Using Communication and Writing Strategies in Mathematics

to Improve Content Knowledge

A Special Project

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Using Communication and Writing Strategies in Mathematics

to Improve Content Knowledge

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ABSTRACT

National and state expectations have clearly stated the need for an emphasis to be placed on student communication in mathematics. This study was designed to examine if focused instruction in communication and writing in mathematics would improve student performance on short and extended response items. Writing exercises were integrated into curriculum during the 2006-2007 school year. Formal assessments were given to students five months apart and a holistic rubric was used to assess student performance. A non-independent *t*-test was used to determine significance. The hypothesis statement was rejected and the null accepted. Writing strategies integrated into the mathematics curriculum did not show greater than expected gains in performance for students on open ended response items.

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Introduction

Background for the Project

In 2000, the National Council for Teachers in Mathematics (NCTM) published the *Principles and Standards in School Mathematics* in which the following communication standards for mathematics were stated:

> Instructional programs from pre-kindergarten through grade 12 should enable all students to: 1) organize and consolidate their mathematical thinking through communication, 2) communicate their mathematical thinking coherently and clearly to peers, teachers, and others, 3) analyze and evaluate the mathematical thinking and strategies of others, and 4) use the language of mathematics to express mathematical ideas precisely (2000, p. 60).

In addition, under mandates of the No Child Left Behind (NCLB) act, schools were required to demonstrate measures of academic progress and growth for all students. Washington State standards were outlined in the *Essential Academic Learning Requirements* (EALRs) and progress was tested by the Washington Assessment of Student Learning (WASL). The EALRs (OSPI, 2006a) echoed similar expectations of students in mathematics under the communicates understanding mathematics strand as those stated above by NCTM. The WASL, a criterion based assessment, was designed to measure student progress and growth in such areas. The WASL included multiple-choice, short-answer, and extended-response question formats. The open ended format of some of the WASL items allowed students to develop and articulate answers using higher level thinking skills beyond rote memorization of processes learned. In result, students were tested and assessed not only on mathematical ability but also on how content was communicated.

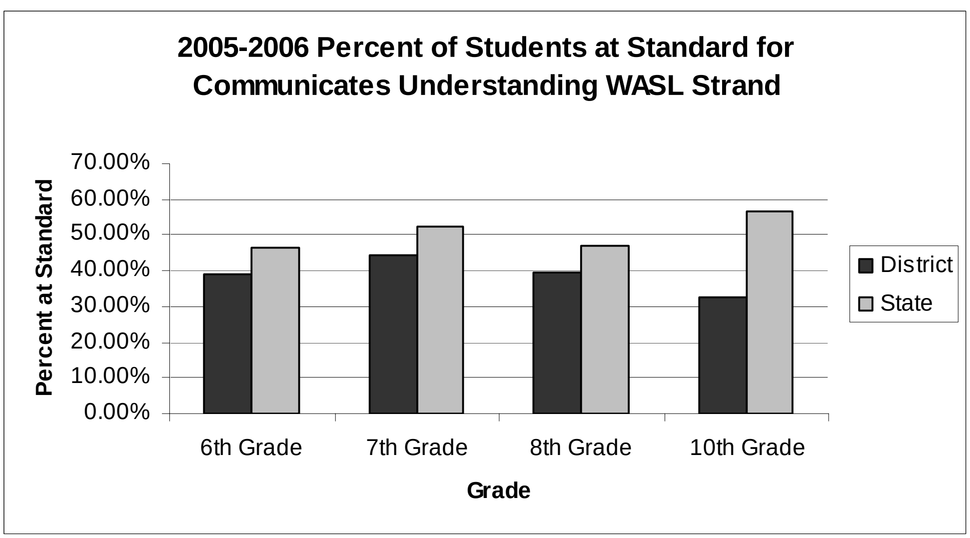
Russek (2006) claimed that communication standards were necessary in mathematics because after speech, written work in the classroom was one of the primary ways students conveyed thoughts and ideas. Quality writing tasks included opportunities for students to clarify, organize, and reflect about mathematics. Burns (1995) claimed that such tasks further enabled students to expand upon mathematical concepts and master content. Through reflection and revision of written work, higher level thinking skills were instigated and students deepened understanding of embedded concepts.

Statement of the Problem

In 2000, the school district of study adopted new mathematics curricula. Connected Mathematics Project (CMP) was selected for use for sixth through ninth grade students and Investigations was selected for use in the elementary school K-5. Both curricula emphasized discovery based approaches and encouraged students to reflect and write about mathematical findings. Students performed less rote memorization skills and engaged in open ended learning tasks that required frequent reflection. Teachers learned that students did not naturally engage in such tasks and further instruction and strategies were necessary to prepare students with the skills needed to write and communicate mathematically about content learned.

Furthermore, low performance demonstrated by data from the communicates understanding WASL strand also indicated the need for instructional modifications. In 2005-2006, 38.8% of 10th grade students met performance for the strand as compared to the state performance of 56.9% (OSPI, 2007d). As shown below in Figure 1, middle grade students had also shown similar deficiencies in performance as compared to the percent of students meeting standard at the state level (OSPI, 2007d).

Figure 1. 2005-2006 Percent of Students at Standard for Communicates Understanding WASL Strand



Note. Figure is adapted from information found at OSPI (2007d)

Purpose of the Project

The project was designed to determine if specific instruction in communication and writing in mathematics improved student performance on open ended assessments such as short answer and extended response items. Moreover, the study identified whether well defined instruction in writing in mathematics provided students with the skills necessary to communicate mathematical thinking more clearly. While 2006-2007 WASL results were not available during the timeline of this project, improved scores for the communication strand on the 10th grade WASL were also desirable to demonstrate progress.

Delimitations

The study used teacher designed pre and post assessments to gauge improvements in presentation of content knowledge. The sample size consisted of 42 10th grade students. The gender of the selected population was 54.8% female and 45.2% male while 69% of students were Caucasian, 30% Hispanic, and 1% Other.

