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The Word Problem Factor: Assessing the Ability of Utah High School Career and Technical Education Students to Do the Math Involved in Formulating and Calculating Energy Cost Factors

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ABSTRACT

The Word Problem Factor: Assessing the Ability of Utah High School Career and Technical Education Students to Do the Math Involved in Formulating and Calculating Energy Cost Factors

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Much research has been done showing the difficulty people have with word problems. This has been shown to be true for many types of word problems and for different demographics. Questions have remained unanswered regarding the reasons for this difficulty. It has been unclear if the word problems were hard because the people had forgotten or had not yet learned how to do the math calculations involved or for some other reason.

This study deals with high school students who are currently in a high school level math class. They were given an assessment involving word problems and number-only problems. The results demonstrate that these students can do the math calculations needed for the problems but that the difficulty lies in their ability to formulate the word problems into correct mathematical expressions.

Among the students in math classes higher than Secondary 2, it cannot be shown that those who have passed Financial Literacy demonstrate a significantly higher ability to do word problems with $p > 0.05$.

Keywords: word problems, story problems, math, numeracy, high school, energy costs, financial literacy

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1 INTRODUCTION

Math is of fundamental importance in our daily lives. Our understanding and ability to use math impacts our finances, our environment, our career and our health. As a technological society the principles of math surround us. We may not always realize it, but math is a part of our work and lives in ways we may not recognize as the math we learned in school. (Goos, Dole, and Geiger 2012, 3-7) It is not enough to be skilled in literacy; it is also important to be competent in numeracy skills as well. (Athanasou 2012, 173-182)

> "Mathematics is the key to opportunity. No longer just the language of science, mathematics now contributes in direct and fundamental ways to business, finance, health, and defense. For students, it opens doors to careers. For citizens, it enables informed decisions. For nations, it provides the knowledge to compete in a technological community." (Gainsburg 2005, 1-22)

Though most jobs only require basic math skills, those skills need to be used in a particular context. In *Numeracy across the Curriculum* Merrilyn Goos asserts that "all kinds of occupations require numeracy" but that the "mathematics used is either invisible to the user or is used in different ways from how mathematics is taught at school." (Goos, Dole, and Geiger 2012, 3-7) The problems in real life are seldom presented as they would be in a textbook or mathematics classroom.

1.1 Terminology

The terms numeracy and word problems are used throughout this thesis. Since they may have different meaning to different people and in different contexts, a brief discussion is given here.

1.1.1 Numeracy

While "literacy" is a term that is commonly understood to mean the ability to read and write, the Oxford dictionary notes that in more general terms it also includes "basic arithmetical competence." Thus, a companion to reading literacy is mathematical literacy. Just as it is important for students to understand and interpret what they read, it is also important for students to be able to understand and apply mathematical concepts in real world problems. A term for this, often used in research, is "numeracy." (Oxford 2011)

Oxford defines numeracy as "the ability to apply and interpret numbers and numerical information" and notes that it is "one of the essential skills needed in the world of work." (Oxford 2011) Goos defines it as "the capacity to use mathematical knowledge and skills purposefully." (Goos, Dole, and Geiger 2012, 3-7) Other definitions also exist but all seem to point to numeracy as "being essential to employability" and the "key to future success." (Durrani and Tariq 2012, 419-434)

1.1.2 Word Problems

Another term that is used extensively throughout this paper is "word problem." This term is not defined in the Utah math core but requirements are set for students to be able to solve these kinds of "real-world" problems beginning in kindergarten. (Utah Core Standards 2014) The core does give examples which agree with Oxford's definition of "a mathematics exercise presented in the form of a hypothetical situation that requires an equation to be solved." (Oxford 2011)

This study involves word problems with contextual situations. These types of problems are sometimes called story problems. These word problems are different from number-only problems, sometimes called abstract problems, which do not involve words or situational contexts such as those shown in figure 1.1. They are also more focused on real-world situations than abstract types of word problems that use words but do not involve a contextual situation as shown in figure 1.2. The word problems in this thesis involve real-life contexts that are familiar to students and would be applicable in their daily lives.

$$4.2 + \frac{(25 \times 7 \times 0.23 \times 181)}{500} =$$

$$(1 - 35\%) \text{ x } 340 =$$

Figure 1-1: Sample Abstract Number-only Problem

Add 7 and 9, and then multiply by 3.

What angle is half of 90 degrees?

Figure 1-2: Sample Abstract Word Problem

Jim's gas bill for December was $180.00. In January he lowered his thermostat by 3 ℉ and his gas bill was 15% lower. How much was Jim's gas bill in January?

Figure 1-3: Sample Contextual Word Problem

1.2 Background

Math ability has been tested in many fields and careers and students have often been found struggling as shown below. Studies such as the ability of nursing students to calculate drug dosages, construction management students to calculate basic measurements, and American adults to calculate their electric bill all identify poor mathematical ability when applied to one's actual work. This seems to concur with Pestalozzi's thoughts that acquiring knowledge while neglecting skill "produced not only a one-sided education but an individual out of phase with his environment." (Bennett 1926, 453)

Nurses need to use math to make calculations and understand results yet many nursing students are deficient even in calculating drug dosages. A study of 52 nursing students in Australia in 2010 had an average score of only 56.1% on questions involving drug dosage calculations. Conceptual, arithmetical and computational errors were all identified. Over one third of the errors involved the "inability to formulate the mathematical question correctly from the information given." (Eastwood, et al. 2011, 815-818)

Elementary math skills are used in many areas of construction work but a study of construction management students found they had difficulty with those basic skills. (Davis 2011) Even students who had passed math classes up to the level of pre-calculus struggled with problems as basic as converting one unit of measurement to another. The study's author, Kirsten Davis, pointed to the problem as an inability to apply math skills.

In 2011 the *Energy Behavior, Knowledge, and Opinions Survey* was administered to 816 American adults. One of the goals of the survey was to assess the ability of US consumers to interpret utility bill information. Only 39% of those responding could correctly calculate a basic electric bill even without taxes or other factors included. (Southwell et al 2012)

1.3 Problem

Each of these studies demonstrates the difficulty that many people have applying math. Each points to word problems as one of the factors in this difficulty. Yet they also note other factors that may be involved as well including a time gap since the participants last studied math and difficulty with other aspects of math skills. They do not isolate word problems as a difficulty separate from these other aspects.

The goal of this study is to isolate the word problem factor. Utah high school students in Career and Technical Education (CTE) classes were tested on their ability to answer both abstract and word problems involving the same math skills with similar numbers. Testing high school classes resolves the time gap dilemma regarding mathematical instructional experience.

1.4 Purpose

This study does not attempt to address all of the aspects of energy decisions or even all the math that may be needed for those decisions. Its purpose is to describe the ability of students, specifically Utah high school students enrolled in Career and Technical Education (CTE) classes, to do the math involved in formulating and calculating word problems involving energy cost factors. It attempted to answer the question:

1. *Do the students have the ability to set up equations needed to work word problems and do the necessary math to determine energy costs?*

This question was answered through the use of a quiz involving number and word problems given to Utah CTE high school students. Three sub-questions involved in the solving of word problems were also evaluated. (Supap, Naruedomkul, and Cercone 2009, 49-53) To wit:

2. *How well did the students correctly identify the relevant information in the word problems?*

3. *How well did the students correctly transfer the information from the word problems into mathematical expressions?*

4. *How well did the students correctly perform the mathematical operations associated with the mathematical expressions they created?*

1.5 Delimitations

The ability to apply mathematical concepts in real life such as in contextualized word problems is an important skill. This study focuses on the ability of high school students in Utah who are in career and technical education classes to apply math in every-day energy cost types of problems.

2 REVIEW OF LITERATURE

2.1 Introduction

Word problems can pose challenges for many students. These types of contextual problems are designed to imitate real-world situations and can include a variety of facts and information that require not only numeracy but literacy and problem solving skills as well. By learning to solve story problems well, students can develop critical thinking skills and improve their ability to transfer classroom learning to daily life. (Perso 2009, 11-16)

2.2 Types of Word Problems

Several types of problems can fall under the category of word problems. Anne Roche notes that word problems can include “any mathematical problem written in a sentence or sentences.” These can range from abstract word problems to open-ended problems in problem-based learning situations. Word problems may involve single or multiple calculations and provide too much or too little information. A more in-depth discussion of these can be found in Roche’s 2013 article *Choosing, Creating and Using Story Problems: Some Helpful Hints.* (Roche 2013, 30-35)

Simple word problems without context are shown in figure 1.2. These are really just abstract problems with some of the numerical signs such as an addition symbol replaced by words. They are verbal descriptions of abstract problems and sometimes fall into the category of word problems, but do not present real situations or relate to the lives of the students. Yet, researchers have found that simply adding words to a math question sometimes confounds students. Students were able to solve the basic algebraic equation of $7x - 3 = 13x + 15$ yet were unable to answer the question “Is 10 a solution to the equation $7x – 3 = 13x + 15$?” (Romberg 1995)

A step up from abstract word problems are simple, one-step problems with a single correct answer. These problems use simple context and contain all the information needed with no unnecessary numbers. They usually only require the basic operations of addition, subtraction, multiplication, and division and may include percentages, ratios and decimals. An example is shown in figure 2-1.

