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A study of measurement in the Algebra I classroom

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A STUDY OF MEASUREMENT IN THE ALGEBRA I CLASSROOM

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Abstract

The purpose of this research was to supplement and reorganize the existing Unit 7: Measurement of the East Baton Rouge Parish School System Comprehensive Curriculum (EBRCC) to improve student performance. To restructure the unit, I analyzed the Measurement Standards outlined in both the Common Core Standards and the National Council of Teachers of Mathematics. I also studied the existing structure of the unit to reorganize the topics in a manner that is more succinct and effective in promoting student learning.

In addition to reorganizing the unit, I also implemented my own supplements over the three week period. To determine if the supplements I introduced and the changes I made were effective, I gathered and reviewed student data, including performance on a benchmark assessment, student responses to open-ended questions about the subject matter, and pre- and post- assessments involving student scripts on the key ideas the unit.

The analysis of the pre- and post-assessments demonstrate that there were considerable advantages to the changes I made. Students' scores showed an overall average learning gain of 111.5% on the post-assessment. Seventy percent of my students scored proficient or above on the Edusoft Benchmark assessment, which is 23% higher than that of the students that I taught last year. This was also approximately 38% higher than the percent of students scoring proficient or above in other Algebra I classes at my school this year.

Introduction

The Study of Measurement in the Algebra I Classroom, as outlined in the East Baton Rouge Parish Comprehensive Curriculum (EBRCC), is an attempt to convey the ideas of Precision, Accuracy, Uncertainty, and Significant Figures. It was my objective to reorganize and supplement the unit, taking into account the curriculum and national learning standards. After examining these, I created a unit plan to provide a description and outline of the lessons and activities I planned to teach. Subsequently, I prepared a summary to report the implementation of the plan. The data from the pre- and post-assessments and the data from the final exam are used to formulate a final conclusion.

I began by examining the unit as outlined in the curriculum. The goals of the unit are identified by the state standards, formally identified by Grade Level Expectations of GLEs. These standards define what students should know at the end of the unit. The curriculum provides suggested activities on the topics introduced in the unit and lists the vocabulary and prior skills students will need to be successful.

I also examined national learning standards for mathematics developed by the National Council of Teachers of Mathematics (NCTM) and Common Core State Standards (CCSS). According to the NCTM, students should “Understand Measureable Attributes” and “Apply Appropriate Techniques, Tools, and Formulas”. The Common Core State Standards address measurement objectives in the Measurement and Data Domain, which contains a cluster of standards related to measurement. Both NCTM and CCSS put greater emphasis on the measurement standards in the lower grades.

After examining both the EBRCC unit and the national measurement standards, I reorganized the unit and developed additional supplements to address the grade level expectations. When I developed the unit plan for this unit, in addition to considering the EBRCC unit and the national measurement standards, I considered the demographics, performance, and motivation of the students I teach.

The unit plan consists of a day-by-day plan of activities and assessments for the three week period. Later in this thesis, I provide details of each lesson topic that I planned to cover. These details give an overview of what I hoped would happen each day according to the introduction, guiding questions, activities, and lessons I planned. In addition to the unit plan, I also provide an explanation of my approach for each topic introduced in the unit and my rationale for rearranging the topics.

At the end of the unit, students were given an Edusoft Benchmark assessment to serve as the final exam for the unit. This assessment consisted of 14 multiple choice questions and 2 short answer questions. Similar to the Algebra I End-Of-Course test, the assessment divides the multiple choice questions into a calculator section and a non-calculator section.

In addition to the final exam, students were assessed throughout the unit at the end of each major topic. The weekly assessments were in the form of writing prompts and real-life short answer problems. Students also completed a unit pre- and post-assessment to determine student growth and understanding over the three week time period. Student work samples of the activities and lessons completed throughout the unit, including the pre- and post-assessments, are exhibited in this paper to support the description of what happened when the plan was implemented.

An analysis of the final exam results shows that the average student score on the final exam was 11.5/17 points and that 70% of the students scored proficient. Later in this paper, we will identify specific standards and we will describe how students performed on the questions that address them.

The results of the pre- and post-assessments show my students demonstrated considerable growth in the average scores. The final exam data shows significant improvement by standard and overall proficiency compared to last year’s results. Comparisons of the final exam results of my students with the results obtained by other Algebra I students show that there were considerable advantages to the changes I made.

Chapter 1. Teaching Measurement Topics in the Algebra I Classroom

1-1 Purpose

As stated by the EBRCC, upon completion of the Measurement Unit in the Algebra I curriculum, “Students should be able to find the precision of an instrument and determine the accuracy of a given measurement. They should know the difference between precision and accuracy. Students should see error as the uncertainty approximated by an interval around the true measurement. They should be able to calculate and use significant digits to solve problems.” To summarize, there are 4 topics of focus in the Measurement Unit. The 4 topics are Accuracy, Precision, Error, and Significant Figures.

A measurement unit featuring these topics is often absent in the Algebra I Curriculum, but is more common in secondary Physics and Chemistry course. Even within the EBRCC, the use of a chemistry textbook as a resources is recommended (EBRCC, P.321). One might question whether the measurement unit is appropriately placed in the high school curriculum, both in terms of grade-level and subject matter, as well as, whether students are equipped with the prerequisite knowledge required to understand such mathematical and conceptual abstractions. However, the EBRCC does not allow any unit or components therein to be omitted from instruction. Therefore, all GLEs outline in the EBRCC must be covered and the Unit and the Edusoft Benchmark exam must be administered for assessment.

The EBRCC Algebra I Measurement Unit includes only suggested activities, with few other resources. It does have a final assessment that provides quantitative data but it does not assess student growth or understanding. While addressing the GLEs as outlined in the curriculum, I studied student understanding and growth by using qualitative assessments and introducing activities that focused on student experiences during learning and instruction.

1-2 The Measurement Unit Goals

The following table displays the Grade-Level Expectations (GLEs) that are covered by the activities within the EBRCC Algebra I Measurement Unit:

Table 1-1. GLEs from EBRCC for Unit 7: Measurement

<u>**GLE(s):**</u>

4. Distinguish between an exact and an approximate answer, and recognize errors introduced by the use of approximate numbers with technology (N-3-H) (N-4-H) (N-7-H)
5. Demonstrate computational fluency with all rational numbers (e.g., estimation, mental math, technology, paper/pencil) (N-5-H)
17. Distinguish between precision and accuracy (M-1-H)
18. Demonstrate and explain how the scale of a measuring instrument determines the precision of that instrument (M-1-H)
19. Use significant digits in computational problems (M-1-H) (N-2-H)
20. Demonstrate and explain how relative measurement error is compounded when determining absolute error (M-1-H) (M-2-H) (M-3-H)
21. Determine appropriate units and scales to use when solving measurement problems (M-2-H) (M-3-H) (M-1-H)

The unit contains 12 activities. Of these 12 activities, 9 are required, two are suggested for homework, and one is optional. These activities are conducted under the "assumption of mastery" of the following prerequisites, as listed in the EBRCC. Students should:

- know how to read a meter stick, clock, scale, graduated cylinder and other measurement instruments;
- be able to correctly use conversion factors;
- be proficient in rational number computation;
- be able to recall or recognize the formulas for perimeter, area, and volume of geometric shapes;
- be able to analyze data using measures of central tendency;
- know the place value of real numbers and be able to round to a given place value.

The vocabulary addressed in the unit includes some terminology that has been previously introduced, such as area, perimeter, volume, and circumference. Students are expected to recall the related mathematics. New and advanced vocabulary that is more conceptual is introduced. It

requires a more sophisticated frame of reference, as it relates specifically to the mathematical strand of measurement. Some of the featured words, such as accuracy and precision, have colloquial meanings that are used loosely and interchangeably, but are completely distinct from the precise mathematical meanings. All of the new vocabulary words are listed in the table below.

Table 1-2. Vocabulary for EBRCC Algebra I Measurement Unit

Vocabulary:		
Measurement	Exact answer	volume
Accuracy of measurement	Significant Digits	circumference
Precision of measurement	Scale of a measuring instrument	
Approximation	Range of values	
Absolute error	Area	
Relative error	Perimeter	

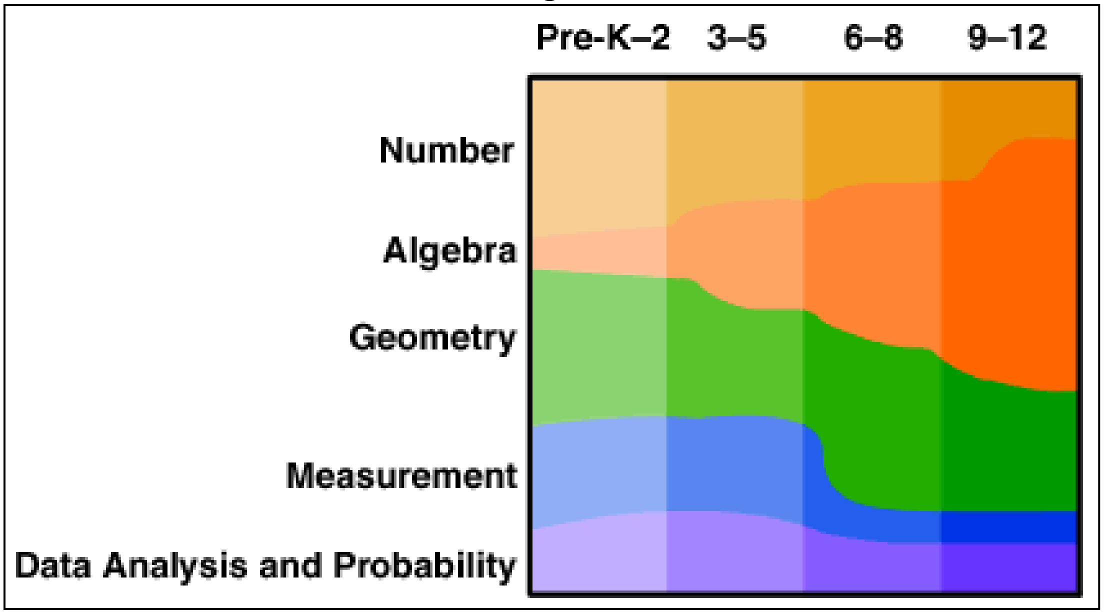
1-3 Standards of Learning Measurement: NCTM

National standards for school mathematics were published by the National Council of Teachers of Mathematics in 1989 (NCTM, 1989). These "present a significantly enhanced vision of mathematical skills and advanced problem solving intended for all high school graduates." (Numeracy: The New Literacy for a Data-Drenched Society).

Principles and Standards for School Mathematics presents the mathematical content and processes that NCTM proposes students know and be able to use as they progress through school. There are ten standards of which 5 are content and 5 are process. The Content Standards—Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability—explicitly describe the content that students should learn. These standards are specifically organized by content, but are not divided by mathematical subject areas. The Process Standards—Problem Solving, Reasoning and Proof, Communication, Connections, and Representation—specify the understanding, knowledge, and skills that students should acquire from prekindergarten through grade 12. The standards remain the same across grade levels;

however they progress in a sophisticated manner in terms of the depth and fluency expected at each grade level. Table 1-3 shows roughly how the Content Standards might receive different emphases across the grade bands. This is a proposed arrangement of the standards within the curriculum, but it is permissible that this arrangement be adjusted based on materials, instruction, assessments, and framework.

Table 1-3. The Content Standards should receive different emphases across the grade bands



The two Measurement Standard objectives described by the NCTM are as follows:

- **Understand Measurable Attributes** of objects and the units, systems, and processes of measurement;
- **Apply Appropriate Techniques, Tools, and Formulas** to determine measurements.

In the earlier grade bands, there is a great focus on the Measurement Standard. This focus tends to decrease as the grade levels increase. In the earliest grade band, K-2, the expectations are that students understand how to measure using standard and nonstandard units and select an appropriate unit and measuring tool for the attribute being measured. In the 3-5 grade band,

students understand such attributes as length, area, weight, volume, and size of angle, select the appropriate units for measuring each attribute, carry out simple unit conversions within a system of measurement, and understand that measurements are approximations and that differences in units affect precision. These objectives define mastery of "Understand Measurable Attributes." To satisfy the requirements of the "Apply Appropriate Techniques, Tools, and Formulas" standard, students in the K-2 grade band are expected to use repetition of a single unit to measure something larger than the unit and to measure with multiple copies of units of the same size. Students are also expected to use tools to measure. Subsequently, in the 3-5 grade band students select and apply appropriate standard units and tools to measure length, area, volume, weight, time, temperature, and the size of angles.

At the middle school level (the 6-8 grade band) students expand their experiences with measurement. To demonstrate fluency in "Understand Measurable Attributes," students become proficient in selecting the appropriate size and type of unit for a given measurement situation. Also, in this grade band, students develop an understanding of precision and measurement error, a component of "Apply Appropriate Techniques, Tools, and Formulas." Students also develop and master skills in composing and decomposing two-and three-dimensional shapes to find the lengths, areas, and volumes of various objects. Finally, students become proficient in the understanding of different angle relationships and understand how to measure angles.

As seen in Table 1-3, the Measurement Standard receives least emphasis in the 9-12 grade band. It is expected that students enter this grade band with a good understanding of measurement concepts and well-developed measurement skills. The "Understand Measurable Attributes" standard expects students to make decisions about units and scales that are appropriate for problem situations involving measurement. The "Apply Appropriate Techniques,

Tools, and Formulas" standard expects students to analyze precision, accuracy, and approximate error in measurement situations. When students arrive at this grade band, they should be able to make reasonable estimates and sensible judgments about the precision and accuracy of a measurement. Students should also understand the use of formulas for area, surface area, and volume of geometric figures.

