Using Formative Assessment and Linguistic Representation in Math Instruction

Emily Lorenzen

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Using Formative Assessment and Linguistic Representation in Math Instruction

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University Honors Capstone
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Senior Honors Project/Thesis
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# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page number(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>Background</td>
<td>3</td>
</tr>
<tr>
<td>Introduction</td>
<td>3-6</td>
</tr>
<tr>
<td>Participants</td>
<td>6</td>
</tr>
<tr>
<td>Methods and Materials</td>
<td>6-8</td>
</tr>
<tr>
<td>Results</td>
<td></td>
</tr>
<tr>
<td>Data Analysis</td>
<td>8-14</td>
</tr>
<tr>
<td>Discussion and Conclusions</td>
<td>14-16</td>
</tr>
<tr>
<td>References</td>
<td>17-18</td>
</tr>
<tr>
<td>Appendix</td>
<td>18-27</td>
</tr>
</tbody>
</table>
  - Appendix A: Unit 5 Pre-test Questions      |
  - Appendix B: Unit 5 Midpoint Check Questions|
  - Appendix C: Unit 5 Exit Ticket Examples    |
Abstract

This capstone project reports the instructional strategies and formative assessments implemented throughout an elementary mathematics unit. The capstone reports the benefits and effectiveness of two instructional strategies that promote student learning with the content of telling time, creating and analyzing graphs, and word problems. The unit included a pre-test, midpoint check, post-test, and 17 lessons taught over the course of five weeks. I collected and analyzed data from the pre-test, midpoint check, post-test, and various exit tickets throughout the unit.

*Keywords:* instructional strategies, formative assessment, linguistic representations

Background

I completed my Clinical Practice at Wheeler Elementary school in the Millard Public Schools District (MPS). This school is located in West Omaha. I was placed in one of five sections of second grade. My cooperating teacher has been teaching for 34 years and is in her 14th year at Wheeler. I co-planned, implemented, and assessed the 5th unit from the MPS mathematics curriculum.

There were 24 total students in my class. Three of the students were a part of the Alternative Curriculum Program (ACP). The ACP students are only in the classroom for the first thirty minutes of the day during our morning meetings and did not participate in unit of instruction. There were three students of color in my class, and twenty-one Caucasians. Wheeler Elementary’s school population is 85% Caucasian, 6% Hispanic, 4% Asian, 1.5% Black, > 1% Alaska Native, > 1% Pacific Islander, and 4% two or more races.

*Using Formative Assessment and Linguistic Representation in Math Instruction*
The goals for this unit were for students to understand how to create and analyze bar and picture graphs, understand how to tell time, and accurately complete word problems using addition and subtraction. The purpose of the study was to determine if the formative assessment strategy “exit tickets” and the midpoint check would provide improve student learning.

Before instruction began the students completed a pre-test. Following lessons, exit tickets were completed by the students. The students also participated in a midpoint check. The unit concluded with students completing a post-test. The pre-test and midpoint check were identical in the setup of a Google Form of 12 questions. Four of the questions addressed time, four questions were story problems, and four questions addressed graphing. The post-test was not the same format as the pre-test. The post-test was a district assessment that included 12 questions addressing the same skills as the pre-test. The questions on all three assessments were the same questions with different numbers. Throughout the unit, I also incorporated linguistic representations and physical manipulatives. The first instructional strategy implemented during the unit was the use of physical manipulatives with Judy Clocks. A Judy clock is an individual clock that allowed students to change the time using the minute hand.

I utilized manipulatives to assist the students in developing an understanding of mathematical concepts through representation. The visual and physical aspects of manipulatives create a clearer understanding for students as they explored new skills during learning. Shaw (2002) conducted research on integrating manipulatives during instruction. Shaw found that when students could see their learning in action and apply it their understanding was deepened. She also found that manipulatives made skills practice more meaningful. Manipulatives can be used in a variety of ways and appeal to every type of learner, especially those who have a visual preferred learning style.
When used, manipulatives also keep students actively engaged in the lesson creating better learning outcomes. Through manipulating objects during skills acquisition student understanding can increase. Cockett and Kilgour (2015) shared that physical representations allow students to practice what they are learning with a physical object they can manipulate themselves. They noted that materials like clocks and base ten blocks increased student curiosity and increased student understanding through physical practice. They found that by allowing students to use a physical object and apply what they had learned helped them make connections between content and their life experiences.