Susan worked 8 hours each day for 4 days. How many hours did she work?

Figure 2-1: Sample Simple Word Problem

Even within this simple type of problem there are varying levels of difficulty. Problems where the initial quantities are known are considered easier than problems where the result is given but the initial quantity is unknown. Examples of these types of problems are shown in figures 2-2 and 2-3.

Mark had 6 dollars. He earned 8 more.

How many dollars does he have now?

Figure 2-2 Sample Initial Quantities Known Word Problem

Juan had some pesos. He spent 9 pesos. Now he has 7 pesos. How many did he have to start with?

Figure 2-3: Sample Initial Quantities Unknown Word Problem

Word problems increase in difficulty when they involve fractions or multiple steps. An example is given in figure 2-4.

There are 2 bags of wheat. Each bag contains 25 lbs. If 7 people share the wheat equally, how much wheat will each person get?

Figure 2-4: Sample Multiple Step Word Problem with Fractions

Of even greater difficulty are problems that also include unnecessary information. These types of problems require the students to not only understand and solve the problem but also to identify the relevant information. These are the types of problems included in this study.

A final level of difficulty is open-ended problems. These problems invite the students to explore and investigate different strategies, methods and ideas. Often the emphasis is on the ability of the students to explain why they did what they did and defend why they chose the method they used to get their answer. It encourages the students to examine if the answer they got makes sense rather than whether or not they found a single correct answer. (Utah Core Standards 2014)

2.3 Word Problem Solving Skills

Correctly solving word problems requires certain skills including reading and understanding the vocabulary in the problem, understanding the overall problem itself, and being able to do the math calculations. (Jitendra et al 2007, 283) These skills have been identified in several studies with similar characteristics. They can be summarized as four problem solving steps:

1. Read and comprehend the problem,

2. Identify the relevant information,

3. Set up an appropriate mathematical equation, and

4. Accurately solve the equation.

James Hewitt teaches these steps kinesthetically using the five fingers of the hand. He calls it the IFSMU method identified as: I - identify known and unknown information, F -

formulate equation, S - substitute into the formula, M - mathematical processes, U - units labeled. He suggests that this method helps students deal with even difficult problems. The kinesthetic nature of this method is also geared toward helping students remember it. (Hewitt 2007, 57)

In *Steps toward Accurate Math Word Problem Translation* Supap and others list these steps as comprehension, extraction, construction and then solving. They note that some of the difficulties students have with reading such as vocabulary and grammar can be problematic. If a student doesn't know that a dozen is twelve or that kilowatt means one thousand watts, then they may struggle with an otherwise easy problem. (Supap, Naruedomkul, and Cercone 2009, 49-53) An example of the grammar issue is referred to by Mansoor Niaz as "reversal error" such as students translating the phrase "six times as many students as professors at this university" into the problem 6S = P instead of S = 6P where S represents students and P represents professors. (Niaz, Herron, and Phelps 1991, 306)

Other studies deal specifically with how students read and comprehend word problems and stress the "importance of teaching vocabulary in each mathematics lesson." (Monroe, Panchyshyn, and Bahr 2006, 4-5) The term "code-breaking" is used by Thelma Perso in her discussion of how students need to understand what is being asked in word problems. She discusses the "mathematical jargon" of words that mean specific things in mathematical context and can be clues to creating the mathematical equation needed to solve the question. Understanding words such as complete, total, more than and even "of" in a math context can help students be more numerate. (Perso 2009, 11-16)

2.4 Word Problems in Education

As students confidently solve complex word problems, they demonstrate their proficiency in many of the math standards of the National Council of Teachers of Math (NCTM) as well as those in the National Research Council's report *Adding It Up*. These include such abilities as problem solving, reasoning, representation, conceptual understanding, and the "inclination to see mathematics as sensible, useful, and worthwhile." (Utah Core Standards 2014)

Word problems help students transfer what they learn in school to what they need to know in everyday life. They allow students to practice problem solving real-world situations without the inconvenience and full consequences real-life decisions can bring. They can prepare for some of the problems of life while being mentored and guided. (Dewolf, Van Dooren, and Verschaffel 2011, 770-780) Indeed these types of problems help students develop problem solving skills that they can use in other situations as well. (De Corte, L. Verschaffe, and B. Greer 2000, 66-73)

Research has shown that using math problems with contexts that relate to everyday situations helps students not only do better but be more interested in education. Even engineering students, a group who typically have already demonstrated a proficiency in math and science, preferred learning in the context of real world applications. They were found to be more motivated and successful in their classes. (Guner 2013, 507)

Even with this understanding of the importance and benefits of using word problems in mathematics curriculum, few studies pay attention to the percent of these types of problems given to students. Most studies analyze the math concepts covered (e.g., decimals, volumes, exponents) but not whether they are presented in context or just abstractly.

United States basic math books have relatively few story problems compared to countries such as Japan and China. Those they do have tend to be more computational in style and involve mainly single-answer one-step problems rather than complex problems. The Third International Mathematics and Science Study (TIMSS) revealed that, while Japan emphasized conceptual problems 54% of the time, the United States did so only 17% of the time. (Hiebert and Stigler 2004, 10-15) A more recent study done in 2010 comparing problems using the distributive property analyzed typical US and Chinese elementary grade math books and found that that the Chinese books had over five times more word problems than the American ones did. Furthermore, the U.S. problems use almost exclusively whole numbers rather than numbers involving fractions, decimals and percentages. (Ding and Li 2010, 146-180)

The Common Core State Standards (CCSS) were developed in part to help states to improve their standing in international assessments such as TIMSS. A 2012 study examining the common core and state standards recognizes that less than one-third of high school seniors are considered mathematically proficient and suggests that this deficiency comes from the nature of curriculum content. It identifies when several concepts are taught through eighth grade and notes that most of the material covers memorizing definitions, performing routine procedures and solving routine problems. Less than three percent of the material covers “solving non-routine problems.” No mention is made of how much of the material is used in the context of word problems. (Schmidt and Houang 2012, 294-308) It is still unclear if these new standards will improve the ability of American students to effectively use math in their daily lives.

2.5 Similar Studies

Although it may be expected that there are many studies directly comparing the ability of students to do word problems to their ability to do number-only problems, very few actually compare them in the way this study does. One study which is very similar is *Defining the Problem: Mathematical Errors and Misconceptions exhibited by First-year Bioscience Undergraduates*. In this study V. N. Tariq had 326 first-year bioscience undergraduates in the United Kingdom take a paper based math test “comprising 10 pure abstract mathematical calculations and 10 brief word problems set within biological context.” He then looked at the individual test items and compared the two types of problems to see if there was “any correlation between the students’ performance on the ‘abstract’ test items and the ‘contextualised’ word problems.” (Tariq 2008, 889-904)

Tariq’s study, as with this one, involved convenience and volunteer sampling. Ethics requirements, similar to the IRB requirements for this study, meant that the participants were free to withdraw at any time or to not answer any questions. In Tariq’s study this resulted in as many as 12% of the students not attempting to answer some of the abstract questions and as many as 75% of the students not answering one or more of the word problems. Calculators were allowed and only correct answers were counted with no points deducted for incorrect answers or for answers which were left blank. (Tariq 2008, 889-904)

The average score of these bioscience students was only 38.5%. Over half of the students scored below 40%. Of particular note are the differences in the scores between the abstract questions and the word problems; the average score on the abstract questions was 55% while the average word problem score was only 23%. (Tariq 2008, 889-904)

The study presented in this paper differs in several ways from Tariq's study. First, it involves high school students instead of college students. The purpose for this was to ensure that the students have recently had math. It is not known if the first-year undergraduates from Tariq's study have come directly from high school or may have had a number of years since taking math before entering college. Using high school students eliminates the issue of that possible gap.

Second, Tariq describes the math in his study as "basic" in that his assessment uses math such as fractions, unit conversions and volume calculations found up through algebra and geometry. The math level of some of the questions in this study is similar. They both use fractions and conversions. However, this study does not present problems involving algebraic equations. This study only uses math that is taught before algebra.

