2010

Fraction competency and algebra success

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FRACTION COMPETENCY AND ALGEBRA SUCCESS

Submitted to the Graduate Faculty of
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
Requirements for the degree of
Master of Natural Sciences

In
The Interdepartmental Program in Natural Sciences

By
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I want to thank a host of friends and colleagues who have given me that extra push when I needed it. I want to acknowledge Dr. James Madden. Thank you for challenging me to work to my potential. I want to thank Dr. Frank Neubrander and Dr. Padmanaban Sundar for their support and input in this endeavor. Thank you to the members of this cohort who supplied laughter when I needed it and the encouragement when I could not see the end of the tunnel. This project is dedicated to the memory of my mother, Mrs. Flora L. Thomas. Her dedication to family and hard work set a wonderful standard to follow. You will always be with me in spirit.
# Table of Contents

Acknowledgements .................................................................................................................. ii

List of Tables .............................................................................................................................. v

List of Figures ............................................................................................................................ vi

Abstract ....................................................................................................................................... vii

Introduction ................................................................................................................................ 1

Chapter 1 Literature Review ...................................................................................................... 5
  How to Get Students Ready for Algebra .................................................................................. 5
  How to Determine If A Student Is Ready for Algebra ............................................................. 6
  Fraction Proficiency .................................................................................................................. 6
  Summary of the Articles ............................................................................................................. 7

Chapter 2 Fraction Competency? .............................................................................................. 13
  What Is It? ................................................................................................................................ 13
  How Is It Tested? ......................................................................................................................... 14
  How Does It Support Algebra? ................................................................................................. 17

Chapter 3 Pre-Assessments ....................................................................................................... 21
  The Fraction Pretest .................................................................................................................. 21
  The Algebra Pretest .................................................................................................................. 24
  Comparing Fraction Success and Algebra Success ................................................................. 25
  Relationships between Pretests ............................................................................................... 26

Chapter 4 Test Scores and Their Connection to the Midterm Grade ...................................... 27

Conclusion .................................................................................................................................. 32

References ................................................................................................................................. 34

Appendix

  A-1 List of Grade Level Expectations ...................................................................................... 37

  A-2 List of GLEs by Unit ........................................................................................................... 39

  A-3 Division of Units within the Algebra Curriculum ............................................................... 40
<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-4</td>
<td>Algebra I Pretest</td>
<td>41</td>
</tr>
<tr>
<td>A-5</td>
<td>Student Test Scores and LEAP21 Scores</td>
<td>59</td>
</tr>
<tr>
<td>A-6</td>
<td>Fraction Pretest</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>Vita</td>
<td>64</td>
</tr>
</tbody>
</table>
List of Tables

Table 2.1 The breakdown of questions per strand on the LEAP21 test ..................15
Table 3.1 A breakdown of fraction pretest results ........................................... 23
Table 3.2 A breakdown of algebra pretest results .............................................24
List of Figures

Figure 3.1 The bars show the number of students getting the nth problem wrong........22
Figure 3.2 Fraction pretest vs algebra pretest ..........................................................26
Figure 4-1 Fraction pretest vs the midterm grade .....................................................28
Figure 4-2 Algebra pretest vs the midterm grade .......................................................29
Figure 4-3 2009 LEAP Scaled Score vs. the midterm grade ......................................30
In this thesis, I investigated the importance of fraction competence to success in algebra. I studied 107 of the students whom I teach. These students were all enrolled in Algebra I. A fraction pretest and an algebra pretest were given at the beginning of the 2009-2010 school year. A comparison was done to study the connection between the fraction pretest score and the semester grade as well as the algebra pretest score and the semester grade. The strongest correlation was between the fraction pretest and the semester grade. This supported the theory that fraction competence is a strong predictor of algebra success.
Introduction

*The proper study of fractions provides a ramp that leads students gently from arithmetic up to algebra. But when the approach to fractions is defective, that ramp collapses, and students are required to scale the wall of algebra not at a gentle slope but a ninety degree angle. Not surprisingly, many can’t.*

Hung-Hsi Wu (Wu 2001).

A high-school teacher cannot control the skills that students arrive with, but has to work with the skills that are present. Unfortunately, large numbers of students leaving middle school struggle in pre-algebra and in high-school algebra courses. This phenomenon is appearing in every sector of the US educational system: poor, wealthy, urban, rural, private and public. NAEP 2007 results show that only 39% of our students are at or above the “proficient” level in grade 8 (NAEP, p. 25). This is less than 2 out of every 5. “It is clear that a broad range of students and adults also have difficulties with fractions, a foundational skill essential to success to algebra (NMPR, p. 31).”

As a 9th grade algebra teacher, I find the lack of consistent knowledge that my students bring into my classroom very frustrating. By state mandate, students must reach a particular level of proficiency in order to be promoted to high school. However, when given a pretest, it is obvious that these students lack proficiency in number relations and in the manipulation of rational numbers. With these deficiencies, it is very hard to bring them up to the level of skill in algebra that the state expects. Students who cannot perform basic fractional operations tend to do poorly in or fail Algebra I.

Mathematician Hung Hsi Wu has said, “there are at least two major bottlenecks in mathematics education of grades K-8: the teaching of fractions and the introduction of algebra
In this study, I will examine the hypothesis that a lack of competency with fractions is a major contributor to students’ lackluster performance in algebra.

What makes this a reasonable hypothesis? My observation from 17 years of teaching in the 6th-9th-grade band is that students who can’t work with fractions don’t do well in Algebra I. Some students can do arithmetic with calculators but are unable to do it by hand. These students struggle in Algebra I. In solving equations with rational numbers, they can learn the rules but they cannot apply them. The reason is that the procedures of algebra require proficiency with rational numbers. For example, consider the following equation and its solution:

\[ \frac{1}{2} - \frac{1}{3} = \frac{1}{6} \]

This is an example of a typical 9th-grade algebra problem. To perform the steps, the student must be able to change mixed numbers to fractions, add fractions and whole numbers, and multiply and divide fractions. Even though this problem is a part of the algebra curriculum, competency with rational numbers is required to answer it correctly. In other words, being able to work with rational numbers is an essential component to algebra success, since fractions are manipulated throughout the curriculum.
The reasons for the hypothesis go beyond this, however. “For students to achieve access to and succeed in the formal study of algebra, they need to achieve fluency using mathematical thinking tools and informal algebraic ideas (Krieger, p. 10).” Thought processes that are used in algebra are pre-shadowed in the learning of fractions. Algebra is more abstract than the courses that come before it, so in order for students to do well, they must have a solid foundation in the uses and meanings mathematical operations. When doing arithmetic with fractions, the student must pay more careful attention to the structure of the expressions and the manner and order in which the operations of arithmetic are applied. This means that learning to compute with fractions makes the mechanics of the language clearer. As Wu says, “With the proper infusion of precise definitions, clear explanations, and symbolic computations, the teaching of fractions can eventually hope to contribute to mathematics learning in general and the learning of algebra in particular (Wu, 2010, p. 6).”

The third supporting reason for the hypothesis is that abstract reasoning begins in the learning of fractions. Wu has said, “The study of fraction arithmetic is rife with opportunities for getting students comfortable with the abstraction and generality expressed through symbolic notation (Wu, 2010, p. 3).” Most students have only heard about fractions being “a part of a whole.” But one must consider fractions that include decimals, or fractions that are more than one whole? Students struggle with these ideas and are inadequately prepared for the concepts that algebra involves. The student cannot address algebraic concepts because he or she cannot mentally process what the variables represent. To summarize, we have identified three reasons why learning fractions supports the learning of algebra:

1. fractions are used in algebra;
2. studying fractions forces students to pay attention to mathematical structures that they work with in algebra;
3. fractions are inherently abstract, so studying fractions is an introduction to abstraction.

In this study, we will examine how student fractional competency affects success in Algebra I. At the beginning of the school year, students took two tests. The first was a district-mandated test intended to pre-assess what students already know about the course. The second assessed the student’s ability to manipulate fractions. If the hypothesis is true, then competence with fractions should be a good predictor of course success. (We recognize that correlation does not prove causation, but certainly a strong correlation would not be meaningless.)