The study was conducted in a small rural community located in Eastern Washington. The study began in the winter of 2006 and concluded in the spring of 2007. The high school where the research was conducted had approximately 305 students. The gender of the school was 57.7% male and 42.3% female. The demographics of the school included 78.3% Caucasian, 20% Hispanic, .3% Black, and .7 % American Indian. 30.7% of students were on the free and reduced lunch program. Special education students consisted of 13.5 %, transitional bilingual at students at 3 %, and migrant students at 0% (OSPI, 2006b).

The annual dropout rate at the school of study was 6.6% while the on time graduation rate was 66%. The teacher demographics of the school consisted of 23 classroom teachers, including two mathematics teachers. Teachers averaged 19.2 years of experience and 56.6% of the teachers had at least a master's degree (OSPI, 2006b).

Assumptions

The researcher assumed that the instructor was properly trained and able to successfully integrate communication and writing strategies into mathematics curricula. The researcher also assumed implemented instruction would improve all students' abilities to communicate mathematical understanding and content. Student work demonstrated a low level of written communication skills prior to implemented instructional strategies.

Hypothesis

Tenth grade students receiving instruction in communication strategies in mathematics will make greater than expected gains as tested by the pre and post WASL short answer and extended response item assessments.

Null Hypothesis

Tenth grade students receiving instruction in communication strategies in mathematics will not make greater than expected gains as tested by the pre and post WASL short answer and extended response item assessments.

Significance of the Project

The researcher's interest in the project stemmed from a continued study of the effectiveness of writing strategies utilized and applied in the content area of mathematics. The study investigated the impact of this type of instruction on student performance on open ended short answer and extended response items and whether significant content gains for students were made. As a result of the study, instructional methods were improved or modified to better impact classroom results. The results of the study were also shared with other disciplines to demonstrate how an emphasis on writing across the curriculum would benefit student learning as a whole.

Procedure

Three geometry classes were used as treatments for this study at a high school in Eastern Washington. Of the 90 total geometry students from all three classes, only results of 10th grade students were tabulated. Thus, 14 students were selected from each class consisting of a total of 42 student participants. Students were given a set of pre assessment problems that included four short answer and three extended response items in November of 2006. Student work was then assessed using a holistic rubric from *Show what you know on the 10^{th} grade WASL* (Arnold, Creek, McGuinness, and Washam, 2001). A separate rubric was used to score the short answer response items and to score the extended response items.

Following the pre test, writing strategies were integrated into the mathematics curriculum. The instructor modeled and discussed written work regularly. Students engaged in both expressive and product writing assignments. The instructor provided prompts for students to guide reflection. Students wrote journal entries that reflected on content learned. Students engaged in daily investigations that required conjecturing and note taking skills. Students were instructed on how to use proper vocabulary and clarity when writing mathematically. Classroom definitions were edited and modified as content knowledge increased. Students completed practice short answer and extended response format questions as regular tasks and on quizzes and tests. Sample student work was analyzed and edited in whole group settings using the classroom document camera. Students practiced scoring written work according to the 0 to 4 and 0 to 2 WASL rubric scales.

Following four months of implemented instruction, students completed a post test. The pre and post tests measured whether focused instruction spent on writing in mathematics improved student content knowledge demonstrated on open ended and short answer response items.

Definition of Terms

extended response item. Extended response items called for an essay on a single topic or several short paragraphs in response to individual items. Students were allowed to use illustrations or graphs to support work. Student work was scored as 0 to 4 points based on specific scoring criteria developed for each item.

item. An item was a question or set of directions on the WASL. Items can be multiple choice in format and could have included a prompt.

rubric. A rubric was a hierarchy of standards used to score student work.

short answer response item. Short answer response items ranged from a few words, numbers, pictures, or involved several sentences. Student responses on short-answer items were scored 0 to 2 points as based on a scoring guide.

Acronyms

CMP. Connected Mathematics Project

EALRs. Essential Academic Learning Requirements

NCLB. No Child Left Behind

NCTM. National Council of Teachers in Mathematics

OSPI. Office of Superintendent of Public Instruction

TAC. National Technical Advisory Committee

WASL. Washington Assessment of Student Learning

CHAPTER 2

Review of Selected Literature

Introduction

Research regarding writing across the curriculum was most prevalent beginning in the late nineteen eighties and early nineties. Following that period, state and national standards were published by NCTM outlining expectations for student communication in mathematics. The standards launched communication as a main element to student success in mathematics. NCTM (2000) stated that communication was "…an essential part of mathematics and mathematical education" (p.60). Communication in the classroom came in a variety of forms. Students who had strong mathematical skills were able to reason, problem solve, connect ideas, and communicate mathematics well using multiple representations. Successful students also engaged in and learned mathematics by doing, investigating, discovering, and discussing ideas. Through discussion and comparison, students shared ideas and were able to connect content at a deeper level. Communication skills included being able to write about ideas discussed and learned clearly and coherently. Moreover, most formal assessments of student communication in mathematics required students to explain mathematical thinking and understanding in writing.

Research discussed a variety of best practice writing strategies used in the mathematics classrooms to improve student learning outcomes. Related qualitative and quantitative research studies including the *Writing to Learn* program were investigated. Writing as an assessment strategy and accountability measure was also examined. Research outlined assessment strategies for teachers when implementing and evaluating written work and reliability and validity of such assessment on high stakes tests was also discussed. Lastly, recommendations for teachers and schools for school wide implementation of writing across the curriculum programs were provided.

Writing Strategies Used in Mathematics Classrooms

Cross-curricular writing activities researched generally fell into two categories of best practice. The first category included open ended written work. Written work focused on the use of everyday vocabulary in student samples. Typically, such writing samples were considered to be expressive in format. Expressive writing samples included learning logs, journals, exit summaries, problem analysis, or peer dialogues. Expressive written work was not intended to be formally assessed by the teacher for a grade. Instead, students were encouraged to write down mathematical thoughts even if the thoughts and ideas were still in the developmental or elementary stages. Written work was designed to encourage and prompt students to write freely about mathematical ideas and content learned.

