THE EFFECTS OF SELF-GRAPHING AND FEEDBACK ON THE QUANTITY AND QUALITY OF WRITTEN RESPONSES TO MATHEMATICAL WORD PROBLEMS

Thesis

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ABSTRACT

Education in the United States has undergone major changes over the last 15 years. Between No Child Left Behind and Common Core State Standards, teachers are under more pressure than before to achieve excellence with their students. This study looked to see if there was a relationship between a self-graphing plus feedback intervention and the quantity and quality of written responses to math word problems. There seemed to be a functional relationship between the two resulting in increases across the board in total words written and math vocabulary. Limitations, future directions, and implications for practice are all discussed.
DEDICATION

Dedicated to my very supportive and devoted husband, Sam. I love you.

To my parents, Mark and Becky, thank you for always supporting me no matter what.

To Chelsey, I’m so glad that we met and went through this journey together. You were my rock and support system through it all.
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Chapter 1: Literature Review

With the reauthorization of the Elementary and Secondary Education Act (ESEA) in 2002, now known as No Child Left Behind, education standards were raised in the hopes of closing the achievement gap between underserved students and their more affluent counterparts (Klein, 2015). This put extreme pressure on both teachers and administrators to meet the growing demands of the federal government. In 2009, the need for a consistent set of academic standards was realized and the Common Core State Standards were created (Common Core State Standards Initiative, 2010).

One academic area that shows a need for improvement is writing. In 2011, the National Assessment of Educational Progress (NAEP) tested over 50,000 8th and 12th graders in writing. What they found was that only 24% of those students were able to perform at the proficient level. Further, 54% of eighth graders and 52% of twelfth graders were only able to perform at the basic level, which is below what is expected of those students (National Center for Education Statistics, 2012). Writing is such an important part of daily life that students cannot afford to fall behind. Not only is writing used in the school setting, but it is also used in the workforce and in the community.

Not only does there seem to be a crisis in education with writing, but mathematics is also a cause for concern. The Program for International Student Assessment (PISA) has been testing the performance of 15-year old students in reading, math and science every three years since 2000. In 2012, the United States performed lower in math than 29
other countries that participate in this study (PISA, 2012). This performance is consistent with each assessment given (2003, 2006, 2009, and 2012). In the NAEP national report card for math, scores have either remained stagnant or gone down since the previous testing in 2013 (NAEP, 2015). With the implementation of the Common Core State Standards, it is not only important to be able to perform mathematical functions, but students must now be able to write about their thought processes in solving.

In order to address the problem of writing, specifically in the area of mathematics, teachers need to employ evidence-based practices into their classrooms. An evidence-based practice is “a treatment or intervention method that has been demonstrated to be effective through substantial, high-quality scientific research” (Cooper, Heron, & Heward, 2007, p. 94). These interventions need to be explicitly taught to teachers so that they may implement them effectively in their classrooms.

Feedback

Using feedback in the classroom is one strategy that teachers can implement that may help improve the quality of work of their students. Feedback is “information a person receives about a particular aspect of his or her behavior following its completion” (Cooper et al., 2007, p. 282). Feedback is very useful in that it can be used to help a learner achieve a variety of goals. Sometimes feedback is used as reinforcement to increase the target behavior, but it can also be used as a form of punishment, reducing aspects of the target behavior that are undesirable. Studies employ feedback in a variety of ways in order to affect the target behavior of participants.

In Eckert, Dunn, and Ardoin (2006), two different forms of feedback were used to study their effects on students’ oral reading fluency. Six elementary school students who
were identified by their teachers as having difficulties in their basic reading fluency participated in this study. A multi-element design was used to show the differences between the baseline condition and the performance feedback conditions. During baseline, the participants were asked to read three different reading passages, and no feedback was given. In the performance feedback for words read correctly condition, students were given feedback on their mean number of words read correctly from the previous session of that intervention phase. The performance feedback for words read incorrectly phase looked identical to the previous phase except feedback was given for words read incorrectly instead of words read correctly. Results showed that improvements were seen in both words read correctly and words read incorrectly when given any form of feedback. This showed a functional relationship between performance feedback and the oral reading fluency of students.

In a study by Labuhn, Zimmerman, and Hasselhorn (2009), the relationship between self-evaluative standards and feedback on accuracy and performance in mathematics was analyzed. The participants in this study included 90 fifth grade students in a German grammar school. These students were placed in groups of ten in nine different experimental groups. During the baseline phase, all students received identical instructions about their task along with the same problem solving strategy, regardless of the condition the student was assigned to. As the students moved into the intervention phase, they received individualized instructions based on the condition they had been assigned to. What the researchers found was that there was no real relationship between the self-evaluative standards and accuracy, but that there was a functional relationship between feedback and accuracy and performance on the math tasks.
Self-Monitoring

Another evidence-based practice used in many interventions is self-monitoring. Self-monitoring is “a procedure whereby a person observes his behavior systematically and records the occurrence or nonoccurrence of a target behavior (Cooper et al., 2007, p. 598). Self-monitoring has been the focus of numerous studies and can be used in a variety of situations with any population of participants. One type of self-monitoring is self-graphing. Self-graphing is self-monitoring with a graphing component included. This allows participants to see their growth over time in a picture form that is easy to understand (Stotz, Itoi, Konrad, & Alber-Morgan, 2007). There are many studies which show the benefit of using self-graphing to improve student’s behaviors or academic skills.