Professional opinion, mine included, says that fraction competence is necessary for algebra success, that there is a link between success with fractions and success in algebra. The former is a foundation for the latter. Can this be demonstrated empirically? Can this dependence be quantified and measured? This is the issue we have addressed.
Chapter 1: Literature Review

Algebra readiness, simply defined, is preparation needed to make sense of the skills and procedures of Algebra I and to perform them accurately and reliably. In an effort to find information about the correlation between fraction competency and algebra success, a Google search was done with the key words “fractions and algebra.” After retrieving and reading a selection of these articles and their bibliographies, a selection of articles was identified that were more specific to the focal point of fraction competency and algebra success. A review of this material revealed three main themes: how to get students ready for algebra, formal vs. informal teaching techniques, and fraction proficiency.

How to Get Students Ready for Algebra

These articles (NMPR, 2008), (NAEP, 2008), (Bracey, 1996), (Darley, 2009), (Ruth 2010), (Van Ameron, 2008), (Wu, 2001), (Wu, 2008) and (Wu 2010) centered on intervention strategies, focusing on methods to prepare students for algebra, whether they were on a traditional track or needed special assistance. One of these strategies was to allow students to move to algebra only when their cognitive mindset was ready. Another readiness strategy was to reinforce the usage of the number line as a teaching strategy. One author suggested the compression of concepts as a method of mastering concepts.

The authors of these articles believe that it takes more than the traditional algorithms to be prepared for algebra. They supported using alternative strategies to prepare students for algebra. While using alternative strategies may go against the grain, these authors believe that not every student can walk the same path to get to the same destination.
How to Determine If A Student Is Ready for Algebra

This set of articles (Chappelle & Thompson, 1999), (Cavanagh, 2008), (Herscovics & Linchevshi, 1994), (Warren, 2008), (Gersten, 2008) helped their readers determine if students who were enrolled in algebra were actually ready for it. Formal and informal strategies can be used to determine if a student is ready for algebra or to prepare a student for algebra. One author (Chappelle) believes that “internal processing by students is more important than learning algorithms.” Chappelle discussed open-ended questions as a tool to track the student’s understanding of mathematical concepts. Chappelle also mentioned that the open-ended questioning method forced the student to think beyond the skills questioned.

This section of articles discussed a student’s cognitive development as a whole. These authors believed that thinking is just as critical as computation. These authors endorsed open response questions as well as constructed response questions to follow the thought process of students.

Fractional Proficiency

Finally, fractional proficiency was the third main focal point in the articles that I examined (Brown & Quinn, 2007), (Pace, 1978), (Pearn & Stephens, 1996), (Gelman, Cohen & Hartnett, 1989), (Wu, 2008). Pace’s article discussed matching cognitive development with skills. Fraction operation, use, and applications were some of main concerns of Pearn. She said that “algebra is the generalization of arithmetic and the first experiment in symbolic representation of numbers.” In the article, Investigating the relationship between fraction proficiency and success in algebra, Brown & Quinn note how important it is for students to be proficient with fractions.

The National Math Panel Report (NMPR) points out the weakness of mathematics education in the United States. It discusses data from the National Assessment of Educational
Progress (NAEP) and shows the correlation between skills that are taught in grades K-8 and algebra. The NMPR specifically recommends the skills that need to be mastered prior to algebra and how these skills are related.

This third section tells us what fraction proficiency is and how it is important to the learning of algebra. These articles make connections between abstract and concrete ideas. These articles describe one of the foundations on which algebra is laid.

With these articles in mind, this thesis was written to support a belief that competency with fractional concepts play a crucial role in a student’s success in algebra. How to get a student ready for algebra, determining if a student is ready, and fraction proficiency are three factors that are stressed throughout this study to show the correlation between fractions and algebra.

Summary of the Articles

National Math Panel Report

This document is published regularly to show the progress or demise of the mathematical educational system. In this report, many experts are consulted to offer explanations or solutions to problems within the mathematical educational realm. With this focus, the panel reported that students entering algebra “must have fractional competency and mastery of whole numbers, and facets of geometry.” The National Math Panel Report of 2008 is a resource that “grades” the effectiveness of mathematics education in the United States. This report offers insight into what may be needed to increase the United States’ national testing average to the level attained by high-performing countries such as Singapore and Thailand.

Bracey: Fractions: no piece of cake

The author discusses how the generalized concept of teaching fractions as a piece of cake, pie or pizza does not aid in the process of teaching students the complete truth about
fractions. Using pieces of pie or cake to depict fractions does help younger students to visualize what a fraction is; however, it does not aid in the process of performing operations with them. Bracey discusses how deeper thought and understanding is needed to manipulate fractions in a real-life context. Nor does the use of pieces address very small numbers or fractions larger than one. Also pieces do not help to teach multiplication of fractions.

Darley: *Traveling from Arithmetic to Algebra*

In this article, the author discusses the importance of a student’s understanding of fractions as numbers and points on a number line. In many cases, students see fractions as abstract concepts and do not master their usage. “historically, students have had a difficult time transitioning from arithmetic to algebra in part because of the effort needed to connect the two (p. 458).” This causes a major disruption in learning, understanding and applying algebra. In this article, the process of moving from arithmetic to algebra begins with whole numbers, progresses to fractions and then moves to algebra.

Van Ameron: *Focusing on informal strategies when linking arithmetic to early algebra*

This article differentiated between formal and informal learning strategies for students. While students are taught methods and algorithms, it is the internal processing that determining how successful the student will be at understanding what is taught. This article stresses the importance of making connections between the formal and informal as well as the push toward making the connections between arithmetic and algebra symbolism.

Wu: *Fractions, Decimals and Rational Numbers*

The main ideas of this article were the relationships between fractions, decimals, and rational numbers. The time frame was around 5th through 7th grade. The article addresses the need to severely alter the way fractions are taught so that algebra is more “user friendly.” Wu offers several examples of how these versions of real numbers are related and interchangeable.
He discusses the transition from concrete to abstract in terms of fingers and pie pieces, and how the missing link of a transitional element only

Wu: *How to prepare students for algebra*

Wu’s contribution in this article was that he laid a foundation that showed the connection between fraction knowledge and learning algebra. He gave examples of how the abstract nature of algebra can be linked back to fundamental rules of fractions. He gives examples of using the addition property as well as the division property to build algorithms commonly used in algebra. Wu used common examples such as the means and extremes property and the algorithm for adding fractions to illustrate the importance of fraction competence.

Chappelle & Thompson: *Modifying Our Questions to Assess Students’ Thinking*

This article addresses how using diverse types of questions can offer insight into what a student understands. Oftentimes, we assume that students understand a concept because he or she can compute an answer. “Such communication helps in assessing not only the mathematics that students know but also their understanding of the mathematics (p. 470

Cavanaugh: *Low Performers Found Unready to Take Algebra*

This article addressed the efforts made by teachers, administrators, superintendents and school leaders to place 8th grade students in Algebra I. “Preparing students for algebra is the culmination of many, many years of teaching and learning, and the product of hard work by students, teachers and families.” The article discusses that some students who are enrolled in algebra are as much as six grades below grade level. In this source, the subject of diluted subject matter is addressed as a form of algebra. Could it be that students in 8th grade algebra are really taking 8th grade advanced math? The struggling student would need an extra remediation course according to this source. So one wonders how viable 8th grade algebra as a requirement really is.
Herscovics & Linchevshi: A cognitive gap between arithmetic and algebra

Herscovics addresses the need to improve students’ preparation for algebra. This includes possibly spreading out algebra over multiple years. He does not talk about a inner issue with learning algebra except the speed or timing of its teaching. He also discusses common errors made by students who come from arithmetic and carry over into algebra.

Pearn & Stephens: Whole number knowledge and number lines helps to develop fraction concepts

Pearn’s key concept in this article is about how students’ understanding of the number line can be a propellant or a hindrance to success in understanding fractions. Students often do not use the number line for whole number because they use their fingers. However, fingers are not a viable resource for fraction numbers. So the number line should become a resource tool for teachers of fraction concepts. Pearn and Stephens illustrate methods to use the number line as a tool to help students visualize the meaning of fractions.

Warren: Not Ready for Algebra

In this article, Irene Warren discusses how students who are not academically mature are forced into taking Algebra I. Supposedly, it is a part of a national push to have more students taking the course. This decision does not take into account the number of students who fail this course due to being ill-prepared. Also included in this article are issues such as teacher preparation, teacher equality and school equality. Warren mentions that all of these points play an integral role in the success rate of students who are enrolled in Algebra I.