The second category of written work researched involved product writing. Product writing included short answer, essays, test question responses, and lab reports. Product writing often concluded an experimental activity where students were directed to present results or write about the findings of an experiment. Product writing prompted students to organize mathematical thoughts about an experiment or investigation. In product writing, students typically restated the problem, expressed the findings, and summarized the key mathematical ideas. Students also integrated and used multiple representations such as graphs, tables, diagrams, and equations to demonstrate findings. Product writings were more formal and structured and used for formal assessment.

Related Studies

Research that evaluated the significance of writing across the curriculum as related to gains in content knowledge was analyzed. Research has indicated that writing in mathematics generally fostered achievement gains for students. While evidence suggested that writing across the curriculum was successful, program implementation had varied largely from school to school and many variables were likely to have affected results. Thus, high quantity quantitative studies demonstrating growth in student performance lacked.

One writing across the curriculum program discussed was *Writing to Learn*. The purpose of the *Writing to Learn* program was to create opportunities for students to discover new knowledge and sort through previous understanding. Specific activities used in the *Writing to Learn* study included journals, learning logs, and entrance or exit slips (NWP & Nagin, 2003, as cited in NWREL, 2004). Writing assignments were generally short, informal and designed to help students think through key concepts or ideas presented in class. The teacher avoided evaluating the style of the work and placed greater emphasis on content covered. In one study, students in a low achieving mathematics classroom who received *Writing to Learn* strategies integrated into instruction were shown to have made greater than expected gains on the state competency test as compared to average mathematics students in a traditional classroom (Gladstone, 1987 as cited in Sorenson, 1991).

A second study examined the improvements in grades of a high achieving physics class. The teacher had also integrated *Writing to Learn* techniques in the classroom. The teacher reported improvements in overall grades of each group of students over a three year period (Kurfiss, 1986; Self, 1989). The teacher concluded students made fewer errors in thinking, and work was more organized as a result of implemented writing instruction in mathematics. Poorly written work was attributed to a lack of understanding regarding the content rather than poor writing skills. From a student perspective, writing was "…perceived as a tool for mastering content: 38 out of 43 students surveyed believed that writing essays had helped them understand the physics better" (Kurfiss, 1986, p. 2).

In a third study, high school students read passages and then studied the passage by either taking notes, answering study questions in writing, or writing short "thought-question" essays (Kurfiss, 1986, p. 2). The results of the study stated knowledge increased far more for students who wrote essays than for students in either of the other two conditions. The research also demonstrated that the thinking processes evoked by essay writing were more complex and varied. Thus, students were using higher order level thinking skills when answering questions.

Research has also shown that written work included in curricular areas created attitudinal shifts among students (Winchester, 1987 as cited in Sorenson, 1991). As demonstrated from survey responses, “Most students experienced less apprehension about writing and felt they were better writers after only a year in a school-wide writing across the curriculum project” (Sorenson,1991, p. 2). As a result, the researcher described that student confidence in mathematics and communication increased. Students were forced to make associations between new and old concepts when articulating the mathematics and thus confidence and content knowledge improved.

Student Writing Utilized for Assessment

Research discussed how writing emphasized in the mathematics classroom was beneficial to more than just students. Communication through written work created different interactions between the teacher and student. Classroom environments became more student centered and less teacher centered. As students wrote, organized, and clarified thoughts, teachers were given a clearer picture of what students knew. Sanchez and Ice (2004) discussed how “In this age of accountability, teachers need more and more varied data about their students’ mathematical understanding than ever” (para.1). Open-ended assessment items provided a means for collecting such data from students while students engaged in the learning tasks. Burns (1995) supported such claims stating that classroom assessment was best when “used in the context of the classroom learning and when integrated into the instructional program” (p. 29).

Many open-ended items allowed for more than one answer or different solution processes as well as discussion regarding those different processes. Sanchez and Ice (2004) reported that “Because open ended items invite a wider range of solutions and solution methods than more traditional assessments items, they are better at revealing students’ understanding of mathematics” (para.1). When student work from more traditional tasks was assessed, the instructor evaluated the work based on whether the students performed the procedural task correctly. Written work provided teachers with a different kind of assessment to determine what students knew. Open ended tasks provided opportunities for the teacher to evaluate the level of reasoning and understanding that was applied by the student. By modifying procedural questions to be more open ended, more information about the conceptual understanding of students was acquired.

Beyond the classroom, research demonstrated that the use of open ended items was also evident in high school exit exams and in state mandated exams. A rise in evidence based education and increased attention toward increasing accountability measures for teachers and students through the NCLB act gave rise to such tests. By 2008, Milou (2003) reported that 26 states had planed to implement high stakes exit exams to assess mathematics proficiency. Five states gave the district of each school the option to require a high school exit exam. Of the 26 states that had planned to have exit exams, 17 states included constructed response, short answer, and extended tasks, in addition to multiple choice questions. Eight of the remaining 26 states used only multiple choice formats. The 22 states that did not require exit exams required some form of accountability measure testing. Sixteen of these 22 states used tests that included item formats other than multiple choice (Milou, 2003). The mathematics portion of the WASL was not unique in format when compared to other state tests. The WASL required students to answer multiple choice, short answer, and extended response items.

Writing Assessment Tools

Assessing open ended responses in mathematics required different assessment tools. Writing rubrics were the most common form of assessment used to evaluate written mathematics. A rubric was described as a hierarchy of standards used to score student work (NCTM, 1999). Rubrics focused assessment on student performance as compared to a set of stated criteria. Rubrics provided descriptions of the requirements for the performance and clearly identified the objectives and standards that a student needed to meet to have performed well. “Teachers who have successfully used rubrics report that their students produce higher-quality work when they know the rubric used for scoring" (NCTM, 1999, p. 90). Two types of rubrics, the holistic and the analytic, were discussed.

Analytic rubrics were also used in the classroom setting. Analytic rubrics were most useful when performance on a task was reviewed from several different perspectives or when performance was broken down into several distinct categories. Each of the perspectives or components of the rubric was then scored separately. Analytic rubrics described several levels of performance for each of the perspectives or components given. The combined score obtained from adding analytical scores did not necessarily measure overall quality. NCTM (1999) reported that analytic rubrics failed to address how components contributed to a particular level of overall performance.