In Stotz et al. (2007), self-graphing was used to improve the written expression of fourth grade students with high-incidence disabilities. This study looked at three 10-year-old fourth graders who exhibited poor writing skills and were nominated by their teachers as being students who could benefit from the intervention. A multiple baseline across subjects design was used to show the effects of self-graphing on total words written (TWW) and correct word sequences (CWS). During the baseline phase of this study, students received their regular classroom instruction and data were collected on TWW and CWS. In the intervention phase of this study, everything was kept the same except for the inclusion of a self-graphing component. After completing their writing probe, students in the intervention met with the experimenter to count and graph their TWW. Students were then moved into the maintenance phase where they would self-graph without the prompting of the experimenter. It was determined that there was a
functional relationship between self-graphing and the writing quantity and quality of these fourth grade students.

Another study that looked at the effects of graphing on writing quantity and quality was by Geisler, Hessler, Gardner, and Lovelace (2009). This study used a multiple baseline across subjects design to study the effects of self-counting and graphing on the TWW and the number of different words generated by high-achieving African American first graders. Five “high-achieving” students were chosen to participate. Before baseline, students received one mini-lesson on the importance of word variation was used before the beginning of baseline. During baseline, all students were given a story starter and were asked to write as many and as varied words as they could. They were given a one minute think time followed by eight minutes of writing. Students were asked to mark their writing after three minutes had passed. Praise and prompting were used throughout the eight minute writing time. The intervention phase was introduced with a mini-lesson on self-counting before the first session began. In the intervention phase, students would self-count and record their results at the bottom of their paper. The experimenter would graph the students’ results for them and show them their graph before the new writing session began. Once the data stabilized, a synonym list was provided to the students to increase further the participant’s variation in word usage. It was found that all five students saw an increase in the amount of writing, both in total words written and in variety of words, they produced as compared to their baseline results.
Purpose of the Study

To date, no mathematics treatment package combining self-graphing, writing, and feedback has been studied. Therefore, the purpose of this study was to examine the effects of feedback and self-graphing on the quantity and quality of written mathematical responses to word problems. Specifically, we sought to answer the following research questions:

1. What are the effects of self-graphing and feedback on TWW?
2. What are the effects of self-graphing and feedback on math vocabulary?
3. What are the effects of self-graphing and feedback on accuracy of math word problems?
4. What are the students’ opinions about the intervention used in this study?
Chapter 2: Methodology

This chapter will discuss the participants and setting of the study, the definition and measurement of the dependent variables, the materials used, the experimental design, the experimental conditions and procedures, and the procedures used for interobserver agreement and procedural reliability.

Participants

Three participants were recruited from a fourth grade classroom in a general education classroom in an urban charter school in central Ohio. All three participants were female and all participated in the school’s afterschool tutoring program, which is where the experimenter conducted the majority of the sessions. Table 2.1 provides more information about the participants in this study.

Table 2.1: Student Data

<table>
<thead>
<tr>
<th>Student</th>
<th>Gender</th>
<th>Age</th>
<th>Math PARCC Score*</th>
<th>Classroom Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB</td>
<td>Female</td>
<td>9</td>
<td>797</td>
<td>Math – A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ELA – A</td>
</tr>
<tr>
<td>RC</td>
<td>Female</td>
<td>9</td>
<td>786</td>
<td>Math – B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ELA – B</td>
</tr>
<tr>
<td>SB</td>
<td>Female</td>
<td>9</td>
<td>789</td>
<td>Math – B-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ELA – A</td>
</tr>
</tbody>
</table>

*The possible range for math PARCC scores was 650-850, with 750 being the lowest possible passing score.
Setting

The study took place in an urban charter school in central Ohio. The school serves approximately 700 children in grades kindergarten through ninth grade. Sessions either took place in an empty classroom during the first 15 minutes of the participant’s afterschool tutoring time or in an empty classroom during the participant’s recess time. A participant’s recess time was used in the case of making up a missed session or working after the conclusion of the afterschool program.

Definition and Measurement of Dependent Variables

Three dependent variables were measured over the course of the study. These included total number of words written (TWW) in a three-minute timed writing, the number of math vocabulary words or terms used in the three-minute writing, and the accuracy in solving the math word problem.