Another instructional strategy I implemented throughout the unit was turn and talks. A turn and talk is when students are encouraged to discuss their thinking with a peer in the classroom during a lesson. The turn and talk instructional strategy is most often implemented by a teacher who may first state a question to the whole class. The teacher then pauses and asks the students to share their responses with another student. Hindman et al. (2022) found in their research that turn and talks supported the development of language. They noted that by engaging students in conversations with their peers they are building their vocabulary. When students practiced sharing their thoughts with others in a structured environment, they found that this instructional strategy challenged students to share their ideas with peers, which in turn allowed for a deeper understanding of content.

Tarbell (2017) elaborated on the importance of teachers asking meaningful questions that provoke thoughts and discussions in supportive environments. Tarbell (2017) noted that if students did not feel comfortable in the environment, or if the questions posed were not engaging, the conversations were not productive. He elaborated that if a teacher has created an environment where the students feel comfortable discussing and interacting with their peers, the
teacher could encourage scholarly conversations with their students. Tarbell also noted that it is essential to know that turn and talks need to have direct and clear questions that students are discussing so that they know exactly what is expected of them as they engage in these conversations.

**Participants**

There were 24 students in my classroom. Twenty-one of the students participated in the study. Three students who are a part of the Alternative Curriculum Program and were not included in this project as they receive alternative instruction. Two students had Individualized Education Plans for speech and language service, five students received individualized or small group reading intervention, and four received math intervention. Intervention is considered an extension of classroom learning through the use of an intensive remedial program. Of the 21 students participating in this project, 14 were boys and seven were girls. All of the students were between the ages of six to eight.

**Methods and Materials**

This math unit aligned with four Nebraska State Standards for Math Grade 2:

- 2.3.3.b Identify and write time to five-minute intervals using analog and digital clocks and both a.m. and p.m. (NDE, 2015, p. 9).
- 2.2.3.a Solve real world problems involving addition and subtraction within 100 in situations of addition and subtraction, including adding to, subtracting from, joining and separating, and comparing situations with unknowns in all positions using objects, models, drawings, verbal explanations, expression (NDE, 2015, p. 9).
- 2.4.1.a Create and represent a data set using pictographs and bar graphs to represent a data set with up to four categories (NDE, 2015, p. 9).
• 2.4.2.a Interpret data using bar graphs with up to four categories. Solve simple comparison problems using information from the graphs (NDE, 2015, p. 10).

The second grade MPS curriculum for time, graph and word problem unit was completed over the course of five weeks. Before I started teaching the content curriculum, I administered a pre-test in the format of a Google form to each student. The pre-test consisted of twelve questions regarding time, graphs, and word problems. After students completed the pre-test, I reviewed skip counting and basic addition and subtraction facts that were used throughout the unit and then I began teaching unit five curriculum.

The first two weeks were focused on teaching students how to tell time. After I taught students about time, they learned about the different types of graphs. I administered a midpoint check halfway through the unit during the third week. The midpoint check assessment was created on a Google form that followed the same format of the pre-test.

I used the data from the formative assessment midpoint check to guide the rest of the unit. I continued to teach students how to make graphs and interpret their data. I also covered word problems, and comparison bars. In addition, I taught a strategy to assist students in deciding if they should add or subtract to solve a word problem.

Instructional Strategies

Linguistic Representations and Manipulatives

For this unit, I integrated two research-based instructional strategies. The first strategy I used to engage students was linguistic representation through the use of turn and talks. I integrated turn and talks to encourage students to participate in academic conversations with their peers to further their knowledge and understanding of the content at hand. The second instructional strategy that I incorporated throughout the unit was the use of physical
manipulatives, specifically Judy clocks. Judy clocks allowed students to manipulate a clock to
learn how analogue clocks work and how to properly tell time.