In contrast, the holistic rubric captured the overall quality of students' performance on an assessment item. A holistic rubric specified several levels of overall performance along with a list of criteria that characterized each level. Because holistic rubrics focused on the overall quality of students' work, very different papers could have met the same criteria for the same holistic score. Short answer and extended response WASL results were based on holistic rubric scores. The short answer response items were based on a 2, 1, or 0 scale with 2 being high and 0 low. The extended response items were also scored using a holistic rubric, but the rubric was based on a 4, 3, 2, 1, or 0 scale with 4 being high and 0 low.

Much debate was found regarding the consistency and reliability of the scoring process used for open ended items on state mandated tests and exit exams. OSPI (2007e) reported stringent methods used to increase the validity and reliability of the scoring process for mathematics WASL items. Item by item scoring by highly trained scorers was reported to increase consistency and decrease scoring bias and fatigue. One out of 20 item responses were scored twice and supervisors reread an average of 5% of papers scored daily. Validity papers were also inserted into scorer piles and used by supervisors to monitor and ensure consistency. Unique responses were handled by supervisors and scoring directors and scorers were retrained if necessary. Scorers included Washington educators but also pulled from other sources when needed.

Implementation of Writing in the Content Area

Proponents of writing across the curriculum have suggested that teaching students to write should not be equated with integrating writing strategies into the curricular area. Teachers need not have been proficient writers to have incorporated quality written exercises into curriculum. Many teachers lacked the confidence to implement and integrate written components into the content area. Without sufficient training, teachers were reluctant to take on part of what was perceived as the English teacher's job. Most school districts found a year-long plan for in-service and group dialogue necessary in writing in the content area for successful implementation (Sorenson, 1991). Some schools implemented literacy coach positions in buildings or in district. One of the roles of the literacy coach was to help teachers successfully implement reading and writing strategies into all curricular areas.

Teachers who implemented writing in the content area started small. Activities suggested included open-ended writing prompts that encouraged students to write freely following class discussions or at the end of major concepts. Teachers also frequently modeled quality writing samples for students. In addition, time and patience were key factors for improving the written work of students. Students needed time and repetition to become comfortable with writing about mathematics. NCTM supported such research by stating “Students become better writers and thinkers of mathematics when they have regular opportunities to write about mathematics” (1999, p. 62).

Summary

Research covered two main types of writing assignments that were integrated into mathematics curriculum. Expressive writings provided students with opportunities to reflect and summarize learning on a regular basis. Product writings provided students with opportunities to identify the problem, identify a solution, and clearly express a solution to the stated problem in a written format. These two types of writings provided students with a variety of opportunities to express and reflect upon content learned. *Writing to Learn* and writing across the curriculum strategies were investigated and reported that writing had a positive impact on student learning. In addition, the researcher also discussed methods for evaluating written work. Two kinds of rubrics, holistic and analytic, provided the learner with clearly stated learning outcomes and the teacher with specific content guidelines for assessment. The use of rubrics as an assessment tool was important because students were subject to evaluation by a holistic rubric on the WASL. Most importantly, research indicated not all written work created by students in the classroom should be assessed. Students needed to be allowed the opportunity to develop and express ideas and thinking known at the time rather than what should be known. The use of open ended items and assessment of those items on exit and state proficiency exams was also explored. Lastly, recommendations for teachers and schools for implementation of writing across the curriculum were provided and writing across the curriculum was most influential when implemented school wide.

CHAPTER 3

Methodology and Treatment of Data

Introduction

Performance on open ended response items on state mandated tests demonstrated a need for more focused instruction for students in communication in mathematics. Rigorous standards demanded that students be able to perform high level mathematical tasks that demonstrated student understanding. Assessment formats provided opportunities for students to demonstrate understanding and appropriately interpret, organize, and represent mathematical information. Multiple choice and true or false assessment formats were no longer sufficient. To better prepare students for such expectations, the teacher integrated and emphasized writing strategies in regular student learning tasks. The teacher also used WASL item formats and preparatory materials regularly to reach this goal.

Methodology

The study was conducted in the educational setting of a high school in Eastern Washington. The participants of the study included 42 10th grade students from three separate geometry classrooms. The academic results recorded were quantitative in nature. Results of the pre and post test instruments were measured using a holistic scoring rubric for the short answer and the extended response sample WASL items.

Participants

The participants of the study were selected from a population of 90 students enrolled in three different geometry courses at a small rural high school in Eastern Washington. The student population is mostly bicultural, being composed of Caucasian students and Hispanic students. The sample population was then further narrowed. Only data collected from tenth grade students was used in the study reducing the participant number from 90 to 42.

Table 1. Participant Demographics

Participant Demographics	
Caucasian	69%
Hispanic	30%
Other	1%
Male	45.2%
Female	54.8%

Note. Demographics from OSPI (2006b)

As shown above in Table 1, of the forty-two tenth grade students, the predominant race was Caucasian while 30% were Hispanic. The genders were similar with 54.8% female and 45.2% male (OSPI, 2006b). Students ranged in ability level from low to high.

Students in all three geometry classes received instruction from the same geometry teacher and were exposed to the same instructional methods and strategies. The classroom instructor had been teaching the geometry course for four years prior to the start of the study. The instructor had received several in district trainings regarding WASL scoring methods and items analysis. The instructor had also participated in trainings at professional development workshops and summer institutes where strategies for improving communication in the mathematic classroom were discussed.

Instruments

The data gathering instrument used in this study was developed from a variety of WASL preparatory and practice materials collected by the researcher. Questions for the pre and post tests were selected that matched content previously covered in the geometry classroom prior to each test. Four short answer questions and three extended response questions were selected for each. In January of 2004, the National Technical Advisory Committee (TAC) reported results to OSPI regarding a review of the quality of the WASL (OSPI, 2007c). The committee reported methods used to develop and improve the quality of items and tests were consistent with standard technical practices for development of criterion-referenced tests (OSPI, 2007c). TAC further outlined that methods of item development, analysis, and selection were consistent with standard practices for the construction of criterion-referenced tests (OSPI, 2007c). Furthermore, the committee reported that the item development and review processes had contributed significantly to the content validity of the assessments (OSPI, 2007c).

