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Transactional Writing: Constructing Knowledge and Reshaping Beliefs in Mathematics*

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Engineering employers agree that a good understanding of engineering science fundamentals, e.g. mathematics, and a good understanding of verbal and written communication, are among the attributes held by successful engineers. Observations confirm that males, particularly at higher levels, excel over females in mathematics performance, but not written performance. Yet research confirms that good writers show higher mathematics achievement than poor writers. This article discusses an interdisciplinary project that improves mathematics achievement and attitude, and communication skills, and hence, equips more students to consider the field of engineering. Potentially, it could increase the numbers of engineering students among underrepresented groups, especially females.

BACKGROUND

A NUMBER of articles, reports and studies confirm the need for exploration and implementation of innovative ways to convince students of the vital importance of studying mathematics which is fundamental in science, engineering and technology. Reflected in the following statements are the risks that must be taken and the changes that must be made so that students receive greater benefits from our teaching efforts.

- Dr Roger Perry, President, Champlain College (Burlington, VT) states, that while it may be fashionable to blame students and teachers for inadequacies, the problem is more systemic in nature. We must start teaching the way people learn.
- Dr Andrew Cherry, professor of social work at Barry University (Miami, FL) suggests that environment plays a significant role in our ability to learn. Students in leading academic countries such as Germany and Japan achieve high grades because dialogue and class participation are not only encouraged, but they are the rule.
- In Community College Week (January 13, 1997) Dr John E. Roueche, director of the Community College Leadership Program at the University of Texas, says the 'real tragedy' is that despite years of massive initiatives to reform and improve our public schools, those efforts have failed and we are still seeing more and more students leaving high schools ill-prepared, under-prepared . . . [in mathematics]'.
- From the research collected by Elizabeth Fennema and Gilah Leder, editors of the text, Mathematics and Gender, it is clear that at the end of secondary school, 'males have learned more and different math than have females' [1]. As all students fully attend to their tasks, teachers should increase mathematics activities, encourage divergent and independent thinking, and perhaps most important, expect all students to work independently and encourage them to engage in independent learning behavior.
- A *Wall Street Journal* editorial (November 22, 1995) noted that '. . . one such emerging reality is that math skills are more important than ever for the American worker.' It has been said that what we achieve in junior high makes a tremendous difference in the wage differential of males with strong versus average skills, females with good versus weaker math skills and generally, the numerate versus innumerate.
- According to Stephen R. Cox (professor of engineering at Temple University, Philadelphia, PA), over the next century, the current scientific and technological workforce assessment of our national needs indicates that if the United States is to be competitive with its foreign counterparts, approximately 600 000 scientists, engineers, and mathematicians will be needed. The decrease in the number of undergraduate degrees earned in these areas, especially among underrepresented students, has become a national issue.

It has been suggested that the most important population to target to fill the workforce needs of this country is a population that is currently underrepresented in science, engineering, technology and

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mathematics. Women, especially minority women, continue to be underrepresented in these male dominated occupations, thus perpetuating women's and minorities' inability to reach higher income levels. In spite of making modest strides in their standardized test scores, and in their academic preparation, females continue to lag behind males in the study of trigonometry, precalculus, calculus, computer mathematics and physics. Their lower levels of participation in the mathematics/science pipeline lead to the economic differences in genders.

According to results from the Third International Mathematics and Science Study (TIMSS), student achievement falls short as students move through middle school and into high school. In mathematics, by eighth-grade, students score slightly below average when compared with their peers in 40 other countries, and by twelfth-grade, all US students are behind children in other countries [2]. It is interesting to note that countries whose students ranked highest on the TIMSS, implement practices that are closer to *Standards*-based mathematics education [3]. The *Standards* are a set of guidelines and benchmarks that insure that mathematics students have been given ample opportunities to communicate with their peers and their teachers in ways indicative of true learning.

In a discussion focused on the challenges that females face in learning math, science and technology, a past National Council of Teachers of Mathematics (NCTM) Board member, Francis Fennell, the Secretary and Deputy Secretary of Education, and other distinguished panelists concluded that the misperception that females can't do as well in math as males may be the biggest culprit. This hidden belief often manifests itself in the classroom. According to recent studies males tend to dominate experiments, discussions and question-and-answer sessions in mathematics and science. Teachers, both male and female, tend to call on males more than females and don't always 'push' females to work diligently on challenging problems. Teachers should develop model strategies that encourage female and minority students and empower them to say, 'I know I can do this!'. According to Fennell, females are sometimes on the edge of involvement. They need to be involved as active speakers, writers and contributors to the process—not only in mathematics and science but in all disciplines.

Within a cognitive framework, 'what a student learns depends to a great degree on how he or she learned it' in terms of active, constructive processes [3]. How a female learns may be dependent on more use of verbal and written problems. The following observations support the need for implementing writing programs in mathematics:

1. Teachers fail to give female mathematics students ample opportunities to communicate in ways indicative of true understanding. This impedes the learning of mathematics.
2. Students, particularly females, hold unhealthy beliefs about mathematics, concerning its nature, behavior, and tasks, e.g. isolation and conceptions of self and others.

These beliefs influence how female students learn mathematics [4]. The paths to advanced levels of mathematics and employment opportunities are hindered often by powerful institutional influences that discourage females from studying mathematics. These influences include assessment and instructional practices that may lead to mathematics avoidance. In particular, all teachers need to be more aware of inequities in their teaching. Educators must **explore** and **implement** innovative ways to convince females of the vital importance of studying mathematics, and **expect** that females will be successful. The teacher is in a key position to motivate and encourage females to continue the study of mathematics and science. Risks must be taken and changes made in the way that things are done so that females receive a greater benefit from our teaching efforts [5]. Studies continue to show that women who drop out of mathematics do so because they lack confidence in the classroom rather than because their grades are low. Females report less confidence and exhibit behaviors that inhibit persistence. If equivalent educational outcomes between the sexes are desired, teachers should increase interactions with females on high-cognitive-level mathematics activities, encourage divergent and independent thinking, and perhaps most important, expect females to work independently and encourage them to engage in independent learning behavior.