Gersten: Mathematics Interventions & Algebra Readiness: Best Evidence from Scientific Research and Research Mathematicians

This presentation was focused upon the best interventions for mathematically weak students. It not only offers recommendations on what to teach, but what key points to teach within a strand. It shows a connection between concepts so that students can “compress” ideas
and use them accordingly. In this presentation, the authors make a relevant connection between the number line and fractions as well as what it means to the instructor and the student. “For students to be algebra ready, they must really learn and master concepts and procedures related to the rational number/fractions.”

Brown & Quinn: *Investigating the relationship between fraction proficiency and success in algebra*

This article discusses the link between understanding fractions operations, usage and application and those connections to algebra. The article states that knowing and understanding these concepts is essential, since algebra is the generalizations of arithmetic and the first experience in symbolic representation of numbers (p.8).” If students do not master these concepts in middle school, they will not succeed in algebra I. “It seems reasonable to assume that the ability to manipulate common fractions is essential for the typical student to be successful in elementary algebra and subsequent mathematics courses (p.9).”

Brown & Quinn: *Fraction proficiency and success in algebra: what does the research say?*

This article addressed the needs of students to be fractional competent before entering algebra classes. It discusses the research to support this theorem and offers teacher practices. Some of the researchers support allowing students to only learn about rational numbers when they are ready as opposed to a structured program. This would support the effort to make students develop their own connections. “Algorithms that are taught when the concept is beyond the learner’s cognitive development, force the learner to abandon their own thinking and resort to memorization—doing without understanding.”

Ellis: *Connections between generalizing and justifying students’ reasoning with linear relationships*

This article discusses the source o common errors made by students in algebra. The author ties these errors to a lack of reasoning skills. The study specifically looks at seven
students and how they address particular problems in algebra. As a result, the authors identifies four mechanisms for change that support engagement in algebraic reasoning: iterative actions/reflective cycles; mathematical focus; generalizations that promote deductive reasoning; and influence of deductive reasoning on generalizing.

Gelman, Cohen & Hartnett: *To know mathematics is beyond thinking that fractions aren’t numbers*

There are four major concepts that the authors concentrate on in this article. They are how fractions are taught, the conceptual understanding of the fraction, the foundations knowledge of the whole number, and class instruction. Using these four concepts, the author focuses on how teachers are handling fraction instruction in the classroom. How these concepts are handled determine how much success the students have in understanding fractions.

Moses, Robert: *Radical Equations: Civil Rights from Mississippi to the Algebra Project*

The focus of this book was the discussion of how civil rights impacted the thirst for knowledge in a group of people. The foreground of this story is the civil rights movement in Mississippi. In the midst of trying to change the mindset of a generation, the organizers of the movement use this forum to propel mathematics education to a level of prominence. This book discusses the importance of mathematical literacy in an age when literacy among African-Americans was not expected, encouraged or supported. Moses discusses how the belief that” illiteracy in math is acceptable the way illiteracy in reading and writing is unacceptable (p.9)” should be the battle cry of every educator. He continues on to show the interactive connection between math literacy and success in society.
Chapter 2: Fraction Competency?

In this chapter, we continue to discuss some of the themes that were discovered in the literature review. We will consider what it means to be competent with fractions, how this is tested on standardized tests, and the connection between the concrete and abstract parts of mathematics and how this all correlates to algebra.

What Is It?

According to Webster’s dictionary, competent means “having the capacity to function or develop in a particular way; specifically: having the capacity to respond (Webster, 2010).” Fractional competency would therefore mean the ability to perform basic operations involving fractions. This is to add, subtract, multiply or divide fractions, and/or mixed numbers as well as understand the “whys” of the process. Fraction usage begins as early as 2\textsuperscript{nd} grade and progresses through the middle school grades. In fact, many of the EBR-mandated tests (unit tests) incorporate fractions into the assessments. The state-wide grade-level expectations (GLE’s) reflect exactly what fractional skills are expected to be mastered by the end of each grade level (see Appendix A-1)

It is not merely procedures with fractions that the students must master but the concept of what the fraction means. Pearn & Stephens suggest “difficulties experienced by children solving rational number tasks arise because rational number ideas are sophisticated and different from natural number ideas …[and]…children have to develop the appropriate images, actions, and language to precede the formal work with fractions, decimals, and rational algebraic forms (p. 601).” Understanding what the fraction represents and how the fraction can be represented seems to play a key role in the level of success in Algebra I. Mathematical concepts are just as important as algorithmic ability.
The thought process is drastically different in algebra than in prior mathematics courses. Bracey discusses this idea in his article, “Fractions: No Piece Of Cake”. He makes the statement that fractions are often taught and accepted as parts of a whole, such as cake or pie. However, as the student moves into upper grades and other forms of a fraction must be considered, the student becomes overwhelmed because he or she has no source or reference. In like manner, Hung-Hsi Wu mentions the use of fingers as the primary mathematical resource when manipulating whole numbers. But there is not a resource so readily available for fractions. As Wu says, “How do you multiply two pieces of pizza?”

To summarize this section, competence with fractions has both procedural and conceptual components. Conceptual competence involves having access to useful and appropriate representation. Procedural competence involves using appropriate algorithms learned in an appropriate context.

**How Is It Tested?**

Most students who enter Algebra I in EBR have had some level of success with standardized tests, because for most students, the 8th grade LEAP21 test is a hurdle that must be cleared for promotion. Yet teachers are encountering many students who are poorly prepared for algebra. Since we have seen that fraction competence is generally considered to be an important component of algebra readiness, it is reasonable to ask if the tests that students are taking are measuring this.

The Louisiana Educational Assessment Program for the 21st century (LEAP21) test is given to all 8th graders and it is a prerequisite for promotion to grade 9. It is a test of general proficiency, and it covers a much broader set of skills than the National Math Panel has listed as necessary for algebra readiness. The “number and number relations” and “algebra” sections of LEAP21 make up between 30 and 40% of the questions as Figure 3.1 shows. (The data here is
the most recent that I was able to obtain from the Louisiana Department of Education web site. It is assumed that the make-up of the test has remained constant.) Not much more than 1/3 of the entire assessment addresses the strands of number relations and algebra. (This does not include questions that address other expressions for rational numbers, such as decimal numbers and percentages.)

Table 2.1. The breakdown of questions per strand on the LEAP21 test. Source: Louisiana Department of Education, page 104.

<table>
<thead>
<tr>
<th>Strand/Standard</th>
<th>Number of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blueprint</td>
</tr>
<tr>
<td>N(Number)</td>
<td>12</td>
</tr>
<tr>
<td>A(Algebra)</td>
<td>9</td>
</tr>
<tr>
<td>M(Measurement)</td>
<td>9</td>
</tr>
<tr>
<td>G(Geometry)</td>
<td>12</td>
</tr>
<tr>
<td>D(Data)</td>
<td>12</td>
</tr>
<tr>
<td>P(Patterns)</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>60</td>
</tr>
</tbody>
</table>

While LEAP21 is the testing tool of choice for the state of Louisiana, its standard of success is not the same as the standard for algebra readiness. The National Math Panel Report clearly lists the recommended standards that students should meet prior to entering algebra. Therefore, sending a student to a course in algebra without mastery of these skills is setting them up for failure or a very hard road. LEAP21 is a comprehensive testing that judges a varied set of skills. However, the skills required for success in algebra are not strongly reinforced on the LEAP21. The benchmarks for the “critical foundations of algebra” clearly state what is needed and expected from students entering grade 9 and Algebra I. This includes and emphasizes fractions.
LEAP21 itself does not measure fraction competency per se. This is also true of the unit tests within the EBR curriculum. GLEs are not taught or tested individually. Moreover, with the aid of a calculator, a student can successfully complete a unit, score at a level of “BASIC” or above but not be fractionally competent. Each test is designed to address at least six GLE’s that may or may not be connected to each other. If a student is competent in five of them and not efficient in fractions, the student is still regarded as successful.

It is difficult to find a testing instrument that measures efficiency in every area; however, while we compile concepts and test them in contexts that are not related, we may be masking a problem that will become a major stumbling block for students when they enter Algebra I. Tests that are not specific enough are an open gate for students who have endemic weakness in a particular area. Therefore, it is fair to say that Louisiana and EBR does not test fraction competence separately. There are tests that do exactly that. Tests such as these provide some opportunity to assess conceptual understanding and can be a predictor of algebra success. One of these tests was used in this study.