Chosen assessment items had survived a rigorous development and review process. The TAC reported findings that questions used for the WASL adequately represented content appropriate for the tenth grade level as specified by the EALRs (OSPI, 2007c). The aforementioned processes contributed to the content validity of the pre and post assessments used for this research project, assessing whether writing strategies integrated into mathematics classrooms improved student content knowledge.

Validity and consistency in the scoring process of the pre and post assessments were also considered. Holistic WASL rubrics for the communication in mathematics strand were used to score questions and ensured that assessments were based on a specific set of criteria. Scores were totaled for each student. The total score from the pre test and the post test was then used to identify overall significance. Both instruments, the pre and the post test, helped the teacher identify further areas of instructional need for students.

Design

This experimental study used a pre and post test to measure improvements in communication of mathematics in the classroom after implemented writing and communication strategies. The pre test data was collected in November 2006 and the post test data was collected in March 2007. The 42 10th grade students were spread among three classrooms throughout the day. Two classes were morning classes, first and third period, and the third class was in the afternoon during sixth period. All students in every class took the pre and the post test within the 55 minute class period.

<u>Procedure</u>

In the second week of November, all geometry students received a pre-test of four sample WASL short answer questions and three sample WASL extended response questions. The allotted time for the test was one class period of 55 minutes. Additional time was offered if necessary. Questions on the pre-test covered content already presented in the geometry class prior to November. The researcher assumed that all students retained mathematical content covered prior to the November test. The researcher also assumed that because the content had been previously covered, students would be more familiar with the mathematical questions, and thus, results focused more on how those mathematical ideas were communicated rather than the correctness of the problems.

After the administration of the pre-test, the instructor integrated writing and communication strategies into the mathematics curriculum on a regular basis. Students were required to use words, diagrams, and/or pictures to explain answers at all times. Students were prompted to write conjectures and describe mathematical findings from daily lessons. Proper vocabulary was also discussed and used in writings. Furthermore, the instructor provided students with open-ended prompts once per week that created opportunities for students to reflect, explain, and describe content learned. Regularly scheduled assessments such as weekly quizzes and chapter tests also included short answer questions in which students where required to use words, diagrams, and/or pictures to demonstrate understanding. Prior to the post test in March, students also engaged in preparatory work for the mathematics WASL assessment to be held the third week in April. During this time, students worked through *WASL Power!* (New Readers Press, 2006), a booklet that served as a review of mathematics content, contained guided practice questions in each mathematical strand, promoted problem-solving strategies and process skills, and familiarized students with WASL question formats. Some sample WASL questions contained guided practice and instructional tips while others did not.

In March of 2007, a post test was given to all 90 geometry students during the regularly scheduled class period. The post test was identical in design to the pre test. The post test included four sample WASL short answer questions and three sample WASL extended response questions. Questions focused on content covered from January to February. The post test was scored using the holistic WASL scoring rubric.

Treatment of the Data

The data for analysis comprised of the scores gathered from the pre test short answer and extended response WASL practice questions and the post test of the same assessment. The pre test was completed and scored in November and the post test was given and scored the following spring. Instruction in each classroom remained consistent in design and presentation.

A non-independent *t*-test was used to determine growth in student performance. The *t*-test was based on total scores collected from the pre and post test rubrics for each student. The maximum score for each test was 20. The results of the t-test were calculated using the STATPAK (Gay & Airasian, 2006) software and formulas published in *Educational Research: Competencies for Analysis and Application* (Gay & Airasian, 2006, pg. 571).

Summary

Students completed the pre test in November of 2006. The pre test contained four short answer and three extended response WASL format questions. The pre test was scored using the communication in mathematics rubric as a guideline. Following the pre test, the instructor taught writing and communication strategies in daily and weekly lessons. Students also completed WASL preparatory problems from *WASL Power!* (New Readers Press, 2006). The post test was completed the following March of 2007. The post test was scored using the same rubric as used to score the pre test.

CHAPTER 4

Analysis of Data

Introduction

The study compared pre and post short answer and extended response assessment gains in communication in mathematics from three high school geometry classrooms. Of the ninety students in all three classrooms, only the results of 10th grade students were used. The study took place from November 2006 to March 2007 in a small rural Eastern Washington high school. Writing and communication strategies were emphasized in regular curricular tasks. Furthermore, WASL preparatory materials and question formats were covered during March of 2007. All three geometry classrooms were instructed by the same teacher.

Description of the Environment

The study was conducted in a small rural community located in Eastern Washington with 42 10th grade geometry students. The study began in the winter of 2006 and concluded in the spring of 2007. The high school where the research was conducted had approximately 305 students. The gender of the high school was 57.7% male and 42.3% female. The demographics included 78.3% Caucasian, 20% Hispanic, .3% Black, and .7 % American Indian. There were 30.7% of students on the free and reduced lunch program. Furthermore, special education students consisted of 13.5 %, transitional bilingual at students at 3 %, and migrant students at 0% (OSPI, 2006b).

The annual dropout rate at the school was 6.6% while the on time graduation rate was 66%. The teacher demographics of the school consisted of 23 classroom teachers, including two mathematics teachers. Teachers averaged 19.2 years of experience and 56.6% of the teachers had at least a master's degree (OSPI, 2006b).

The treatment classroom contained a variety of learning manipulatives that were available for student use. Students were encouraged to use tools to solve problems. Tools included but were not limited to: a compass and straightedge, patty paper, ruler, string, and calculators. Daily class schedules, lesson delivery, emphasized strategies, and skills remained consistent throughout the study.

Hypothesis

Tenth grade students receiving instruction in communication strategies in mathematics will make greater than expected gains as tested by the pre and post WASL short answer and extended response item assessments.

Null Hypothesis

The purpose of this study was to show that focused instruction that includes an emphasis on communication in mathematics would show greater than expected gains in student short answer and extended response mathematics assessments. The null hypothesis for this study was: 10th grade students receiving instruction in communication strategies in mathematics will not make greater than expected gains as tested by the pre and post WASL short answer and extended response item assessments.