A number of efforts are responding to the cry for innovation, but few of these efforts have capitalized on using writing to create within the mathematics classroom '. . . an environment that fosters extensive interaction among students and faculty. [Where] students discuss mathematics inside and outside of class, with faculty members and with each other' [6]. In order to begin to change some of the teacher/female student negative practices and beliefs that interfere with the female student's deeper understanding of mathematics, the focus of educators must shift from learning products to learning processes [4]. A method to teach students mathematics based on writing exercises invites students to be more active and to see themselves as mathematicians [7]. Female students and their teachers will regard mathematics in a new way. The female student who writes is not likely to succumb to emotions and attitudes that impede learning, commonly known as 'math anxiety.' Furthermore, Lax suggests that a sense of camaraderie or belonging, will develop [8]. Birken suggests that the bored female student will be revived, the math-anxious or underprepared student will be less threatened, and the strong student will have been given the opportunity to be creative. Birken also suggests that writing will provide an opportunity to vent frustrations. Writing will generate enthusiasm as female students pass from passivity to activity [9]. Besides serving as a teaching strategy, writing encourages collaboration, develops trust, and improves the atmosphere inside and outside of the classroom [10]. In a study by Lesnak, remedial algebra students in the control group, i.e. those not exposed to the writing-to-learn activities, completed the course with a mean grade of 74.5%, whereas students in the experimental group, averaged 77.7%. Lesnak believes that writing is a valuable tool in improving academic skills [11].

It is by changing behaviors, beliefs, and attitudes *within the classroom* that women become more confident and successful in mathematics and facilitate their pursuit of male-dominated careers. These locales can provide greater educational equity for women in non-traditional fields by implementing activities that will encourage the adaptation of instructional delivery styles and classroom behaviors to meet the needs and concerns of female students. It is important to note that in a two-year study Sue Rosser, Director of the Center for Women's Studies and Gender Research, University of Florida, Gainsville, FL, showed that 'female-friendly' teaching methods may very well help all students [12].

METHODOLOGY

Transactional writing

Britton developed a theory of language and learning based upon language function. As a part of this theory, written text was defined holistically. A discourse category system, i.e. a way of categorizing written text according to its function and audience, resulted. This system is comprised of three main categories of writing: expressive (everyday talk), poetic (poetry, drama), and transactional (expository, persuasive, informing) [13]. These categories represent a continuum of strategies and linguistic techniques, and have been used and/or examined in 26 studies of writing, and 11 critiques of the system [14]. These categories have been empirically tested by Applebee [15]. Britton, Burgess, Martin, McLeod, and Rosen were able to reach a relatively high rater reliability (0.73) when coding writing for function by modifying a calculation used by Loban and Squire [16–18]. Extending Britton's work, Williamson showed the dominance of transactional uses of language, especially in secondary schools and beyond [19]. According to Rose, transactional writing is the kind of public writing students use to develop a clear expression of their mathematical understanding [20]. Students, through written language, record their understanding of mathematical concepts, processes, and applications. It is the kind of writing used in summaries and notetaking [21]. Transactional writing, rather than expressive writing, is most frequently assigned in the mathematics classroom and is meant to be read by an audience, usually the teacher. This distinguishes it from expressive writing.

Sites

The three participating middle schools, from a large, urban public school system in the southeastern United States, were selected in light of recommendations made by the district personnel. Further consideration was given to middle schools with which the funded institution had an articulation agreement. This institution, also located in the southeastern United States, is a large, urban two-year college with six campuses. Middle schools selected had student enrollments that represented the county's racial diversity.

Personnel

At each middle school, two members of the mathematics faculty were selected based upon their assigned classes, their interest in participating (especially their desire to go 'on-line') and the recommendation of school-based administrative personnel. A member of the English faculty knowledgeable in the Florida Writing Assessment Program model was selected [22]. These three faculty members constituted a school project team. The faculty comprising the college team (three members of the mathematics faculty—the principal investigator and two co-principal investigators, and two members of the English faculty) were selected from interested and qualified mathematics and English faculty. One of the members of the English faculty was knowledgeable of the essay component of the College-Level Academic Skills Test (CLAST) model [23]. The project's statistician was formerly of Institutional Research, Miami-Dade Community College (M-DCC). These professionals represented a racially diverse group of females.

Participants

This three-year project, academic years 1996–1999, permitted the application of transactional writing in different groups of student participants in the basic, intermediate and college level mathematics courses, as well as in groups of participants in sixth-, seventh-, and eighth-grade middle school mathematics sequences. The project was to determine whether the combining of communication skills with mathematical skills had a positive effect on female students' achievement/attitude.

College Years #1 and #2

During the Fall terms the transactional writing project experimental group was comprised of students enrolled in four sections of College Preparatory Algebra; four other sections of this course comprised the control group. MAT 0024 introduces students to the basic concepts of algebra. Topics include operations with algebraic expressions, solving linear equations and inequalities in one variable, elementary factoring of polynomials, solving systems of equations in two variables, and an introduction to graphing. Grades earned in college-preparatory courses are not used in Grade Point Computation [GPA]. They are: S: Satisfactory, may continue to the next level of study, generally equated to A, B, or C; P: Progress, course requirements not met, student must repeat, generally equated to D; U: Unsatisfactory, equivalent to F in a college-level course. During the Winter terms the transactional writing project experimental group was comprised of students enrolled four sections of Intermediate Algebra; four other sections of this course comprised the control group. This course, MAT 1033, includes operations with algebraic expressions, linear equations and inequalities, systems of linear equations and inequalities, quadratic equations, exponents and exponential equations, radicals and radical equations, algebraic fractions and fractional equations, applications, graphing, and an introduction to functions. Grades earned in college level courses are used in GPA computation—A [Excellent], B [Good], C [Average], D [Poor], and F [Failure]. In order to meet state-mandated mathematics requirements, i.e. to 'pass', students must earn a grade of C or better.

College Year #3

During the Fall term the transactional writing project experimental group was comprised of students enrolled in one section of Integrated Algebra and Arithmetic (MAT 0012); one other section of this course comprised the control group. MAT 0012 is an integrated course that combines basic mathematics and beginning algebra. Rather than teach arithmetic and algebra skills separately, this course will integrate the two so that arithmetic and algebra skills are taught in an orderly integrated series. Grades earned in this college-preparatory course are not used in Grade Point Average computation [GPA]. They are: S: Satisfactory, may continue to the next level of study, generally equated to A, B, or C; P: Progress, course requirements not met, student must repeat , generally equated to D]; U: Unsatisfactory, equivalent to F in a college-level course. The project was also implemented in one experimental section each of General College Mathematics I (MGF 1113) and College Algebra (MAC 1102). One additional section of each one of these courses comprised the control group. MGF 1113 addresses the essential mathematical competencies in geometry, probability and statistics, and sets and logic. MAC 1102 is a survey of college algebra from an operational rather than theoretical viewpoint. Grades earned in these college level courses are used in GPA computation—A [Excellent], B [Good], C [Average], D [Poor], and F [Failure]. In order to meet state-mandated mathematics requirements, i.e. to 'pass', students must earn a grade of C or better.