1-4 Standards of Learning Measurement: Common Core State Standards

For over a decade, research studies of mathematics education in high-performing countries have pointed to the conclusion that the mathematics curriculum in the United States must become substantially more focused and coherent in order to improve mathematics achievement in this country. The Common Core State Standards are a set of shared goals and expectations for mathematics that address this. The development of CCSS was a state-led effort to create rigorous, internationally benchmarked standards. Though adoption of the CCSS is not federally mandated, a large majority of states have chosen to adopt and begin implementing them." (Align, Assess, Achieve. 2011) The state of Louisiana adopted the CCSS on July 1, 2010 and is scheduled to launch the implementation of CCSS upon the start of the 2014-2015 school year.

The CCSS set grade-specific standards and define what students should understand and be able to do in their study of mathematics, but do not define the intervention methods or materials necessary to support students who are well below or well above grade-level expectations. The standards are organized into clusters, or groups of related standards. Clusters may fall under a larger umbrella called domains. Domains are larger groups of related clusters. See Figure 1-1 below.

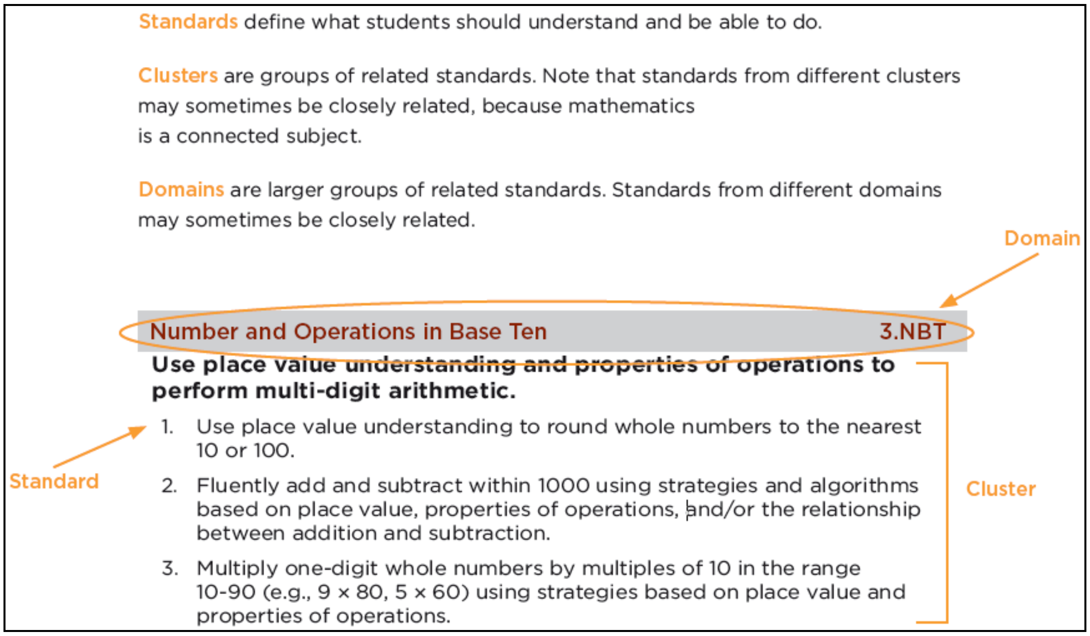


Figure 1-1. How to Read Grade Level Standards

The Grade Level Standards are organized in the fashion just described for grades Kindergarten through 8^{th}. The Measurement strand is first introduced in the CCSS under the domain, "Measurement and Data" in Grade K (Kindergarten). Various coherent topics of measurement are subsequently introduced under the Measurement and Data domain through Grade 5. After Grade 5, the Measurement and Data Domain does not appear again in CCSS. However, there are some standards that can relate measurement topics that appear in Grades 6-8 as shown in Table 1-4 below.

Table 1-4. Measurement Standards that appear in Grades 6-8 CCSS

6th Grade
*Geometry- Solve real world and mathematical problems involving area, surface area, and volume
7th Grade
*Geometry- Solve real world and mathematical problems involving angle measure, area, surface area, and volume
8th Grade
*Geometry- Solve real world and mathematical problems involving cyclinders, cones, and spheres

The Common Core Standards state, "The high school standards specify the mathematics that all students should study in order to be college and career ready." The high school standards are

listed in conceptual categories to provide a more comprehensible idea of high school mathematics. These conceptual categories are as follows:

- Number and Quantity
- Algebra
- Functions
- Modeling
- Geometry
- Statistics and Probability

The High School Conceptual Categories of the CCSS are far broader than the measurement strand. There are some related measurement standards in the categories Number and Quantity, Geometry, and Statistics and Probability. There were no standards related to the Measurement Strand featured in any of the remaining High School Conceptual Categories, Algebra, Functions, and Modeling. These standards are outlined in Table 1-5 below.

Table 1-5. Measurement Standards that appear in High School Conceptual Categories CCSS

Number and Quantity
• Reason quantitatively and use units to solve problems Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and data displays.interpret the scale and the origin in graphs and
Algebra
Functions
Modeling
Geometry
• Explain volume formulas and use them to solve problems • Visualize relationships between twodimensional and three-dimensional objects
Statistics and Probability
• Summarize, represent, and interpret data on a single count or measurement variable

There is a much greater emphasis on the Measurement and Data Domain in the earlier elementary grades than that of the latter high school grades.

1-5 Instructional Plan

I analyzed the EBRCC Unit 7: Measurement Curriculum and identified some general issues of the curriculum's design. I also gathered and analyzed student data, which included performance on benchmark assessments, responses to open-ended questions, and a comparison of pre- and post- assessments. I also undertook an in-depth study of the Standards of Learning for Measurement as outlined by National Council of Teachers of Mathematics (NCMT), and Common Core State Standards. Finally, I composed what I deemed a more appropriate Measurement Unit of Study that incorporated desirable teaching strategies, such as discovery-based and project-based learning, curriculum-based math probes, and cooperative learning, and demonstration. My contributions were based on investigating Measurement Units of other district and state curricula.

1-6 The Students

Belaire High School is an inner city High School with approximately 870 students enrolled. Approximately 98% of the students are in a minority race/ethnicity group including the African-American, Hispanic/Latino, and Asian/Pacific Islander race/ethnicity groups. Seventy-nine percent of the students qualify for free or reduced lunch. Of the entire student population approximately 230 students are enrolled in the Algebra I course. Most students enrolled in the Algebra I course have scored an Achievement Level of "Basic", "Mastery", or "Advanced" on the 8th grade Louisiana Educational Assessment Program (LEAP) exam or have completed 1 high school credit equivalent in a LEAP Remediation course. There are some cases where students who scored Approaching Basic in the LEAP may be enrolled in Algebra I.

I taught about 47% percent of the total 230 students enrolled in Algebra I. Many of my students were Regular Education students, meaning they did not receive any services from

Exceptional Student Services (ESS) for learning or behavior disabilities. Approximately 21% of my students were Exceptional Students, "students that have been evaluated in accordance with specific regulations and are determined according to the Louisiana Department of Education Pupil Appraisal Handbook (formerly Bulletin 1508), to have an exceptionality which significantly affects educational performance to the extent that special education is needed" (www.ebrschools.org).

In addition to teaching Exceptional Students, I also taught English Language Learners (ELL). These students possess a native language other than English and in many cases have just recently emigrated from other countries. These students are expected to meet the same State academic content and student academic achievement standards as regular students, while attempting to attain English proficiency. English Language Learners represent about 18% of my student enrollment.

Based on whole-group discussions, I found that there are multiple reasons students are motivated to learn. Some are motivated because they want to score high achievement levels. Some students receive gratification when they are able to compete with their peers. Some students are motivated by a desire for knowledge and learning. Some students are motivated because of expectations set by their parents, teachers, and/or role models that they desire to meet. For many of my students, motivation comes from an end goal. The end goal may be to prepare for post-secondary study, to complete secondary study, to acquire a sufficient amount of credits to satisfying advancement requirements, to pass the course, or to simply pass the assessment.

In any case, to trigger intrinsic motivation of my learners, I try to utilize strategies and develop creative learning activities that demonstrate how mathematics topics are relevant to and are used in my students' everyday lives. I also grab their interest when I pose questions asking

how efficiently the world would operate if mathematics, specifically quantity and the concept of measurement didn’t exist. Students are then motivated to conjure ideas and examples of how life would be in the absence of quantity and measurement. Such topics serve to help open discussions to introduce the Measurement Unit.

Chapter 2. Implementation

2-1 Goal

My goal was to develop a Measurement Unit that will better address the GLEs outlined by the state's comprehensive curriculum and that will provide students opportunities to develop their understanding of the four main Measurement topics of this Unit: Accuracy, Precision, Measurement Errors, and Significant Digits. Among other changes, I planned to reorganize order in which the topics in this unit would be taught to allow students to develop their understanding in a more sequential and more succinct manner. It was my objective to compose a more appropriate Measurement Unit of Study by analyzing and utilizing specific teaching strategies, such as discovery-based and project-based lessons, curriculum-based math probes, cooperative learning, and demonstration. I hoped to find material to support this by investigating the Measurement Units of other district and state curricula. In addition, I also created some teacher-made supplements for the unit.

I planned that prior to addressing the topics of the unit, students would complete a pre-assessment to determine familiarity of the topics of this unit, as well as, to determine the presence of prerequisite skills such as the ability to use measurement tools, understanding appropriate units of measure, and identifying tools and units for standard measurable attributes. The same instrument used for pre-assessment was also to be administered in the form of a post-assessment to measure student growth. I also planned to utilize the quantitative data provided from the Edusoft Benchmark Assessment to analyze students' ability to meet state standards on a standardized Measurement Unit assessment.

2-2 Final Exam

The Final Exam for the Unit is the Unit 7 Measurement Edusoft Benchmark Assessment. (This is not the pre/post assessment I devised.) The content of the assessment is created by the East Baton Rouge Parish School System to assess student knowledge and is based on the GLEs taught within the Measurement Unit. The GLE Distribution can be found in Table 2.1 below.

Table 2-1. GLE Distribution on Unit 7: Measurement Edusoft Benchmark Assessment

Grade Level Expectations	Number of Test Items
GLE # 4	Not Tested
GLE # 5	Not Tested
GLE # 17	3
GLE # 18	1
GLE # 19	3
GLE # 20	4
GLE # 21	5

The exam is a paper and pencil assessment that is administered during a single class period. It consists of 16 questions, 14 of which are multiple choice and 2 that are short answer. The 16 questions are divided into 3 sections: Multiple Choice-Non-Calculator (7 questions), Short-Answer-Calculator (2 short answer questions), and Multiple Choice-Calculator (7 questions), respectively. The 3-sections model the design of the Louisiana Algebra I End-Of-Course test. However, unlike the Louisiana Algebra I End-Of-Course test, there are no questions on the Unit 7 Measurement Edusoft Benchmark Assessment within the Multiple Choice-Calculator section that require computing. Each multiple choice question is valued at 1 point and each short answer question is valued at 2 points. Students may receive partial credit on the 2 short answer questions. Because the district omitted one of the multiple choice questions after the exam was administered, there are 17 total possible points. The point distribution and Achievement Levels will be discussed in the "Results on Final Exam" section of Chapter 3.

2-3 Unit Plan

In this section, I will describe the lessons and activities of the unit as planned. Prior to making the daily lesson plans, I constructed a unit plan to outline the order in which the topics would be discussed and the number of days each topic would be allocated. The entire unit was allotted 15 days according to the EBRCC Pacing Guide. My plans included the pre- and post-assessments and the Edusoft Benchmark assessment. The Pre-Assessment was scheduled on the first day of the unit, March 12. The Post-Assessment was scheduled on March 29, followed by the Edusoft Benchmark assessment on March 30 because the Edusoft Benchmark assessment is generally administered on the last day of the unit. After scheduling the assessments, the remaining time was allocated to the lesson topics. The topics were the scheduled as follows: Standard Measurement Units (1 day), Accuracy (2 days), Errors (3 days), Significant Digits (2 days), Precision (3 days), and Accuracy vs. Precision (1 day). The remainder of this section will provide daily descriptions of the unit as planned.

On Day 1 after completing the pre-assessment, students were to complete a vocabulary self-awareness assessment. This activity allows students to assess themselves to determine the level of knowledge they have of the vocabulary for the unit. Students were to read each vocabulary word/phrase and determine if they knew its meaning, have only heard it or seen it but do not know its meaning, or if they have never heard nor seen it before at all. These activities would allow the students and me to assess their level of readiness for the unit.

On Day 2 the goal was to provide students with familiar equivalents to standard units. A Power-Point that relates many standard units to items that students may be much more familiar with was prepared. After watching and discussing the power point, students were expected to classify units into categories for length, time, temperature, capacity, and weight on the

ActivBoard. Students were also to measure with the following measurement instruments: a balance scale, rulers, and beakers. Group members were to collaborate about arriving at different results. This was how I planned to introduce the first major topic of the unit, Accuracy.