A fraction test is published by Silver, Burdett & Ginn. (A copy is in Appendix A-8.) This assessment is often offered as a culminating fraction unit test in the seventh grade. Its twenty-four questions address all of the basic operations with fractions. This test shows how much core fraction knowledge the student has mastered. Its primary purpose is to assess student mastery of fraction manipulation and to what show what skills a student might lack. The format of the test is open response, not multiple-choice. The test consists of computational problems, and students must work out responses. Approximately 40% of the test is in word problem format, but these problems are still single-step problems and only address one basic skill at a time.
In conclusion, we have considered the primary testing tool in EBR and LA, the LEAP21 test. While this test is the tool used to determine promotion to high school and algebra, it does not test fraction competence. The number and number relation strand and the algebra strand accounts for approximately 1/3 of the entire test. There are tests that exist to assess fraction competence specifically but these assessments are not used for promotion purposes.

**How Does It Support Algebra?**

Because Algebra I requires more abstract thought than basic arithmetic, a very strong foundation of rational numbers is needed. As Krieger (2004) states, “[T]eachers who help students to understand the specific procedures of arithmetic in ways conceptually consistent with the generalized procedures of algebra give students networks of connections that they can draw upon when they begin the formal study of algebra (p.3).” In this section, we shall discuss how prior knowledge plays a role in algebra success and what national and state experts in math education have recommended.

According to Wu and other scholars, understanding fractions is a cornerstone of algebra: The learning of algebra is impossible without the ability to deal with abstract ideas. Fraction competency is at the root of mathematical abstract learning. In fact, Wu calls fractions “a child’s first excursion in abstract mathematics (p. 4).” Fraction mastery and usage are critical in algebra because without even realizing it, fractions are a part of the rules, theorems and algorithms that are so important in algebra. For example, in working with proportions students often pass from a statement like

\[
\frac{a}{b} = \frac{c}{d}
\]

to

\[ad = bc\]
by “cross multiplying.” Thoughtlessly performed, this conceals a process of reasoning that uses fractions. Instead, the student who uses fraction reasoning moves from

\[
\begin{array}{c}
\hline
& \quad & \\
\hline
\end{array}
\]

To conclude that

\[
\begin{array}{c}
\hline
& \quad & \\
\hline
\end{array}
\]

Because \( \quad \) \( \quad \) \( \quad \). So, because the denominators are the same,

\[
a d = b c.
\]

While this concept is commonly used in proportional reasoning, it is not commonly taught using variables. It is used in 8th grade mathematics and consistently used in later lessons. However, the abstract concept is the most crucial part.

The same ideas provide an explanation of how to add fractions, based on the idea that any rational number multiplied by one has the same value. Consider this following example from Wu (2010).

How do we add \( \quad \) and \( \quad \) ?

Using the fact that

\[
\begin{array}{c}
\hline
& \quad & \\
\hline
\end{array}
\]

, we can rewrite these fractions:

\[
\begin{array}{c}
\hline
& \quad & \\
\hline
\end{array}
\]

So, \( \quad \) \( \quad \) \( \quad \) \( \quad \). This leads to \( \quad \).

(Wu, 2010, p. 3)

This is the algorithm for adding fractions with different denominators. The understanding of this abstract formula becomes increasingly important when students encounter adding rational expressions in the latter stages of Algebra I. So not understanding this idea does cause algebraic difficulties. Again, the relevance of fractional competency is shown past the level of simply
manipulation of numerical expressions. It is the understanding and the application of the concept itself.

The NMPR specifically sites “three clusters of concepts…about the most essential mathematics to learn thoroughly prior to algebra course work (NMPR, p. 17).” The panel expresses the opinion that a lack of these specific skills can hinder a student’s success in algebra. They are: “fluency with whole numbers; fluency with fractions; and fluency with particular aspects of geometry and measurement (NMPR, p.18).” These “benchmarks for the critical foundation of algebra” are described by the panel as follows:

**Fluency With Whole Numbers**

1) By the end of Grade 3, students should be proficient with the addition and subtraction of whole numbers.
2) By the end of Grade 5, students should be proficient with multiplication and division of whole numbers.

**Fluency With Fractions**

1) By the end of Grade 4, students should be able to identify and represent fractions and decimals, and compare them on a number line or with other common representations of fractions and decimals.
2) By the end of Grade 5, students should be proficient with comparing fractions and decimals and common percent, and with the addition and subtraction of fractions and decimals.
3) By the end of Grade 6, students should be proficient with multiplication and division of fractions and decimals.
4) By the end of Grade 6, students should be proficient with all operations involving positive and negative integers.
5) By the end of Grade 7, students should be proficient with all operations involving positive and negative fractions.
6) By the end of Grade 7, students should be able to solve problems involving percent, ratio, and rate and extend this work to proportionality.

**Geometry and Measurement**

1) By the end of Grade 5, students should be able to solve problems involving perimeter and area of triangles and all quadrilaterals having at least one pair of parallel sides (i.e., trapezoids).
2) By the end of Grade 6, students should be able to analyze the properties of two-dimensional shapes and solve problems involving perimeter and area, and analyze the properties of three-dimensional shapes and solve problems involving surface area and volume.
3) By the end of Grade 7, students should be familiar with the relationship between similar triangles and the concept of the slope of a line. (NMPR, p. 20)

Considering this, it is obvious how important fractions and rational numbers are in the course of algebra to the NMPR. “Research suggests that every effort be made to connect
students’ existing fraction knowledge to a quantitative model so that fractions are recognized as numbers before engaging in formal algebra (Bracey, 1996; Gelman, Cohan, & Hartnett, 1989).”

In conclusion to this chapter, fractional competency is the ability to manipulate fractions in abstract and applied mathematical contexts. We have discussed the importance of this skill in the context of the curriculum, both prior to and concurrent with algebra. While fractions are addressed in assessments prior to algebra, they are not the primary focus and therefore problems may surface for the first time during algebra. LEAP21 is the primary tool used for promotion to high school but is not a strong tool for assessing fraction competency. The NMPR stresses key skills that should be mastered prior to entering high school mathematics. This report not only notes that students should be familiar with these “critical benchmarks of algebra,” but states that students should be “fluent.” The NMPR brings to the forefront the importance of whole numbers and fractions as key skills needed for success in algebra.
Chapter 3: Pre-Assessments

This chapter discusses the two primary assessments that were given at the beginning of the school year, in August 2009—one in fractions and one in algebra. We describe how the students performed and offer further elaboration of the reasons for the hypothesis that fraction competence should be related to success in algebra. A clear correlation between performance in the fraction pretest and performance in the algebra pretest was seen.

One hundred seven (107) students participated in this study. All of them were taking Algebra I in Fall 2009, in one of the five classes I was teaching. The students varied in age and mathematical experience. About 75% of the students had repeated at least one grade, i.e., were at least one year over age. Approximately 53% of the students were taking algebra for the first time. 82% were freshmen, 8% were sophomores, 4% were juniors and 6% were seniors. The students completed two assessments at the beginning of Algebra I: an Algebra I pretest and a fraction pretest. The common objective of each of these examinations was to assess the knowledge attained prior to entry in Algebra I.

In grading this assessment, only 11 out of the 107 students (or 10.3% of the class) were found to have a score of 60% or better. In other words, only 11 students could manage to get a minimum of 14 questions correct.

The Fraction Pretest

This pretest was described in Chapter 3 section 2. As stated there, this test measures procedural and conceptual knowledge of fractions, and does not include question about decimals, percents, proportions, roots nor any other topics of algebra. However, more importantly, these questions require an understanding of more than a rote algorithm. Some of the frequently-missed questions required the student to perform some type of conversion (e.g., from mixed
number to improper fraction). This calls for a level of understanding of the representation of the number itself. These are the kind of errors that the National Math Panel was pointing to in stating, “The types of errors these students make when attempting to solve algebraic equations reveal they do not have a firm understanding of many basic principles of arithmetic (NMAP, p.7).” This is not indicative of a complete lack of ability with fraction use but comes from a lack of conceptual understanding, and it calls to mind Wu’s warning, “If we want students to achieve algebra, we cannot allow fractions to be presented, as it is commonly done, as a collection of factoids held together only by hands-on activities and manipulatives (2008, p.2).”