Third, a key aspect to this study is its use of problems that involve energy costs the students have or would soon have in their everyday lives. Questions in the study for the bioscience undergraduates related to questions they might encounter in a chemistry class involving chemistry and biology types of word problems. (Tariq 2008, 889-904)

2.6 Other Word Problem Studies

There are other studies which look in depth at the responses students give to word problems. Many of these are follow-up work to word problem studies by Verschaffel, DeCorte, and Lasure. Vershaffel's work was not as concerned with the ability of students to correctly solve the given word problems with the information provided as with the ability of the students to recognize when the information given did not model reality. (Verschaffel, De Corte, and Lasure 1994, 273-294)

One of these studies, by Wyndhamn and Säljö, describes as “non-realistic” and “logically inconsistent” answers students give to word problems. (Wyndhamn and Säljö 1997, 361-382) Brian Greer noted the “tendency of school children to answer school mathematics word problems with apparent disregard for the reality of the situation.” (Greer 1997, 293-307; Reusser and Stebler 1997, 309-327) Similar results were obtained by Reusser and Stebler. (Reusser and Stebler 1997, 309-327) These all present the case that students have difficulty transferring math knowledge learned in school to that used in real life. (Verschaffel, De Corte, and Lasure 1994, 273-294)

This disconnect of school learning and real-life situations is also described by Lowrie. He proposes that skills taught in school do not carry over to real-life experiences. This can cause a disconnect such that the students go through the motions of the process being taught and find an answer without considering whether or not the answer is realistic. (Lowrie 2005, 275-286)

The problems used in curricula in school are often seen as "contrived or simplistic." In contrast to real life, textbook questions are usually made to have a single correct answer and are designed to be solved using the method taught in the adjacent section of the book. (De Corte, L. Verschaffe, and B. Greer 2000, 66-73) This can lead children to believe that real-world problems should be as predictable to solve. When they face problems in real-life that do not fit nicely into a well-practiced algorithm, they are unprepared and unable to find a suitable answer. (Lowrie 2005, 275-286

This issue has even been found in pre-calculus textbooks where students are “neither required to construct models based on the contexts nor are they asked to validate or discuss the limitations of the applied formulas.” A study by Sokolowski shows that word problems given in textbooks can actually limit problem solving ability rather than encouraging it. It stresses that these types of problems teach “algorithms of the mathematical operations instead of mathematical modeling” that would be transferrable to real life. (Sokolowski, Yalvac, and Loving 2011, 283-297)

2.7 Other Numeracy Issues

Students often dislike, fear or try to ignore school mathematics. Many consider upper-level math classes as intentionally hard and without practical application in their lives. Julie Gainsburg talks about the prevalent notion that math is often a "filter" class designed "to stratify students and weed out the less able." (Gainsburg 2005, 1-22).

Most of the math we need in our daily life and in the workplace requires only basic skills such as addition, subtraction, multiplication, division, percentages, decimals, fractions and ratios. (Gough 2007, 31-39) These skills are typically taught in elementary school and expected to be understood by the sixth grade. (Utah Core Standards 2014) The math taught in high school is far above the level used by the average person in everyday life. Almost all of the concepts taught beyond elementary school are, as John Gough describes "wholly for the sake of later study in mathematics classrooms, or in specialized areas of study–that is, not for everyday use!" (Gough 2007, 31-39)

The concept of fractions is introduced by third grade and included in the curriculum every year thereafter. Ratios are introduced in sixth grade. (Utah Core Standards 2014) Yet the study “Fractions: the new frontier for theories of numerical development,” published in 2013, found that fractions, though key to learning math, were a “serious educational problem” for all ages. They note fractions and word problems were the biggest reasons algebra students struggled. (Siegler et al 2013, 13-19) Tariq also noted that difficulties with fractions had a significant role in the low scores in his study. This was particularly true in questions requiring unit conversions. (Tariq 2008, 889-904)

2.8 Energy Costs

Usually only basic math skills are needed to solve the word problems we encounter in energy costs decisions made in daily life. These energy related choices affect not only our finances but our environment. Yet, despite its importance, there is very little understanding about how much Americans know about energy facts and utility bill information. (Southwell et al 2012) Most studies of American's understanding of energy deal with conservation attitudes and scientific energy facts such as how lasers work and the relative size of electrons and atoms.

Three studies deal specifically with the skills necessary to understand energy costs and make energy decisions. Jan DeWaters and Susan Powers tested the energy literacy of over 3700 secondary students in New York State in 2010. They found that these students wanted to conserve energy but their knowledge and skills in these areas were low including fewer than 20% who knew that electric energy is measured in kilowatt-hours. They concluded that students in secondary grades needed more energy-related instruction that emphasizes "practical knowledge." (DeWaters and Powers 2011, 1699-1710)

A study in 2011 by Brian Southwell, DeWaters and others entitled *Americans' Perceived and Actual Understanding of Energy* tested energy knowledge including the ability of Amercans to interpret an energy bill. Only 27% of their respondents could answer all three of the energy bill questions in the study. Fewer than 40% could calculate the electricity cost savings that would be realized if a family decreased power usage by 300 kWh in a billing month (before taxes and other factors) at a rate of \$0.12/kWh. The study found a "demonstrable gap between perceived understanding and factual knowledge" especially in the ability to calculate energy costs. (Southwell et al 2012)

Bladh and Krantz studied Swedish attitudes and behavior regarding electric consumption from household lighting. Their study showed that replacing incandescent bulbs with florescent bulbs is a "fast and effective measure to decrease household electricity consumption" but that many people lack an understanding of bulb wattage, light output and costs. Their respondents particularly had difficulty computing electricity consumption in terms of kWh and costs. (Bladh and Krantz 2008, 3521-3530)

2.9 Financial Literacy

Utah's Financial Literacy class is designed to enable students to have decision-making skills that they "must apply and use to become wise and knowledgeable consumers. . . ." It aims to empower students to incorporate skills from math and technology to use in their lives as they manage their finances and "understand personal and societal consequences of financial decisions." (USOE - CTE 2014)

In an article in the *Iowa Law Review* Lauren Willis challenges the efficacy of financial literacy education. This article recognizes that financial decisions require the same kinds of skills as those required for accurately completing word problems: "knowledge of concepts and terminology; extraction of information from text; understanding of arithmetic calculations; comprehension of fractions, percentages, and probabilities." Even with calculators students can have problems because they don't know which calculations to make. (Willis 2008, 197)

She states that financial education appears to increase confidence without improving ability, leading to worse decisions. Her article notes that there are not many studies that have measured the benefits of students taking financial literacy. Furthermore, most of the studies that have been done have used self-assessments of how much more confident and knowledgeable people feel they are after taking a financial literacy class. (Willis 2008, 197) Tyrone Frazier's study in 2008 of Utah high school students is an example of this with 84% of the students stating that they "spend money more wisely than before" their financial literacy class. (Frazier 2008, 11-51) Another survey of high school seniors in 2008 by JumpStart showed that financial education classes do not help to improve financial knowledge among high school students. (Jumpstart 2008; Willis 2008, 197)

2.10 Conclusion

These many studies recognize that students struggle with word problems. Suggested possible reasons for these struggles include the possibility that individuals may not have known or may have forgotten how to do the math involved in the problems. Fractions and conversions were noted as particularly difficult. The disconnect students may have between word problems in school and those they encounter in real life is noted. These problems are raised but not identified as issues students have specifically with word problems separate from abstract number problems.

This study addressed these issues. Using students currently in high school math classes eliminated the issue of forgotten or unlearned math skills. Fraction and conversion struggles were focused on separate from word problem struggles and the disconnect from real life problems was addressed by using word problems involving everyday energy costs with which the students would be familiar.

3 METHODOLOGY OF RESEARCH

3.1 Population

The target population for this study was Utah high school students in Career and Technical Education classes. These students had successfully completed grades K-8 including the math requirements of those grades. Math proficiency in those grades includes the basic skills such as addition, subtraction, multiplication, division, percents and ratios as listed in Table 3.1. As explained in the Utah Standards, students who are proficient "can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace." (Utah Core Standards 2014) Thus these students should have been able to use these skills in word problems involving cost energy questions similar to what they may face in their lives.

A minimum of three years of math instruction is required to be taken during high school. The math class progression for students in Alpine district is similar to that in Nebo district and is shown in Figure 3.1. (Alpine 2012) This means that the students in this study:

1- Had demonstrated proficiency at least up thru Secondary 1 math, and

2- Were currently in a math class or had a math class within the past year.