Following instruction on how to solve word problems I spent two class periods
(approximately 90 minutes altogether) to review all content learned throughout the unit. I
provided students with example problems that looked similar to the test. They also participated
in two reviews activities. They answered questions on whiteboards and participated in IXL group
jams. IXL is a website that allows a small group of students to answer a question at the same
time on their individual devices. I then administered the post-test, which was a district
assessment. Students were given a paper copy to show their work and circle each answer. They
then typed their answers into the district’s mathematics assessment program titled School City.

Results

Appendix 1 includes the questions on the pre-assessment. Appendix 2 contains midpoint
check questions. Figure 1 is a breakdown of each student’s scores on the pre-test administered
the first day of the unit. Four students did not complete the pre-test due to various reasons.
Figure 2 shows 19 student responses on the midpoint check taken during the third week of the
unit. Figure 3 is a breakdown of all 21 student responses on the post-test. Finally, Figure 4 is a
graph comparing the data results of each of the three unit five assessments.

Pre-test Data Analysis

Figure 1

Overall Pre-Test Scores
Note. Figure 1 reports the pre-test student results.

The pre-test was a twelve question Google Form covering the content of telling time, analyzing graphs and story problems. Students completed this assessment before the start of the unit. Figure 1 shows a breakdown of the students and their responses to the assessment. Questions one, five, six, and seven were based on knowledge of clocks and telling time. Questions eight, ten, eleven and twelve involved graphs, and two, three, and four were story problems. The correct answer for each question is highlighted in pink under each column, and are represented by a white box for the students who answered the questions correctly. Those that are highlighted yellow are incorrect answers. The blue boxes represent questions that were answered partially correct (either due to a student only selecting one response instead of the 2 as stated in the question, or one of the two selections being incorrect).

Based on the data collected, I knew that students were most familiar with telling time, and had some knowledge on story problems. An average of 13 students answered the questions on clocks and telling time correctly. The previous unit was on story problems, therefore I knew that it would be important to reteach strategies to solve story problems throughout the unit.

The independent worksheets completed by students at the end of each math lesson usually included at least one word problem. My cooperating teacher and I created our own worksheets on comparison word problems and two-step problems. I used the self-created worksheets to review before the unit test. An average of 12 students answered the questions on graphs correctly, not including the students who answered number eleven partially correct. If I were to include the partially correct answers, the average would have been 14 students answering the problems correctly. I chose to not include the partially correct responses in the data averages because I knew that it would be important for those students to practice selecting more than one
Formative Assessment and Linguistic Representation

correct response. I also wanted to gain a better understanding of the test taking strategy of analyzing each answer option then selecting all that apply.

I reviewed the data on the questions students answered incorrectly. I made sure that I taught the basic foundational knowledge of each content area. I wanted to ensure that all students were learning new information correctly or reviewing what they had previously learned. I also used the data from the pre-test to gauge when I would want to administer the midpoint check. I decided to administer the midpoint check to students after learning about clocks and graphs, but before we reviewed story problems. I made this decision because it was an appropriate time to assess student learning thus far, before reviewing material on how to solve word problems that they had learned in the previous unit.

Midpoint Check Data Analysis

Figure 2

Midpoint Check Content Knowledge

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Note. Figure 2 represents the midpoint check student results.
Following analysis of the pre-test data I chose to have students complete the midpoint check after learning about time and graphs, but before reviewing word problems since they had just worked on word problems in the previous unit. During the pre-test students asked for help on the word problems. They questioned whether they needed to add or subtract. Figure 2 shows a breakdown of the students’ responses to each question. The format of the midpoint check was the same as the pre-test, and included the same questions, but with some of the numbers changed. Questions one, five, six, and seven were about time and clocks. Questions two, three, and four were word problems, and eight, ten and twelve were about graphs.