Results of the Study

Table 2 below displays the data collected from the pre and post assessments during the 2006-2007 academic year for 42 10th grade geometry students as well as the class period of each participant.

Table 2.

Pre and Post Data Assessment Results

Participant	Class Period	Pre	Post	Participant (continued)	Class Period	Pre	Post
1	6	2	5	22	3	9	7
2	6	4	10	23	3	10	10
3	6	5	8	24	3	11	12
4	6	5	8	25	3	11	12
5	6	8	12	26	3	13	14
6	6	8	15	27	3	15	10
7	6	9	11	28	3	15	15
8	6	9	10	29	1	5	4
9	6	11	18	30	1	7	6
10	6	12	12	31	1	8	13
11	6	13	11	32	1	9	10
12	6	13	14	33	1	10	4
13	6	14	16	34	1	10	9
14	6	14	12	35	1	11	6
15	3	1	8	36	1	13	8
16	3	5	4	37	1	13	5
17	3	6	9	38	1	14	17
18	3	7	9	39	1	14	12
19	3	7	10	40	1	16	20
20	3	8	6	41	1	16	10
21	3	9	11	42	1	18	19

Note. Maximum score for both the pre and post tests were = 20.

Calculations of independent *t*-scores were produced using the STATPAK (Gay & Airasian, 2006) software. Values used to determine significance were found in the text *Educational Research: Competencies for Analysis and Application* (Gay & Airasian, 2006, pg. 571). The following table, Table 3, indicated the results of the pre and post test short answer and extended response WASL items for the 42 participants of the study.

Table 3.

t-test of Pre and Post Assessment Results

Test	*N*	*M*	*SD*
Pre	42	9.95	3.93
Post	42	10.52	4
df = 40		*t* = 1.20	*p* > .20

Note. Maximum score for pre and post test = 20.

Based on the results of the study, there were not significant differences in the pre and post assessment scores for the 42 participants from the winter of 2006 to the spring of 2007. The hypothesis statement was rejected and the null hypothesis was accepted. There was an increase in the mean scores of the pre and post assessments.

Narrowing the population of the study, Tables 4 indicated the results of 14 1st period students. For this sub population, the null hypothesis was again accepted. A decrease in the mean scores for students on the pre and the post test was evident.

Table 4.

t-test of 1st Period Pre and Post Assessment Results

Test	*N*	*M*	*SD*	
Pre	14	11.71	3.63	
Post	14	10.21	5.18	
df = 13		*t* = -1.38		*p* >.20

Note. Maximum score for pre and post test = 20.

Tables 5 indicated the results of the 14 3rd period students. For this sub population, the null hypothesis was again accepted. An increase in the mean scores on the pre and post test was shown.

Table 5.

t-test 3rd Period Pre and Post Assessment Results

Test	*N*	*M*	*SD*	
Pre	14	9.07	3.73	
Post	14	9.79	2.88	
df = 13		*t* = .94		*p* >.20

Note. Maximum score for pre and post test = 20.

Table 6 indicated the results of the 14 6th period students. For this sub population, the hypothesis statement was accepted with $p<.01$ and the null hypothesis rejected. An improvement in the mean score of the pre and post test was shown.

Table 6.

t-test 6th Period Pre and Post Assessment Results

Test	*N*	*M*	*SD*	
Pre	14	9.07	3.81	
Post	14	11.57	3.31	
df = 13		*t* = 3.25		*p* <.01

Note. Maximum score for pre and post test = 20.

Findings

The results of the study indicated focused instruction in communication in mathematics did not make a significant impact on student performance on the pre and post short answer and extended response assessments with $p>.20$ for total population of 42 10th grade students. However, when results were broken down by class period, significance was shown for the 14 6th period students at $p<.01$. Significance was not shown for 3rd and 1st period students with $p>.20$ for each. Thus, for the population of 42 students studied, instruction in communication in mathematics did not significantly increase student performance and content knowledge on short answer and extended response items. Yet, for 6th period students significant gains were made.

Furthermore, the mean score for all 42 participants did improve slightly from the pre to post test results. The means further demonstrated that 3rd and 6th period students performed similarly on the pre test. First period students performed better on average on the pre test than both 3rd and 6th period students. The means of the pre and post tests demonstrated slight improvement for the 3rd and 6th period students. The means of the pre and post test demonstrated no improvements for 1st period students.

Discussion

Research findings did not support that writing and communication strategies integrated into mathematics instruction increased student performance on short answer and extended response assessment items for the larger population of participants. First period students performed better on the pre test than the post test where as the other two classes showed an increase in mean scores from the pre to the post. These results may have indicated that 1st period students were more confident with content covered in November than in March. Thus, results of the study seemed to have resembled research findings of the *Writing to Learn* program. Students that did not feel confident in the content were less likely to communicate clearly about the solution of the problem. The teacher had assumed that students would retain content learned from instructional lessons presented prior to the pre and post tests. A comparison of student grades on traditional assessments during the same time of the pre and post tests may have yielded more information to explain why significance was achieved for 6th period students but not the other two classes.

Summary

Students in the studied classrooms showed minimal improvements in average scores on the pre-post test assessments from November 2006 to March 2007. The null hypothesis was accepted for the larger population of students as the short answer and extended response assessment results did not support that writing and communication strategies implemented into curriculum significantly contributed to an increase in performance on the assessments.

CHAPTER 5

Summary, Conclusions and Recommendations

Introduction

Many school districts across Washington State have promoted the implementation of writing strategies in all content area and grade level classrooms. Some schools hired literacy coaches to work with teachers district wide to implement high quality reading and writing instructional programs across all disciplines. In mathematics, implemented writing and communication strategies impacted how students constructed, organized, and presented solutions to others. Students explained and reflected about mathematical processes learned, and organize ideas more effectively and clearly. State assessments further mandated that students be capable of demonstrating said learning through open ended question formats. In response, teachers modified curricular approaches and regular assessments to better expose and prepare students for success.

Summary

Writing and communication instructional strategies integrated into the mathematics classroom created more opportunities for students to represent and explain content learned. In this research study, students wrote in multiple ways as guided by best practice research. Students did not naturally know how to apply writing strategies to present mathematical concepts. A curricular need was clearly evident for student success. Related research supported that students assembled old and new knowledge by utilizing the articulation process, and thus, students used higher level thinking skills resulting in better quality work.