During the Winter term the transactional writing project experimental group was comprised of students in one section of Intermediate Algebra, MAT 1033; one additional section of this course comprised the control group. The project was again implemented in two sections each of General College Mathematics I (MGF 1113) and College Algebra (MAC 1102); two sections (one of each) comprised the experimental group while two sections (one of each) comprised the control group.

Middle School Year #1

The transactional writing project was implemented in five classes of sixth-grade Regular Mathematics at middle schools A and B (the experimental group); five other classes of this course comprised the control group. The purpose of M/J Mathematics 1 is to continue the development of the skills of arithmetic and to introduce mathematical content fundamental for higher-level coursework. The content should include . . . numeration, whole numbers, fractions, mixed numbers, decimals, percent, problem-solving, estimation, geometry, measurement, graphing, number theory, and knowledge of the use of calculators and computers. At middle school C, the project was implemented in one class of seventh-grade Regular Mathematics (the experimental group); one other class of this type comprised the control group. The purpose of M/J Mathematics 2 is to continue developing the skills of arithmetic and to continue developing mathematical content fundamental for higher-level coursework. The content should include whole numbers, fractions, decimals, percents, integers, estimation and approximation, number theory, ration and proportion, measurement, geometry, probability, statistics, graphing, algebra, problem-solving,and knowledge of the use of calculators and computers.

At this school, the project was also implemented in one class of Gifted Pre-Algebra (the experimental group) with a second class of this type comprising the control group. This course is develops the skills necessary for success in algebra. Students may be recommended by teacher, counselor or parent and must be tested/identified through Miami-Dade County Public Schools (M-DCPS) Student Services. Topics shall include those that prepare students for advanced level mathematics courses, for example, operations with rational numbers, equations and inequalities, evaluation of formulas, square roots and polynomials.

Middle School Year #2

The project was implemented in nine classes of seventh-grade Regular Mathematics (M/ J Mathematics 2) at middle schools A and B (five experimental and four control). At middle school C, the project was implemented in one class of sixth-grade Regular Mathematics, M/J Mathematics 1, (the experimental group); one other class of this type comprised the control group. Here the project was also implemented in two classes of Gifted Pre-Algebra (seventh- and eighth-grades—the experimental group) with classes of these types comprising the control group.

Middle School Year #3

The transactional writing project was implemented in nine classes of eighth-grade Regular Mathematics, M/J Mathematics 3, at middle schools A and B (five experimental and four control). At middle school C, the project was implemented in two classes of sixth-grade Regular Mathematics, M/J Mathematics 1, (the experimental group); one other class of this type comprised the control group. At middle school C, the project was also implemented in two classes of Gifted Pre-Algebra seventh- and eighth-grades (the experimental group) with two additional classes of this type comprising the control group.

DESIGN

The investigators used 'a two-group design, which allows for more control over extraneous variables' [24]. A non-randomized control group, pre-test/post-test quasi-experimental design was used. The students of the selected mathematics faculty were the student participants and were placed in these classes based upon existing M-DCPS/M-DCC academic criteria. Student participants were not randomly assigned to treatments and were similar in their level of mathematics performance. The first year, half of the number of classes were selected at random to comprise the experimental group. The remaining classes comprised the control group. These selections continued in the second and third years. The experimental and control groups were further separated, by level, according to gender; female components of each group were the focus of the project.

A three-year project permitted the application of transactional writing in different groups of student participants on the college and middle school levels in order to determine whether the combining of communication skills with mathematical skills had a positive effect on female students' achievement/attitude. The tenure of the project permitted validation and enabled formative evaluations to be used as a guide for redesign and restructuring of the program. This time frame increased the validity and reliability of the project's results.

PROCEDURES

The project design is a result of actual experimentation with writing-to-learn that began in Spring, 1989 and doctoral level research conducted during Winter 1990 [25]. During the Fall term of 1996, all teams conducted a hands-on pilot study. The actual research project was implemented during the Winter term of 1996 and the Fall and Winter terms of 1997 and 1998. The experimental group received whole class instruction including transactional writing exercises. Transactional writing exercises (Fig. 1) exemplified writing as a tool to learn, reflected discoveries made by students in the classroom, and as appropriate, adhered to specific objectives of the mathematics components of the CLAST and the Stanford Achievement Test [23, 26]. These writing exercises were a significant part of the teaching/learning process and were given as a regularly scheduled part of students' homework or classwork; the subject matter was relevant to the instruction received in class, and grades earned on these writing exercises were considered in the computation of course grades. Furthermore, evaluation of the exercises by the respective English faculty team member followed the state-mandated writing assessment paradigms of the essay/writing component of the CLAST or the Florida Writing Assessment Program, respectively [23, 22].

A split-page format was used; students wrote on the left side of the paper (Fig. 1). Writing exercises were 'collected' by the assigned mathematics investigator and examined for content and accuracy. The mathematics investigator acted as the audience for the writing exercises. The investigators commented on any errors, omissions, and inconsistencies that were observed; typically, occurrences that the investigator looked for were failure to define terms/provide reasons, and failure to answer the question [27]. In light of the project's goal of continued superior performance in the area of literacy, students were held accountable for *what* they put on paper and *how* they put it. Rather than teach them that 'incompetence in their language is acceptable', this project sought to 'demonstrate the [mathematics] and . . . English [departments] are unified in valuing writing' [28]. Drafts were critiqued for syntax and coherence by a designated English faculty project member. This collaborative effort towards state-mandated quality writing supported an interdisciplinary writing-across-the-curriculum effort. Each investigator recorded for her classes appropriate comments/suggestions on the right side of the paper (Fig. 1). The exercises were returned to the students. Using the critiques of both the mathematics and English investigators, students were required to submit a revision of each exercise. The revision was commented upon and rated for accuracy on a six-point scale (Fig. 2) by the respective mathematics investigator and was also rated for content and syntax according to the appropriate state-mandated essay/writing rubric (Fig. 3) by the respective English investigator. These scores were recorded by the mathematics investigator. The control group also received whole class instruction, as did the experimental group, but without transactional writing exercises.

It was hypothesized that female students enrolled in mathematics classes receiving whole

MAT 0024

Name____________________ **REVISION**
Instructor____________________ Term Fall Grade M/L 5/5

W. A. #1: Explain to Jezel how to ADD INTEGERS. Give an example that demonstrates that these explanations apply to numbers that are not integers.

The explanation of how to add Integers is as follows. When finding the sum of two Integers there can be two cases. Either they'll have like signs (either both positive or both negative), or they'll have unlike signs (one positive and one negative). When adding two integers that have like signs, you add the absolute values of the two Integers, and keep the same sign. On the other hand, when adding two Integers that have unlike signs, you subtract the absolute values of the two Integers (smaller from larger) and give the answer the sign of the largest number.