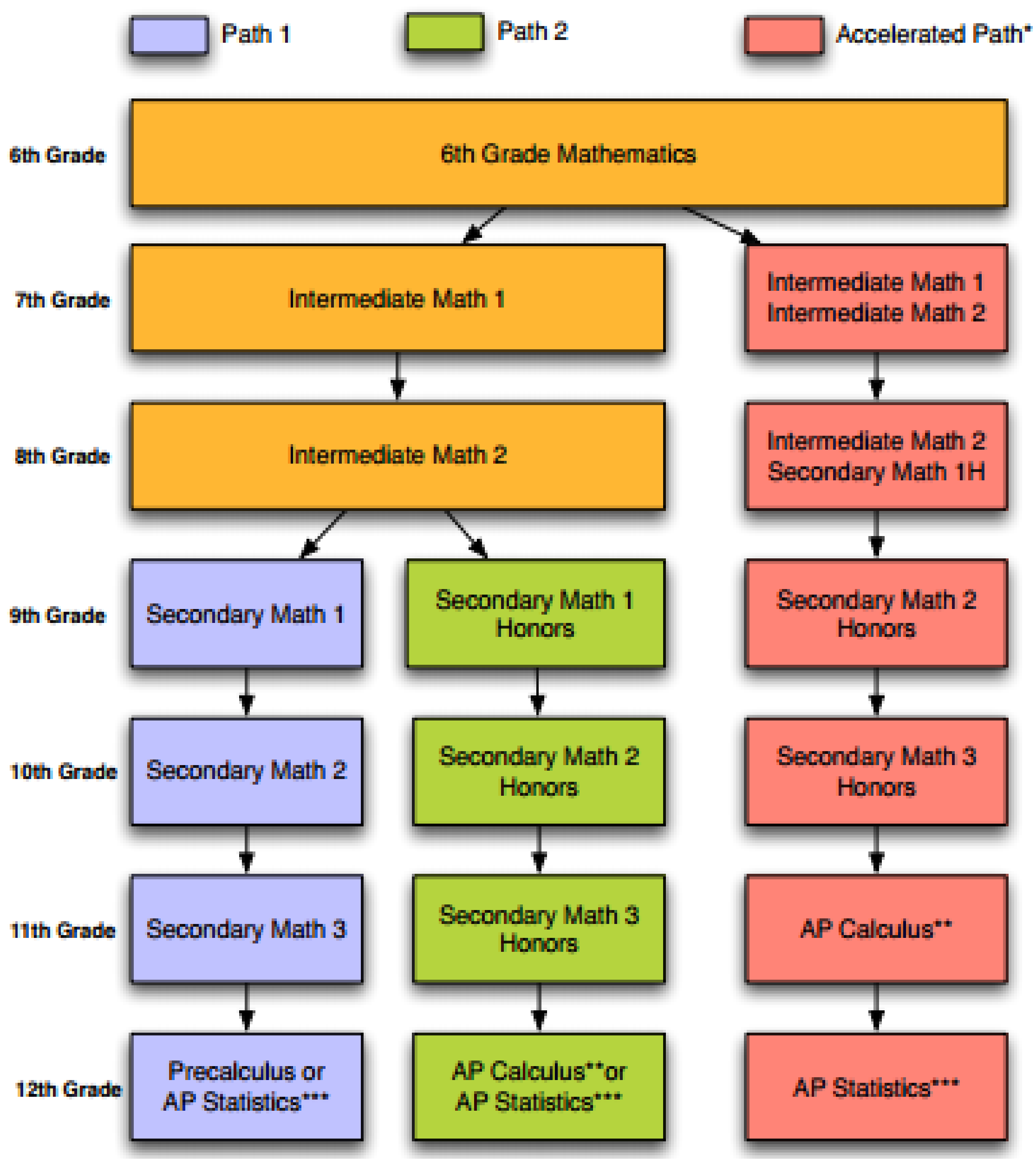

Figure 3-1: Math Class Progression

Unlike some adults, these students recently had taken math classes and used at least basic math skills. These math skills are taught before algebra and continue to be needed for more advanced math classes so students who are in a math class at or above the level of Secondary 1 are considered to have learned these skills. (Utah Core Standards 2014).For these reasons, these current high school students were chosen as the target population.

This constitutes a descriptive study involving a convenience sample of a variety of sophomore, junior and senior Utah high school students in Career and Technical Education classes. The classes in this study included approximately 400 students consisting of six classes of Physics with Technology at Lone Peak High School in Alpine district, six classes of Welding 1 & 2 students at Salem Hills High School in Nebo district and six classes of various CTE classes at Springville High School, also in Nebo district. Approvals were obtained from BYU, the Internal Review Board (IRB), the school districts, and teachers involved. The tests were administered during May 2014.

3.2 Design

The data collection method used was 15 open-answer math questions given to the students in a paper and pencil assessment. Students were allowed to use calculators and had up to 30 minutes to complete the test. This instrument was based on the Utah Core Standards, Bahr's "hierarchy of numerical complexity" and Roche's advice on creating story problems as discussed above in chapter 2.2. Selected Utah Core Standards are shown in table 3-1. Word problems and number only problems were alternated and the order of the questions was the same for each student in accordance to Ronald Hambleton's article, *The Effects of Item Order on Test Performance and Stress.* (Hambleton, Ronald K., Traub, Ross E., Traub,Rose E. 1974, 40-46)

In an effort to ensure that the students did their best, they were required to write their name on the quiz and take the quiz as a graded part of their regular curriculum. This also facilitated the collection of tests from only those who had given permission to be included in the study. Once the tests were collected, the names were discarded so no personally identifying information was used in the analysis and results. The full assessment is given in Appendix A.

Table 3-1: Selected Utah Core Standards

Grade and Domain	Standard
5 Measurement & Data	1. Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems. 5. Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume.
6 Ratios & Proportional Relationships	1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. 2. Understand the concept of a unit rate a/b associated with a ratio a:b with $b \neq 0$, and use rate language in the context of a ratio relationship. 3. Use ratio and rate reasoning to solve real-world and mathematical problems. 3 b. Solve unit rate problems including those involving unit pricing and constant speed. 3 c. Find a percent as a quantity as a rate per 100; solve problems involving finding the whole, given a part and the percent. 3 d. Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.

Table 3-1, Cont'd.

6 Number System	1. Interpret and compute quotients of fractions, and solve word problems involving division of fractions by fractions. 2. Fluently divide multi-digit numbers using the standard algorithm. 3. Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation. 5. Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts. 8. Solve real-world and mathematical problems.
6 Expressions & Equations	2 c. Evaluate expressions at specific values of their variables. Include expressions that arise from formulas used in real-world problems. Perform arithmetic operations, including those involving whole-number exponents, in the conventional order when there are no parentheses to specify a particular order. 6. Use variables to represent numbers and write expressions when solving a real-world or mathematical problem. 7. Solve real-world and mathematical problems by writing and solving equations.

3.2.1 Mathematical Design

Eight of the questions on the quiz consisted of numbers and operations only. They included subtraction, multiplication, fractions, decimals, ratios, percentages and parenthesis. The other seven questions were word problems. These involved the same mathematical concepts and operations as the number problems but were in the context of energy problems that are typically encountered in daily life. All of the concepts involved were those taught during or before sixth grade and all of the students taking the quiz were in high school, well past the sixth grade. (Utah Core Standards 2014)

The contextual word problems and abstract number-only problems in the assessment involved similar types of numbers. Problems #3 and #4 are an example of this. They both involved a single digit number multiplied by a two-digit number and divided by a two-digit number.

The difficulty level in terms of algorithms were also the same. The mathematical operations needed for the abstract problems were the same ones that were needed for the word problems. For example #6 and #9 both required a percentage to be subtracted from one and that total to be multiplied by a three-digit number.

The assessment was given to math teachers who gave their assurance that the level of difficulty of the problems was appropriate for students who had passed sixth grade. They also gave their assurance that the level of math involved in the word problems was comparable to the level of math concepts involved in the number-only problems.

In addition to the math teachers the assessment was given to CTE and science teachers who checked for content validity and ensured that the assessment would measure the ability of the students to do the math needed to determine the associated types of energy costs.

After review by the teachers, the quiz was piloted to five high school students of varying levels of math ability. This ensured that the students could understand what the questions were asking without ambiguity.

3.2.2 Word Problem Design

To create the word problems in the assessment, studies which investigated Americans' knowledge of energy use and costs were evaluated. The questions regarding electricity costs from *Americans' Perceived and Actual Understanding of Energy* were the basis for questions #9-11 used in this thesis. (Southwell et al 2012)

The questions involving lighting were based on the research by Bladh and Krantz involving bulb wattage and electricity consumption. (Bladh and Krantz 2008, 3521-3530) Word problems # 13-15 in this thesis were created in response to this study.

The questions used in the assessment for this thesis were of the type that high school students have or will soon encounter in their daily lives. The information in the word problems was taken from real-life types of experiences and was familiar to the students. (Monroe, Panchyshyn, and Bahr 2006, 4-5) Numbers used in the story problems were based on actual energy and cost data.

3.3 Scoring

For the sake of time, cost, and convenience most studies done with large numbers of students use multiple choice computerized tests. These types of tests are easier and faster to score than paper and pencil, open answer tests but can result in the loss of valuable information. (Szetela, Walter,Nicol, Cynthia 1992, 42-45) (Mcallister and Guidice 2012, 193-207) Problems with multiple choice tests include students who do not understand the material guessing the correct answer because of the limited number of choices. The tests also mask the ability to discern students who do understand the material but made a simple or slight error. For these reasons this assessment is open answer or free-response.