The plan for Days 3 and 4 was to introduce and discuss the topic of Accuracy. Accuracy of measurement is the "closeness of the agreement between the result of a measurement and the true value of the measurand."(Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results. 1994) Students are expected to come away from this lesson understanding this meaning. The lesson plan began with the pre-discussion question sheet. Students were to be given a sheet and told to answer the question, "What is Accuracy?". Five minutes was allocated. The students' responses were to be shared with the class anonymously by mixing them up and reading them aloud. Without providing a definition or much input, I planned to ask the students several questions to lead a discussion about what accuracy means and what it means to be accurate. Students were to be placed into groups of 2-3 to prepare for the activity. One student from each group would be weighed on 3 different scales. Another student would record the weight from each scale on a form. After the weighing is complete, students of each group must compare the weights from each scale to determine which scale is the most accurate and explain their reasoning. The activity creates a situation of puzzlement that is expected to cause the students to recognize that accuracy cannot be determined unless they know the true value, in this case the true weight of the student being weighed. During the following class period, the responses submitted by each group would be shared with the entire class. After sharing the responses, I planned to provide students with the definition of accuracy and ask students if they would now reconsider which scale is the most accurate. Students would also be given several scenarios in which they would compare and state if accuracy can be determined or not based on

the given information. If accuracy could be determined, students would state which measurement is the most accurate from the scenario. To close, students would complete a Post-discussion question, again answering “What is Accuracy?”

After discussing Accuracy, the topic of Errors in Measurement was to be introduced on Days 5, 6, and 7. I planned to prompt students to recall that when determining the measurements that were the most accurate, we looked for the measurement that was the closest to the known or accepted value. I planned to ask students how were they able to determine which measurement was the closest. Students would be given various examples orally. Rather than introducing absolute value, in the discussion I planned to have students to consider how far off the measurements were. In the examples given, I planned to provide measurements that are both less than and greater than the actual value, but to stress that the deviations are always viewed as positive because we are calculating the distance of how far the measurements are from the actual values. I will discuss with students that they are actually calculating and comparing errors to determine the measurement with the smallest absolute error. Students would be assigned exercises in which they would calculate the absolute error of the measurements provided.

On Day 6, I planned to introduce relative error. To introduce the topic, student would be presented with the following two scenarios: “On a test you missed 1 question. There were 100 questions on this test. On another test in the same class you missed 1 out of 2 questions.” I then would ask students to answer, “How did you fare on each of the assessments?” My goal is for students to identify that the number of items missed on each test is the same, but the percentages and the effect on the grade values are clearly different. Students will likely be able to calculate the percentages on each test without difficulty. Using these scenarios, I hoped to explain to students that at times it is important to calculate the percentage of the error to determine how

significant it may be, and that this the meaning of relative error. Students would complete exercises in which they are asked to calculate the relative error of the measurements provided from the day before.

On Day 7, my plan was to have students distinguish between absolute error and relative error. To assist with the terminology, I planned to give students the following cue: “The absolute error is the actual amount the measure is away from the accepted value.” To help students to remember that the relative error is a percent, I planned to make the comparison and play on words that the relative error is a PERcent, just as “relative” is PERson.” To assess students understanding of each type of error, I planned to present students with the following scenarios: “Scenario 1: Suppose you go to the grocery store and buy what you think is 4 pounds of hamburger for a backyard barbeque. However, when you get home, you realize that the store’s scale is poorly calibrated and you actually have only 2 pounds. Scenario 2: Now suppose that you are buying hamburger for a huge town barbeque and you order 3000 pounds but only receive 2998 pounds. You are short by the same 2 pounds as before. For each scenario, is the error big enough to be of concern or small enough to be unimportant? Explain your reasoning.”

On Days 8 and 9, I planned to cover significant digits. Students would be placed into groups of 4 and given a Cool Colors game sheet. Students would be asked to determine if colored rectangles are “cool” or not by following the Cool Color guidelines. Using the guidelines, I will model several sets on the ActivBoard. Given various arrangements of rectangles, students will collaborate within their groups to label which colored rectangles were “cool” and to list the total number of “cool” rectangles in each set. In the game, colored rectangles represent digits, while white rectangles represent zeroes, and black rectangles represent decimals. The purpose of this game is to get students familiar with following a series of

rules like those they will need in dealing with significant digits. Students would be told to flip the rectangles over to the side with the numbers and to use the same rules for determining which rectangles are cool. I planned that after a few trials, I would post the rules for significant digits. Students would use the same rectangles number side up to determine which digits in each set were significant. To close, students would complete exercises in which they must determine which of the number choices listed have the stated number of significant digits.

On Day 9, I planned to review the rules for significant digits using the exercises assigned the day before and to introduce the rules when using measured quantities in calculations. Several examples would be placed on the ActivBoard, to be completed by student volunteers. Student would be assigned several exercises during Guided Practice time in which they will state the number of significant digits or round a final answer to the appropriate number of significant digits.

On Days 10 and 11, students were to study precision as it relates to a measurement tool. To begin this lesson, students would measure and record measurements obtained with several different rulers that measure to the nearest half, fourth, eighth, and sixteenth of an inch, respectively. This activity is to show students that although they continue to measure the length of the same item; they are able to get a more specific reading as the spaces between the markings get smaller. I will lead a discussion with students to arrive at the understanding that the ruler with the smallest markings will provide the most precise measurement.

On Day 11, students would be given lists of measurements with no measurement tools and asked to determine which one of the measurements was found using the most precise measurement tool. Students would also use a calculator to convert half, fourth, eighth, and sixteenth to decimal forms. Students should be able to see that the numbers with the largest

denominator are also the numbers with the most significant digits after the decimal point. Students will also be asked to compare units to determine which unit would yield a more precise reading. This will require students to consider which one of the units would be a fraction of the other unit.

On Day 12, I planned to explain to students that Precision has 2 definitions and that we have already discussed the first definition, which is related to the precision of a measurement instrument or tool. I would then explain to students that we will now study the other definition as it relates to repeatability. I planned to model an example by displaying the measurement results from two students measuring the same thing 5 times. The lists will each contain 5 different readings in order to demonstrate to students that repeatability does not necessarily mean the same reading multiple times, but could be determined by the closeness of the numbers in the set—in other words, the set with the smallest range. Students would be asked to discuss ways to determine which set of measurements is the most precise based on reliability or repeatability. Additional exercises would be assigned in which students would have to determine which set of measurements is the most precise.

On Day 13, the focus was to be the distinction between precision and accuracy. To introduce this, I planned to state, "Accuracy is like telling the truth, and Precision is like telling the same story over and over again." I would ask students to consider what they understand about accuracy and precision, and to consider their interpretation of what they think the "truth" about accuracy and precision statements means. Students would be given a pre-discussion sheet to complete prior to the lesson. After the pre-discussion sheet, students would participate in a discussion about the difference between accuracy and precision. Students would be presented with the bull's-eye target illustrations and asked to determine if the markings on the target are

accurate, precise, both accurate and precise, or neither accurate nor precise. At the end of the lesson, students would complete the post-discussion answer sheet in which they will answer the same 3 questions as before.

The Post-Assessment was to be administered on Day 14. This will also serve as an assessment that students might use to determine their personal growth and also their readiness for the Edusoft Benchmark Assessment.

Day 15 is the last day of the unit according to the EBRCC Pacing Guide. The Unit 7 Edusoft Benchmark Assessment was to be administered on Day 15.

2-4 Weekly Assessments

To assess student understanding of the content presented, students were given assessments for each major topic. The weekly assessments were in the form of writing prompts and real-life short answer problems. The writing prompts consisted of pre- and post- discussion writing about the topic of the lesson to determine how much understanding students had before the topic was discussed and how much understanding was gained throughout the discussion, facilitation, and exploration of the topic. The real-life short answer problems provided students with realistic scenarios that required students to read, analyze, and apply their understanding of the topic to determine a solution or conclusion for the problems. The weekly assessments were not administered based on a particular week day, but in conjunction with the topic. For example, students were not given an assessment every Friday. For topics of which students were given a pre- and post- discussion writing prompt, the pre-discussion prompt was administered prior to the topic's introduction and the post-discussion prompt was administered when all discussion and activity for the given topic culminated.

The first assessment students completed was a Measurement Unit Pre-assessment. The pre-assessment was given on the first day of unit. The pre-assessment included an open response short answer questions. This assessment included questions that tested prior knowledge about units for standard measureable attributes and asked questions to determine if students had any prior knowledge or frame of reference for the topics that would be introduced in the Unit. The assessment also included vocabulary terms that would be introduced throughout the Unit. This gave students an opportunity to explore various ideas to determine the meaning of the unfamiliar vocabulary and also to relate common terms to their mathematical meanings.

The pre- and post-discussion form of assessment was used to determine student growth in understanding the concept of Accuracy. Students were asked in both the pre- and post-assessment to answer "What is Accuracy?" Students were to write a definition for the term accuracy in their own words. In addition to the definition, students were encouraged to provide examples to support their definition.

While procedural practice was used to teach students how to calculate Absolute Error and Relative Error, students also learned to compare errors using the actual value of the error found by calculating the Absolute Error and the percentage of the error by calculating the Relative Error. To assess the students' understanding of determining the significance of an error, students were given two scenarios that included errors with the same actual value. Students were asked to determine in which scenario the error was small enough to be unimportant and in which scenario the error was large enough to be of concern. To make this distinction, students had to consider both the Absolute Error and Relative Error. Although the questioning did not specifically ask students to find both types of errors, students were required to calculate both to provide sound reasoning. Therefore, the assessment also gauged the students' ability to compute the Absolute

Error and Relative Error of a measurement, in addition to assessing their ability to determine the significance of an error.

The next topic introduced was Significant Digits. The Significant Digits assessment required students to determine the number of significant digits in a given number. Students were also required to calculate the sum, difference, product, and quotient of given numbers and round to the appropriate number of significant digits. Students were allowed to use technology for calculations when completing the assessment. However, the technology did not round answers to the appropriate significant digits. For each question students had to provide an explanation as to how they arrived at the total number of significant digits. The purpose of this assessment was to determine if students could identify significant digits, round to the nearest significant digits when computing, and apply the appropriate rule or rules in determining when digits are considered significant.

Precision was the last topic of study in the Unit. Because the terms “accurate” and “precise” are commonly used interchangeably, I assessed the ability to explain each separately and to differentiate between them. Students completed a Pre- and Post-Discussion assessment in which they had to answer the following questions: 1) What does it mean to be accurate? 2) What does it mean to be precise? 3) Is there a difference between accurate and precise? If so, explain. Students were also given sets of measurements, along with the actual or accepted value of the item measured. Students had to determine which measurement in the set was the most precise and which measurement in the set was the most accurate. After stating which measurements were most precise and most accurate, students were also required to provide an explanation to explain how they determined the most precise and most accurate measurements from each of the

given sets. Using the repeatability definition, students had to also determine which diagrams were accurate, precise, both accurate and precise, and neither accurate nor precise.

Prior to the Final Exam, the Unit 7 Measurement Edusoft Benchmark assessment, students completed a Measurement Unit Post-assessment. The post-assessment contained the same format and questioning as the pre-assessment and also assessed the same skills. The purpose of the post-assessment was to measure student growth from the beginning of the Measurement Unit, prior to the unit's topics being introduced, to the end of the Measurement Unit, after the unit topics were covered. The post-assessment also served to promote individual awareness of growth in understanding of the topics of the Measurement Unit and to determine individual readiness for the Final Exam.

2-5 My Approach

In addition to reorganizing the order of which the topics were presented in the Measurement Unit, I also implemented activities outside of the suggested activities within the EBRCC Unit 7 Measurement Unit. Although measurement is one of the most useful strands of mathematics, it can often also be the weakest strand in student performance. To help students develop a more conceptual understanding of the topics introduced in the Measurement Unit, I chose to develop a unit with activities and supplements that would initially introduce the topics as experiences focusing on real life to develop thinking and skills, rather than focusing directly on concepts of measurement.

By providing situations and scenarios that were relevant to real life or to the students' frame of reference, students were given the opportunity to understand the purpose and importance of the measurement concepts introduced. For example, prior to discussing the "plus or minus" value of an error in a measurement, we discussed "give or take a few". Many students

were familiar with the phrase “give or take a few” and understood the context of how the phrase is used. Students understood this meant to add or subtract. This discussion also included the “Age Guessing Game”, often seen at amusement parks, in which the guesser is normally allowed an absolute error of 2 years. Relating this error to “giving or taking 2 years” allowed an easy transition to introduce the idea of ±2 (plus or minus 2).