Total words written (TWW). Total words written was defined in this study as the total number of words or numbers written by the participant in a three minute timing. Because the study was looking at writing in mathematics, numbers were counted as words for this dependent variable. Mathematical symbols (+, -, x, and /) were not counted for the participant’s TWW.

Number of math vocabulary words/terms. Math vocabulary words/terms was defined as a word or term that had a mathematical definition or was a key word in figuring out how to solve a math word problem. A list of these words was provided as a reference for interobserver agreement (see Appendix A).
**Math accuracy.** Math accuracy refers to the correct or incorrect answer given for each math word problem. This was denoted with a Y (for accurate) or an N (for not accurate) on the student’s data sheet.

**Materials**

**Word problems.** Participants were given a word problem at the beginning of each session. The word problem was printed at the top of a piece of paper with the remainder of the paper left blank for the student work out the problem and then write about it. Students that filled up the paper with writing could continue their writing on the back of the paper (see Appendix B).

An internet search was used to find fourth grade word problems that covered a variety of Ohio’s Learning Standards. Fifteen word problems were chosen and then given to the fourth grade math teacher at the examiner’s school for reviewing. He was asked to provide feedback on each word problem, changing those that he thought were too easy or too difficult in order to have fifteen problems that were of relatively the same difficulty. Nine out of the fifteen were deemed to be the same level of difficulty, while the other six required some edits to make them either easier or more difficult. For example, there was a word problem that asked the student to find the elapsed time between 1:10 and 3:40. The math teacher recommended that the times be changed to 1:40 and 4:10 so that it would be a little more challenging for the students.

**Data sheets.** The experimenter used a data sheet to record the accuracy of solving the problem, the total words written (TWW), and the number of math vocabulary used for each student (see Appendix C).
**Graphing sheet.** At the beginning of the intervention phase, each student was presented with a graphing sheet on which he or she would self-record the total words written and number of math vocabulary words/terms for each session. The graph showed the session date and time met (during recess or after-school tutoring) along the horizontal axis and the number of words written along the vertical axis (see Appendix D).

**Model Response.** The experimenter provided a model written response for each word problem during the intervention phase. The TWW and math vocabulary count was included with each model response (see Appendix E).

**Feedback form.** The experimenter used the feedback form to record TWW, math vocabulary used, positive feedback about the student’s writing, and a suggestion for improving the student’s writing for each session (see Appendix F).

**Timer.** The experimenter used the timer on her phone to time participants for three minutes while they wrote about their math work.

**Experimental Design**

A multiple baseline across participants design was used for this study. This study focused on two primary target skills: total number of words written and number of math vocabulary words/terms used. Baseline data were collected on both of these measures until a stable pattern was observed. Intervention then began with the student who showed the most stable baseline and the greatest need for intervention. Once placed in the intervention phase, the student would remain there for at least eight sessions and until a clear change in trend was noticed. After both of these conditions were met, the student moved into the maintenance phase. The remaining students would then be given another
baseline probe, and the next participant for intervention would be determined, based on stability of data and need for intervention.

**Procedures**

*Baseline.* During baseline, each of the three students was given a math word problem. They were asked to solve the problem and then flip their paper over to signify that they were finished. Once all three students had completed the problem, the experimenter set the timer for three minutes and told the students to write about how they solved the problem they had just completed. The experimenter said “go” and started the timer. After all participants were finished writing and the three minutes expired, the experimenter calculated the TWW and the math vocabulary for each student and then denoted those numbers on the students’ data sheets. Throughout baseline, students continued to receive their regular math instruction, which consisted of 120 minutes of math instruction each day in a classroom setting of approximately 20 students. These participants also participated in the school’s afterschool tutoring program twice a week for small group math instruction. The afterschool tutoring program attendance varied, but the average class size was between 10 and 15 students.

*Self-graphing/feedback condition.* In the self-graphing/feedback condition, regular math instruction and afterschool tutoring continued, and in addition, the student met with the experimenter one-on-one and was presented with a copy of a math word problem. The student was then asked to solve the problem. When the student finished solving the problem, then the experimenter set the timer for three minutes and instructed the participant to write about how he/she solved the problem. At the conclusion of the three minutes, the student and the experimenter counted the words written together. The
experimenter then pointed out the math vocabulary in the student’s writing. After denoting these numbers on the participant’s data sheet, the student then graphed both of these values on his or her personal graph. The experimenter then read the model response for that word problem out loud to the student, pointing out features that were both in common with the student’s response and different from the student’s response. Then, the experimenter provided feedback to the student. One piece of positive feedback and one piece of constructive feedback were provided to the student. After feedback was given, the student returned to the afterschool program.