Example:
add –3 + 7

Solution:
*Subtract the 3 from the 7
*Give the answer the sign of 7 (+) since /7/ > /-3/

Answer would be (4)

*Now here's an example that demonstrates that this explanation applies to numbers that are not integers.

-1.2 + 2.2

Subtract the absolute value of –1.2, from the absolute value of 2.2. When doing this the answer is –1.2 + 2.2 = 1. When by giving the sign of the greatest value, which would be positive (2.2), one comes up with positive 1 is the correct answer.

Comments:

diction (word choice)
☺
☺!
common splice –start a new sentence!
☺!!
also called the?
The sum would always be positive?
and where'd the '3' & '7' come from?
~~why?~~ bravo!
This section is a little confusing! Make sure your directions are complete.
ok!
You've done a really good job of giving directions. Keep it up!
?
wouldn't it always?
Great practice assignment
Thanks for sharing....

Fig. 1. Writing assignment sample.

MATH RUBRIC

0 Pt.	**Unable to read, unscorable**
1 Pt.	**The information provided does not relate to the prompt.**
2 Pts.	**The basic concept is unclear. The writing shows significant confusion.**
3 Pts.	**The writing addresses the prompt, but there are still some mathematical errors.**
4 Pts.	**The writing focuses on the prompt, but there are still minor problems with clarity and mathematical vocabulary.**
5 Pts.	**The writing clearly and adequately addresses the prompt with good mathematical vocabulary and precise directions.**
6 Pts.	**The writing accurately explains the prompt with clear and effective word choice and with individual creativity and style.**

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Fig. 2. Rubric for mathematics.

class instruction, including transactional writing would demonstrate a greater problem solving ability and a more positive attitude towards the study of mathematics than their non-writing counterparts.

MEASURES AND DATA COLLECTION

Data were gathered with respect to demographic variables, gender, ethnicity, and age. Inter- and intra- group comparisons were made on these variables according to pre- and post- attitude and achievement scores. The independent variable in this study was a treatment consisting of level and content-area specific written exercises. The dependent variables were achievement between the female (male) components of the experimental and control groups (by level and class), and attitude between the female (male) students of the experimental and control groups (by level and class).

Achievement on the college level was measured by using a version of the Elementary Algebra Skills test which is one of the four placement tests in mathematics, each designed to provide information about readiness for an entry level course. These tests comprise the Florida Multiple Assessment Programs and Services: Assessment and Placement Services Colleges and Universities Program [29]. This instrument contains thirty-five multiple choice items dealing with topics found in most first-year algebra courses. Students took a different form of the test twice: pre-test and post-test. Achievement was determined by raw scores (the number of correct answers). On the middle school level, achievement was measured using the mathematics portion of the Stanford Achievement Test which is four tests representing a sample of the major components of school mathematics curricula in each grade. This annual test is a basic, multiple choice battery [26]. Achievement was determined by scaled scores.

Attitude was measured by the Revised Mathematics Attitude Scale [30]. (Fig. 4) This instrument contains 20 items; 10 items connoting negative attitudes and 10 items connoting positive attitudes. A five-point scale weighted with integers from one to five, in the direction of strongly disagree-strongly agree is used. The scores for each item were added to yield an individual's score. Participants completed the attitude scale twice; pre-test and post-test. On the college level, pre-tests were administered during the first few class meetings, preceding the achievement instrument. On the middle school level the Stanford Achievement Test is typically administered in the Spring [26]; pre-tests of attitude were administered approximately five (5) months after the pre-tests of achievement.

SIX POINT SCORING RUBRIC FOR
TRANSACTIONAL WRITING: EMPOWERING WOMEN AND GIRLS
TO WIN AT MATHEMATICS
(Based on The Florida Writing Assessment Program rubric)

6 Points
The writing is focused on the topic, has a logical organizational pattern, and has ample supporting examples. The organizational pattern is evident, including a command of transitional devices. The paper demonstrates a sense of completeness or wholeness. The writing demonstrates a mature command of the language, including precise word choice. No grammar, punctuation or spelling errors exist. The paper is written in a consistent voice. The format of the paper is consistent throughout and makes use of spacing to enhance readability.

5 Points
The writing is focused on the topic, has a logical organizational pattern, and has ample supporting examples. There is an organizational pattern, including the use of transitioanl devices, although a few lapses in either may occur. The paper demonstrates a sense of completeness or wholeness. The writing demonstrates a good command of the language, including adequate word choice. There are minimal grammar, punctuation and grammar errors. The paper is written in a consistent voice. The format of the paper is consistent throughout and makes some use of spacing to enhance readability.

4 Points
The writing is generally focused on the topic although it may contain some extraneous or loosely related material. An organizational pattern is evident and uses some transitional devices, although lapses in either may occur. The paper demonstrates a sense of completeness or wholeness. In some areas of the response, supporting examples may be evident; in other areas they may not be developed. Word choice is generally adequate. There are some grammar, punctuation, and spelling errors. The paper is written in a consistent voice. The format of the paper is generally consistent but makes little use of spacing to enhance readability.

3 Points
The writing is generally focused on the topic although it may contain some extraneous or loosely related material. Although an organizational pattern has been attempted, lapses occur and transitional devices may be sparsely used. The paper may lack a sense of completeness or wholeness. Supporting examples may not be developed. Word choice is adequate but occasionally vague. There are some grammar, punctuation, and spelling errors. While the voice of the paper is generally consistent, lapses may occur. The format of the paper is generally consistent but makes no use of spacing to enhance readability.

2 Points
The writing may be slightly related to the topic or may offer little relevant information and few supporting examples or both. There is little evidence of an organizational pattern, including the lack of transitional devices. Development of supporting examples may be inadequate. Word choice may be limited or immature. Frequent errors may occur in basic grammar, punctuation and spelling. The voice of the paper is not consistent. The format of the paper tends to be inconsistent and makes no use of spacing to enhance readability.

1 Point
The writing may only minimally address the topic because there is little, if any, development of supporting examples. Uunrelated information may be been included. There is no evident organizational pattern or use of transitional devices. Word choice is limited or immature. Frequent errors occur in basic grammar, punctuation and spelling. The voice of the paper is not consistent. The format of the paper is inconsistent and makes no use of spacing to enhance readability.

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Fig. 3. Rubric for English.Continued.