**Figure 3-1.** The bars show the number of students getting the nth problem wrong. The questions on the fraction test are listed horizontally by number and the height of the bar shows how many students answered incorrectly. High bars are “difficult” questions.
When looking at the questions corresponding to the highest bars in the graph, we find that these typically involve using multiple skills. It is not only one skill that causes problems for these students. The majority of answers in problem 6 showed a lack of ability to deal with three different denominators. In fact some students did not answer this question. Problems 10 and 11 both addressed the skill of renaming; however, in problem 10 students tended to simply subtract without renaming because the denominators were the same. Conversely in problem 11, the students had to determine a common denominator, rename and then subtract. Problems 21 and 22 addressed division skills while problems 23 and 24 were word problems that required the students to determine the correct operation to use. Problem 3 was missed consistently because the students did not simplify the answer, which may be a problem with factoring or carelessness.

A graph of how student scores’ were broken down is below

<table>
<thead>
<tr>
<th>Grade range (% correct on test)</th>
<th>Percent (%) of participants in this range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>1</td>
</tr>
<tr>
<td>10-19</td>
<td>7</td>
</tr>
<tr>
<td>20-29</td>
<td>23</td>
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<td>30-39</td>
<td>21</td>
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<td>40-49</td>
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<td>50-59</td>
<td>19</td>
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<tr>
<td>60-69</td>
<td>4</td>
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<td>70-79</td>
<td>6</td>
</tr>
<tr>
<td>80-89</td>
<td>1</td>
</tr>
<tr>
<td>90-100</td>
<td>0</td>
</tr>
</tbody>
</table>

We see that 80% of the student score below 50% on the fraction pretest. In fact, half of the students scored below 40%. This shows that, in general, the students did not have very well-developed fraction skills.
The Algebra Pretest

The Algebra I pretest was published by the Riverside Company. A copy is provided in Appendix A-4. This test is mandated by EBR for all students in Algebra I. The goal of this assessment is to determine how ready students are for algebra. Therefore, it includes several problems involving rational numbers, so it tests literacy with fractions to some extent. The test is composed of 51 multiple-choice questions. Students were allowed to use calculators.

In the review of this assessment, students tended to struggle with problems that require more thought than computation (problems 10 and 11). They also had difficulty with problems that asked them to solve problems with various types of rational numbers (problems 15, 16, 17). The thought process in important in algebra because of its abstractness, but students tend to depend on the calculator to do the entire problem. So, when that tool is of no consequence, their ability falters.

The questions missed most often on the algebra pretest were questions 37 and 45. Question 37 asks students to compute a slope. This requires remembering what slope means, applying a formula and carrying out some arithmetic. Likewise, question 45 concerns probability and understanding of a relationship between types of outcomes. The problems that were missed most often were the most complex and conceptual. Of the students, 62% scored below 50%. Only 1 student scored at or above 70%. So these same students struggle with algebraic concepts. The table below shows the breakdown of the algebra pretest scores.

Table 3.2  A breakdown of algebra pretest results

<table>
<thead>
<tr>
<th>Grade range (% correct on test)</th>
<th>0 - 9</th>
<th>10 - 19</th>
<th>20 - 29</th>
<th>30 - 39</th>
<th>40 - 49</th>
<th>50 - 59</th>
<th>60 - 69</th>
<th>70 - 79</th>
<th>80 - 89</th>
<th>90 - 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent (%) of participants in this range</td>
<td>0</td>
<td>2</td>
<td>12</td>
<td>21</td>
<td>33</td>
<td>24</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Comparing Fractions Success and Algebra Success

How is performance of the two tests related? Students can use calculators throughout algebra; so why should fractional competence be critical? To answer this question, it is important to observe that algebra is not simply another math course. Algebra is the first course that strongly relies upon abstract thought and reasoning. As Wu says, “Algebra is the generalization of arithmetic and the first experience in symbolic representation of numbers (2001).” Fractions are core arithmetical concepts. The understanding of the number system and its manipulation is not possible without the successful use of rational numbers. As Gersten commented, “For students to be algebra-ready, they must really learn and master concepts and procedures up to the rational numbers/fractions (p. 3).” According to the National Math Panel Report, “U.S. students’ poor knowledge of the core arithmetical concepts impedes their learning of algebra and is an unacceptable indication of a substantive gap in the mathematics curricula that must be addressed (p. 5).”

As we continue to look at how courses and coursework can be inter-related, it is important to remember that students at this age level are learning in stages. If weaknesses in one stage are overlooked, they can cause stagnancy in the next. “Mathematical topics that are related to proportional reasoning are fractions, decimals, ratios, percent, probability, similarity, linear functions equivalence, and measurement, and many others. Consequently, a sizable gap exists in an individual’s rational number concept, a gap that will become even more apparent as the individual begins to tackle a course in algebra (Brown & Quinn, p. 3).” In other words, how can a student be ready for algebra when he or she has not mastered the pre-requisite skills? Can a student really excel in a course that is mainly abstract when he or she still struggles with concrete ideas?
Relationships between Pretests

It is obvious in Figure 3-2 that there is a positive correlation between the algebra pretest and the fraction pretest. The correlation coefficient \( r \) is 0.502. The statistical package in Mathematica\textsuperscript{TM} shows a \( p \)-value less than \( 10^{-7} \). This means that for a data set this size with no relationship, the probability of an \( r \)-value this large by chance alone is very small. This reflects the positive relationship between the fraction pretest scores and the algebra pretest scores, which is obvious in Figure 3-2.

![Figure 3-2](image.png)

**Figure 3-2.** Fraction pretest (horizontal) versus algebra pretest (vertical); \( n = 107 \). Large circles represent two or three individuals with the same scores on both tests.
Chapter 4 Test Scores and Their Connection to the Midterm Grade

The midterm grade, recorded in December 2009, was used to measure success in Algebra I. Our hypothesis is that fraction competence should influence algebra success. So, we expect to see a correlation between performance on the fraction pretest and midterm grade. In this chapter, we will compare the pretest scores on both pretests to the midterm grade and determine which is the better predictor of algebra success.

Midterm grades were computed from homework (15%), group projects (15%), quiz and test scores (55%) and the midterm exam (15%). Homework was graded weekly, and it was graded for correctness, not merely attempt. There were 3 group projects, and each was graded with a rubric intended to measure level of math skills as well as performance on written presentation. As for quizzes and tests, there were four mandated EduSoft tests, and 12 other assessments prepared by the teacher. The midterm exam was multiple-choice, with 65 questions.

When the scores from the fraction pretest and the midterm grades are compared, a positive correlation is observed; see Figure 4-1. The fraction pretest scores were generated from the 24-question open response test. The scores were converted to a percentage so that they could be compared to the midterm grade. The graph shows that most students who did poorly on the fraction test did poorly during the first semester of Algebra I, receiving a low midterm grade. In like manner, higher scores on the fraction pretest went with higher midterm grades.

The correlation coefficient, $r$, for the data in Figure 4-1 is 0.47. In education research, this would be viewed as a moderate connection between the fraction pretest and the midterm grade. The $p$-value (computed using Mathematica™) is less than $3 \times 10^{-7}$, showing that the observed relationship is almost certainly not due to mere chance.
Figure 4.1. Fraction pretest versus the midterm grade ($n = 107$). The figure shows a comparison between the fraction pretest and the midterm grade. Most students who scored poorly on the fraction test did not perform well during the first semester of Algebra I. Large circles represent two individuals with the same scores on both tests. The correlation coefficient for this data is 0.47.

Figure 4.2 shows the comparison between the algebra pretest and the midterm grade. This figure also shows a positive correlation between these two data sets, indicating the predictability of algebra success based on prior algebra knowledge. While Figure 4-2 does show a positive correlation, it is not as strong as Figure 4-1. The $r$ value for the algebra pretest and the midterm grade is 0.36. The $p$-value (computed using Mathematica™) is about .0001 (one in ten thousand), so the observed relationship is probably not due to mere chance.
Figure 4-2. Algebra pretest vs. the midterm grade (n = 107). This shows the connection between the district-mandated algebra pretest and the midterm grade. Large circles represent two or three individuals with the same scores on both tests. The correlation between the algebra pretest and the midterm grade is 0.36, which is not as strong as in Figure 4-1.

According to figures 4-1 and 4-2, a higher correlation is shown between the fraction pretest and the midterm grade than between the algebra pretest and the midterm grade. The fraction test is a better predictor of algebra success than the algebra pretest.

If other tests capable of predicting algebra success are sought, a likely choice would be the LEAP21 test. This is the last standardized test that students take prior to high school. In order to be promoted to 9th-grade, a student must score at least an “Approaching Basic” or “Basic” in mathematics or English on the 8th-grade LEAP. Of the 107 students who participated
in this study, 57 had accessible 8th-grade LEAP scores from the previous year. Figure 4.3 shows the relationship between the LEAP scores and the midterm grades of these 57.