In November of 2006, students completed a pre test. After the pre test, the instructor implemented several research based practices in writing in the content area into the classroom. Students learned how to integrate mathematical vocabulary and how to explain mathematical work in writing. Students learned how to incorporate and use diagrams, tables, and equations or expressions along with written explanations. Students engaged in high level thinking tasks and focused less on procedural skills. Such tasks required students to gather information from the question posed and to choose the most appropriate representation of the solution. Students also engaged in WASL preparatory materials. In March of 2007, students completed a post test intended to measure improvements in content knowledge through improvements in writing and communication of that content knowledge. Students work was assessed using a holistic scoring rubric. The rubric allowed for different presentation styles and creativity in student solutions.

Conclusions

The researcher hypothesized that students would perform better on short answer and extended response items if students were more prepared to handle the complexity of such tasks. The study concluded that some students performed better on the post test as compared to the pre test because they had the basic mathematical content and skill necessary to construct a thorough and complete solution. For example, students from 6th period performed significantly better on the post test as compared to the pre test with $p<.01$ where as 1st period students scored considerably better on average on the pre test than the post test. Because instruction, content, and presentation were the same for both classrooms, results indicated that base knowledge may have affected the results of the pre and post assessments.

The researcher also believed that those students who struggled with mathematical content may have improved in the presentation of the answer yet still lacked basic mathematical skills necessary to solve given problems. However, measuring growth in communication skills without assessing accurate representation of the content was not demonstrated by the results of this study.

No significance was found using the assessment designed for this study for the larger population of students tested with $p>.20$. The researcher still believed that integrating writing and communication strategies into mathematics curriculum was an effective instructional strategy that improved the students' abilities to present mathematics more clearly. The study failed to show that the implementation of the aforementioned strategies would significantly improve content scores for all students.

Recommendations

Future research is needed to support that writing and communication strategies helped students understand mathematical content better. This study was not able to ascertain such results for a large sample of students. More in depth research may be able to distinguish a student's ability to solve a problem from a student's ability to represent the solution of that problem in an effective manner. Further research should also use ability grouping to determine if writing and communication strategies are more or less effective for specific groups of students.

The validity of the assessment tool would also need to be further investigated based on the identified results of this research. The questions used for the pre and post assessment must be carefully selected and matched to content covered in the classroom. Smaller, more frequent pre and post assessments might also establish a baseline for student performance and provide more telling results.

The researcher recommends that students should be asked to effectively communicate and write mathematical solutions on a regular basis. Such tasks should not be driven by state mandated tests rather by teachers looking to gain more insight about students'mathematical understanding. Real world situations demand that students are able to gather, organize, and interpret mathematical information in an appropriate manner. Students must continue to engage in mathematics in meaningful ways beyond memorizing rote processes. The goal of teachers must be to create opportunities for students to engage in meaningful mathematics and to provide opportunities for deeper understanding of embedded content. Writing serves as one of many avenues for accomplishing such a goal.

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Appendix A

Appendix A. Short Answer and Extended Response Pre Test

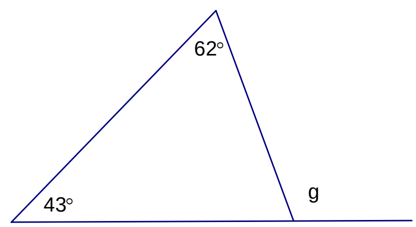
4 Short-Answer Questions (Pre-test)

1. The mean (average) weight of three members of a bobsled team is 161 lb. When the weight of the driver (the fourth member) is added, the mean weight of the team becomes 165.5 lb.

   How much does the driver weigh?

   Show your work using words, numbers, and/or diagrams.

2. Use the triangle below to find the measure of angle g.



   Explain in detail your answer using words, numbers, and/or diagrams.

3. Caprice drives to work 5 days a week. In the morning she takes a 10-mile route. In the afternoon she takes a 12 mile route home to avoid traffic. Caprice's car gets 20 miles to the gallon.

   How many gallons of gasoline will Caprice use each week driving to and from work?

   Show your work using words, numbers, and/or diagrams.

4. Study the pattern shown in the table.

   What is the value of s when r equals 10?

R	0	2	4	6	8	
S	7	11	23	43	71	

   Show your work using words, numbers, and/or diagrams.

3 Extended Response Question (Pre-test)

5. Earl is planning to travel from Seattle to Oklahoma City. His destination is 1,970 miles one-way. He can get a one-way airplane ticket for $400. When he drives, it will take him 3 days to get there, and the cost of renting a car would be $29 per day plus $0.19 per mile.

   Consider his transportation costs alone, would it cost more to fly or drive?

   Show your work to support your answer using words, numbers, and/or diagrams.

6. Mrs. Andrews is supervising an independent study course. Each of the students is required to complete 20 assignments. The list below shows how many assignments each student has completed.

Student	**Number of Assignments Completed**
Mike Cooper	10
Manuel Flores	15
Latasha Williams	11
Sondra Rao	10
Tan Chan	14

   Use the grid to create a bar graph that shows the **percentage** of assignments completed by each student:

   Be sure to include:
   - An informative title that tells who and what the graph is about
   - A scale that fits the data
   - A label for the axes
   - A label for each person
   - A bar to show the number for each completed assignment
   - An accurate display of data

Work Space

7. Naomi and Dana did the following computation.

$$3 \times 4^2 + 7$$

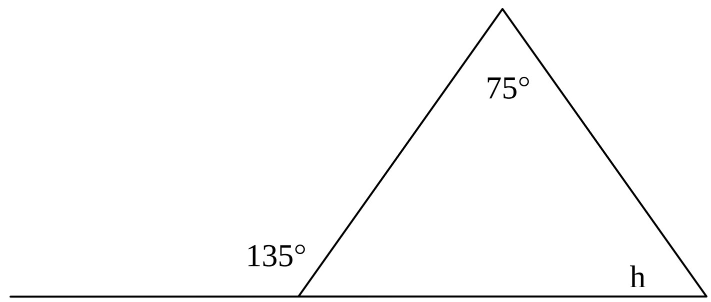
   Namoi's answer was 55. Dana's answer was 151.
   Which student's answer is correct? Describe the other student's error.