Beyond looking at the correctness of the final answer, the assessment also focused on the types of errors demonstrated by the students. These errors included content (variables and relevant information), strategy (formulated equations) and simple errors. (Olsen 2005)

Although the overall scoring only counted completely correct answers, the word problems with incorrect answers were also analyzed separately looking at the steps of word problem solving skills as described previously. (Supap, Naruedomkul, and Cercone 2009, 49-53) Students were specifically asked to "show all the equations and steps" they used. For those who did so, their ability to complete the steps of identifying relevant information, formulating an appropriate equation and correctly solving that equation was followed to help establish the step(s) where disconnect occurred. (Hewitt 2007, 57) Some of the word problems given in this study specifically included non-relevant information for the purpose of recognizing the ability of the students to sort out needed and unneeded facts.

3.4 Data and Instrumentation

Cronbach's Alpha coefficient was used to assess the reliability of the test construction. The quiz was administered once and Coefficient Alpha was used to calculate the reliability index of the scores. Since word problems and number-only problems are different constructs, they were considered two different parts and reliability was calculated separately for each part. The questions on the quiz were not identified to the students as being in different parts but the results were used as such.

Each question had only one correct answer and results for each student were recorded for each question. This allowed for an analysis to be completed on each set of questions (number only and word problems) comparing the percent of students who answered correctly by question.

Analysis of Variance (ANOVA) tests were also performed to determine if there was a statistically significant difference in the average scores of the students based on the level of math they have completed. The dependent variable was the scores. The independent variable was the math level of the students.

4 FINDINGS

4.1 Introduction

The purpose of this study was to determine whether students have the ability to work word problems and do the necessary math to determine energy costs. The assessment used for this purpose helped isolate the ability of the students in the various parts of solving these types of word problems.

4.2 Internal Test Reliability

The original assessment used for this thesis was only able to be given once so the Kuder-Richardson 20 equation, a type of Cronbach's coefficient alpha analysis, was used as a measure of internal consistency. This equation is shown in figure 4.1.Since the test answers were only dichotomous without any questions involving multiple correct answers and with no Lichert type questions, this equation essentially evaluates the mean for all split-half possible reliabilities. (Streiner 2003, 99-103)

$$r_{KR20} = \left(\frac{k}{k-1}\right)\left(1 - \frac{\Sigma pq}{\sigma^2}\right)$$

Figure 4-1: Kuder-Richardson 20 Equation

The word problem and number-only questions of the test were analyzed separately as though they were two different tests as explained in the methodology section above. Because the number only questions were designed at or below a sixth grade level, the KR-20 value for these questions was only 0.55. This low value recognizes that most of the variance in the scores is from random error since the questions were relatively easy for all the students. Especially since the students could use calculators, it was expected that almost all of the students could answer all the problems. This low value shows that these number-only questions were not designed to help discriminate the abilities of the students but rather that the questions are consistently easy. (Traub and Glenn L. Rowley 1991, 37-45)

Question #11 in the assessment is dependent upon the student's answer to question #10. A Kuder-Richardson analysis is not appropriate where one answer depends upon a previous answer so question #11 was discarded from statistical considerations. The remaining word problem questions yielded a KR-20 value of .77. This recognizes a much better level of discrimination. Data used for the KR-20 equations is shown in Table 4.1 and 4.2.

Table 4-1: Kuder-Richardson 20 Data for Number-only Problems

Problem #	1	2	3	6	7	8	12	15
# Correct	148	146	154	145	153	148	156	145
Percent Passed (p)	0.94	0.93	0.98	0.92	0.97	0.94	0.99	0.92
Percent Failed (q)	0.06	0.07	0.02	0.08	0.03	0.06	0.01	0.08
p*q	0.054	0.065	0.019	0.071	0.025	0.054	0.006	0.071
k=157			σ2 = 0.70	∑ p*q = 0.364				

Table 4-2: Kuder-Richardson 20 Data for Word Problems

Problem #	4	5	9	10	13	14
# Correct	89	80	104	47	43	43
Percent Passed (p)	0.57	0.51	0.66	0.30	0.27	0.27
Percent Failed (q)	0.43	0.49	0.34	0.70	0.73	0.73
p*q	0.246	0.250	0.224	0.210	0.199	0.199
k=157			σ2 =3.72		∑ p*q = 1.327	

4.3 Population Data

The assessment was given to approximately 400 CTE high school students in three Utah high schools. All of the students were required by their teachers to take the test as part of their regular curriculum and were encouraged to do their best. The students were not required to allow their tests to be part of the study resulting in only 157 usable tests. Of the tests used in this thesis 72% were taken by sophomores with the remaining 28% being taken by juniors and seniors as shown in figure 4.2.

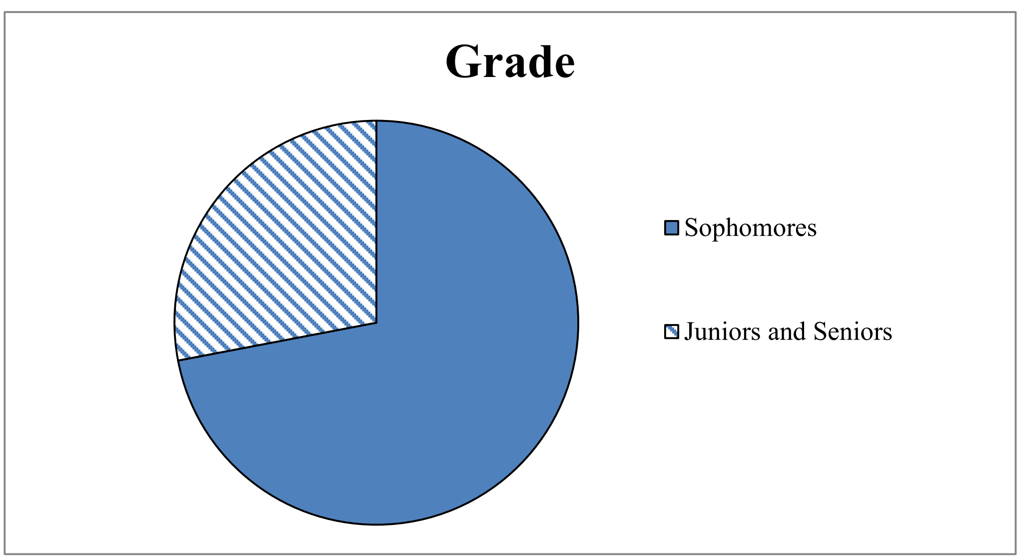

Figure 4-2: Population by Grade

Approximately 4% of the students were not in any math class at the time of the test. The results of this small percentage were removed because one of the factors that this study wants to eliminate is the possibility that students have forgotten the math they have learned because they have not been in a math class for a while. Another 1% of the students were in remedial math. Their tests were also not used since it is not known if they have satisfactorily passed sixth grade math requirements.

There were 157 remaining, useable tests. Students in regular Secondary 2 high school math classes constituted 35% of the population. There were 31% in Secondary 2 honors and 34% who were in math classes beyond Secondary 2. Thirty of the students beyond Secondary 2 were taking calculus or pre-calculus. Six of these higher math students were in college prep or concurrent enrollment college math classes including Math 1010 which is Intermediate Algebra and Math 1050 which is College Algebra. The percent of students in each of the math levels is shown in figure 4.3.

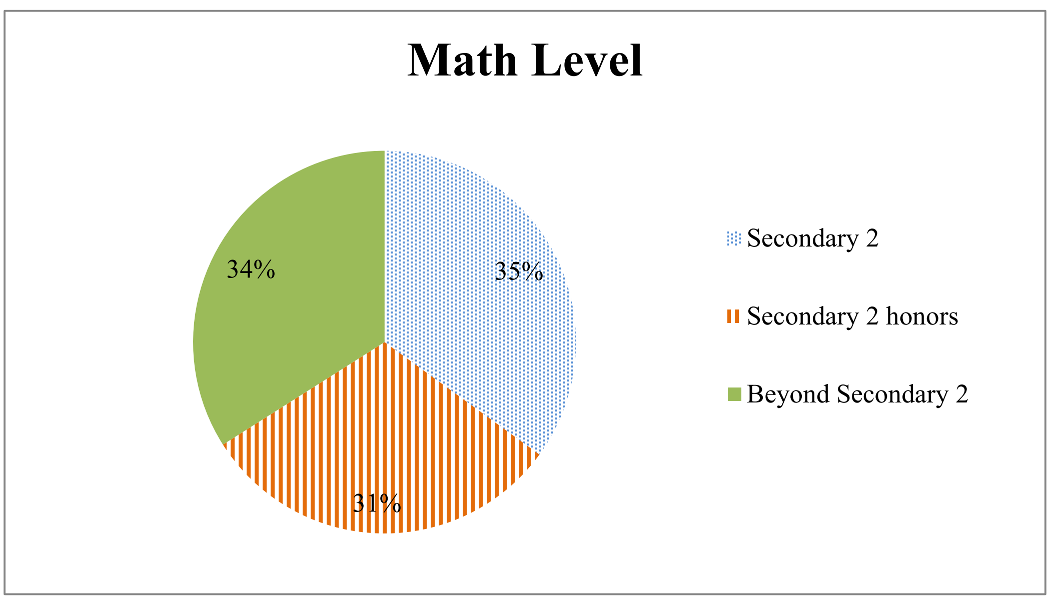

Figure 4-3: Population by Math Level

A final recorded demographic of the students is whether or not they had passed the required Financial Literacy class. Seven students did not answer this question. Of those who did answer 26% had passed Financial Literacy and 74% had not as shown in figure 4-4.