We see a positive correlation. The r-value is 0.45, stronger than the correlation between the algebra pretest and the midterm grade, but weaker than the correlation between the fraction pretest and the midterm grade. In this case, the p-value is about 0.0005 (one in two thousand), reflecting at least in part the smaller number of students.

**Discussion.** In the first semester of the Algebra I course, most of the skills introduced and taught place emphasis on number and number relations. Therefore, one expects the midterm grade to reflect fractional competence, and this is what we have seen. While the midterm did not focus solely on rational numbers, the algebraic concepts did involve problems that required
manipulation of rational numbers in the solution process. Therefore, having core knowledge of rational numbers does enhance the progression of learning and the development of algebraic skills. It is no surprise that fractional proficiency seems to influence algebraic success.

In the previous chapter, we noted a correlation between fraction competence and performance on the algebra pretest. This raises the question of whether or not we can separate fraction competence from other forms of ability that may enhance performance in algebra. In the algebra pretest, students were allowed to use calculators. This might be masking abilities that are actually more important for success in algebra.
Conclusions

We have compared the results from three tests—an algebra pretest, a fraction pretest and the LEAP21—with midterm algebra grades. The better the students did on any of these tests, the higher they scored at midterm but the correlation was strongest for the fraction pretest. Therefore, fraction competency plays a role in success in algebra that is at least as strong as anything else that we measured. This supports the belief that algebra learning is influenced by the fraction knowledge that students have available to build upon when they enter high-school.

Is fraction competency the major determinant of algebra success? Are key concepts such as proportionality, decimal numbers, geometry, and measurement irrelevant? These components of the curriculum may be important, but fraction competence demonstrably has a powerful influence. This is consistent with the National Math Panel Report, which states that students should be fluent in fractions prior to entering high school mathematics. Geometry and measurement are included; but appropriately they are not stressed as much as fraction competency.

What might explain this? Within the last twenty years, mathematicians have hypothesized that students who are not fraction-proficient will struggle in algebra because the thought processes needed to do algebra have roots in the understanding of fractions. Fractions, though considered arithmetic, are the first entry into abstract thought. Fractions, unlike whole numbers, are not computed with “finger and toe” manipulation. This makes dealing with them very different from the arithmetic that students perform in the early elementary years. Because fractions are the beginning of abstract thought, fraction competency is critical to success in algebra.
What are the implications? Algebra is an abstract version of arithmetic. Consequently, students who have problems with arithmetic will struggle in algebra. The more students struggle with fractional concepts, the more they struggle with algebra concepts. Fractions support the learning of algebra. “In teaching fractions, the opportunity to make use of letters to stand for numbers is available at every turn (Wu, 2007, p. 38).”

It is more than computation that students learn when they understand fractions. It is more than “a collection of factoids held together only by hands-on activities and manipulatives.” It is what a fraction is, what it means, how it is represented and how it is applied that every student must inherently master prior to be successful in algebra and high school mathematics in general.

As Robert Moses has said, learning algebra must be considered a basic civil right in our new technological age. Knowledge of fractions has to be a major component of the preparation for this important course.
References


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Appendix

A-1: List of Grade Level Expectations for Algebra I.

Number and Number Relations
1. Identify and describe differences among natural numbers, whole numbers, integers, rational
   numbers, and irrational numbers (N-1-H) (N-2-H) (N-3-H)
2. Evaluate and write numerical expressions involving integer exponents (N-2-H)
3. Apply scientific notation to perform computations, solve problems, and write representations
   of numbers (N-2-H)
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)
6. Simplify and perform basic operations on numerical expressions involving radicals (e.g., )
   (N-5-H)
7. Use proportional reasoning to model and solve real-life problems involving direct and
   inverse variation (N-6-H)

Algebra
8. Use order of operations to simplify or rewrite variable expressions (A-1-H) (A-2-H)
9. Model real-life situations using linear expressions, equations, and inequalities (A-1-H) (D-2-
   H) (P-5-H)
10. Identify independent and dependent variables in real-life relationships (A-1-H)
11. Use equivalent forms of equations and inequalities to solve real-life problems (A-1-H)
12. Evaluate polynomial expressions for given values of the variable (A-2-H)
13. Translate between the characteristics defining a line (i.e., slope, intercepts, points) and
    both its equation and graph (A-2-H) (G-3-H)
14. Graph and interpret linear inequalities in one or two variables and systems of linear
    inequalities (A-2-H) (A-4-H)
15. Translate among tabular, graphical, and algebraic representations of functions and real-
    life situations (A-3-H) (P-1-H) (P-2-H)
16. Interpret and solve systems of linear equations using graphing, substitution, elimination,
    with and without technology, and matrices using technology (A-4-H)

Measurement
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)
22. Solve problems using indirect measurement (M-4-H)
Geometry
23. Use coordinate methods to solve and interpret problems (e.g., slope as rate of change, intercept as initial value, intersection as common solution, midpoint as equidistant) (G-2-H) (G-3-H)
24. Graph a line when the slope and a point or when two points are known (G-3-H)
25. Explain slope as a representation of “rate of change” (G-3-H) (A-1-H)
26. Perform translations and line reflections on the coordinate plane (G-3-H)

Data Analysis, Probability, and Discrete Math
27. Determine the most appropriate measure of central tendency for a set of data based on its distribution (D-1-H)
28. Identify trends in data and support conclusions by using distribution characteristics such as patterns, clusters, and outliers (D-1-H) (D-6-H) (D-7-H)
29. Create a scatter plot from a set of data and determine if the relationship is linear or nonlinear (D-1-H) (D-6-H) (D-7-H)
30. Use simulations to estimate probabilities (D-3-H) (D-5-H)
31. Define probability in terms of sample spaces, outcomes, and events (D-4-H)
32. Compute probabilities using geometric models and basic counting techniques such as combinations and permutations (D-4-H)
33. Explain the relationship between the probability of an event occurring, and the odds of an event occurring and compute one given the other (D-4-H)
34. Follow and interpret processes expressed in flow charts (D-8-H)

Patterns, Relations, and Functions
35. Determine if a relation is a function and use appropriate function notation (P-1-H)
36. Identify the domain and range of functions (P-1-H)
37. Analyze real-life relationships that can be modeled by linear functions (P-1-H) (P-5-H)
38. Identify and describe the characteristics of families of linear functions, with and without technology (P-3-H)
39. Compare and contrast linear functions algebraically in terms of their rates of change and intercepts (P-4-H)
40. Explain how the graph of a linear function changes as the coefficients or constants are changed in the function’s symbolic representation (P-4-H)
## A-2: List of GLE’s by Unit

**Content Area:** Mathematics  
**Course Name:** Algebra I  

**Grade 9 GLEs**

<table>
<thead>
<tr>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Unit 5</th>
<th>Unit 6</th>
<th>Unit 7</th>
<th>Unit 8</th>
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<td>40.</td>
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</tbody>
</table>
A-3: The Division of Units within the Algebra Curriculum

Algebra I
Table of Contents
Unit 1: Understanding Numeric Values, Variability, and Change
Unit 2: Writing and Solving Proportions and Linear Equations
Unit 3: Linear Functions and Their Graphs, Rates of Change, and Applications
Unit 4: Linear Equations, Inequalities, and Their Solutions
Unit 5: Systems of Equations and Inequalities
Unit 6: Measurement
Unit 7: Exponents, Exponential Functions, and Nonlinear Graphs
Unit 8: Data, Chance, and Algebra
Grade 9 Mathematics

Benchmark Assessment

August Pre-Test 2009-2010

East Baton Rouge Parish School System
Department of Accountability, Assessment and Evaluation
1. What type of number is $\sqrt{3}$?
   A. Whole
   B. Integer
   C. Rational
   D. Irrational

2. Which set below contains natural numbers ONLY?
   A. \(\{0, 2, 6, 200\}\)
   B. \(\{0.2424, \frac{1}{2}, -5\}\)
   C. \(\{1, 3, 5, 10\}\)
   D. \(\{-1, 4, 22, 4,800\}\)

