it was done. May include a diagram with most of the elements explained.</td>
</tr>
<tr>
<td>2</td>
<td>Shows some understanding of the mathematical concepts and principles; May contain major computational errors</td>
<td>Identifies some important elements, but shows only limited understanding of the relationship among them</td>
<td>Some written explanation of the solution process; explains what was done, or why it was done; explanation vague or difficult to interpret. May include a diagram with some of the elements explained.</td>
</tr>
<tr>
<td>1</td>
<td>Limited to no understanding of concepts and principles; may misuse or fail to use mathematical terms; may contain major computational errors</td>
<td>Fails to identify important elements or places emphasis on unimportant elements; may reflect inappropriate or inconsistent strategy; gives minimal evidence of solution process; process may be difficult to identify</td>
<td>Minimal written explanation; may fail to explain what was done and why it was done; explanation does not match presented solution process; may include minimal discussion of elements in diagram; explanation of significant element is unclear.</td>
</tr>
</tbody>
</table>

APPENDIX B: DAILY PROBLEMS

1. In Applebee's Restaurant, a circular table seats 4 people. A rectangular table seats 6 people. There are 18 people waiting to be seated. How can it be done?

2. There are 5 students in Mrs. Martin's class who wish to ride on a "bicycle built for two." How many rides must they take so that each person rides with each other person just one time?

3. Arthur is making lunch. He makes sandwiches with white bread or rye bread. He uses either cheese, jelly, or lunchmeat. How many different sandwiches can he make?

4. Nina asked her dad how old he was. He told her, "If I add 10 to my age and double the result, I will get 84." How old is Nina's dad?

5. A farmer has 15 animals, some pigs and some chickens. Together, they have a total of 40 legs. How many pigs and how many chickens does the farmer have?

6. Lucy has a dog, a parrot, a goldfish, and a Siamese cat. Their names are Lou, Dotty, Rover, and Sam. The parrot talks to Rover and Dotty. Sam cannot walk nor fly. Rover runs away from the dog. What is the name of each of Lucy's pets?

7. Start with 99. You can add or subtract 5, 9, and 13. You must use each number at least once. Your goal is to hit 100.

8. A digital clock shows either three or four digits. At what time do the digits have the greatest sum?

9. November 8 is on Wednesday. Gary's birthday is in November. This year his birthday is on a weekend. The date has two digits. You say the date when you count by twos. The sum of the digits is 8. What is the day and date of Gary's birthday?

10. At Henry's Restaurant, a customer gets a free lunch after paying for six. Caroline ate lunch at Henry's 50 times last year. How many of those 50 lunches were free?

11. If you must use two quarters and a total of 8, 9, or 10 coins, how many different combinations of coins can be used to make a dollar?

12. It takes Jerry 12 steps to go across the classroom. It takes Mary 16 steps. If Jerry has taken nine steps, how many steps has Mary taken?
13. Sam, Nancy, Becky and Jimmy all eat lunch in the same restaurant. All of them are eating there today and Sam eats there every day. Nancy eats there every other day, Becky eats there every third day and Jimmy eats there every fourth day. The next time they are all together they will celebrate. How many days before they will all be together again?

14. List the possible pizza combinations you can pick that have only one topping. Size: small, medium, large; Crust: thick, thin, pan; Toppings: cheese, pepperoni, hamburger.

15. Roy bought a ball that bounces exactly half the height from which it is dropped. He drops it from the top of a building that is 30 meters tall. How high will the ball bounce after its fourth bounce?

16. If you write the numbers from 1 to 99, how many times would you write the digit 1?

17. In a fourth-grade class, two out of four students bring their lunches to school. There are 28 students in the class. How many students in the class bring their lunches to school?

18. Tonya is making bracelets for each of 8 girls coming to her party. Each bracelet will be braided with 4 purple, 3 yellow, 2 green, and 3 blue strings. Each string costs 10 cents. It takes Tonya about 20 minutes to braid each bracelet. How much will the string cost? How long will it take to make all the bracelets?

19. The sum of 3 consecutive numbers is 276. What are the numbers?

20. Sue’s group of friends is going into the 5th grade. Their homerooms will be rooms 12, 14, or 16. All of her friends but 4 are going to room 12. All but 4 are going to room 14, and all but 4 are going to room 16. Not counting Sue, how many children are in her group of friends?

21. Together, 6 boys and 12 girls weigh 1050 pounds. The boys all weigh the same, x pounds. Each girl weighs 55 pounds. What is the weight of one boy?

22. Shirley has 18 coins. One sixth of the coins are quarters, one third of the coins are dimes, and one-half of the coins are nickels. What is the value of Shirley’s coins?

23. Sam and Suzie are twins. Sam has as many brothers as he has sisters. Suzie has at least 1 sister, and twice as many brothers as sisters. How many kids are in the family altogether?

24. Maria needed some magazine pictures for a social studies project. She cut out pages 20, 21, 47, 48, and 104. How many sheets of paper did she remove from the magazine?
25. The news costs $0.35 at the newsstand and is published Monday thru Friday. You can also buy a 4-week subscription for $4.75. If you bought a 4-week subscription, how much would you save over buying it for four weeks at the daily rate?