Students did the best on questions regarding telling time, with an average of 17 out of 19 students answering the questions correctly (averages were found by totaling the correct responses for each question regarding that content area, then dividing them by the number of questions). After gathering exit tickets from students, conducting small groups, and asking students to tell me the time on the clock periodically, I anticipated that they would do well on the midpoint check.

Another area students did well on was analyzing graphs. There was an average of 16 students who answered each of the graphing questions correctly (not including the ones who only got partial credit on question number eleven which asked students to choose two correct statements). I also felt confident in how well students would do on this portion of the midpoint check. The students had been creating a graph as a class during their morning seatwork all year and were encouraged to ask and answer questions about the graph with their peers.

There were seven students who only selected one of the two correct statements on question eleven. I used this data to guide my instruction. I asked students to carefully read what
each question was asking them to do. I asked them to then analyze each answer option before moving on to the next question.

I used the data from my class’s results to plan small group instruction with the other second grade students who were in the medium-low range of their ability levels. Not all of the students stayed for small group instruction. For those who did not participate in small group I collected exit tickets and independent assignments to ensure that they were retaining the information taught during whole group lessons. I wanted to be sure that they were accurately practicing during small group and independent time.

From the midpoint check data, I noted that students struggled to determine whether to add or subtract in a word problem. To remediate this, I had students start to circle the key words like “more” or “fewer” in the questions. I also had them underline the question it was asking students. This strategy helped them breakdown word problems into more manageable parts which made it easier to solve the problems. After implementing these strategies, I saw an increase in student’s ability to correctly determine whether to add or subtract. I also observed the students became increasingly confident in their abilities to solve word problems.

**Post-test Data Analysis**

**Figure 3**

*Overall Post-Test Scores*
Note. Figure 3 represents the post-test student results.

To conclude the unit, students took a 12-question test over time, analyzing and creating graphs, and story problems. This was a district assessment, so it was not the same format as the pre-test and midpoint check. There were still twelve problems, but students completed it on paper as opposed to on their devices. Figure 3 shows a breakdown of each students’ responses. Similar to the pre-test and midpoint check, questions one, five, six, and seven were about time, two through four regarded word problems, and eight through twelve were on graphs.

Eight of the 21 students who completed the unit five district post-test received a 100% on it. Two students scored under a 70%. Both of these students receive small group or individualized math and reading intervention. The remaining 11 students scored between a 70% and a 91%.

The most missed questions were regarding story problems. I anticipated that students would struggle to understand when to use addition or subtraction when solving an addition problem. After concluding the unit, I continued to work with students in whole group settings, and small group settings based on the results of their post-test.
Additional Data

Aside from the three major pieces of assessment data of the pre-test, midpoint check and post-test, other forms of formative assessment were administered frequently throughout the unit. Most often, I posted one question on the board at the end of the day regarding the content learned during whole group instruction. Students would then answer the question on a post-it note and turn it in as an exit ticket. I then took note of the students who didn’t answer the questions correctly and made sure to check in with them work during independent work time the next day.

After the second day of learning about graphs, students were asked to list the four necessary parts of a graph. Over 75% of the class was missing at least one of the key parts, so I incorporated a graph into seatwork the following morning to point out the four parts of the graph. I then started the math lesson that day by reviewing the four parts again.

I also had students engage in academic discourse and conversations by asking them a question related to the content being learned. I also asked them to talk to a partner about their answer. To further student learning, they were asked to share why they thought that was their answer, or how they knew that. As they engaged with a partner I walked around the classroom and provided immediate feedback to individual students. I used the walk around as a form of reteaching and to guide them to the correct answer. During the lessons if I observed that students were not understanding the question being asked, or if they didn’t know how to answer it, I was able to reword my explanations or reteach the content in another way to help students better understand.

Discussion and Conclusions

Figure 4

Comparison Graph
Note. Figure 4 represents the student results comparison graph.

Figure 4 is a line graph of the three major assessment data points from the unit. The gaps in lines are due to students who didn’t take the quiz or test due to various reasons. Overall, there was a steady improvement for most students. Student 21 struggled the most with the pre-test and midpoint check. I provided Student 21 with opportunities for small group and individual instruction.