3. Which of the following is a rational number?
   A. $\pi$
   B. $\sqrt{5}$
   C. $\frac{1}{100}$
   D. $\sqrt{7}$

4. Simplify:
   $(-3)^5$
   A. -243
   B. -15
   C. 15
   D. 243

5. Evaluate:
   $5^2 + 10^2 + 3^3$
   A. 25
   B. 152
   C. 187
   D. 134

6. Simplify:
   $\frac{(-4)^5}{(-4)^3}$
   A. -16,384
   B. -64
   C. 64
   D. 16,384
7. Evaluate:

\[(2.0 \times 10^2) + (4.0 \times 10^3) = ?\]
A. 120
B. 600
C. 612
D. 6,000

8. The distance around the Earth at the equator is about 40,074 kilometers. Which of the following is the best approximation of this distance?
A. \(4.1 \times 10^3\) km
B. \(4.1 \times 10^4\) km
C. \(4.0 \times 10^3\) km
D. \(4.0 \times 10^4\) km

9. What is 70,000 written in scientific notation?
A. \(70 \times 10^5\)
B. \(70 \times 10^4\)
C. \(7 \times 10^5\)
D. \(7 \times 10^4\)

10. A student needed to quickly multiply 3.54324765 by 4.873421 without using a calculator. To find the answer the student multiplied 4 by 5. What effect will rounding have on the answer?
A. The answer will be MORE exact than multiplying by the complete numbers.
B. The answer will be SAME as multiplying by the complete numbers.
C. The answer will be LOWER than multiplying by the complete numbers.
D. The answer will be HIGHER than multiplying by the complete numbers.
11. In which of the following situations is estimation the LEAST appropriate strategy?
   A. Identifying the number of cars in a parking lot
   B. Determining the amount of medication a patient should receive
   C. Calculating the time needed to drive from the airport to downtown Baton Rouge
   D. Determining the number of people in a large crowd

12. Evaluate the following expression.
    \[ \frac{1}{2} \times \frac{2}{3} \times \frac{3}{4} \]
    A. \( \frac{1}{4} \)
    B. \( \frac{6}{9} \)
    C. \( 1\frac{1}{3} \)
    D. \( 2\frac{1}{2} \)

13. Evaluate the following expression.
    \[ (-3)^3 (-10)^2 \]
    A. \(-3,600\)
    B. \(-2,700\)
    C. \(2,700\)
    D. \(3,600\)
15. Simplify:
   \[ 3\sqrt{3} + 6\sqrt{3} = ? \]
   A. \( 9\sqrt{3} \)
   B. \( 9\sqrt{6} \)
   C. \( 18\sqrt{3} \)
   D. \( 18\sqrt{9} \)

17. Simplify:
   \[ \sqrt{27} \]
   A. \( 27\sqrt{1x} \)
   B. \( 3\sqrt{3} \)
   C. \( 3\sqrt{9} \)
   D. \( 3\sqrt{3} \)

16. Simplify:
   \[ 4\sqrt{5} + 3\sqrt{5} + \sqrt{5} = ? \]
   A. \( 7\sqrt{15} \)
   B. \( 7\sqrt{25} \)
   C. \( 8\sqrt{5} \)
   D. \( 12\sqrt{25} \)

18. An artist wants to build a proportional statue based on a smaller model. The existing model has a nose that is 4.5 inches long. The new statue will have a nose that is 12 inches long. If the eyes on the model are 2.7 inches wide, how wide will the eyes on the statue be?
   A. 2.6 inches
   B. 7.2 inches
   C. 9.1 inches
   D. 20 inches
22. A paint company wants to test if their new paint mixture is better than their current paint mixture. The company paints 10 boards with the old paint and 10 boards with the new paint. They put all 20 boards outside for five years. At the end of five years they compare how many paint chips have fallen off each board. What is the dependent variable in this example?
A. The type of paint used
B. The color of the paint
C. The number of boards
D. The number of paint chips

23. A restaurant manager knows that the number of customers her restaurant served in a day can be estimated using the equation \( t = \frac{c}{20} \times 60 \), where \( t \) is the total sales and \( c \) is the number of customers. If total sales for a day were $3,508, about how many customers were served?
A. 60
B. 360
C. 1,000
D. 1,200

24. What is the value of the following expression when \( x = 10 \)?
\[ 3x^3 - 3x^2 + 10x - 5 \]
A. 95
B. 995
C. 1,005
D. 2,795
25. Which of the following situations is most likely reflected in the graph below?

A. The population of the world from 2000 to 2008
B. The average heights of 50 students as they grow from grade 1 to grade 7
C. Average monthly temperature in Baton Rouge from January to December
D. The average number of coats sold in Baton Rouge stores from January to December

26. Tyson works 12 hours a week. Trisha works 18 hours per week. Michael works more hours than Trisha. Which number line represents the possible range of hours Michael works?

A. 
B. 
C. 
D. 
29. Four students weighed the same sample of an unknown mineral. Each student weighs the sample two times. Their results are given in the table below.

<table>
<thead>
<tr>
<th>Student</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>15 g</td>
<td>14 g</td>
<td>1 g</td>
<td>14.5 g</td>
</tr>
<tr>
<td>Student 2</td>
<td>16 g</td>
<td>14 g</td>
<td>2 g</td>
<td>15.0 g</td>
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<tr>
<td>Student 3</td>
<td>14 g</td>
<td>14 g</td>
<td>0 g</td>
<td>14.0 g</td>
</tr>
<tr>
<td>Student 4</td>
<td>14 g</td>
<td>18 g</td>
<td>4 g</td>
<td>16.0 g</td>
</tr>
</tbody>
</table>

Which student's measurements were the LEAST precise?

A. Student 1
B. Student 2
C. Student 3
D. Student 4
30. Which of the following rulers would offer the most precise measurements?

A. 

B. 

C. 

D. 

East Baton Rouge Parish School System  
Department of Accountability, Assessment and Evaluation
1. A student was asked to estimate the number of pennies in four different jars. The actual number of pennies in each jar and the student’s estimations are summarized in the table below.

<table>
<thead>
<tr>
<th>Jar</th>
<th>Actual Number</th>
<th>Student's Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,050</td>
<td>890</td>
</tr>
<tr>
<td>2</td>
<td>720</td>
<td>810</td>
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<tr>
<td>3</td>
<td>1,400</td>
<td>1,260</td>
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<tr>
<td>4</td>
<td>3,200</td>
<td>3,005</td>
</tr>
</tbody>
</table>

The estimate for which jar has the highest absolute error but the smallest relative error?

A. Jar 1  
B. Jar 2  
C. Jar 3  
D. Jar 4  

32. What is 0.03615 rounded to two significant digits?

A. 0.1  
B. 0.03  
C. 0.036  
D. 0.0370  

33. Each student is given a bottle of water to take on a hike. What unit of measurement is most likely to be used to indicate how much water each bottle holds?

A. Pounds  
B. Kilograms  
C. Ounces  
D. Meters
34. In a scale drawing of a house, 1 inch equals 4 feet. What is the height of the real house if the height of the house in the drawing is 5 inches?
   A. 9 feet
   B. 10 feet
   C. 20 feet
   D. 21 feet

35. What is the $y$-intercept of the line $3x + 5y = 15$?
   A. 0
   B. 3
   C. 5
   D. 15

36. Which of the following lines has the smallest slope?
   A. $y = 2x + 2$
   B. $y = x + 16$
   C. $y = 5x + 3$
   D. $y = \frac{1}{2}x + 5$

37. What is the slope of the line that passes through (2, 7) and (4, 7)?
   A. 0
   B. $\frac{2}{7}$
   C. 3.5
   D. 7
38. Reflect quadrilateral QRST over the x-axis.
Choose the correct coordinates of the vertices of the image.

A. $Q'(-1, -2)$, $R'(5, 1)$, $S'(-4, -3)$, $T'(2, -7)$
B. $Q'(1, -2)$, $R'(-5, 1)$, $S'(-4, -3)$, $T'(-2, -7)$
C. $Q'(1, 2)$, $R'(-5, -1)$, $S'(-4, 3)$, $T'(-2, 7)$
D. $Q'(-1, 2)$, $R'(5, -1)$, $S'(4, -3)$, $T'(2, 7)$
Use the information below to answer questions 39-41.

The table below shows the number of people, the positions and annual salaries for 50 people at a company.