Aiken's Revised Mathematics Attitude Scale

Directions: Each of the statements on this opinionnaire expresses a feeling which a particular person has toward mathematics. You are to express, on a five-point scale, the extent of agreement between the feeling expressed in each statement and your own personal feeling. The five points are as follows:

A. Strongly Disagree
B. Disagree
C. Neutral
D. Agree
E. Strongly Agree

1. I am always under a terrible strain in a math class.
2. I do not like mathematics, and it scares me to have to take it.
3. Mathematics is very interesting to me, and I enjoy math courses.
4. Mathematics is fascinating and fun.
5. Mathematics make me feel secure, and at the same time, it is exciting.
6. My mind goes blank, and I am unable to think clearly when working math.
7. I feel a sense of insecurity when attempting mathematics.
8. Mathematics makes me feel uncomfortable, restless, irritable, and impatient.
9. The feeling that I have toward mathematics is a good feeling.
10. Mathematics make me feel as though I'm lost in a jungle of numbers and can't find my way out.
11. Mathematics is something which I enjoy a great deal.
12. When I hear the word "math," I have a feeling of dislike.
13. I am afraid of not succeeding in math, so I am hesitant to try.
14. I really like mathematics.
15. I have always enjoyed studying math.
16 It makes me nervous to even think about having to do a math problem.
17. I have never liked math, and it is my most hated subject.

Fig. 4. Aiken's revised mathematics attitude scale.

19. I feel at ease in mathematics, and I like it very much.

20. I feel a definite positive reaction to mathematics: it's enjoyable.

<u>Computer Experience</u> ***Respond "A" for <u>Yes</u> or "B" for <u>No</u>***

21. Do you use a computer to help with your schoolwork?

22. Do you play computer games?

23. Do you have a computer in your home?

24. Do you use a computer in your school?

25. How many hours a week do you ordinarily use a computer?

 A. 0 - 5
 B. 6 - 10
 C. 11 - 15
 D. 16 - 20
 E. 21 or more

Language/family history

What is the highest level of education completed by your parents?
Respond using the most appropriate one in each of the following.

26 **<u>Father</u>**

 A. Elementary
 B. High school
 C. College

27. **<u>Mother</u>**

 A. Elementary
 B. High school
 C. College

28. What Language is most often spoken in your home?

 A. English
 B. Spanish
 C. Creole
 D. Other

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Fig. 4. Continued.

Post-tests on attitude and achievement were administered in the same class meeting on the college level, but the attitude scale was administered before the achievement measure. On the middle school level, the attitude scale was administered prior to the administration of the current year's Stanford Test [26]. Traditional examinations were administered during the treatment period. All instruments, except the achievement measure on the college level, were administered by the investigators.

ANALYSES

Data collected from the classes that comprise the female (male) participants in the experimental group, by level and class, were collapsed in order to conduct the analyses. The data collected from the classes which comprise the female/male participants in the control group were treated similarly. Using the data gathered from the pre- (prior) tests, *t*-tests were conducted to determine the equivalency of the collapsed control and experimental sub-groups on both achievement and attitude. If the respective pairs of groups were equivalent in achievement and/or attitude, *t*-tests were conducted using the data gathered from their post- (current) tests. If the groups were not equivalent in one or both dependent variables, an analysis of covariance (ANCOVA) with the pre- (prior) test as a covariate was conducted to determine the extent of the effect of transactional writing on achievement and/or attitude. Similar analyses were conducted with data according to race/ethnicity, age, etc. All such tests were conducted by the project's statistician. After the statistical analyses were conducted, results, conclusions and possible generalizations were formulated by the statistician and the principal investigator.

RESULTS

The instability of the mathematics classroom population, particularly on the middle school level, made leveling of classes for the purpose of year-long statistical analyses quite a challenge. There were also issues of timely access to public school students' records. Such requests were processed in a priority order established by the M-DCPS.

Table 1. Achievement—Post-test

Writing	Post-test	Male	Female
Mean	24.644	25.154	24.242
St. Dev.	4.748	4.705	4.816
n	59	26	33
Non-Writing	**Post-test**	**Male**	**Female**
Mean	23.808	25.19	23.115
St. Dev.	4.778	5.12	4.488
n	81	26	55

Table 2. Final grades by writing group

Grade	Writing	Non-writing
S	58	48
P	25	53
U	8	9

chi-square = 13.434, df = 3, p = 0.01

College Year #1

Using data collected from the pre-tests, all collapsed experimental and control sub-groups' means were found to be equivalent on achievement and attitude. The means computed based upon post-test achievement data collection revealed no significant difference between males and females within the writing group. No significant differences were found in gender by writing group comparisons of means. However, the value of practical significance should not be ignored. In this classroom research project, the females in the writing group outscored the females in the non-writing group; males, regardless of writing group, performed comparably (Table 1).

Given these results, the statistician conducted analyses of course grades by gender and writing group. Using a chi-square test for independence, a significant difference in grades earned in a college-preparatory course between writing groups was observed at the 0.01 level (Table 2).

Follow-up studies revealed that writers were significantly more likely to pass a college-preparatory mathematics class, at the .10 level, than their non-writing counterparts. Analyses of gender by writing groups revealed that for each gender group significantly more writers passed their college-preparatory mathematics class; females at the 0.005 level and males at the 0.02 level (Table 3).

The next semester, when a chi-square test of independence was conducted using course grades earned in a college-level mathematics class, no significant difference was found among non-writers, i.e. non-writers, regardless of gender, had an equal likelihood of earning grades A, B, C, D, or F. A significant difference at the 0.10 level was found among writers. Specifically, females were more likely to earn and A or a B.

Table 3. Final grades—gender by writing group

Female grade	Writing	Non-writing
S	26	30
P	13	24
U	1	3

chi-square = 7.907, df = 3, p = 0.004797

Male grade	Writing	Non-writing
S	23	13
P	5	17
U	3	4

chi-square = 10.123, df = 3, p = 0.0175

In order to analyze data collected from the attitude scale, the following items, *illustrative of the two attitudes reflected on the scale,* were selected by the statistician:

1. I am always under a terrible strain in a math class.
2. I do not like mathematics, and it scares me to have to take it.
3. Mathematics is very interesting to me, and I enjoy math courses.
4. Mathematics is fascinating and fun.

For items 1 and 2, a decrease, in the direction of 'Strongly Agree' to 'Strongly Disagree', in the mean responses pre- to post- was hypothesized, whereas for items 3 and 4, an increase, in the direction 'Strongly Disagree' to 'Strongly Agree', in the mean responses pre- to post- was hypothesized. A comparison of typical pre- and post-test mean responses to these items, by gender and writing status, was used to report significant changes at the 0.10 level, pre-test to post-test. Analysis of the responses collected from the female non-writers consistently revealed none of the expected changes; whereas, analysis of the responses of the female writers revealed the expected changes on all four items. In short, changes in attitude in the anticipated directions were observed for all gender by writing status groups, except for female non-writers. But the most demonstrative changes, the largest differences in pre- to post-means, were observed among females writers (Table 4).