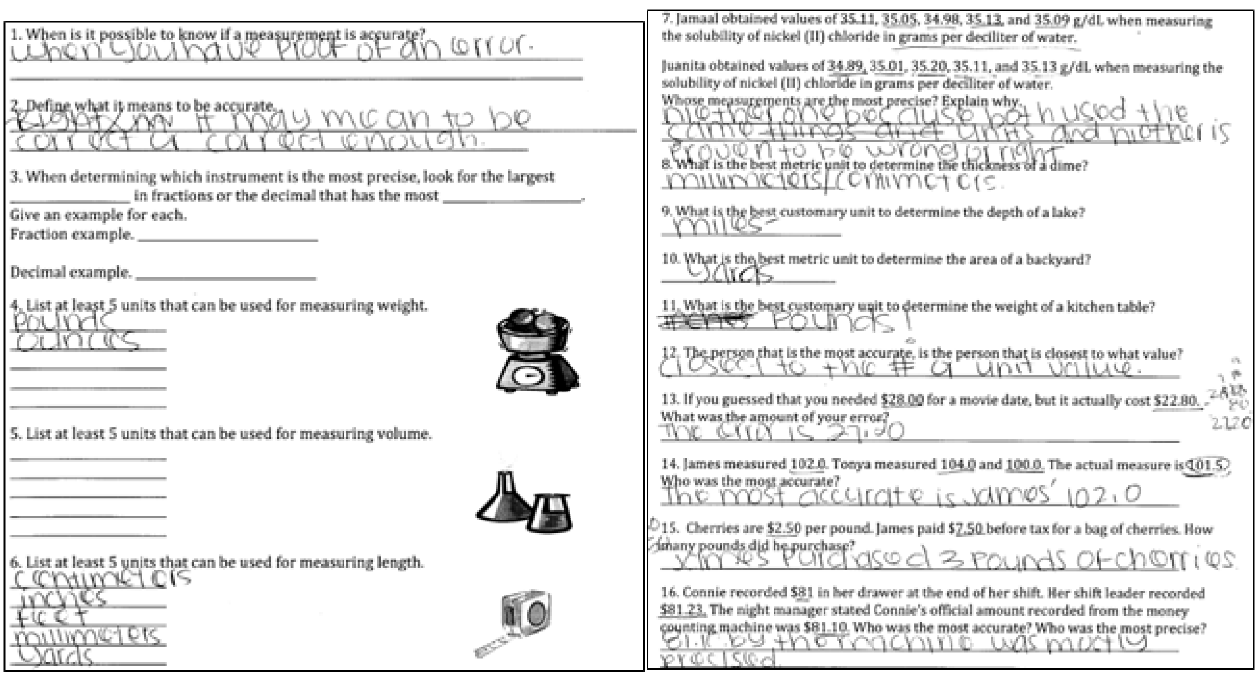
I also adjusted the order of the topics. In the EBRCC the order was: Accuracy, Precision, Errors, and Significant Digits, respectively. I decided to arrange the topics in the following order: Accuracy, Errors, Significant Digits, and Precision. The most important reason for this was to make a clear distinction between accuracy and precision. Because the terms commonly used interchangeably, students are not always swift to understand the difference between them. I also connected the qualitative concept of accuracy with errors because when determining which measurement is the most accurate, one accepts the measurement with the least absolute error as the most accurate. Although precision is often defined as repeatability, this unit also considers the definition of precision in terms of the unit used to measure an object. When looking at the degree of refinement of the measurement tool, understanding of significant digits can be useful. Therefore, prior to introducing precision, determining significant digits is helpful. To bring the unit to a close, accuracy versus precision was discussed. This was strategically placed last to incorporate the other topics of the unit.

Chapter 3. Report on Implementation

3-1 Summary of How It Went

In Chapter 2 I described my plan, along with the assessments, activities, and lesson structures of the Measurement Unit. In this chapter, I will describe “how it went”. I will also provide student work samples with descriptions of what happened during the lessons and activities. The second section of this chapter will be devoted to the results on the final exam. The third will draw preliminary conclusions.

Administering a Pre-Assessment gave me the opportunity to assess students’ prior knowledge and pre-requisite skills. I observed that most students did not know what accuracy and precision were as it related to measurement. I also learned that many students could not easily name more than 2 or 3 standard units of measurement for length, weight, and capacity—especially capacity. This is illustrated in the work sample of Student (A) below.



1. When is it possible to know if a measurement is accurate?
when you have proof of an error.

2. Define what it means to be accurate.
~~Right~~ it may mean to be correct a correct enough.

3. When determining which instrument is the most precise, look for the largest ____________ in fractions or the decimal that has the most ____________.
Give an example for each.
Fraction example. ____________
Decimal example. ____________

4. List at least 5 units that can be used for measuring weight.
pounds
ounces

5. List at least 5 units that can be used for measuring volume.

6. List at least 5 units that can be used for measuring length.
centimeters
inches
feet
millimeters
yards

7. Jamaal obtained values of 35.11, 35.05, 34.98, 35.13, and 35.09 g/dL when measuring the solubility of nickel (II) chloride in grams per deciliter of water.
Juanita obtained values of 34.89, 35.01, 35.20, 35.11, and 35.13 g/dL when measuring the solubility of nickel (II) chloride in grams per deciliter of water.
Whose measurements are the most precise? Explain why.
niether one because both used the same things and units and niether is proven to be wrong or right

8. What is the best metric unit to determine the thickness of a dime?
millimeters/centimeters.

9. What is the best customary unit to determine the depth of a lake?
miles

10. What is the best metric unit to determine the area of a backyard?
yards

11. What is the best customary unit to determine the weight of a kitchen table?
pounds!

12. The person that is the most accurate, is the person that is closest to what value?
closest to the # a unit value.

13. If you guessed that you needed $28.00 for a movie date, but it actually cost $22.80. What was the amount of your error?
The error is 27.20

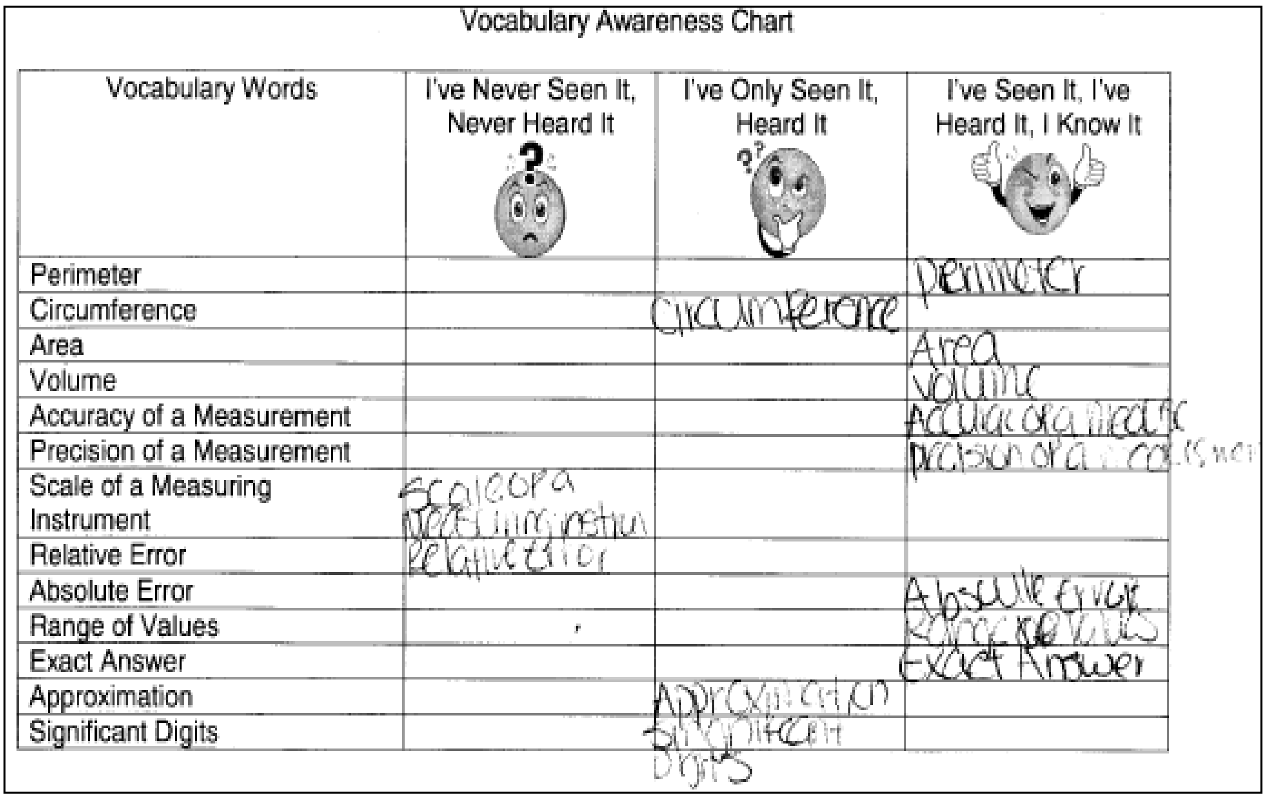
14. James measured 102.0. Tonya measured 104.0 and 100.0. The actual measure is 101.5. Who was the most accurate?
The most accurate is James' 102.0

15. Cherries are $2.50 per pound. James paid $7.50 before tax for a bag of cherries. How many pounds did he purchase?
James purchased 3 pounds of cherries

16. Connie recorded $81 in her drawer at the end of her shift. Her shift leader recorded $81.23. The night manager stated Connie's official amount recorded from the money counting machine was $81.10. Who was the most accurate? Who was the most precise?
81.1 by the machine was mostly precised

Figure 3-1. Student (A) Student Work Sample of Unit 7: Measurement Pre-Assessment

In reviewing the students' initial vocabulary self-awareness charts, most English-speaking students were limited to knowing the terms perimeter, circumference, area, and volume. Most English-speaking students and English Language Learners had never heard of relative error and absolute error. Other terms like approximation, significant digits, and scale of a measuring instrument varied among all student groups. The student work sample below is an example of the Vocabulary Awareness Chart.

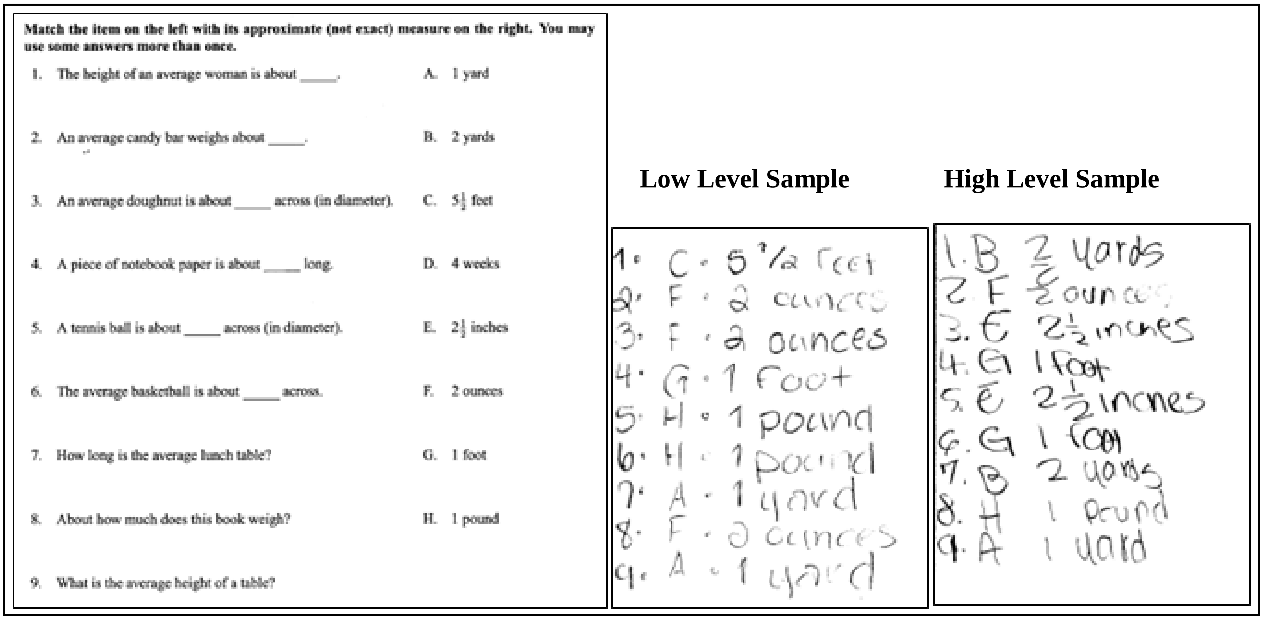


Vocabulary Awareness Chart

Vocabulary Words	I've Never Seen It, Never Heard It	I've Only Seen It, Heard It	I've Seen It, I've Heard It, I Know It
Perimeter			perimeter
Circumference		circumference	
Area			Area
Volume			volume
Accuracy of a Measurement			Accuracy of a measure
Precision of a Measurement			precision of a measurement
Scale of a Measuring Instrument	scale of a measuring instrument		
Relative Error	relative error		
Absolute Error			Absolute error
Range of Values			Range of values
Exact Answer			Exact Answer
Approximation		Approximation	
Significant Digits		significant digits	

Figure 3-2. Student Work Sample of Vocabulary Awareness Chart

Most students were familiar with standard units of the English Measurement System. The student work samples below provide examples both low and high levels of student understanding of approximating customary units. Although few students demonstrated some difficulty, most students were able to approximate these units of measure quite easily.


Match the item on the left with its approximate (not exact) measure on the right. You may use some answers more than once.

1.	The height of an average woman is about _____.	A.	1 yard
2.	An average candy bar weighs about _____.	B.	2 yards
3.	An average doughnut is about _____ across (in diameter).	C.	$5\frac{1}{2}$ feet
4.	A piece of notebook paper is about _____ long.	D.	4 weeks
5.	A tennis ball is about _____ across (in diameter).	E.	$2\frac{1}{2}$ inches
6.	The average basketball is about _____ across.	F.	2 ounces
7.	How long is the average lunch table?	G.	1 foot
8.	About how much does this book weigh?	H.	1 pound
9.	What is the average height of a table?		

Low Level Sample

1. C. 5 1/2 feet
2. F. 2 ounces
3. F. 2 ounces
4. G. 1 foot
5. H. 1 pound
6. H. 1 pound
7. A. 1 yard
8. F. 2 ounces
9. A. 1 yard

High Level Sample

1. B 2 yards
2. F 2 ounces
3. E $2\frac{1}{2}$ inches
4. G 1 foot
5. E $2\frac{1}{2}$ inches
6. G 1 foot
7. B 2 yards
8. H 1 pound
9. A 1 yard

Figure 3-3. Approximating Customary Unit Exercise with Student Work Samples

Students were not able to approximate metric units easily at all. After viewing the measurement power point, students had a better understanding of metric units. The power point related both English and metric units of measure to everyday items. Some examples were as follows: one yard is about the width of a door, one meter is just a little bit more; one milliliter is about a medicine dropper full, and one foot is about the length of a clipboard. After discussing the power point students were able to classify units from both English and Metric Systems. Student volunteers placed entries on a chart on the ActivBoard. Students initially had difficulty using the balance scale and measuring liquid in a beaker. I did find that students were able to measure using different rulers. The student work sample below is an example of a competent student measuring lengths using a rule with a fictitious unit scale similar to a 1 inch unit.