*Model first condition.* For the last participant, sufficient progress was not made using the graphing/feedback condition, so further intervention was needed. In the model first condition, the student was still given a word problem and asked to solve it. Upon completion, the student was told whether they solved the problem correctly or incorrectly. If the solution was incorrect, she was told the correct way to solve the problem. Next, the examiner read the model response to her and then gave her three minutes to write about the word problem. At the conclusion of the three minutes, the examiner and the student counted up the student’s words and math vocabulary. These numbers were graphed on the student’s graph. The experimenter pointed out features between the model response and the student response that were the same and that were different. Finally, the examiner provided positive feedback and constructive feedback to the student in regards to her response. At the conclusion of the session, the student returned to the afterschool program.
Interobserver Agreement

To assess interobserver agreement (IOA), copies were made of 20% of student work samples across all experimental conditions. A second observer then scored these samples for TWW and math vocabulary. IOA was then calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying that quotient by 100.

Procedural Reliability

Procedural reliability was assessed through the use of a checklist (see Appendix G and H). The checklist was used during the intervention phase of the study. The second observer attended three of the sessions and used the checklist to check off each step as it occurred in the procedure. Procedural reliability was then calculated by dividing the number of steps performed correctly by the total number of steps in the checklist and multiplying by 100.
Chapter 3: Results

This chapter will focus on the results of the interobserver agreement, procedural reliability, and the dependent variables of total words written (TWW), math vocabulary, and math accuracy for each student. In addition, social validity data will be presented.

Interobserver Agreement

Interobserver agreement was calculated across all participants and across all conditions for TWW and math vocabulary. The second observer looked at 20% of the written samples across all participants and all conditions. The overall IOA for TWW across all conditions was 92.3%. During baseline, the average IOA for TWW was 78%. During the self-graphing/feedback condition, the average IOA for TWW was 100%. In the model first condition, the IOA for TWW was 100%. For maintenance, the IOA for TWW was 100%.

For math vocabulary, the IOA across all conditions was 53.8%. During baseline, the IOA was 67%. IOA during the self-graphing/feedback condition was 42% for math vocabulary. During the model first condition, the IOA for math vocabulary was 50%. In the maintenance phase, the IOA for math vocabulary was 100%.

Procedural Reliability

Procedural reliability was assessed on three separate occasions across both experimental conditions. The average procedural reliability across all sessions was
94.6%. Procedural reliability ranged from 84.6% to 100% across experimental conditions. In the self-graphing/feedback phase, the average reliability percentage was 100%. In the model first phase, the average reliability percentage was 84.6%. During one session, no differences or constructive feedback was given to the participant.

**Data for NB**

*TWW.* Figure 3.1 shows the data for total words written for participant NB. During baseline, NB’s mean TWW was 25.3 words/3 min. with a range of 20 to 37 words. Baseline data showed a steady trend in the low twenties except for one outlier in the high thirties. During the self-graphing/feedback phase, the word count increased to the forties where the trend held steady apart from one low data point in high thirties and one high data point in the mid-fifties. The TWW during this phase ranged from 37 to 55 words per session with a mean TWW of 44.5 words per session. In the maintenance phase, word count decreased slightly to the mid-thirties and low-forties. The TWW ranged from 36 to 42 words per session during this phase with a mean TWW of 39 words per session which was a slight decrease from the intervention phase.

*Math vocabulary.* Figure 3.2 shows the data for math vocabulary used by participant NB in her written responses. During baseline, data remained steady at two vocabulary words except for the initial response of three vocabulary words. The range of math vocabulary used was two to three words per session with an average vocabulary usage of 2.3 words. In the self-graphing/feedback phase, the participant’s use of math vocabulary was initially steady with three to four words per session. This number increased to five to seven words per session by the end of the intervention phase. Math vocabulary during this phase ranged from two to seven words per session, with a mean of
4.5 words per session. During maintenance, this number remained consistent with the end of intervention phase. Vocabulary usage ranged from five to six words per session with a mean of 5.5 words per session.

*Problem solving accuracy.* During baseline, the participant’s accuracy was 50%; two sessions solved correctly and two solved incorrectly. In the self-graphing/feedback phase, the participant’s accuracy increased to 87.5%; scoring 7 out of 8 sessions correctly. The maintenance phase had an accuracy of 100%, scoring two out of two sessions correctly.
Figure 3.1 – Graphs of Total Words Written

[Graph showing Total Words Written for different conditions and participants]
Figure 3.2 – Graph of Math Vocabulary
Data for RC

_TWW_. Figure 3.1 shows the data for total words written for participant RC. During baseline, RC’s mean TWW was 19.2 words/3 min. with a range of 12 to 26 words. The data showed an initially increasing trend which decreased after the third session. During the self-graphing/feedback phase, the word count showed a variable increasing trend. The TWW during this phase ranged from 23 to 62 words per session with a mean of 37.8 words per session. In the maintenance phase, TWW showed a decrease from the intervention phase. The TWW range was 29 words per session during this phase with a mean of 29 words per session.