Appendix B

Appendix B. Short Answer and Extended Response Post Test

Short-Answer Question (Post-test)

1. Use the triangle below to find the measure of angle h.



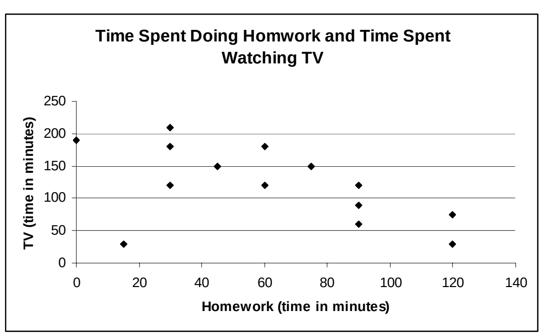
Explain in detail your answer using words, numbers, and/or diagrams.

2. Mr. Lansing has a square garden that is completely surrounded by an old, rickety fence. He plans to tear down the old fence and make his new square garden 4 times the area of his old garden. If the old fence has a total length of 80 ft., how long will the new fence be?

   Determine the total length of the new fence and the area of the new garden.

   Show your work using words, numbers, and/or diagrams.

3. During math class, Mrs. Persico asker her students to keep track of the amount of time they spend watching TV and the amount of time then spend doing homework that night. She then made the scatter plot shown below.



What can you conclude about the relationship between the amount of time spent watching TV and the amount of time spent doing homework?
Explain in detail your answer using words, numbers, and/or diagrams.

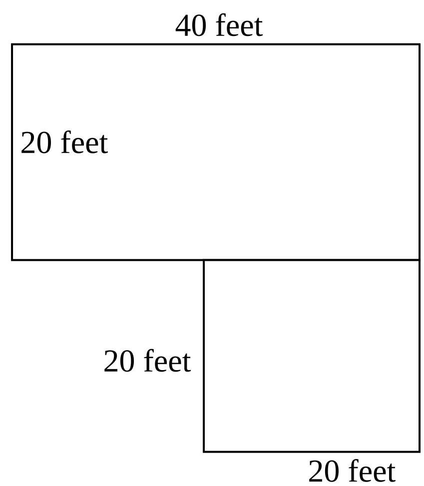
4. Chandra uses an exercise machine at the recreation center for walking. For this machine, 1 lap = 1/16 mile. Chandra sets the speed at 20 minutes per mile and the timer at 30 minutes.

   How many laps will she walk in 30 minutes?

   Explain in detail your answer using words, numbers, and/or diagrams.

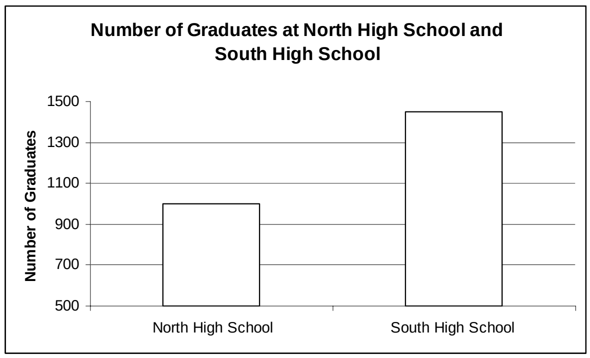
3 Extended Response Questions (Post-test)

5. An Architect created the following floor plan for a house. One of her customers wanted the same floor plan but also wanted to increase the total area by 50%.



What is the total area after the increase? Show your work.

6. Based on the graph below, Susan concluded that the number of graduates at South High School is about twice the number of graduates at North High School.



Explain in detail using words and numbers why Susan's conclusion is not correct.

What is the correct interpretation of the graph? Make a new graph to support your statement.

7. The highway department in a developing country needs to construct roads between eight towns so that there is one road between each pair of towns.

   How many roads are needed?

   Organize your ideas so that you can look for patterns. You may want to create a table or draw a diagram.

   Explain in detail the reasoning behind your answer. Use information from your table or diagram to support your answer.

Appendix C

Appendix C. Rubric for Scoring Short Answer Items

General Scoring Rubric for Short-Answer Items Assessing Mathematical Communication
A **2-point** response shows understanding of how to effectively and appropriately interpret, organize, or represent mathematical information relevant to the concept.
A **1-point** response shows some understanding of how to interpret, organize, or represent mathematical information relevant to the concept; however, the response is not complete or effectively presented.
A **0-point** response shows very little or no understanding of how to interpret, organize, or represent mathematical information relevant to the concept.

Note: Arnold, K., Creek, R., McGuiness, K., Washam, R. (2001). *Show what you know on the 10th grade WASL*. Columbus, Oh: Englefield and Arnold Publishing.

Appendix D

Appendix D. Rubric for Scoring Extended Response Items

General Scoring Rubric for Extended Response Items Assessing Mathematical Communication
A **4-point** response gathers all applicable information from appropriate sources; demonstrates interpretations and understanding in a clear, systematic, and organized manner; represents mathematical information and ideas in an effective format for the task, situation, and audience.
A **3-point** response gathers applicable information from appropriate sources; demonstrates interpretations and understanding in a clear and organized manner; represents mathematical information and ideas in an expected format for the task, situation, and audience.
A **2-point** response gathers information from the appropriate sources; demonstrates interpretations and understanding in an understandable manner; represents mathematical information and ideas in an acceptable format for the task, situation, and audience.
A **1-point** response gathers little information from appropriate sources; demonstrates interpretations and understandings in a manner that may be disorganized or difficult to understand; represents mathematical information and ideas in a format that may be inappropriate for the task, situation, and audience.
A **0-point** response shoes little or no understanding of how to interpret, organize or represent mathematical information relevant to the concept.

Note: Arnold, K., Creek, R., McGuiness, K., Washam, R. (2001). *Show what you know on the 10th grade WASL*. Columbus, Oh: Englefield and Arnold Publishing.