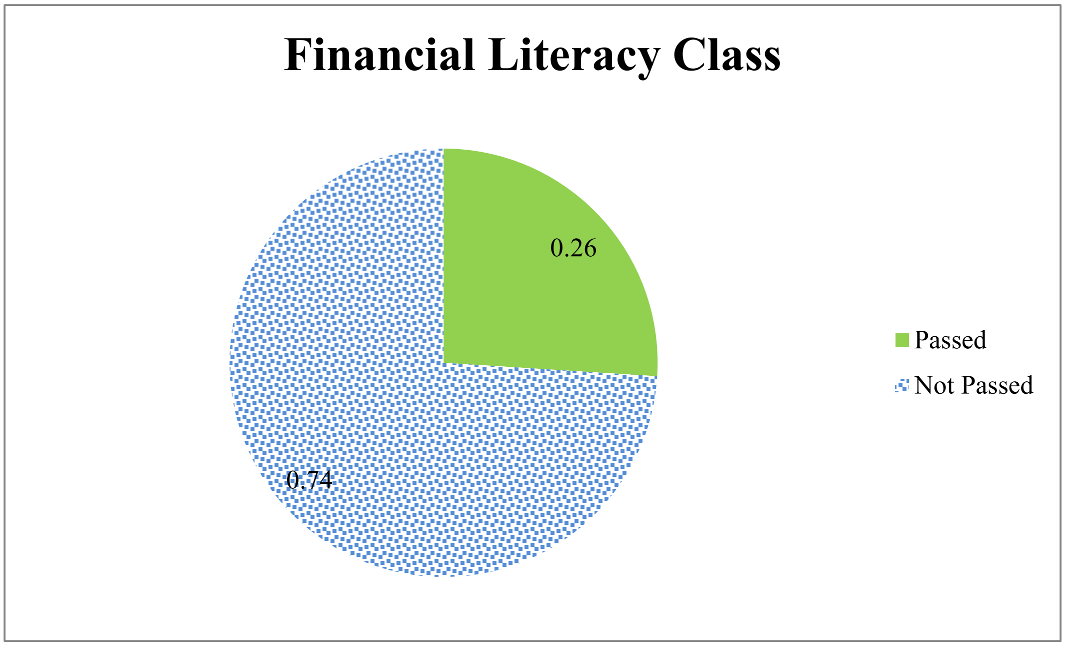

Figure 4-4: Population Passed Financial Literacy Class

4.4 Number-only Problem Results

The purpose of the study was to assess the ability of the students to be able to do the math involved in formulating and calculating energy cost factors. This involved answering the following four questions:

1. *Do the students have the ability to set up equations needed to work word problems and do the necessary math to determine energy costs?*
2. *How well did the students correctly identify the relevant information in the word problems?*

3. *How well did the students correctly transfer the information from the word problems into mathematical expressions?*

4. *How well did the students correctly perform the mathematical operations associated with the mathematical expressions they created?*

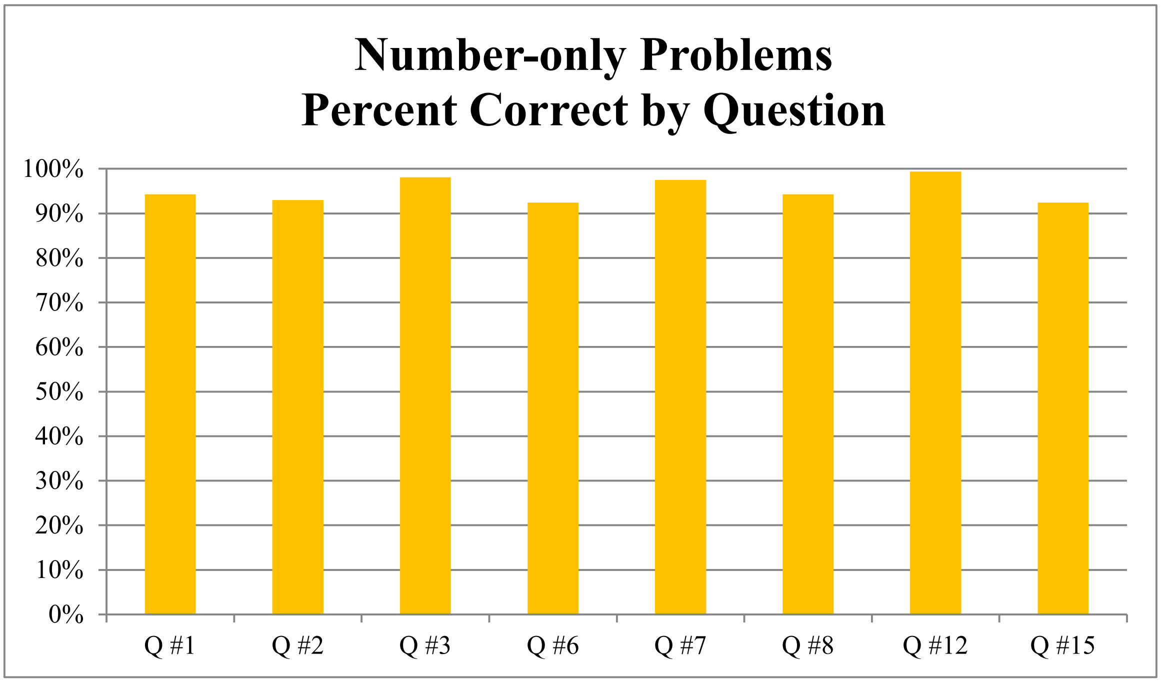

Figure 4-5: Percent Number-only Problems Passed by Math Level

The purpose of the number-only questions on the assessment was to answer the fourth question even if the students were not able to do well on the word problems. Collectively the students did very well with these types of problems. Over 90% of the students answered each of these abstract problems correctly as shown in figure 4-5. Students in all math levels did well on these problems with the lowest average scores being on problems #6 & #15 where the lowest math group averaged over 87%.

Only 2 of the students answered fewer than six of the eight abstract problems correctly. Another 9 students answered exactly six of the questions correctly for a score of 75%. There were 32 students who answered seven of the questions correctly and all eight questions were answered correctly by 72.6% of the students. Clearly the majority of the students can do the math associated with these types of problems. Figure 4-6 shows this distribution.

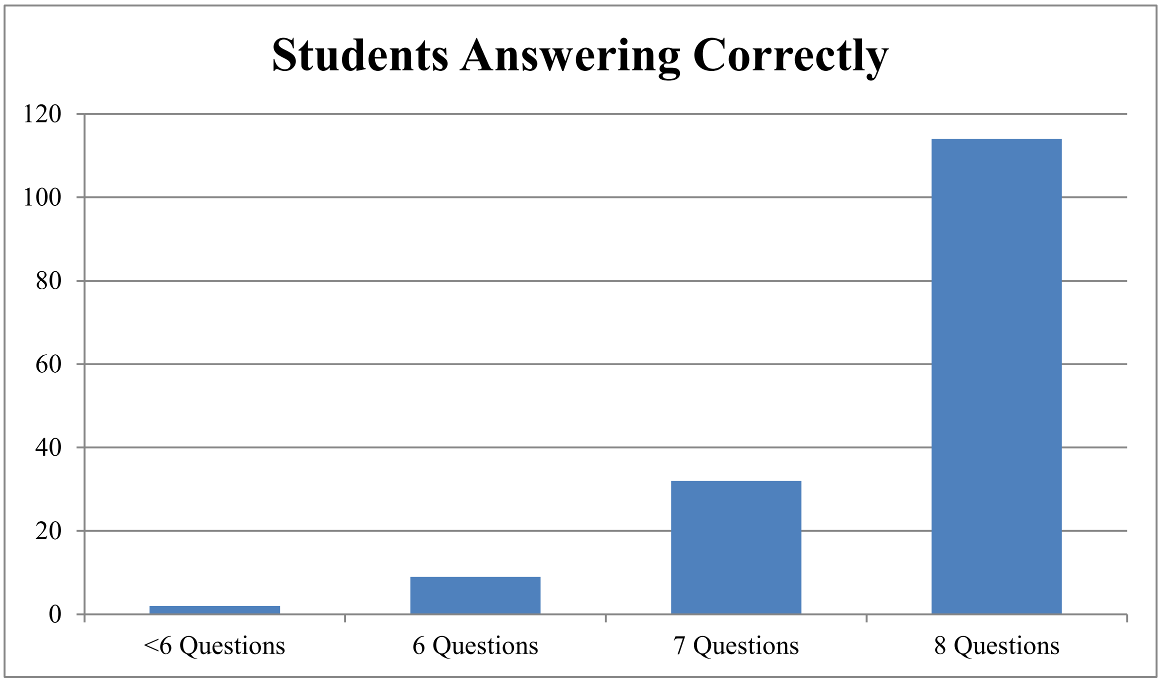

Figure 4-6: Number of Students Answering Number-only Abstract Problems Correctly

Figure 4-7 shows the average scores in all groups for each question. All questions had mean scores above 85% for each math level. As predicted by the KR-20 result and as witnessed as the scores were calculated for each test, most of the fluctuation in the scores was from random error such as the student who had answered every other question perfectly but seemed to have overlooked and completely skipped one of the easier number-only questions.