<table>
<thead>
<tr>
<th>Position</th>
<th>Number of Employees</th>
<th>Annual Salary</th>
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</thead>
<tbody>
<tr>
<td>President</td>
<td>1</td>
<td>$425,000</td>
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<tr>
<td>Vice President</td>
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<tr>
<td>Accountant</td>
<td>1</td>
<td>$95,000</td>
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<tr>
<td>Senior Manager</td>
<td>3</td>
<td>$72,000</td>
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<td>Shop Manager</td>
<td>5</td>
<td>$60,000</td>
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<tr>
<td>Inspector</td>
<td>5</td>
<td>$34,000</td>
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<tr>
<td>Assembly Worker</td>
<td>29</td>
<td>$29,000</td>
</tr>
<tr>
<td>Custodian</td>
<td>4</td>
<td>$24,000</td>
</tr>
</tbody>
</table>

39. The company wants to hire five more assembly workers. The president of the company wants to provide the annual salary of all workers on a Help Wanted advertisement in order to attract applications. Which measure of central tendency should the company president use in the ad if she wants to make it look like the company pays a high annual salary?

A. The median annual income of all workers
B. The mean annual income of all workers
C. The mode of the annual income for all workers
D. The standard deviation of the annual income for all workers
40. In this company, the salary associated with which position is the most significant outlier?
   A. Custodian
   B. Assembly Worker
   C. President
   D. Accountant

41. If a worker is chosen at random from all the workers at this company, what is the probability that the worker chosen will make less than $50,000?
   A. \( \frac{6}{25} \)
   B. \( \frac{19}{25} \)
   C. \( \frac{29}{50} \)
   D. \( \frac{1}{50} \)
42. A survey asked 34 people to share their annual income and the number of years of education they had completed. The results are provided in the graph below.

Annual Income by Years of Education Completed

Which term below best describes the relationship between annual salary and years of education shown in the graph?

A. Curvilinear
B. Linear
C. Accelerated
D. Exponential
43. Each of the numbers from 1 through 10 is written on a slip of paper and the slips are placed in a covered bowl. The bowl is shaken and one slip of paper is drawn at random. Specify the sample space.

A. \{4, 5, 6, 7\}
B. \{1, 3, 5, 7, 9\}
C. \{2, 4, 6, 8, 10\}
D. \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}

44. A student is asked to solve the system

\[
\begin{align*}
3x - 2y + 5z &= -17 \\
2x + 4y - 3z &= 29 \\
5x - 6y - 7z &= 7
\end{align*}
\]

by constructing a matrix containing the coefficient and constants.

\[
\begin{bmatrix}
3 & -2 & 5 & -17 \\
2 & 4 & -3 & 29 \\
5 & -6 & -7 & 7
\end{bmatrix}
\]

The student performs row operations until the student has the matrix below.

\[
\begin{bmatrix}
3 & -2 & 0 & -2 \\
0 & -16 & 0 & -64 \\
0 & 0 & 1 & -3
\end{bmatrix}
\]

At this point, what does the student know?

A. \(x = 3\) and \(y = -2\)
B. \(y = 4\) and \(z = -3\)
C. \(y = -16\) and \(z = 1\)
D. \(y = -\frac{2}{3}\) and \(y = 1\)
45. If the odds in favor of an event occurring is 3:5, specify the probability that the event will occur.

A. \( \frac{3}{8} \)
B. 5:3
C. \( \frac{5}{8} \)
D. 1

46. Which of the following relations is NOT a function?

A. \( f(x) = x^2 \)
B. \( f(x) = |x| \)
C. \( f(x) = \frac{x}{0} \)
D. \( f(x) = \frac{1}{x} \)

47. What is true about the range \( (y) \) of the \( f(x) = x^2 \)?

A. \( y \geq 0 \)
B. \( y \leq 0 \)
C. \( y < 0 \)
D. \( y > 0 \)

48. Eric's family bought a retriever puppy which weighs 17 pounds. The puppy is expected to gain 2 pounds per week and will be considered full grown when it weighs 89 pounds. In about how many weeks will the puppy be full-grown?

A. 21 weeks
B. 26 weeks
C. 43 weeks
D. 52 weeks
49. The graph below shows the heights (in inches) for a person from age 8 to age 20.

During what two year period was the growth rate the greatest?

A. Age 8 to age 10
B. Age 10 to age 12
C. Age 12 to age 14
D. Age 14 to age 16

50. What happens to the y-intercept when the value of $b$ in $f(x) = mx + b$ is increased?

A. It decreases.
B. It increases.
C. It moves to the left.
D. It moves to the right.

51. Choose the answers that best complete the following statement.

“If the coefficient of $x$ in a linear function becomes smaller until it reaches zero, then the graph of the function becomes a _______ line, and the y-intercept _________.

A. horizontal; becomes the x-intercept
B. vertical; becomes the x-intercept
C. horizontal; does not change
D. vertical; does not change
A-5 Student Test Scores and LEAP21 Results (see legend next page)

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<th>Alg pre %</th>
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59
A-5 LEGEND:

FRAC % = FRACTION TEST RESULTS PERCENTAGE
ALG % = ALGEBRA PRETEST RESULTS PERCENTAGE
MIDT % = MIDTERM GRADE PERCENTAGE
LEAP MATH 8 2009 = SPRING 2009 LEAP SCALED SCORE
LEAP NNR = LEAP NUMBER AND NUMBER RELATIONS STRAND
LEAP ALG = LEAP ALGEBRA STRAND
LEAP MEAS = LEAP MEASUREMENT STRAND
LEAP GEOM = LEAP GEOMETRY STRAND
LEAP DATA = LEAP DATA ANALYSIS, PROBABILITY AND STATISTICS STRAND
LEAP PATT = LEAP PATTERNS STRAND
Final Fraction Skills Inventory

Write each answer in lowest terms.

1. A yard contains 36 inches. 21 inches is what fraction of a yard?

2. Reduce \(\frac{18}{32}\)  

3. Change \(\frac{50}{12}\) to a mixed number.

4. Change \(1\frac{5}{8}\) to an improper fraction.

5. \(\frac{9}{8}\)  

6. \(\frac{4}{5}\)

7. \(\frac{5}{8}\)

8. \(+\frac{3}{6}\)

9. \(+\frac{7}{3}\)

7. Mr. Gutierrez usually takes \(\frac{3}{4}\) of an hour to drive home from work. Because of a traffic jam, he took an extra \(1\frac{2}{3}\) hours to get home one night. How long did that ride take him?

8. Find the combined weight of three packages that weigh \(5\frac{1}{2}\) pounds, \(4\frac{7}{16}\) pounds, and \(3\frac{3}{8}\) pounds.
9. \[ \frac{10}{3} - \frac{2}{5} = \]  
10. \[ \frac{15}{11} - \frac{7}{11} = \]  
11. \[ \frac{13}{9} - \frac{4}{6} = \]

12. From a two-pound box of chocolates, Rachel ate \(1\frac{1}{4}\) pounds of the chocolate. What was the weight of the remaining chocolates?

13. The distance from Ellen's home to her school is \(4\frac{1}{3}\) miles. If she has already traveled \(2\frac{1}{2}\) miles, how far does she have to go?

14. \[ \frac{5}{9} \times \frac{4}{7} = \]  
15. \[ \frac{6}{7} \times \frac{14}{15} \times \frac{1}{2} = \]  
16. \[ \frac{2}{7} \times \frac{5}{9} = \]

17. What is the total weight of four cartons if each one weighs \(16\frac{1}{4}\) pounds?

18. If one foot of lumber costs \(18\frac{1}{4}\), how much do \(5\frac{1}{3}\) feet of the lumber cost?

19. \[ \frac{8}{15} \div \frac{7}{12} = \]  
20. \[ 14 \div \frac{4}{9} = \]
21. \( \frac{6}{13} \div 12 = \)  

22. \( 3\frac{1}{8} + 5\frac{5}{8} = \)

23. If a carpenter needs \( 3\frac{1}{2} \) yards of lumber to build a bookcase, how many bookcases can he build from 21 yards of lumber?

24. For a \( 7\frac{1}{2} \) hour day, Ed makes $30. How much did he make in one hour?
Coretta F. Thomas was born in Baton Rouge, Louisiana, the daughter of Jesse Thomas and the late Flora D. Thomas. She is the second child of three children: an older sister and a younger brother. She is a product of the East Baton Rouge Parish School System. She has taught for 17 years in both public and non-public schools in Baton Rouge, Louisiana. She currently teaches high school mathematics at Scotlandville Magnet High School in East Baton Rouge Parish, as well as Baton Rouge Community College as an adjunct professor. She received her Bachelor of Science degree in mathematics in 1992 from Louisiana State University and her Master of Arts degree from University of Phoenix in 2008.