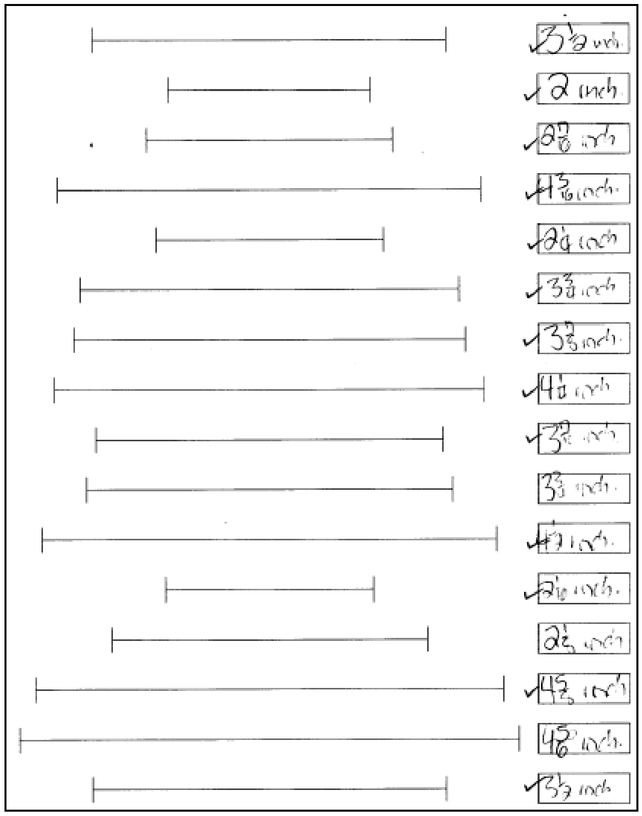
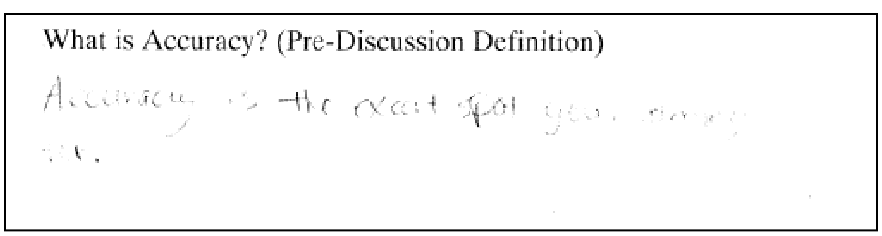


Figure 3-4. Student Work Sample of Measuring Various Lengths

During a pre-assessment that included the question, “What is accuracy?”, many students wrote, “to be correct”, “to be right”, “to be on the mark”, “to be on target”, or “being exact”. This is demonstrated by Student (B) in the student work sample below. There were some students who used the word precise in their definition of accuracy.

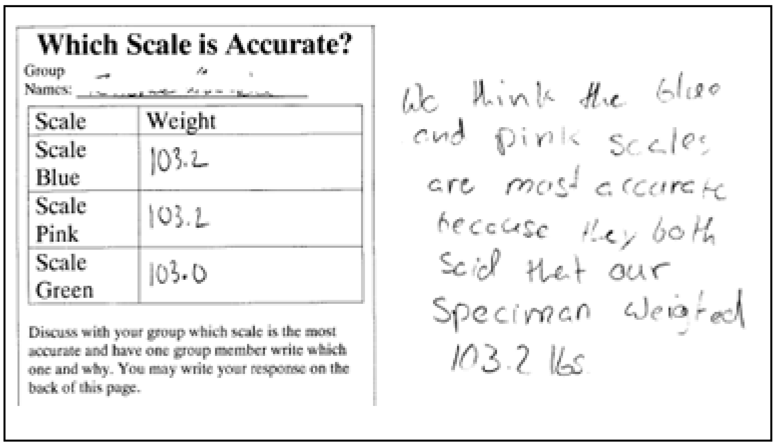


Typed Translation: Student (B) wrote, “Accuracy is the excat spot your aiming for.”

Figure 3-5. Student (B) Student Work Sample of Pre-Discussion Writing

The discussion after the scale activity in which students had to state which of 3 scales was the most accurate was very interesting. I shared the group responses with the whole class. Students

were willing to debate and defend their responses. Student responses varied. The student work sample below shows one group stated the blue and pink scales were most accurate because they rendered the same measurements of weight. Another group selected the green and pink scales because they seemed to be the most exact. (Students of this group are defining exact by the precision of the scales.)



Which Scale is Accurate?

Group Names: [illegible]

Scale	Weight
Scale Blue	103.2
Scale Pink	103.2
Scale Green	103.0

Discuss with your group which scale is the most accurate and have one group member write which one and why. You may write your response on the back of this page.

We think the blue and pink scales are most accurate because they both said that our Speciman Weigted 103.2 lbs.

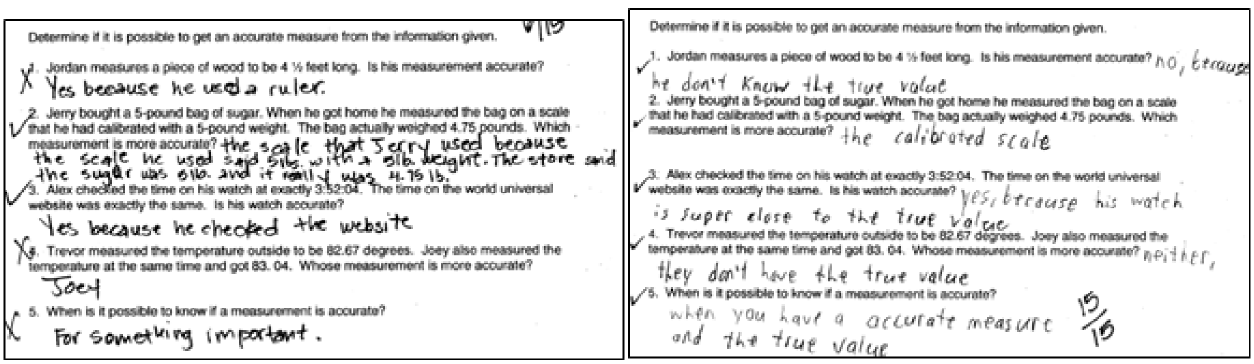
Typed Translation: We think the blue and pink scales are most accurate because they both said that our specimen weigted 103.2 lbs.”

Figure 3-6. Student Work Sample of "Which Scale is Accurate?" Activity

When the discussion did not arrive at the realization that one cannot determine which scale is the most accurate without knowing the actual weight of the student, I posed questions to students such as: “If I am grading your paper for accuracy, I am checking for [pause]?” Students would say things such as, “The right answer.” I then asked students, “How can I determine if your answers are right?” I led students to conclude the only way I can grade their papers for accuracy is if I know the correct or accepted answers. This helped students to realize that we must know the actual weight of what is being measured to determine the accuracy of the measurement. I then took a 20lb weight and placed it on each of the scales to see which scale would measure exactly 20lbs. I explained to students that any scale that produced a result of 20lbs would be considered accurate because the 20lb weight represented the accepted true value. I also asked several students to seek the exact time from different sources, such as Internet, school clock, etc.

I asked students which reading was the correct one—or most accurate one. We repeated the activity again using the www.time.gov website to determine which readings were most accurate. I explained to students this time would be the true accepted value for time.

Students were also given several scenarios in which they had to determine if it is possible to get an accurate measure from the information given. In this exercise students were expected to consider if an accepted true value is known when determining the accuracy of the measure. Examples of this exercise are provided in the student work samples below.


Determine if it is possible to get an accurate measure from the information given.

1. Jordan measures a piece of wood to be 4 ½ feet long. Is his measurement accurate?
Yes because he used a ruler.

2. Jerry bought a 5-pound bag of sugar. When he got home he measured the bag on a scale that he had calibrated with a 5-pound weight. The bag actually weighed 4.75 pounds. Which measurement is more accurate? the scale that Jerry used because the scale he used said 5lbs. with a 5lb. weight. The store said the sugar was 5lb. and it really was 4.75 lb.

3. Alex checked the time on his watch at exactly 3:52:04. The time on the world universal website was exactly the same. Is his watch accurate?
Yes because he checked the website

4. Trevor measured the temperature outside to be 82.67 degrees. Joey also measured the temperature at the same time and got 83. 04. Whose measurement is more accurate?
Joey

5. When is it possible to know if a measurement is accurate?
For something important.

Determine if it is possible to get an accurate measure from the information given.

1. Jordan measures a piece of wood to be 4 ½ feet long. Is his measurement accurate? no, because he don't Know the true value

2. Jerry bought a 5-pound bag of sugar. When he got home he measured the bag on a scale that he had calibrated with a 5-pound weight. The bag actually weighed 4.75 pounds. Which measurement is more accurate? the calibrated scale

3. Alex checked the time on his watch at exactly 3:52:04. The time on the world universal website was exactly the same. Is his watch accurate? yes, because his watch is super close to the true value

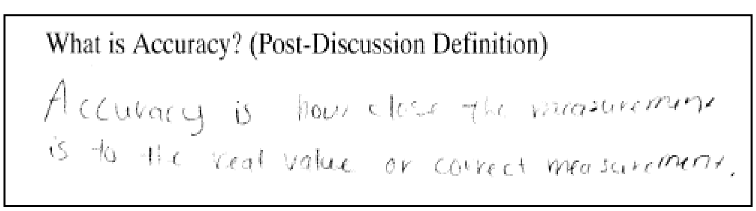
4. Trevor measured the temperature outside to be 82.67 degrees. Joey also measured the temperature at the same time and got 83. 04. Whose measurement is more accurate? neither, they don't have the true value

5. When is it possible to know if a measurement is accurate?
when you have a accurate measure and the true value

15/15

Figure 3-7. Student Work Samples of Determining Accuracy Exercise

After discussing accuracy, students reconsidered the definitions as they completed the Post-Discussion assessment, which posed the same question as before, "What is Accuracy?". Based on the responses I received on the Post-Discussion, I found that students understood that to determine accuracy there must be a comparison between a measurement and the accepted "true" value. A student work sample is shown below, also completed by Student (B).

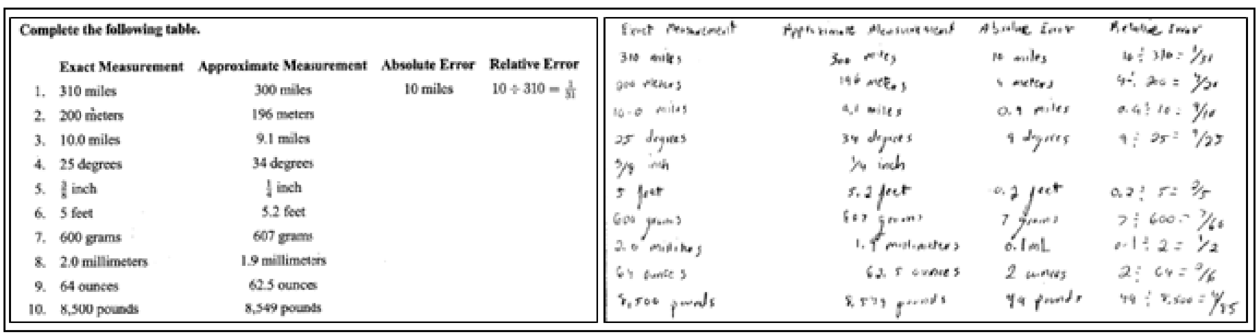

What is Accuracy? (Post-Discussion Definition)

Accuracy is how close the measurement is to the real value or correct measurement.

Typed Translation: On the Post-Discussion form Student B wrote, "Accuracy is how close the measurement is to the real value or correct measurement."

Figure 3-8. Student (B) Student Work Sample of Post-Discussion Writing

After measurement, students were introduced to "Errors." Although, I thought I introduced absolute errors in a manner that would allow students to understand that—because we are measuring a distance—this value is always positive, some students struggled with the idea. To explain further and void misconceptions, I provided students with more real life scenarios in which the absolute values are considered, like the distance by which a target is missed. I also modeled using the formula. To my surprise, some students actually preferred the formula because the formula showed the absolute value bars. Most students were able to calculate absolute errors with little difficulty. As shown in the student work sample below (in which students were only required to complete the chart) students were also able to calculate the relative error with little difficulty when using the formula only.

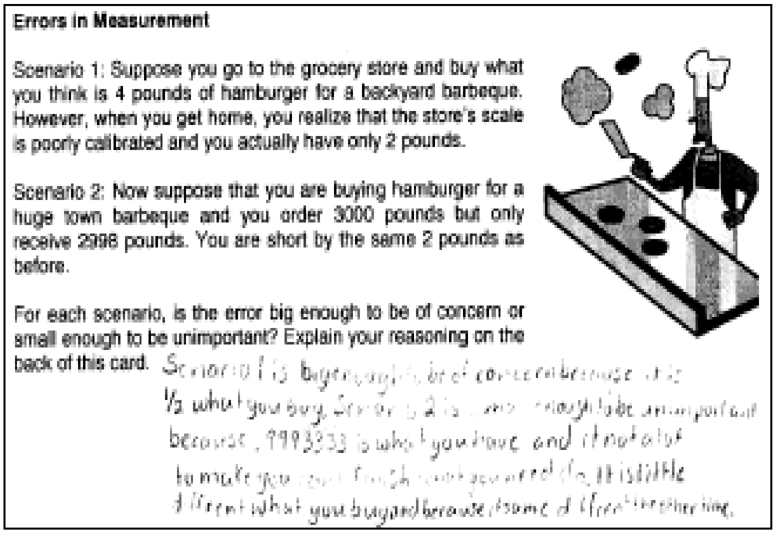


Complete the following table.