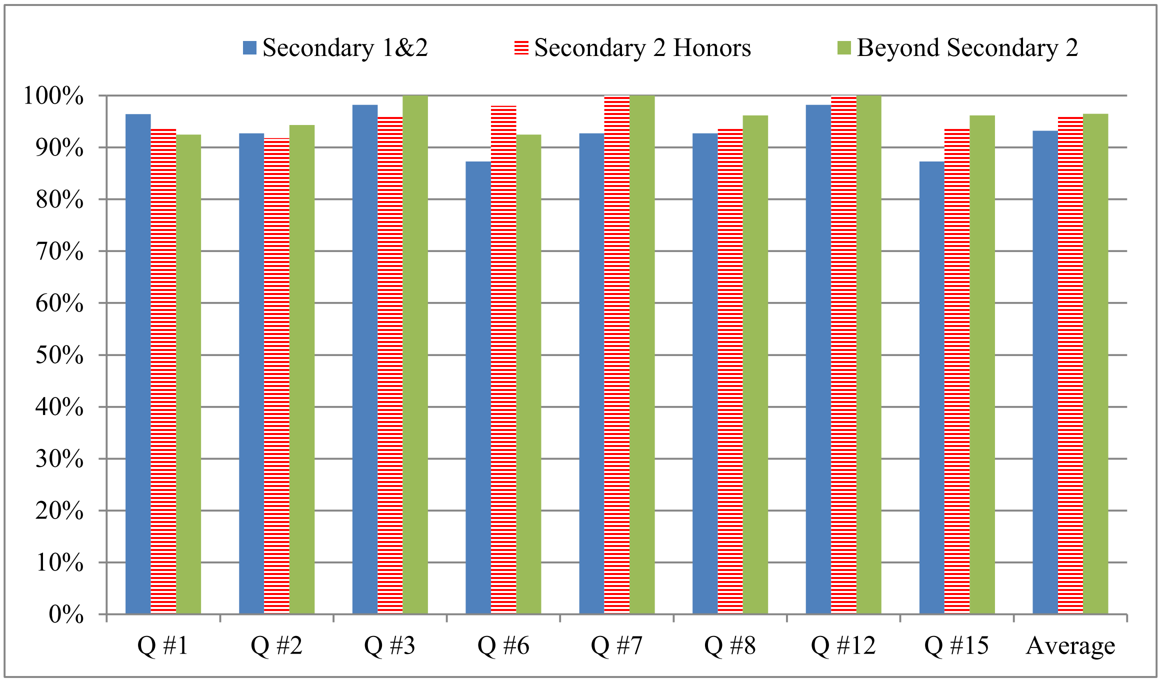

Figure 4-7: Percent of Number-only Problems by Math Level

4.5 Word Problem Results

Three sets of word problems comprising questions #4, #5, #9, #10, #11, #13 and #14 were included in the test to answer the question of whether or not the students can set up the equations needed to work word problems and do the necessary math to determine energy cost. Results showing the overall answer to this question are shown here and the word problems are analyzed individually in the next sections.

Three of the problems, #4, #5 and #9, have overall scores above 50%. The highest was #9 which only required the students to determine what number is 15% less than $180. Over 66% of the students could do this problem correctly. Problems #4 and #5 deal with the amount and cost of gas consumed and had respectively 56.7% and 51.0% percent of the students answering correctly. Calculating kilowatt hours in problem #10 proved too difficult for almost 70% of the students. Kilowatt hours were also a factor in problems #13 and #14 and over 70% of the students got those questions wrong. Figure 4-8 shows the average percent correct by question. Clearly word problems were more challenging for the students than were the abstract problems.

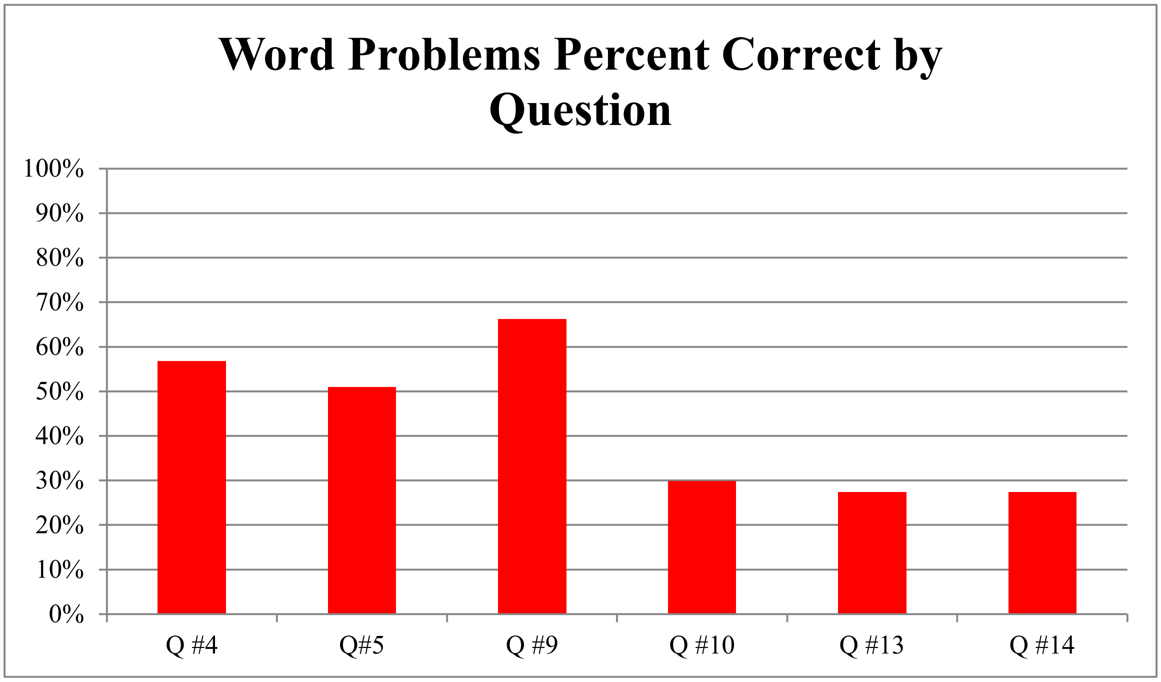

Figure 4-8: Word Problems Percent Correct by Question

Figure 4-9 shows the distribution of students answering each question correctly based on their math class level. From this chart we can see that the students taking the higher math classes did do much better than those in the regular Secondary 2 class yet no clear difference is shown between those in Secondary 2 Honors and those in math classes beyond Secondary 2.