These analyses suggest that among females, changes in attitude towards mathematics, in the anticipated directions, may be attributable to writing. For males, the same kinds of changes in attitude occur regardless of treatment group. Further analyses conducted on responses to the attitude scale included baseline data on two additional sections assigned to the control group. These sections were also given pre- and post-tests. But these sections were taught by instructors not assigned to the grant/not using the writing component. One of these instructors was male. The responses of the baseline students were very much like those given by the non-writers in the project.

Table 4. Attitude—pre-test vs. post-test

	Pre	Post	Trend
Question 1			
Males, writing	2.773	2.318	+
Males, non-writing	2.350	2.150	+
Females, writing	3.000	2.613	+
Females, non-writing	2.620	2.778	–
Question 2			
Males, writing	2.227	2.136	+
Males non-writing	2.300	2.100	+
Females, writing	2.806	2.710	+
Females, non-writing	2.467	2.511	–
Question 3			
Males, writing	3.136	3.18	+
Males, non-writing	3.300	3.40	+
Females, writing	2.871	2.968	+
Females, non-writing	3.133	3.089	–
Question 4			
Males, writing	3.00	1.36	–
Males, non-writing	2.85	3.30	+
Females, writing	2.645	2.968	+
Females, non-writing	3.04	2.978	–

Table 5. Achievement—writers: Middle School #1

Gender	Mean	St. Dev.	n
Females	56.97	19.1	36
Males	69.16	27.3	38

$t = -2.22098$, $p < 0.0303$

Middle School

Because three different middle schools were involved, this population was very volatile. Extreme, significant achievement and attitude differences existed among and between these groups at the onset of the project. In light of this, the statistician conducted analysis by research site and level rather than by level alone. These analyses revealed a more stable equivalence. When t-tests were conducted on mean percentile scores, in general, writers outperformed non-writers at all three middle school sites. The 'out-performance' comparisons of female writers versus male writers varied according to the site. In the area of mathematics concepts, at one site male writers significantly out-performed females writers at the 0.03 level (Table 5) and at another site female writers significantly out-performed male writers at the 0.08 level (Table 6).

The same four items, *illustrative of the two attitudes*, were again selected by our statistician. Another two items were added because they reflect a decidedly strong 'anti-math' attitude prevalent in the middle school population:

16. It makes me nervous to even think about having to do a math problem.
17. I have never liked math, and it is my most hated subject.

For items 1, 2, 16, and 17, a decrease in the mean responses pre- to post- was hypothesized, whereas for items 3 and 4, an increase in the mean responses pre- to post- was hypothesized. A comparison of pre- and post-test mean responses to the these items by gender, level (seventh-grade gifted, seventh-grade regular, and sixth-grade

Table 6. Achievement—writers: Middle School #2

Gender	Mean	St. Dev.	n
Females	48.67	23.2	24
Males	38.57	21.2	37

$t = 1.7548$, $p < 0.0845$

regular) and writing status, was used to report significant changes, pre-test to post-test. Although the differences were not significant regardless of level, more anticipated changes in attitude were found among female writers than among female non-writers. In short, changes in attitude in the anticipated direction were observed for all gender by level by writing status groups. But the more demonstrative changes were observed among females writers.

These analyses suggest, again, that among females, changes in attitude towards mathematics, in the anticipated direction, may be attributable to writing.

College Year #2

A complete data set for the second year was not secured until late in the Fall, 1998. What follows below are the result of **preliminary** analyses.

At the end of the second year, an examination of transcripts has revealed nearly half of the female writers were attending college for the first time. In each of the other subgroups continuing students outnumber new students at a ratio of 2 : 1 (Table 7). On the college-preparatory level, among the students receiving a grade of 'S', new students that were female writers had, by far, the best results. This would seem to indicate that writing best serves female, first-time students.

No significant differences in the distribution of grades have been found in comparisons of grades by gender, and grades by gender by writing group. However, it is worth noting that fewer writers failed (or withdrew) from the second semester course. A difference in the distribution of grades was found in comparisons of grades by writing group. The degree and nature of this association are still under investigation.

Initial tracking investigations have revealed that in spite of students' failure to follow the suggested 'flow' of coursework, more female writers 'passed' (earned at least a grade of 'C') their next two mathematics courses and the likelihood of doing this was significant. The median GPA was highest for female writers (Fig. 5). Female writers had a larger percentage difference of students in 'Good Standing' over male writers than did female non-writers over male non-writers.

Table 7. Cross-tabulation—new vs. continuing students

Treatment	Gender	Grade 961	p	s	Total
n	Female	cont	7	20	27
		new	5	9	14
		Total	12	29	41
	Male	cont	3	12	15
		new	4	3	7
		Total	7	15	22
w	Female	cont	6	13	19
		new	6	11	17
		Total	12	24	36
	Male	cont	2	13	15
		new	2	6	8
		Total	4	19	23

In a study of completion rates, Institutional Research found that, independent of the level at which they score, students have only a 50% chance of completing college-preparatory math courses in *three years*. Legislation in place during the first and second years required students to pay the full cost of instruction after the first or second unsuccessful attempt. This would quadruple fees. As a result, completion of degree programs by students starting their studies at the college-preparatory level is very risky. It is rare and somewhat amazing that a student initiating her/his studies at this level completes his/her degree program within two years! Although the graduation numbers are very small from within the project population, a higher percentage of female writers graduated.

A Writing Assignment Survey was administered for the first time (Fig. 6). Some of the data collected from one section follows. In spite of general agreement that the writing assignments made the course easier, helped them understand the material better and increased their understanding of material, participants disagreed that they felt more confident as a result of the assignments and that writing assignments should become a part of other mathematics courses. An analysis of responses to the attitude scale, similar to those observed in Year #1, and subsequent surveys will permit further investigation into these areas of disagreement.

Middle School

At two of the three middle schools, a multi-year component was initiated, i.e. the sixth-graders from year one continued as seventh-grade participants in year two. This was not possible in the third middle school. Therefore, the participants at this site were from sixth-grade 'regular' classes and seventh- and eighth-grade 'gifted' classes. Paired samples tests conducted on scaled pre- and post-mathematics computation means revealed a higher percentage of significant differences in the writing classes.

Among the writing classes, there were more significant positive correlations between pre- and post-attitude scale responses respective to positive and negative items. Among the non-writers, with respect to responses provided on the pre-test of attitude, post-test responses appear to be random. The desired negative correlation between post-test negative and positive responses was found more often among writing classes.