26. You can roll two dice at a time, a white one and a red one. There are 36 different ways for the "up faces" to land. How many ways will give a sum of 7 on two faces?

27. A tropical storm passed through the town. It began to rain Monday morning at 8:45 a.m. and did not stop until the next day at 2:30 p.m. How long did it rain?
APPENDIX C: STORY PROBLEM

Goldilocks’s grandmother hands a basket of freshly made peanut-butter-and-chocolate muffins to Goldilocks and says, “These are for you, darling, but they just came out of the oven and need to cool before you can eat them. Please set them outside on the porch. You can enjoy them later.”

Goldilocks thanks her grandmother and carefully places the basket on the front porch of their forest home. She then goes inside to take nap while the muffins cool.

Three bears stroll by the cottage and smell the wonderful aroma of the sweet muffins. They follow the smell right to Goldilocks’s front porch and smile when they see both the nameplate on the door and the basket of marvelous muffins. Papa Bear approaches the basket first and eats exactly \( \frac{1}{4} \) of the muffins. “Mmm,” groans Papa Bear, “these are yummy.” Next, Mama Bear eats exactly \( \frac{1}{3} \) of the remaining muffins. “You are right, Papa,” she declares. “These are yummy.” Finally, Baby Bear goes to the basket and eats exactly \( \frac{1}{2} \) of the muffins left by Mama Bear. He licks his lips and says, “Mmm, much better than porridge.” The three bears pat their full bellies, smile contentedly, and continue their walk through the forest.

When Goldilocks awakens from her nap, she immediately runs to the porch to grab the basket of muffins. She is startled to discover that only 3 muffins remain in the basket. “What happened to all the muffins?” she exclaims. “I know there were more than 3 in this basket when I put it here. I wonder how many muffins were in the basket to begin with.”
Use the information from this story to help Goldilocks determine how many muffins were in the basket. If Papa Bear took \( \frac{1}{4} \) of the original muffins, Mama Bear took \( \frac{1}{3} \) of what he left, Baby Bear took \( \frac{1}{2} \) of what remained, and only 3 muffins are left in the basket, how many muffins were in the basket when Goldilocks first put them on the porch? Once you have a solution, explain to Goldilocks how you came up with your answer.
APPENDIX D: PARENTAL CONSENT FORM

January 6, 2006

Dear Parent/Guardian,

I am a graduate student at St. John Fisher College conducting research on the effects of journal writing on student achievement and attitudes in problem solving. The purpose of this study is to compare students' problem solving and communication skills before and after using problem-solving journals as a part of mathematics instruction.

The action research that I will be conducting consists of a pre and post Writing Inventory, student journals, and informal discussions. Students will keep problem solving journals that will contain their daily problem solving efforts as well as reflections written about the problem solving experience. I will be assessing student problem solving achievement using an analytical rubric.

With your permission, your child will meet with me and other participants of the study. Participants will be asked to complete problem-solving questions and participate in informal discussions. Participants will be tape-recorded during various instructional periods. The journals audiotape(s), and any work done by the children will be accessible only to the researcher for data collection and verification purposes, and will be destroyed when the research is complete. Although children will be asked to write their names on their work, their identity will be kept confidential to the extent provided by law. Pseudonyms or coding will be used in all research reports.

You and your child have the right to withdraw consent for your child’s participation at any time without consequence. There are no known risks or immediate benefits to the participants. No compensation is offered for participation. If you have any questions about this research project, please contact me at my home (585) 241-3712.

If you understand the research procedures outlined above and consent to your child’s participation, please sign and return one copy of the parental consent form attached.

Sincerely,

Ms. Jacqueline Fluent
Parental Consent Form

[Blank] I have read the procedure described in the letter from Ms. Fluent dated January 6, 2006.

[Blank] I voluntarily give consent for my child, ____________________________, to participate in Ms. Jacqueline Fluent's study of the effects of journal writing on student achievement and attitudes in problem solving.

[Blank] I would like to receive a copy of the procedure description.

[Blank] I would not like to receive a copy of the procedure description.

Parent/Guardian ____________________________ Date ____________________________
Dear Teacher,

I am a graduate student at St. John Fisher College conducting research on the effects of journal writing on student achievement and attitudes in problem solving. The purpose of this study is to compare students' problem solving and communication skills before and after using problem-solving journals as a part of mathematics instruction.

The student ________________________________ who is in your classroom has been permitted to participate in my action research study by their parent/guardian. The study will take place after school and will not require participants to miss classes, or take on any extra assignments.

I am asking for your assistance in this study by completing an evaluation of this student’s academic progress in the area of mathematics as well as record any observations you may have. You will receive an evaluation form each week from me, and can return the form to me by the student or mail.

If you have any further questions, or choose not to participate, please feel free to call me at my home, (585) 241-3712.

Thank you for your assistance.

Sincerely,

Jacqueline Fluent
REFERENCES