	Exact Measurement	Approximate Measurement	Absolute Error	Relative Error
1.	310 miles	300 miles	10 miles	$10 \div 310 = \frac{1}{31}$
2.	200 meters	196 meters		
3.	10.0 miles	9.1 miles		
4.	25 degrees	34 degrees		
5.	$\frac{3}{8}$ inch	$\frac{1}{4}$ inch		
6.	5 feet	5.2 feet		
7.	600 grams	607 grams		
8.	2.0 millimeters	1.9 millimeters		
9.	64 ounces	62.5 ounces		
10.	8,500 pounds	8,549 pounds		

Figure 3-9. Finding Absolute and Relative Errors Exercise with Student Work Sample

However, students were not always clear about how to apply the formula when given a word problem. I presented students with additional scenarios in which they had to apply both the absolute and relative error formulas and consider various ranges of errors. Students were given a final assessment on errors in which they had to determine if an error was significant or unimportant by calculating and comparing the absolute error with the relative error. Students again had to explain their reasoning. An example is provided in the work sample below. This student referred to the relative error to defend his reasoning.



Typed Translation: "Senario 1 is big enough to be of concern because it is ½ what you buy. Senario 2 is small enough to be unimportant because .9993333 is what you have and it not a lot to make you can finish what you need do. It is little different what you buy and because it is same different the other time."

Figure 3-10. Student Work Sample on Absolute and Relative Error Exercise

Getting students to remember the rules for significant digits has always been challenging for me. When I pondered the idea of how to introduce this lesson, I decided it was necessary to approach the topic differently. I created a game in which students had to use rules very similar to those of significant digits, but the rules applied to colored rectangles. Some students, having studied significant digits before, realized that the rules were very similar. A student said, "I know what this is like. This is like what you do with those numbers." The student could not remember significant digits or figures, but did see the similarity of the rules.

My goal with the game was to get the students to see that because the non-white colored rectangles were automatically cool, they only had to focus on the white rectangles when determining the coolness of the colors. Students enjoyed the game and were able to easily transition to determining significant digits, and they related the white rectangles to the zeroes almost immediately. Although students work cooperatively, each group member was required to analyze sets on their own. Students who were more comfortable assisted students who were less confident. A student work sample of the Cool Colors game sheet is provided below.

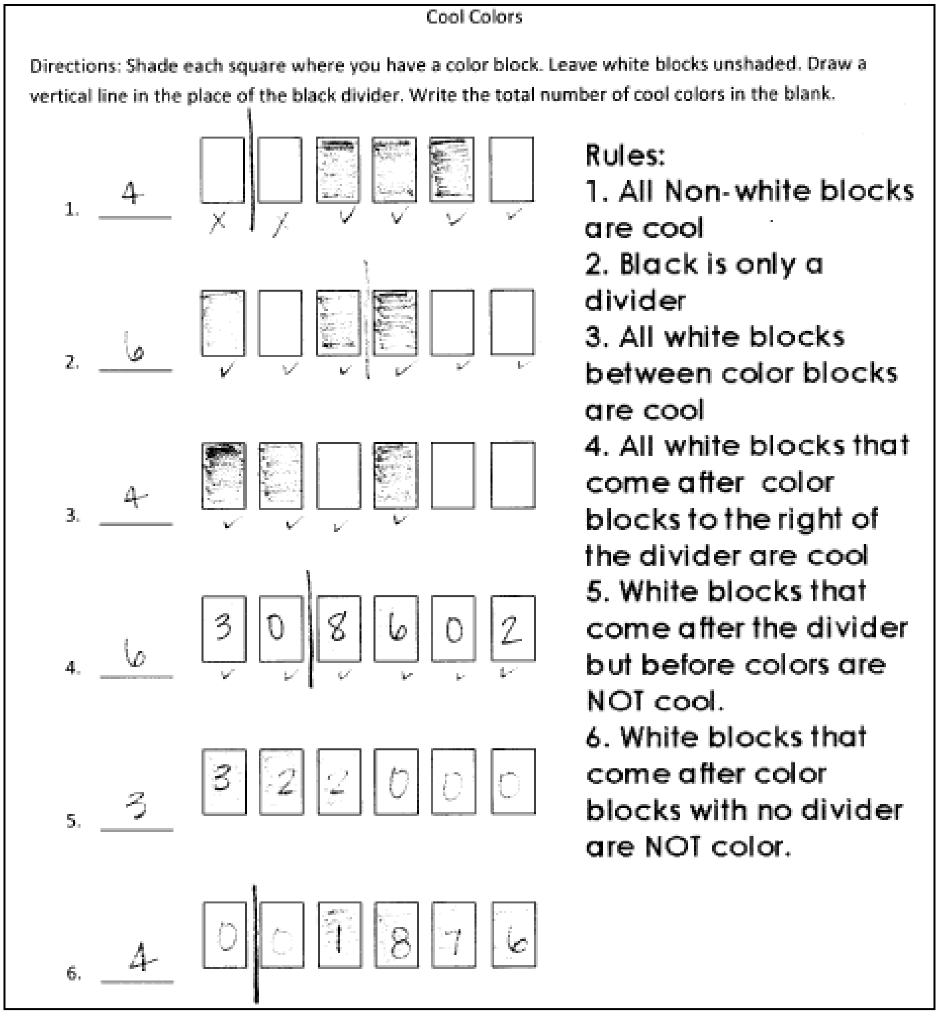
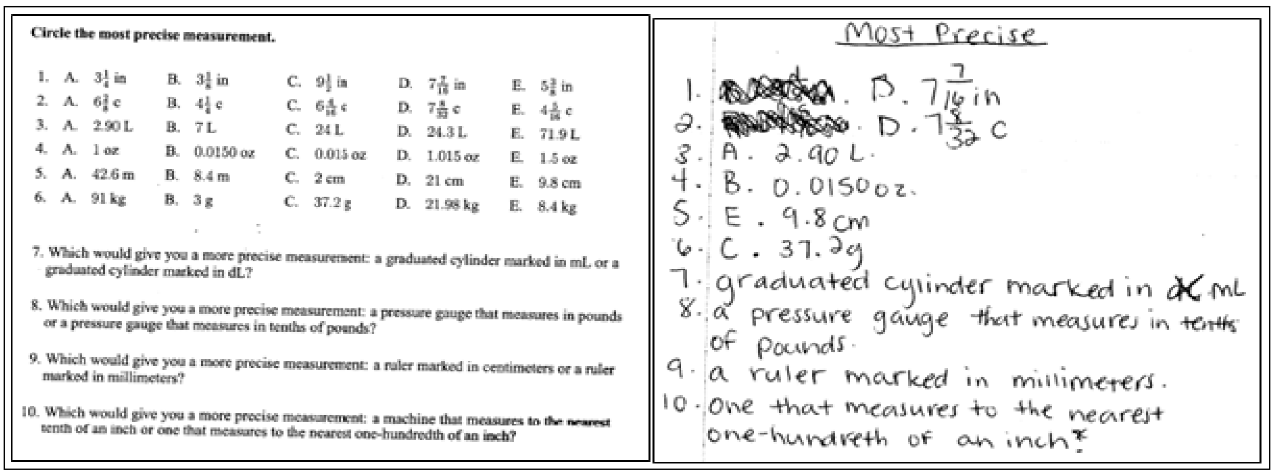


Figure 3-11. Student Work Sample of "Cool Colors" Significant Digits Activity

The last major topic in the unit was Precision. When completing exercises to select the measurement that was most precise according to the measure instrument, students did not have much difficulty if all measurements in the set had the same unit. Students were comfortable with analyzing the digits after the decimal or the denominator in the fraction. However, when dealing with various units within a set or comparing units to determine which would yield a more precise measurement, students displayed some confusion. Students were also less confident when comparing metric units that are not commonly used, such as deciliters (dL) and dekaliters (daL). I directed students back to the introduction of precision, when they compared the different rulers

that measured to the nearest half, fourth, eighth, and sixteenth of an inch. I had to remind students that the ruler with the smallest markings provided the most precise measurement. Therefore, the smallest unit would provide the most precise measurement. Revisiting the rulers helped students to gain a better understanding. When making comparisons among the Metric Units, some students used “King Henry Died While Drinking Chocolate Milk” to remember the prefixes kilo-, hecto-, deka-, deci-, centi-, milli-. Figure 3-12 gives an example of the exercise along with a student work sample.



Circle the most precise measurement.

1. A. $3\frac{1}{4}$ in B. $3\frac{3}{8}$ in C. $9\frac{1}{2}$ in D. $7\frac{7}{16}$ in E. $5\frac{3}{8}$ in
2. A. $6\frac{3}{4}$ c B. $4\frac{1}{4}$ c C. $6\frac{5}{16}$ c D. $7\frac{5}{32}$ c E. $4\frac{3}{16}$ c
3. A. 2.90 L B. 7 L C. 24 L D. 24.3 L E. 71.9 L
4. A. 1 oz B. 0.0150 oz C. 0.015 oz D. 1.015 oz E. 1.5 oz
5. A. 42.6 m B. 8.4 m C. 2 cm D. 21 cm E. 9.8 cm
6. A. 91 kg B. 3 g C. 37.2 g D. 21.98 kg E. 8.4 kg

7. Which would give you a more precise measurement: a graduated cylinder marked in mL or a graduated cylinder marked in dL?

8. Which would give you a more precise measurement: a pressure gauge that measures in pounds or a pressure gauge that measures in tenths of pounds?

9. Which would give you a more precise measurement: a ruler marked in centimeters or a ruler marked in millimeters?

10. Which would give you a more precise measurement: a machine that measures to the nearest tenth of an inch or one that measures to the nearest one-hundredth of an inch?

Most Precise

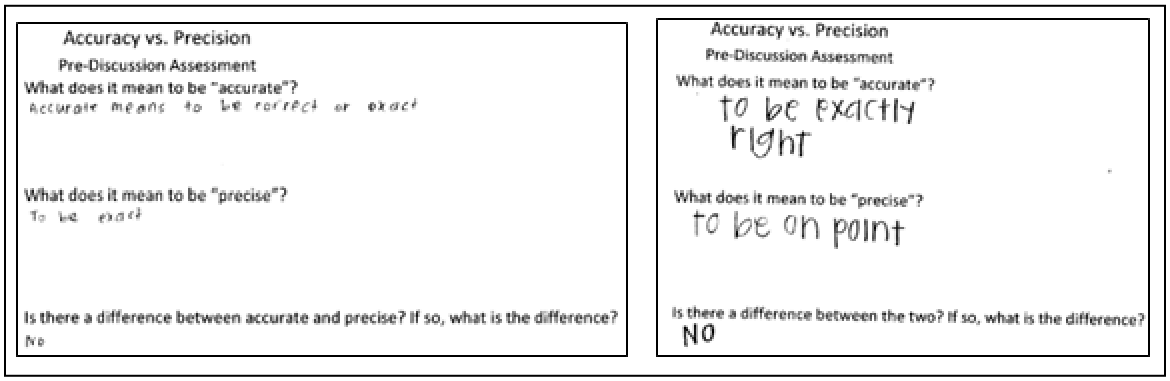
1. [illegible]. D. $7\frac{7}{16}$ in
2. [illegible]. D. $7\frac{5}{32}$ c
3. A. 2.90 L.
4. B. 0.0150 oz.
5. E. 9.8 cm
6. C. 37.2 g
7. graduated cylinder marked in ~~d~~ mL
8. a pressure gauge that measures in tenths of pounds.
9. a ruler marked in millimeters.
10. One that measures to the nearest one-hundreth of an inch.

Figure 3-12. Precision of Measurement Instrument Exercise and Student Work Sample

A pre-discussion exercise on precision and accuracy proved that many students either used these words interchangeably or used one to define the other. The two work samples below demonstrate what students stated prior to the discussion the topic of accuracy vs. precision. The student work samples of these same students are also provided in Figure 3-14 to demonstrate what students wrote after the discussion.

In discussing ‘The “Truth” about Precision and Accuracy’ I explained accuracy as “telling the truth” and precision as “telling the same story over and over again.” To include both definitions for precision, I added that precision is “telling the same story over and over again

with specific or tiny details." In the post-discussion exercise, most students were able to state that accuracy and precision are different. However, as seen in the work samples below, although students were able to explain separately what it means to be accurate and precise, not all students were able to explain the difference.


Accuracy vs. Precision

Pre-Discussion Assessment

What does it mean to be "accurate"?

Accurate means to be correct or exact

What does it mean to be "precise"?

To be exact

Is there a difference between accurate and precise? If so, what is the difference?