_Math vocabulary_. Figure 3.2 shows the data for math vocabulary used by participant RC in their written responses. During baseline, data showed a steady decline from three to four words per session to two to three words per session. The range of math vocabulary used was two to four words per session with a mean vocabulary usage of 3 words. In the self-graphing/feedback phase, the participant’s use of math vocabulary was initially variable but became steady before slightly increasing. Math vocabulary during this phase ranged from three to seven words per session, with a mean usage of 5.5 words per session. During maintenance, this number remained consistent with the end of intervention phase. Vocabulary usage was six words per session with a mean usage of 6 words per session.

_Problem solving accuracy_. During baseline, the participants accuracy was 60%; three sessions solved correctly and two solved incorrectly. In the self-graphing/feedback phase, the participant’s accuracy increased to 69.2%, scoring correctly for 9 out of 13
sessions. The maintenance phase had an accuracy of 100%, scoring one out of one session correctly.

**Data for SB**

_TWW_. Figure 3.1 shows the data for total words written for participant SB. During baseline, the data was variable with a slightly decreasing trend. SB’s mean TWW was 27.8 words/3 min. with a range of 18 to 36 words. During the self-graphing/feedback phase, the TWW showed an initially decreasing trend which turned into a gradually increasing trend about halfway through the phase. The TWW during this phase ranged from 27 to 59 words per session with a mean of 39.5 words per session. In the model first phase, the TWW showed an overall increasing trend with one low outlier. The TWW range was 44 to 88 words per session during this phase with a mean of 64 words per session. There is no data on the maintenance phase as this participant did not make it to this phase before the end of the school year.

_Math vocabulary_. Figure 3.2 shows the data for math vocabulary used by participant SB in their written responses. During baseline, data showed a variable trend, showing no increasing or decreasing trend over six sessions. The range of math vocabulary used was zero to four words per session with a mean of 2 words per session. In the self-graphing/feedback phase, the participant’s use of math vocabulary was initially variable but became steady before becoming variable again at the end of this phase. Math vocabulary during this phase ranged from one to seven words per session, with a mean of 3.8 words per session. During the model first phase, the number of math vocabulary showed a steady increase over the four sessions. Vocabulary usage ranged from five to eight words per session with a mean of 6.5 words per session.
Problem solving accuracy. During baseline, the participants accuracy was 50%; three sessions solved correctly and three solved incorrectly. In the self-graphing/feedback phase, the participant’s accuracy increased slightly to 58.3%, scoring correctly for 7 out of 12 sessions. In the model first phase, the participant had an accuracy of 100%, scoring correctly five out of five sessions.

Social Validity

Social validity was assessed through the use of a questionnaire given to the three participants who received the intervention (see Appendix I). The questionnaire used seven statements to assess how the participants felt about the study, including each component of the intervention and their overall feelings towards math and writing. Students were asked to rate their feelings on each statement on a scale of 1 to 4, with 1 being the lowest rating (“disagree”) and 4 being the highest rating (“agree”). After rating the seven statements, the students were then asked to choose which part of the intervention they thought was the most helpful.

NB rated all statements at a 3 or 4 except for “learning to write about math is important” which was rated at a 2. NB thought the most helpful part of the sessions was getting feedback from the teacher. RC rated all statements at either a 3 or a 4, stating that seeing the model response was the most helpful part of each lesson. SB rated all statements at a 3 or a 4 except for “the lessons would be good for other students” which she rated at a 2. The most helpful part of the intervention to SB was writing about math.
Chapter 4: Discussion

This chapter will present a discussion of the research questions, limitations to the study, directions for future research, and implications for practitioners.

Research Question #1. What are the effects of self-graphing and feedback on total words written (TWW)?

There appears to be a functional relation between self-graphing and feedback on total words written. Each participant saw an increase in their average TWW between the baseline condition and the self-graphing/feedback condition. NB saw an increase in her average from 25.3 words per session during baseline to 44.5 words per session during intervention. RC’s TWW average increase from 19.2 words per session to 37.8 words per session between baseline and intervention. SB’s mean TWW increased from 27.8 words per session in baseline to 39.5 words per session in the self-graphing/feedback phase. This improvement across the board is consistent with the research found on self-graphing and feedback. These findings are consistent with those found by Stotz et al. (2007) who found that self-graphing increased the total words written in fourth grade students with high incidence disabilities. However, this finding extends the existing literature in this area because this study looked at students’ writing in mathematical responses rather than responses given to a writing probe. These findings are also consistent with Eckert et al. (2006) who found that feedback increased the oral reading fluency of school aged students. However, the findings of this study extend the existing
literature in this area because this study looked at the effects of feedback on written responses, not just oral reading fluency.