Middle School Year #3

A complete data set for the third year was not secured until late in the Fall, 1999. Complete analyses for Years #2 and #3 are expected by July, 2000.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	2	5.6	5.6	5.6
	.86	1	2.8	2.8	8.3
	1.36	1	2.8	2.8	11.1
	1.69	1	2.8	2.8	13.9
	1.71	1	2.8	2.8	16.7
	1.74	1	2.8	2.8	19.4
	1.75	1	2.8	2.8	22.2
	1.78	1	2.8	2.8	25.0
	1.80	1	2.8	2.8	27.8
	1.91	1	2.8	2.8	30.6
	1.94	1	2.8	2.8	33.3
	2.15	1	2.8	2.8	36.1
	2.23	2	5.6	5.6	41.7
	2.24	1	2.8	2.8	44.4
	2.31	1	2.8	2.8	47.2
	2.38	1	2.8	2.8	50.0 **Median GPA Writing females**
	2.41	1	2.8	2.8	52.8
	2.43	1	2.8	2.8	55.6
	2.44	1	2.8	2.8	58.3
	2.50	1	2.8	2.8	61.1
	2.52	1	2.8	2.8	63.9
	2.55	1	2.8	2.8	66.7
	2.56	1	2.8	2.8	69.4
	2.58	1	2.8	2.8	72.2
	2.64	1	2.8	2.8	75.0
	2.80	1	2.8	2.8	77.8
	2.87	1	2.8	2.8	80.6
	2.92	1	2.8	2.8	83.3
	3.00	2	5.6	5.6	88.9
	3.08	1	2.8	2.8	91.7
	3.23	1	2.8	2.8	94.4
	3.29	1	2.8	2.8	97.2
	3.35	1	2.8	2.8	100.0
	Total	36	100.0	100.0	

a. GENDER = female

GPA[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	1	4.3	4.3	4.3
	1.08	1	4.3	4.3	8.7
	1.09	1	4.3	4.3	13.0
	1.70	2	8.7	8.7	21.7
	1.78	1	4.3	4.3	26.1
	1.80	1	4.3	4.3	30.4
	1.91	1	4.3	4.3	34.8
	1.93	1	4.3	4.3	39.1
	2.00	1	4.3	4.3	43.5
	2.06	1	4.3	4.3	47.8 **Median GPA Writing Males**
	2.13	1	4.3	4.3	52.2
	2.15	1	4.3	4.3	56.5
	2.18	1	4.3	4.3	60.9
	2.78	1	4.3	4.3	65.2
	2.96	1	4.3	4.3	69.6
	2.98	1	4.3	4.3	73.9
	3.03	1	4.3	4.3	78.3
	3.06	1	4.3	4.3	82.6
	3.27	1	4.3	4.3	87.0
	3.31	1	4.3	4.3	91.3
	3.42	1	4.3	4.3	95.7
	3.75	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

a. GENDER = male

Fig. 5. Transcript study—grade point average.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	3	7.3	7.3	7.3
	.82	1	2.4	2.4	9.8
	1.00	1	2.4	2.4	12.2
	1.14	1	2.4	2.4	14.6
	1.36	1	2.4	2.4	17.1
	1.64	2	4.9	4.9	22.0
	1.77	1	2.4	2.4	24.4
	1.89	1	2.4	2.4	26.8
	1.91	1	2.4	2.4	29.3
	2.00	1	2.4	2.4	31.7
	2.14	1	2.4	2.4	34.1
	2.15	1	2.4	2.4	36.6
	2.24	1	2.4	2.4	39.0
	2.25	1	2.4	2.4	41.5
	2.29	1	2.4	2.4	43.9
	2.30	1	2.4	2.4	46.3
	2.34	1	2.4	2.4	48.8
	2.40	1	2.4	2.4	51.2
	2.43	1	2.4	2.4	53.7
	2.50	1	2.4	2.4	56.1
	2.66	1	2.4	2.4	58.5
	2.67	1	2.4	2.4	61.0
	2.77	1	2.4	2.4	63.4
	2.78	3	7.3	7.3	70.7
	2.85	1	2.4	2.4	73.2
	2.86	2	4.9	4.9	78.0
	2.88	1	2.4	2.4	80.5
	2.90	1	2.4	2.4	82.9
	3.00	1	2.4	2.4	85.4
	3.01	1	2.4	2.4	87.8
	3.36	1	2.4	2.4	90.2
	3.37	1	2.4	2.4	92.7
	3.43	1	2.4	2.4	95.1
	3.63	1	2.4	2.4	97.6
	4.00	1	2.4	2.4	100.0
	Total	41	100.0	100.0	

Median GPA Non-writing Females (between 2.34 and 2.40)

a. GENDER = female

GPA[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	3	13.6	13.6	13.6
	.79	1	4.5	4.5	18.2
	.89	1	4.5	4.5	22.7
	1.00	1	4.5	4.5	27.3
	1.30	1	4.5	4.5	31.8
	1.71	1	4.5	4.5	36.4
	1.90	2	9.1	9.1	45.5
	2.08	1	4.5	4.5	50.0
	2.13	1	4.5	4.5	54.5
	2.14	1	4.5	4.5	59.1
	2.31	1	4.5	4.5	63.6
	2.59	1	4.5	4.5	68.2
	2.61	1	4.5	4.5	72.7
	2.66	2	9.1	9.1	81.8
	2.75	1	4.5	4.5	86.4
	2.93	1	4.5	4.5	90.9
	3.00	1	4.5	4.5	95.5
	3.50	1	4.5	4.5	100.0
	Total	22	100.0	100.0	

Median GPA Non-writing Males (between 2.08 and 2.13)

a. GENDER = male

Fig. 5. Continued.

Survey
Writing Assignments
MAC 1102

Use the scale at the right of each statement and bubble-in the number that shows how much you agree/disagree with the statement.

Strongly Disagree	Disagree	Agree	Strongly Agree
1	2	3	4

51.	The writing assignments helped make the course material easier to learn.	1	2	3	4
52.	The writing assignments have helped me understand the material better.	1	2	3	4
53.	Being required to revise assignments increased my understanding of the material.	1	2	3	4
54.	Being able to complete the writing assignments has helped me feel more confident in this course.	1	2	3	4
55.	Writing assignments should become a part of other mathematics courses.	1	2	3	4

From which writing assignment (see list below) have you learned
56. the most? _______

57. the least? _______

A	WA#1	comparing equations and inequalities
B	WA#2	writing a practical word problem
C	WA #3	non-linear inequality
D	WA #4	exponential and logarithmic functions

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Fig. 6. Writing assignment survey.