No

Accuracy vs. Precision

Pre-Discussion Assessment

What does it mean to be "accurate"?

to be exactly right

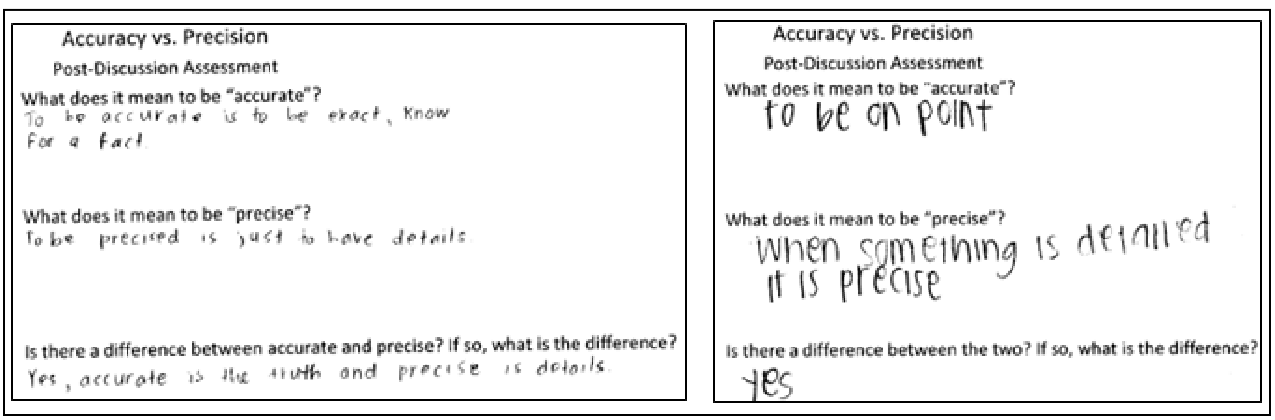
What does it mean to be "precise"?

to be on point

Is there a difference between the two? If so, what is the difference?

NO

Figure 3-13. Student Work Samples of Accuracy vs. Precision Pre-Discussion Assessment


Accuracy vs. Precision

Post-Discussion Assessment

What does it mean to be "accurate"?

To be accurate is to be exact, Know for a fact

What does it mean to be "precise"?

To be precised is just to have details

Is there a difference between accurate and precise? If so, what is the difference?

Yes, accurate is the truth and precise is details.

Accuracy vs. Precision

Post-Discussion Assessment

What does it mean to be "accurate"?

to be on point

What does it mean to be "precise"?

when something is detailed it is precise

Is there a difference between the two? If so, what is the difference?

yes

Figure 3-14. Student Work Samples of Accuracy vs Precision Post-Discussion Assessment

Despite some confusion, when the marks were only precise but not accurate, students were able to label the bull's-eye target illustrations when asked to determine if the markings on the target were accurate, precise, both accurate and precise, or neither accurate nor precise. As an added unplanned activity and to provide more spontaneous illustrations, students flipped poker chips over a bull's-eye target on the floor, and stated if the results were either accurate, precise, both, or neither.

3-2 Results on Final Exam

The Edusoft Benchmark Assessment was administered as the Final Exam for the Measurement Unit. I administered the Final Exam to 113 students. The exam consisted of 14 multiple choice questions and 2 constructed response questions. Each of the multiple choice questions was worth 1 point. Each of the constructed response questions was worth up to 2 points. The average score on the Final Exam was 11.5/17 points. According to the EBR Achievement Levels, 70% of the students scored within one of the proficient Achievement Levels. The percent of students scoring within each proficient Achievement Level, listed in order of least to greatest proficiency respectively, are Basic (36%), Mastery (19%), and Advanced (14%). Most students scored in the Basic Achievement Level, scoring in the range of 9.35-13.25 points. The Per Band Performance chart below shows the range of each Band (Achievement Level), the total number of students that scored within each band, along with a bar graph illustrating the percent of students within each Band.

Table 3-1. Overall Student Performance on Edusoft Benchmark Assessment 2011-2012

Overall Performance:

Percent of students at **Basic** or above:

70%

Average Score: 11.5/17 (67%)

Per Band Performance:

Band	Range	# Students	%	20 40 60 80
Unsatisfactory	0.00-6.79	10	9%	
Approaching Basic	6.80-9.34	24	21%	
Basic	9.35-13.25	41	36%	
Mastery	13.26-15.12	22	19%	
Advanced	15.13-17.0	16	14%	

The information in the table below provides the Grade Level Expectations (GLEs) assessed on the Edusoft Benchmark Assessment. Each GLE is a Mathematics GLE from the Measurement Standard for Grade 9as outlined by the Louisiana State Department of Education. Included for each GLE is the Test Section, the question time, and if the question was or was not in the section which permitted the use of a calculator.

Table 3-2. Unit 7 Edusoft Benchmark Assessment GLE Descriptions

Standards:

LAGLE--Mathematics--Grade 9--MEA

-MEA: 17 - Distinguish between precision and accuracy
Section 1 - Multiple Choice - Non-Calculator: 1 Section 2 - Constructed Response - Calculator: 9 Section 3 - Multiple Choice - Calculator: 13

-MEA: 18 - Demonstrate and explain how the scale of a measuring instrument determines the precision of that instrument
Section 1 - Multiple Choice - Non-Calculator: 6

-MEA: 19 - Use significant digits in computational problems
Section 3 - Multiple Choice - Calculator: 14, 15, 16

-MEA: 20 - Demonstrate and explain how relative measurement error is compounded when determining absolute error
Section 2 - Constructed Response - Calculator: 8 Section 3 - Multiple Choice - Calculator: 10, 11, 12

-MEA: 21 - Determine appropriate units and scales to use when solving measurement problems
Section 1 - Multiple Choice - Non-Calculator: 2, 3, 4, 5, 7

The Per Standard Performance chart below illustrates the number and percent of students that scored both Non-proficient and Proficient for each GLE assessed on the Edusoft Benchmark assessment. From the Per Standard Performance chart, the results show that most students were proficient in MEA: 21. As noted in the GLE Descriptions, MEA: 21 involves five questions that were multiple choice and appeared in Section 1: Non-Calculator. This GLE assessed students' ability to determine the appropriate unit to use when solving measurement problems. The GLE in which results show the largest number of students who were Non-proficient was MEA: 19. There were three questions on the assessment that assessed this GLE. All three of these questions were multiple choice and appeared in Section 3: Calculator. This GLE assessed students' ability to round the answers of computation problems to the appropriate number of significant digits.

Table 3-3. Per Standard Performace on Unit 7 Edusoft Benchmark Assessment 2011-2012

Per Standard Performance:

Standard	Non-proficient	Proficient
MEA: 17	62 (54.87%)	51 (45.13%)
MEA: 18	39 (34.51%)	74 (65.49%)
MEA: 19	74 (65.49%)	39 (34.51%)
MEA: 20	35 (30.97%)	78 (69.03%)
MEA: 21	5 (4.42%)	108 (95.58%)

3-3 Conclusion

In addition to analyzing the results of the final exam, I also analyzed the results of the pre- and post-assessments. Prior to the final exam, students completed a post-assessment of the unit. The pre- and post-assessment comparison yielded promising results. Only the results of students who completed both the pre- and post-assessments were included in the data posted in the histogram below. The histogram shows there were no students who got scores in the top two bins on the pre-assessment, while on the post-assessment no student scored in the lower two bins. The data presented in the bar graph and histogram below can lead to a misinterpretation or assumption that all students shifted their scores by two levels. But, this assumption does not hold true for all students because there could have been some students in the median bins who decreased. Also, some students could have remained the same. These charts do not show the distribution of individual gains.

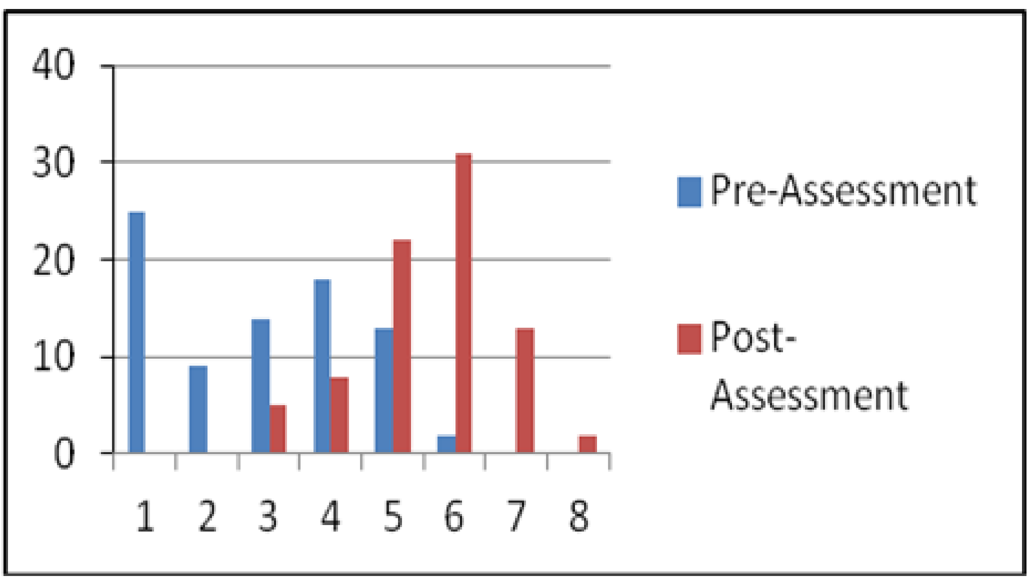


Figure 3-15. Bar Graph Illustrating Histogram Results

Table 3-4. Histogram Results from Pre- and Post-Assessment Scores

Pre-Assessment			Post-Assessment	
Bin	*Frequency*		*Bin*	*Frequency*
4	25		4	0
8	9		8	0
12	14		12	5
16	18		16	8
20	13		20	22
24	2		24	31
28	0		28	13
32	0		32	2

However, the overall class average score increased from 9.78 points to 20.69 points, an overall gain of 10.91 points. The overall class average increased by 111.5%. According to the bar graph below, most students gained 4-6 points on the post-assessment. An analysis of the raw data did show there was one student who decreased in score from the pre-assessment to the post-assessment.

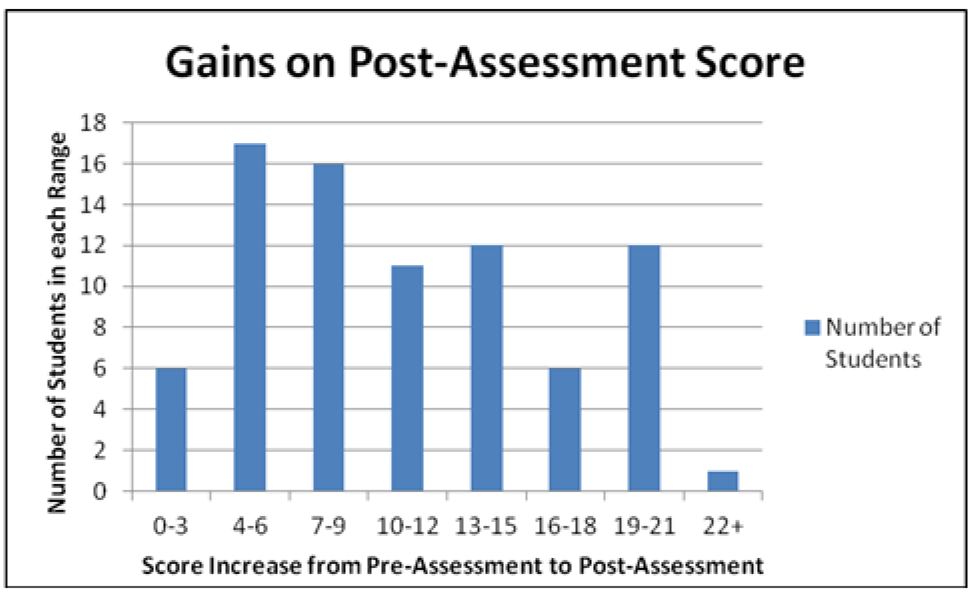
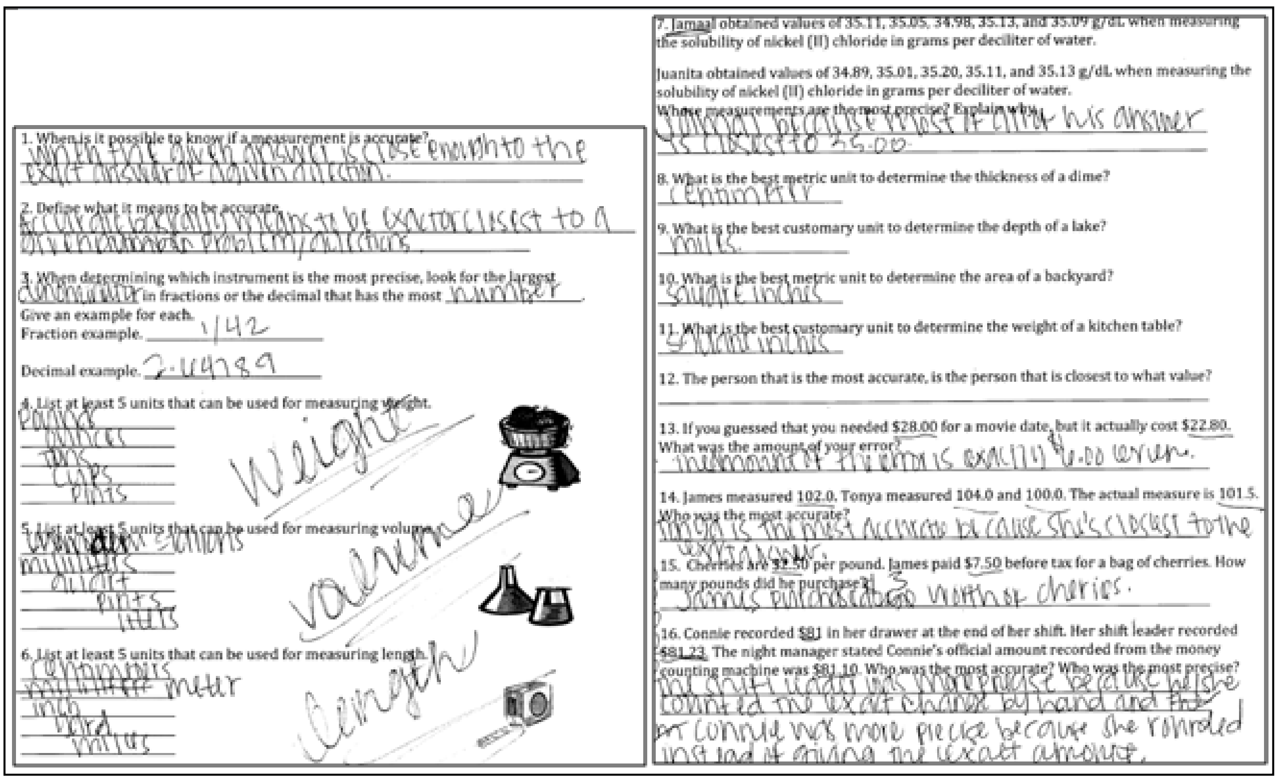