**Research Question #2. What are the effects of self-graphing and feedback on math vocabulary?**

In terms of math vocabulary usage in written responses, there appears to be a functional relation between self-graphing and feedback and the average number of math vocabulary words used. Each participant in the study saw an increase in her means between the baseline condition and the self-graphing/feedback condition. Participant NB saw an increase from 2.3 to 4.5 words per session between baseline and intervention. Participant RC’s average math vocabulary usage increased from 3 words per session in baseline to 5.5 words per session in the self-graphing/feedback condition. SB’s improvements were not as dramatic as the previous two participants, but her average still increased from 2 words per session in baseline to 3.8 words per session in the self-graphing/feedback condition. These increases are consistent with the research on self-graphing and feedback on the quality and quantity of written responses. This study is consistent with the findings of Stotz et al. (2007), which concluded that there was a functional relation between self-graphing and total words written. However, this study extends the existing literature in this area because not only did this study look at the total words written, but specific content area words were also counted. This study’s findings were also consistent with those found by Geisler et al. (2009) in which both quantity and quality of written responses were positively affected by self-graphing. This study extends the existing literature in this area because specific content area words were looked at specifically along with the total number of words written by the participant.
The variations in word choice were notable after intervention began with each participant. Once the model response was shown and feedback was given, students started using synonyms in their writing rather than repeating the same word. For example, instead of using the word “answer” repeatedly throughout their responses, students started using synonyms for “answer” that aligned with the mathematical operation being used in the word problem. “Answer” might become “sum” or “total” in an addition problem or “product” in a multiplication problem. New vocabulary taught during the feedback portion of the intervention also started to appear in the students’ written responses. One notable example of this was use of the word “conversion”. All of the students knew how to perform the conversions in their solving of the word problem, but none of them used the word in their written responses. After being taught the word, it appeared in subsequent word problems in which conversions were used.

**Research Question #3. What are the effects of self-graphing and feedback on accuracy of math word problems?**

A functional relation could not be determined for this variable, although students’ accuracy appeared to increase with the intervention. All three students showed an increase in their problem solving accuracy between baseline and intervention conditions. Participant NB increased her problem solving accuracy from 50% in baseline to 87.5% in the self-graphing/feedback condition. This effect continued into the maintenance phase with participant NB scoring 100% accuracy. Participant RC had a baseline accuracy of 60% which increased to 69.2% once in the intervention phase. This participant’s accuracy increased further to 100% in the maintenance phase. Participant SB’s accuracy during baseline was 50%. This increased to 58.3% during the self-
graphing/feedback condition and increased to 100% in the model first condition. There
demand for improved writing across all academic content areas, so while no functional
relationship could be determined for this variable, this intervention does show some
promise for improving math problem solving through writing.

**Research Question #4. What are the students’ opinions about the intervention used in this study?**

Overall, the participants seemed to enjoy the intervention and find the aspects of
the intervention useful. Out of the seven statements given to the students, all were rated
at a 3 or 4 except for two. One student gave a rating of 2 to the statement “learning to
write about math is important” and another student gave a 2 to the statement “the lessons
would be good for other students.” Each student classified a different aspect of the
intervention as being the most helpful. One student liked the feedback component,
another student said seeing the model response was most helpful, and the third student
like writing about math. The high acceptability from the students means that this
intervention is socially valid and therefore has a greater likelihood of being used in future
studies or classroom interventions (Wolf, 1978).

**Limitations**

There were several limitations to this study. Though the word problems were of
the same difficulty, some word problems required longer written responses than
others. Variability in length was a limitation in this study because it gave a high
variability to the TWW that each student produced in their written responses.

There were no data collected on the exact amount of time it took students to write
their responses. Some students chose to use the whole time to write their responses,
whereas others completed their responses in less time than what was given. This is a limitation because it was indeterminable whether there was a connection between length of time spent writing and the dependent variables.

A further limitation to the study was that there was no generalization probe given. Generalization is “the extent to which a learner emits the target behavior in a setting or stimulus situation that is different from the instructional setting.” (Cooper et al., 2007, p. 625). In this study, generalization might be characterized as the improvement of writing across all content areas, not just mathematics.

Another potential limitation to this study was the low amount of fidelity data. The researcher was only observed on three occasions during the course of the study. The percentage for procedural reliability is 94.6%, so even with the low number of observations; it does seem to be a huge limitation to the study.

IOA for TWW was high with an overall average of 92.3%. This is because the second grader only had to count the words and number used by the participants. The written responses were clear and easy to read. The IOA for math vocabulary usage, however, was low at 53.8%. In this case, both scorers had to pick out the math vocabulary used in each written response. Even with the chart provided, there were words that were missed between the experimenter’s scoring and the second observer’s scoring. This led to low IOA for this dependent variable. Low IOA could mean that the measurement system was too ambiguous and difficult to define (Cooper et al., 2007). Even with the provided chart, the two observers could have missed a math vocabulary word or counted a word that the other observer did not.
**Future Directions**

This study was done with students who are considered “at risk.” Future research should look at the effects of self-graphing and feedback on a wider variety of students including students with disabilities, high-achieving students, students with low motivation, and English language learners.

It would also be interesting to see the effects of self-graphing in a whole-group setting, rather than a one-on-one setting. The feedback component would have to be modified so that it does not interfere with instruction time. This could be done by meeting with students once a week rather than every day during study hall, recess, or any other down time that they have.