DISCUSSION OF IMPORTANT FINDINGS

College

- The writing group produced a significantly higher number of 'S' grades among males and females. Follow-up studies reveled that members of the writing group were more likely to obtain a grade of 'S' and consequently, would be allowed to continue their study of math at the college level; whereas, member of the non-writing group were more likely to obtain a grade of 'P' and consequently, have to repeat college preparatory work.
- Within the non-writing group there exists an equal likelihood of earning a grade of A, B, C, D, or F, regardless of gender. Whereas, within the writing group, male participants were more likely to earn a grade of C while female participants where more likely to earn grades of A or B. This observed gender-related difference in final course grades earned in the writing group was significant. Overall, the writing group produced a higher percentage of passing grades, i.e. grades of A, B, or C (75%); writers are more likely to 'pass' MAT 1033.
- Changes in attitude were observed for all gender by writing status groups except for female non-writers. But the most demonstrative changes were observed among female writers. These analyses suggest that among females, positive changes in attitude towards mathematics may be attributable to writing. For males, the same kinds of changes in attitude occur regardless of treatment group. Analyses conducted on responses to the attitude scale included baseline. These sections were taught by instructors not assigned to the grant/not using the writing component. The responses of these students were very much like those given by the non-writers in the project.

Middle School

- Among female participants: Writers showed a greater increase in achievement than nonwriters.
- Among writers: Females showed a greater increase in achievement than males.

- Regardless of level, more anticipated changes in attitude were found among female writers. Positive changes in attitude were observed for all groups. But the most demonstrative changes were observed among females writers and male non-writers. These analyses suggest, again, that among females, positive changes in attitude towards mathematics may be attributable to writing.

Limitations

The research was conducted in a classroom setting, where full control of the scheduling of experimental conditions and the ability to randomly assign subjects to groups cannot always be realized [31]. Intact groups were used which pose threats to internal validity [32]. The administration of the pre-test, and the point in the term at which it was administered, may 'produce effects confounded with the effect of the experimental stimulus' [32, p. 5]. According to Bracht and Glass, novelty effects of the treatment, characteristics of the experimenter, and pre-test sensitization are potential threats to external validity [33]. As suggested by Rosenthal, control of extraneous variables is one of three ways to minimize these threats [34]. In order to control for such effects the researcher was the instructor for each set of the experimental and control groups over the three-year period. Furthermore, within each research site, the same text was used for both groups, comparable syllabi were used to plan instruction and equivalent forms tests were administered. The classes met for the same amount of time weekly/daily.

When data was collected from students completing a survey designed by the researcher, the results revealed that students were generally undecided in their feelings about the written assignments. Selections of the assignments from which they learned the most (least) reflected their desire to cling to the lowest levels of learning and the current levels of instruction. The aforementioned indecisiveness was confirmed by responses to an open-ended question concerning the completion of the written assignments. A wide range of comments resulted, some of which indicated that anxiety and intellectual discomfort were experienced. Students were generally undecided in their feelings about the written assignments. This indecisiveness may be attributable to the novelty of the treatment and may be a consequence of prior instruction, i.e. instruction without written assignments [35, 36]. Without a process approach, which would show students how to write English sentences in a mathematics class, additional intellectual discomfort may result [36, 37].

Implications

Transactional writing does appear to enhance problem solving ability. A different view of student understanding, one which is missed by traditional assessment techniques, is provided. The instructor gained a wealth of pedagogical information that is usually unavailable. Students were generally undecided in their feelings about the written assignments. Thus, the researchers conclude that students could be convinced of the value of the intervention if given the opportunity to become more accustomed to its use.

Given the controls to internal and external validity (researcher control of treatment, testing, experiment length; lack of subject assignment to groups, random selection of groups; use of intact groups, and awareness of factors contributing to experimenter effect), it is also reasonable to assume that this research is generalizable to similar populations, especially mathematics classes with students identified as poor in mathematical skills/applications [38].

Future research

- A similar study in which students receive process-oriented instruction on how to complete the written assignments before the assignments are made, e.g. develop a specialized writing course for mathematics or combine the components of a writing course with a mathematics course.
- A similar study in which good writers and poor writers are identified before the experiment. Then, by separating each of these groups into control and experimental groups, a more valid determination can be made of the effects of the treatment on (good) writers.
- In spite of this success and students' general agreement that the writing assignments made the course easier, helped them understand the material better and increased their understanding of the material, participants disagreed that they felt more confident as a result of the assignments and that writing assignments should become a part of other mathematics courses. Further investigation into these areas of disagreement and inconsistency is needed.
- A replication of this investigation using a similar or different population [38]. Other possible populations to consider would be students studying at higher levels of mathematics. At these levels of study, writing proficiency, in general, may have improved. It would be interesting to observe what, if any effect, transactional writing has on achievement and attitude between experimental and control groups, as well as between writing proficiency groups.

CONCLUSIONS

In spite of researchers' efforts to engage mathematics students in writing activities, 'failure' on the part of some to achieve instant literacy within a course(s)/academic year is not surprising. This researcher concludes, in agreement with Knoblauch & Brannon and Gahn, that this occurrence speaks to the process-oriented nature of such literacy, and not to the worth of the goals [36, 37].

The implementation of this highly focused, innovative project focused on two critical points which hinder the successful pursuit of mathematics-based careers by women, lack of achievement and poor attitude. It is interesting to note that the attitudes about mathematics, held by females, start relatively high in the early years when compared to males. These attitudes are the same as those held by males around grade six, but drop more drastically than males from that time on. At crucial transition points in females' education, empowerment will replace disenfranchisement and eventual exit from the mathematics' pipeline. Worsley suggests that such results will contribute to the evidence that proposes that writing facilitates mathematics teaching and learning, especially for underachievers and their teachers, and corresponds to other powerful learning strategies found by Powell and Lopez [39, 40]. The myth of 'the mathematical elite', males, will be challenged. English will be added to the mathematics classroom; and more female students will enter the dialogue and find success [9]. Something will have been done to eliminate the estranged, oppressive relationship that typically exists between female students and the discipline. Female students, as responsible learners, will have been empowered to use writing as a vehicle for learning, to develop a criteria for monitoring progress, and to be at the center of their learning.

If the United States is to remain competitive in the international arena, recent national workforce assessment indicates a great need for scientists, engineers and mathematicians. It has been suggested that the one of the most important population to target to fill the workforce needs of this country is a population that is currently underrepresented—women. Hence, given the urgent need to recruit women into technical fields and the attributes held by successful engineers, i.e. good verbal and written communication and a good understanding of engineering science fundamentals, continued superior performance in the area of literacy and at the highest levels of mathematics is expected. Furthermore, gender equalization in the attainment of mathematical knowledge is required. In this context, transactional writing will have been an instrument in the construction of increased literacy, mathematical knowledge and the reshaping of attitudes and beliefs.

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