Figure 3-16. Histogram illustrating the number of students showing gains in each range

After reviewing the Edusoft Benchmark Data and analyzing the results of the pre- and post-assessments, I am pleased with the overall results. I did not want to rely solely on the Edusoft Benchmark assessment to determine the relevance or impact of the adjustments and supplements I made when teaching this unit. I was extremely gratified when I saw the difference in the pre- and post-assessments. Many students who left several questions blank on the pre-assessment were confident enough to enter a response on the post-assessment. I consider that in itself a gain. This is demonstrated below in the post- assessment student work sample of Student (A) whose pre-assessment was shared above (Figure 3-1). After scoring the results, 98.7%


1. When is it possible to know if a measurement is accurate?

2. Define what it means to be accurate.

3. When determining which instrument is the most precise, look for the largest ______ in fractions or the decimal that has the most ______.
Give an example for each.
Fraction example. 1/42
Decimal example. ______

4. List at least 5 units that can be used for measuring weight.

5. List at least 5 units that can be used for measuring volume.

6. List at least 5 units that can be used for measuring length.

7. Jamaal obtained values of 35.11, 35.05, 34.98, 35.13, and 35.09 g/dL when measuring the solubility of nickel (II) chloride in grams per deciliter of water.

Juanita obtained values of 34.89, 35.01, 35.20, 35.11, and 35.13 g/dL when measuring the solubility of nickel (II) chloride in grams per deciliter of water.
Whose measurements are the most precise? Explain why.

8. What is the best metric unit to determine the thickness of a dime?

9. What is the best customary unit to determine the depth of a lake?

10. What is the best metric unit to determine the area of a backyard?

11. What is the best customary unit to determine the weight of a kitchen table?

12. The person that is the most accurate, is the person that is closest to what value?

13. If you guessed that you needed $28.00 for a movie date, but it actually cost $22.80. What was the amount of your error?

14. James measured 102.0. Tonya measured 104.0 and 100.0. The actual measure is 101.5. Who was the most accurate?

15. Cherries are $2.50 per pound. James paid $7.50 before tax for a bag of cherries. How many pounds did he purchase?

16. Connie recorded $81 in her drawer at the end of her shift. Her shift leader recorded $81.23. The night manager stated Connie's official amount recorded from the money counting machine was $81.10. Who was the most accurate? Who was the most precise?

Figure 3-17. Student (A) Student Work Sample of Unit 7: Measurement Post-Assessment

of my students demonstrated growth. There was only one student who did not. Also, achieving 70% proficiency overall on the Edusoft Benchmark assessment was extremely exciting. Again, I am very pleased with the results.

Chapter 4. Conclusions

4-1 Results

According to the EBR Achievement Levels, 70% of my students scored proficient on the Unit 7 Measurement Benchmark Assessment. Students are required to score within the range of a Basic, Mastery, or Advanced achievement level on the Edusoft Benchmark assessment in order to be proficient. The proficiency level of my students on the Edusoft Benchmark assessment is 23% higher than that of the students that I taught last year. This proficiency level is also approximately 38% higher than the other student group taught by other teachers at my school in 2011-2012. See the charts on the next page.

In analyzing the Per Student Performance data on the Measurement Standards assessed last year and this year, students demonstrated higher proficiencies in GLEs MEA:18 (demonstrating and explaining the scale of a measuring instrument determines the precision of that instrument) and MEA:21 (determining the appropriate unit to use when solving measurement problems). Statistically, students demonstrated a low proficiency in GLE MEA: 19 (rounding answers of computation problems to the appropriate number of significant digits) both last year and this year. However, the percentage of students proficient in GLE MEA: 19 this year is 20% higher than that of the student performance on last year. I conclude, while students still demonstrated a weakness in this area, the data shows that the percentage of students proficient more than doubled.

Table 4-1. Student Performance on Edusoft Benchmark **2010-2011 (Stovall)**

Overall Performance:

Percent of students at **Basic** or above: **47%**

Average Score: 9.6/18 (54%)

Per Band Performance:

Band	Range	# Students	%
Unsatisfactory	0.00-7.19	26	26%
Approaching Basic	7.20-9.89	27	27%
Basic	9.90-14.03	39	39%
Mastery	14.04-16.01	8	8%
Advanced	16.02-18.0	0	0%

Table 4-2. Student Performance on Edusoft Benchmark **2011-2012 (Other Teachers)**

Overall Performance:

Percent of students at **Basic** or above: **32%**

Average Score: 8.0/17 (47%)

Per Band Performance:

Band	Range	# Students	%
Unsatisfactory	0.00-6.79	41	39%
Approaching Basic	6.80-9.34	30	29%
Basic	9.35-13.25	23	22%
Mastery	13.26-15.12	7	7%
Advanced	15.13-17.0	3	3%

Table 4-3. Student Performance on Edusoft Benchmark **2011-2012 (Stovall)**

Overall Performance:

Percent of students at **Basic** or above: **70%**

Average Score: 11.5/17 (67%)

Per Band Performance:

Band	Range	# Students	%
Unsatisfactory	0.00-6.79	10	9%
Approaching Basic	6.80-9.34	24	21%
Basic	9.35-13.25	41	36%
Mastery	13.26-15.12	22	19%
Advanced	15.13-17.0	16	14%

Like my students, the other teachers' students also scored higher on questions assessing GLE MEA: 21. These students also performed lower on questions assessing GLE MEA: 19. I think this illustrates that overall students performed weaker on questions that required them to round answers of computation problems to the appropriate number of significant digits, while they generally performed higher on questions on which they had to determine the appropriate unit to use when solving measurement problems. See the Per-Standard results below.

Table 4-4. Per Standard Student Performance Stovall 2011-2012

Per Standard Performance:

Standard	Non-proficient	Proficient
MEA: 17	62 (54.87%)	51 (45.13%)
MEA: 18	39 (34.51%)	74 (65.49%)
MEA: 19	74 (65.49%)	39 (34.51%)
MEA: 20	35 (30.97%)	78 (69.03%)
MEA: 21	5 (4.42%)	108 (95.58%)

Table 4-5. Per Standard Student Performance Stovall 2010-2011

Per Standard Performance:

Standard	Low	Middle	High
MEA: 17	16 (16.00%)	61 (61.00%)	23 (23.00%)
MEA: 18	38 (38.00%)		62 (62.00%)
MEA: 19	86 (86.00%)	13 (13.00%)	1 (1.00%)
MEA: 20	35 (35.00%)	50 (50.00%)	15 (15.00%)
MEA: 21	2 (2.00%)	31 (31.00%)	67 (67.00%)

Table 4-6. Per Standard Student Performance Other Teachers 2011-2012

Per Standard Performance:

Standard	Non-proficient	Proficient
MEA: 17	85 (81.73%)	19 (18.27%)
MEA: 18	55 (52.88%)	49 (47.12%)
MEA: 19	93 (89.42%)	11 (10.58%)
MEA: 20	50 (48.08%)	54 (51.92%)
MEA: 21	35 (33.65%)	69 (66.35%)

4-2 Conclusions

Although the results show there are still some areas that present a challenge, the data show that the supplements and changes I implemented in the unit made a strong impact on my students' overall performance. From direct observation, their comfort level when studying the measurement topics presented in this unit was also improved. The performance of <u>my</u> students <u>this</u> year on the Edusoft Benchmark assessment, compared with <u>my</u> students <u>last</u> year and students of <u>other</u> teachers <u>this</u> year show the changes were beneficial to my students. There are

several possible factors that may have contributed to the good performance: the order of presentation, teaching strategies, weekly assessments, and pre- and post-assessments.

On the Edusoft Benchmark assessment, there were 3 questions that assessed GLE MEA: 17 (distinguishing between precision and accuracy). On these, only 45% of students scored proficient. This is about 22% more students than last year, and, about 27% more students than the other teachers' students. I rearranged the order in which the topics were presented primarily to make a clear distinction between accuracy and precision, because I had observed this to be an area of difficulty for my students. Although there was improvement, I would not consider this improvement to be large enough to recommend rearranging the order strongly to others.

Secondly, the teaching strategies could have been a factor contributing to the good performance. The teaching strategies I used this year were different from those that I used last year. In addition to the activities, students actively participated in discussions and wrote about the topics introduced. I led students in whole-group and small-group discussions by posing questions that required them to share ideas about the topics introduced. During these discussions, students had to infer, reason, and defend their ideas. The discussions gave students an opportunity to compete with their peers, which motivated some of them to participate more. They received gratification when they were accurate and were more eager to learn when their ideas were erroneous. Students were also required to express their ideas in writing. During discussions students were encouraged to hypothesize liberally, but rationally. However, when students completed the writing exercises, they seemed to want their responses to be more accurate. The written responses were detailed and included examples that helped to explain the students' rationale. Many times, I shared the students' responses with the whole group. Although I did not state the identities of the students when sharing the written responses, students openly

identified themselves as the writers when their responses were accurate. Students wanted to receive recognition from their peers, which is one of the reasons students stated they were motivated to learn.

Another possible factor that may have increased student performance was the weekly assessments. I noticed that students valued the learning when they knew that they would face an assessment. For students, the notion that they had until the end of the unit to learn the information was eliminated. Administering weekly assessments also allowed me to assess students more immediately, rather than waiting until the end of the unit to check for student understanding. I was able to identify topics that may have been unclear to students and address misconceptions in real time.

There also exists evidence that testing itself may increase learning. The testing effect is defined as the improved performance on a later test arising from an earlier test (McDaniel, Roediger, McDermott, 2007). Studies show frequent testing may also present additional benefits such as exposing students to new material, keeping students motivated, and encouraging students to study more. Not only were students given a pre- and post-assessment in short-answer format for the unit, but students were also given short-answer pre- and post-discussion assessments throughout the unit. In addition to improved performance on a later retention test, studies show that greater testing effects exist when initial short-answer assessments are given than when initial multiple-choice assessments are given, even when the final assessment is in multiple-choice format.

These factors may benefit learning the current curriculum and may have positive impacts on students in the future. Nonetheless, the data shows some areas where more growth is desired, such as student understanding of GLE MEA: 19. With that as a focus, in addition to continuing

to use the unit design and supplements I created for the measurement unit, I will also strive to create and find tools that will help to improve student comprehension and retention to increase proficiency in GLE MEA: 19.

While I cannot be certain, I believe the "weekly assessments" was the factor that had the greatest influence on the good performance. I found that students were more engaged when I administered a pre- and post- assessment during a lesson or topic. Students wanted to assess what they wrote during the pre-assessment. Students were able to receive automatic feedback because the topic assessed was immediately discussed. In some of the other assessments, I also increased the amount of writing and reasoning required. In addition to drill and skill procedures, having students write more allowed me to assess if students genuinely understood and if there were any misconceptions that needed to be addressed. In reflecting on how the unit went, I am most pleased with the assessment choices that were chosen to assess student understanding.

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Vita

Ni'Shawn Stovall is an Algebra I teacher of the Ninth Grade Academic Academy at Belaire High School in Baton Rouge, Louisiana. A native of Baton Rouge, she is a graduate of Belaire High School.

Earning a Bachelor of Science Degree in Secondary Education in December 2001, Ms. Stovall completed her collegiate studies at Southern University Agriculture and Mechanical College. While at Southern University, she accepted an invitation to have a literary work published in the Honors College Anthology of student work.

She holds a State of Louisiana Teaching Certificate of Highly Qualified Status. She has complete Phase 1 of Nation Board Certification in the Take One! Program.

Ms. Stovall has been active in many roles in the East Baton Rouge Parish School System. She completed observations at Glen Oaks High, Lee High and Scotlandville High. She completed student teaching at Capital High and taught various Secondary Mathematics courses at Istrouma High. Ms. Stovall was also selected as East Baton Rouge Parish School System's 2013 High School Teacher of the Year.

Hoping to increase the interests of the fundamentals of mathematics and the relevance in everyday life problem solving in her students, Ms. Stovall says her interests lie within her students. She has a goal to bridge the gap and help students identify their own connections between real life and mathematics. She wants to help them see that mathematics is not only a subject, but a way of thinking.

If she had to sum it up, Ms. Stovall would say "My philosophy on teaching is students should gain knowledge in the content areas, while developing social skills to become successful productive citizens."