Further research could also keep data on the time it takes students to write their responses instead of just giving them set amount of time. This way experimenters could look to see if there was any correlation between the length of time and the length of the response. Research may also want to shorten the time to write from three minutes to two, as in the majority of sessions, participants were finished before the time was up. If a student does stop writing, the experimenter could use a prompt to get them to continue writing until the timer runs out.

Future researchers will also want to add a generalization component to any future studies. The experimenter might administer a writing probe at the beginning of the study in another content area other than mathematics (e.g., reading, social studies, science). After administering the intervention with their population, the experimenter could then administer the same or similar probe as was given at the beginning of the
study and see if there was an improvement in the writing quality of the student’s response in regards to an increase in both TWW and content vocabulary.

**Implications for Practice**

In order to implement this intervention successfully, students must be able to graph points on a coordinate grid. This requires that the background knowledge for graphing be present if students are going to graph their data on their own. If students do not have this background knowledge, it would be up to the practitioner to support the students in graphing. Teachers would either need to tell students where to graph their data or graph the student’s data themselves. Graphs could be shared with parents on a weekly basis to keep them informed on the performance of the student. Teachers will need to make time in their schedule, whether daily or weekly, to meet with the students to provide feedback and make sure their graphs are correct. Immediate written feedback could also be given on the response itself, rather than verbally.

Teachers may want to set goals, both classroom wide and individually, so that students are motivated to improve their writing. Rewards could be given to the class or the student who reaches their goal. It may also be beneficial to give the students word problems that cover material recently learned in class. This will help students incorporate specific math vocabulary that they might forget unless practiced. Teachers should sporadically include word problems from earlier in the year as well to ensure that students have not forgotten material already taught.
BIBLIOGRAPHY


### APPENDIX A: LIST OF MATH VOCABULARY

<table>
<thead>
<tr>
<th>Add/Added/Adding/Addition/Adds</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount</td>
<td>Less than</td>
</tr>
<tr>
<td>Answer</td>
<td>Minus</td>
</tr>
<tr>
<td>Any name of place value (ex. hundreds place, thousands place, etc.)</td>
<td>Multiply/Multiplied/Multiplying/Multiplication/Multiplies</td>
</tr>
<tr>
<td>Chart</td>
<td>Number</td>
</tr>
<tr>
<td>Combined</td>
<td>Place value</td>
</tr>
<tr>
<td>Compare</td>
<td>Plus</td>
</tr>
<tr>
<td>Convert</td>
<td>Problem</td>
</tr>
<tr>
<td>Difference</td>
<td>Product</td>
</tr>
<tr>
<td>Divide/Divided/Dividing/Division/Divides</td>
<td>Quotient</td>
</tr>
<tr>
<td>Dividend</td>
<td>Remainder</td>
</tr>
<tr>
<td>Divisor</td>
<td>Round/Rounds/Rounded/Rounding</td>
</tr>
<tr>
<td>Each</td>
<td>Solve</td>
</tr>
<tr>
<td>Equal/Equals</td>
<td>Subtract/Subtracted/Subtracting/Subtraction/Subtracts</td>
</tr>
<tr>
<td>Equal to</td>
<td>Sum</td>
</tr>
<tr>
<td>Feet</td>
<td>Times</td>
</tr>
<tr>
<td>Greater than</td>
<td>Total/Totals</td>
</tr>
<tr>
<td>“How much more”</td>
<td>Value/Values</td>
</tr>
<tr>
<td>In all</td>
<td>Yard</td>
</tr>
</tbody>
</table>
APPENDIX B: EXAMPLE OF WORD PROBLEMS

1) A McDonald’s made $376,415 dollars on Saturday and $129,354 on Sunday. About how much money did they make over the two days?

2) A recycling center recycles plastic bottles, aluminum cans, and glass bottles. The table shows the amount of each material the center recycled in one day.

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount Recycled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Bottles</td>
<td>13,952</td>
</tr>
<tr>
<td>Aluminum Cans</td>
<td>8,596</td>
</tr>
<tr>
<td>Glass Bottles</td>
<td>3,735</td>
</tr>
</tbody>
</table>

Did the center recycle more plastic bottles or more aluminum cans and glass bottles combined that day?

3) Monique had $3892 dollars in her checking account at the bank. She bought two end tables for $69 a piece, a sofa for $1,543, a recliner for $806, and two lamps for $40. How much money did Monique have left in her bank account?

4) A 4th grade teacher bought 4 new pencil boxes. She has 260 pencils. She wants to put the pencils in the boxes so that each box has the same number of pencils. How many pencils will there be in each box?

5) The workers paved 1,254 feet of a road today. That is 3 times longer than the amount they paved yesterday. What is the total amount of road paved in the two days?