Students 6 and 17 also took the post-test in a quiet area. These students had assistance from my cooperating teacher per changes in their education plans formed by the interventionist and the Multi-Tiered System of Supports Team. I believe the support had a positive impact on their ability to succeed on the post-test.
All students made improvements from the midpoint check to the post test. The results of the tests administered in this unit thus far in my clinical practice experience, have evidenced the most notable improvements in all previously taught math units.

I found that integrating exit tickets provided me with the opportunity to check in with my students and assess their learning process based on their answer to the question on the exit ticket. Using the data collected from the pre-test, midpoint check, and post-test allowed me to plan and implement curriculum throughout the unit based on students’ background knowledge and new learning.

The implementation of linguistic representations through turn and talks, the use of physical manipulatives such as Judy clocks, exit tickets and formative assessment, and a midpoint were strategies that assisted me in collecting data during the unit. When data from each assessment was compared, there was continual and steady overall growth for the class as the unit progressed. 19 of 21 students scored above a 70% which is on level for second graders in the district. Overall, the instructional strategies and formative assessments implemented throughout the unit were beneficial to my students’ second grade mathematics learning.
References


Formative Assessment and Linguistic Representation

Performance. Educational Psychology Review.


Appendix A

Unit 5 Pre-test Questions
Formative Assessment and Linguistic Representation

1. John has 24 books. Mary has 19 books. How many more books does John have than Mary? 
   **Answer:** John has 5 more books.

2. **What time does the clock show?**
   - A. 8:30
   - B. 6:00
   - C. 12:30
   - D. 6:12
   **Answer:** B. 6:00

3. **Use the clock. Which shows the same time?**
   - A. 9:30
   - B. 9:20
   - C. 9:25
   - D. 9:23
   **Answer:** B. 9:20
Formative Assessment and Linguistic Representation

**Question 1:**
How many flowers are in one hour?

- A: 24
- B: 30
- C: 60
- D: 100

**Question 2:**
Choose the correct answer to complete the sentence.

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Dear has ______ cars than Tyler.

- A: 2 more
- B: 3 fewer
- C: 4 fewer

**Question 3:**
Use the bar graph. Which statement is true?

- A: There are 5 more orange flowers than yellow flowers.
- B: There are 5 more purple flowers than orange flowers.
- C: There are 6 more orange flowers than yellow flowers.
- D: There are 2 more yellow flowers than red flowers.

**Question 4:**

- A
- B
- C
- D
Appendix B

Unit 5 Midpoint Check Questions
1. What time does the clock show?

   - 11:35
   - 10:35
   - 10:07
   - 7:50

2. Nolan swims 27 laps in the pool. He swims 14 laps fewer than Josh. How many laps did Josh swim?

   Short answer text

3. Karyn draws 32 flowers. She draws 18 fewer than Melissa. How many trees does Melissa draw?

   - 14
   - 49
   - 50
   - 40
4. Kamora has 23 blocks. Jordyn has 18 blocks. How many more blocks does Kamora have than Jordyn?

5. What time does the clock show?

A. 6:30  
B. 6:00  
C. 12:00  
D. 6:12

Circle the correct answer:

6. Use the clock. Which shows the same time?

A. 9:20  
B. 9:25  
C. 9:30  
D. 9:35

Circle the correct answer:
87°
How many minutes are in one hour?
A. 20
B. 60
C. 62
D. 100

88°
Choose the correct answer to complete the sentence.

Apples have ______ more seeds than grapes.

A. 4
B. 8
C. 40
D. 2

89°
Use the bar graph. Which statement is true?

- There are 3 more pet hamsters than cats.
- There are 2 more pet fish than hamsters.
- There are 3 more pet hamsters than dogs.
- There are 4 more pet cats than hamsters.
Appendix C

Unit 5 Exit Ticket Examples
Exit Ticket
2/22
What are the 4 parts of a graph?