6) Each apartment building holds 4,234 people. If there are 6 buildings, how many people live in the apartments total?

7) David was planting rows of corn in the field. He wanted to have 7 corn plants in each row. How many rows would David make if he has 987 corn plants?

8) Your class is collecting bottled water for a service project. The goal is to collect 300 bottles of water. On the first day, Max brings in 3 packs with 6 bottles in each container. Sarah wheels in 6 packs with 6 bottles in each container. How many bottles of water still need to be collected?
|                          | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 0 |
| Accurate Solving (Y/N)   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Total Words Written      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Number of Math Vocabulary Used |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
APPENDIX D: STUDENT GRAPHING SHEET
APPENDIX E: EXAMPLE OF MODEL RESPONSES

1) McDonald’s made about $500,000 over the two days. I know this answer because the word “about” means rounding. When rounding, you round to the highest place value which would be the hundred thousands place. The first number rounds up to $400,000 because the seven in the ten thousands place is greater than five. The second number rounds to $100,000 because the two in the ten thousands place is less than five. When added together, the total is $500,000.

TWW – 78
Math Vocabulary – 10

2) The center recycled more plastic bottles. To solve this problem, you first needed to add the aluminum cans and the glass bottles. The word “combined” means addition, so when you add up the aluminum cans and the glass bottles you get a total of 12,331 materials. Then you have to compare that sum to the number of plastic bottles. The two in thousands place is less than the three, so the sum of aluminum cans and glass bottles is less than the plastic bottles they recycled.

TWW - 86
Math Vocab – 9

3) Monique would still have $1,325 in her checking account. To solve this problem you could add all her expenses together and then subtract that total from the amount of money in her back account. There are two end tables, so you would multiply $69 by 2 to get the total amount spent on end tables. There were also two lamps, so $40 times 2 is $80. Then you add up the total of all expenses, $138 + $1543 + $806 + $80, which gives you a sum of $2557. You can then take that total and subtract it from her starting amount. $3892 minus $2557 gives you a difference of $1325.

TWW - 108
Math Vocab – 11
APPENDIX F: FEEDBACK FORM

Participant ID __________________

Total Words Written:__________________

Number of Math Vocabulary Used:__________________

Positive Feedback:____________________________________

________________________________________________________________________

Suggestion for Improvement_____________________________

________________________________________________________________________

________________________________________________________________________
Self-Graphing/Feedback Intervention Checklist

- Pass out word problem
- Give student time to work out word problem
- After completing word problem, tell student they have 3 minutes to write about how they solved the problem
- Set timer for 3 minutes
- When time is up, have student count their words
- Go through the writing with the student to pick out math vocabulary words
- Graph both the total words written and the math vocabulary used on the graph
- Read the model response to the student
- Point out features that the student’s response had in common with the model response
- Point out features that the student’s response had that were different from the model response
- Give positive feedback – “This is something I thought you did well”
- Give constructive feedback – “One thing I think you could improve on…”
- Send student back to regular class
APPENDIX H: MODEL FIRST PROCEDURAL CHECKLIST

Model First Checklist

☐ Pass out word problem
☐ Give student time to work out word problem
☐ Tell student if the answer is correct or incorrect and…
  ○ If the student is incorrect, go through the correct way to solve the problem with them. And then read the model response to the problem.
  ○ If the student is correct, read the model response to the student
☐ Tell student they have 3 minutes to write about how they solved the problem
☐ Set timer for 3 minutes
☐ When time is up, have student count their words
☐ Go through the writing with the student to pick out math vocabulary words
☐ Graph both the total words written and the math vocabulary used on the graph
☐ Point out features that the student’s response had in common with the model response
☐ Point out features that the student’s response had that were different from the model response
☐ Give positive feedback – “This is something I thought you did well”
☐ Give constructive feedback – “One thing I think you could improve on…”
☐ Send student back to regular class
APPENDIX I: STUDENT INTEREST SURVEY

<table>
<thead>
<tr>
<th>Student Intervention Rating Profile</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Learning to write about math is important.</td>
<td>Agree</td>
<td>Disagree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. This was a good way for me to improve my math skills.</td>
<td>Agree</td>
<td>Disagree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. This was a good way for me to improve my writing skills.</td>
<td>Agree</td>
<td>Disagree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I liked the lessons, which included writing, self-graphing, and feedback from the teacher.</td>
<td>Agree</td>
<td>Disagree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I think being more fluent with my writing will help me do better in school.</td>
<td>Agree</td>
<td>Disagree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I think the feedback given helped me improve my writing.</td>
<td>Agree</td>
<td>Disagree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. The lessons I participated in would be good for other students.</td>
<td>Agree</td>
<td>Disagree</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Check off which part of the lessons you think was **most helpful**. Choose **only one**—the one you thought helped you most.

- [ ] writing about math
- [ ] counting and graphing my words
- [ ] seeing what the teacher wrote
- [ ] getting feedback from the teacher