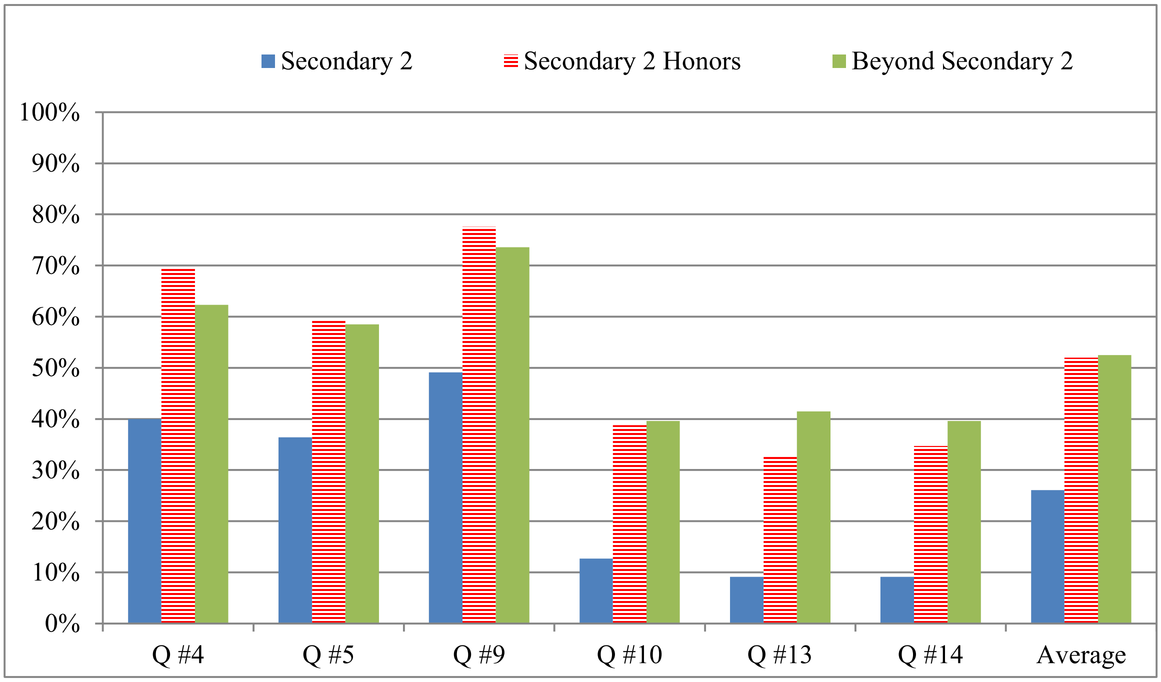

Figure 4-9: Percent of Word Problems Correct by Math Level

4.6 Abstract and Word Problems Compared

While the charts in the previous sections do show quite a difference in the average scores between the abstract and the word problems, a paired t-test was done to test for statistical significance at the 0.05 alpha level. For this test the total percent of correct number-only problems is compared with the total number of correct word problems for each student. The dependent variables are the average scores on the number-only problems and word problems. Since we expected the word problem score would be lower, a one-tailed paired t-test was used. The result shows $p < 0.001$. Therefore, the hypothesis that the variance of the mean scores is statistically significant is accepted. Table 4-3 shows this data.

Table 4-3: Paired t-test Data

	Number Problems	*Word Problems*
Mean	0.951433121	0.430997877
Variance	0.010947452	0.103292231
Observations	157	157

Next an ANOVA test was done to compare how students at different math levels performed with the abstract and contextual problems. The variance of the mean scores between the three math levels in the abstract problems was not statistically significant with $p > 0.05$. The variance with the word problems was statistically significant with a p value even much less than 0.001. Following up with Tukey HSD showed that there are significant differences between the students in Secondary 2 and each of the other two math groups but there is no significant difference between those in Secondary 2 honors and those in math beyond Secondary 2. Tukey's HSD equation is shown in Figure 4-10. Table 4-4, 4-5 and 4-6 show the data.

Table 4-4: ANOVA Number-only Problems

Math Groups	*Count*	*Sum*	*Average*	*Variance*
Secondary 2 (group "a")	55	51.25	0.932	0.019
Secondary 2 Honors (group "b")	49	47	0.959	0.005
Above Secondary 2 (group "c")	53	51.125	0.965	0.008

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.033	2	0.017	1.532	0.219	3.055
Within Groups	1.674	154	0.011			
Total	1.708	156				

Table 4-5: ANOVA Word Problems

Math Groups	*Count*	*Sum*	*Average*	*Variance*
Secondary 2 (group "a")	55	14.333	0.261	0.072
Secondary 2 Honors (group "b")	49	25.500	0.520	0.085
Beyond Secondary 2 (group "c")	53	27.833	0.525	0.109

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.458	2	1.229	13.863	0.000	3.055
Within Groups	13.655	154	0.089			
Total	16.114	156				

$$\frac{M_1 - M_2}{\sqrt{MS_w\left(\frac{1}{n}\right)}}$$

Figure 4-10: Tukey's HSD Equation

Table 4-6: Tukey's HSD for the Word Problems

Word Problems	alpha = .05
group a vs b	significant with q = 6.16
group a vs c	significant with q = 6.29
group b vs c	not significant with q = .12

Tukeys HSD
n=49
k=3
df = 154
for alpha of .05, q = 3.68
for alpha of .01, q = 4.5

4.7 Word Problem Errors

An important part of the design of the test was the open-ended questions. These allowed for a more in-depth analysis of the incorrect word problem responses, especially when students showed their work. Where students showed their work, errors in identifying relevant information, equation formulation, and calculations were evaluated.

4.8 Car Travel Costs

Problems #4 and #5 dealt with commuting costs. Many of the students in this study had or soon would have their drivers' licenses and would be dealing with gasoline costs such as those in these equations. Students in the study averaged over 50% correct overall on these questions though students in the lowest math group only averaged about 40% correct.

For students who answered this question incorrectly the main problem that could be identified was that they misread the question and gave answers based on one-way rather than round trip information. About 10% of the students, including those from each of the three math groups, made this simple mistake relating to the first of the problem solving steps, "read and comprehend the problem," discussed in Chapter 2 above. (Jitendra et al 2007, 283)

Another mistake several students made was to try to incorporate the amount of miles per hour instead of the miles per gallon numbers given in the problem. This showed an inability to identify the relevant information needed to solve the problem.

The third commonly made mistake involved setting up the equation. The students identified the relevant information of miles and miles per gallon but then they multiplied the two instead of dividing. This, along with other errors students made, resulted in unrealistically large answers ranging from needing 19 to 960 gallons of gas costing up to $365 for a daily commute.

These results agree with the studies done by Wyndhamn, Säljö, and others where students did not seem to notice that the answers were not realistic. (Wyndhamn and Säljö 1997, 361-382)

4.9 Heating Costs

Over 66% of the students answered question #9 correctly with even the lowest math group answering it correctly 49% of the time. Another 9% appear to have found the correct answer of $153 for the gas costs but then added on an additional amount for the electric costs of the space heater. This, again, is a simple error in reading and comprehending what is being asked in the problem.

While this question was the easiest of the word problems for most students, there were nine who took the 15% reduction and simply subtracted it from $180. Another nine students multiplied it by $180 but then did not subtract that result from $180.

Question #10 proved very difficult for the students with only 47 of them recognizing the need to multiply days x hours/day x kilowatts/hour. There were 34 students who only multiplied days x hours/day. Ten of these labeled the units on their answer correctly as hours while 15 of them used the unit label "kWh" even though the answer only represented hours. Nine students did not use units in their answer at all. Realizing what units the answer should have and correctly recognizing units in the problem you set up and the answer you get can greatly help the student correctly solve the problem. (Hewitt 2007, 57)

Because the answer to #11 depended upon the student's answer to #9 and #10, the average scores from this problem were not used in the comparison of number-only to word problems. It is interesting to note, however, that at least six students got unrealistic answers to this problem. Even if they didn't understand how to do the math problems, common sense should dictate that one cannot save $1210 on a bill of only $180.

4.10 Lighting Costs

Questions #13 and #14 involving lighting costs were certainly the hardest for the students. Fewer than 30% could answer either question correctly. Of those in the lowest math group, fewer than 10% could answer them correctly.

Unlike heating costs, it is not expected that these students are very familiar with electric bills. It is telling to note though that 27 students, over 17%, had answers ranging from $7000 to $31000 as the cost of electricity for a single porch bulb for a year with no comments as to how unrealistically expensive that would be. All of these students had identified the appropriate information except they had failed to recognize that the cost of electricity was for kilowatts, not watts, but that the power usage for the light bulbs was only in watts. Other than this error, the equations they set up were fairly accurate.

About 10% of the students gave random numbers, words or no answers to these questions. The vast majority of the students seemed to recognize and correctly set up and calculate the light bulb costs. Twenty of the students recognized the need to make some calculations with the hours per day the bulb was burning multiplied by the number of days in a year and even by the cost of electricity ($0.11/kWh) but failed to include the bulb wattage at all. Approximately fifty other students used various equations involving some or all of the relevant numbers. These problems most clearly indicate that the main problem the students have is in setting up correct equations.

4.11 Financial Literacy Factor

The Financial Literacy class requirement began in 2003 with Utah Senate Bill 154. All high school students graduating after 2007 are required to pass the half credit course. Objectives of the course include enabling students to:

- ". . . implement those decision-making skills they must apply and use to become wise and knowledgeable consumers . . ."
- ". . . incorporate concepts and skills from mathematics . . ."
- ". . . be prudent managers of financial resources . . ."
- "demonstrate an understanding of . . .sound money management skills . . ." and,
- ". . . understand personal and societal consequences of financial decisions."

A task force in 2013 noted that an "end-of-course exam should be implemented to provide data and accountability" and that the course should "better align with the Core Curriculum." It noted that there currently is no "statewide student assessment" which would allow data to be collected to determine the efficacy of the course. Since the word problems in this study concern economic decisions, the results were analyzed to determine whether students who have passed the required Utah Financial Literacy course scored higher than those who did not. (USOE - CTE 2014))

Figure 4-11 compares the test results based on whether or not the students have passed the required Utah Financial Literacy class. There were 111 students who had stated they had not yet passed Financial Literacy, 39 who had passed it and 7 who gave no response to that question.

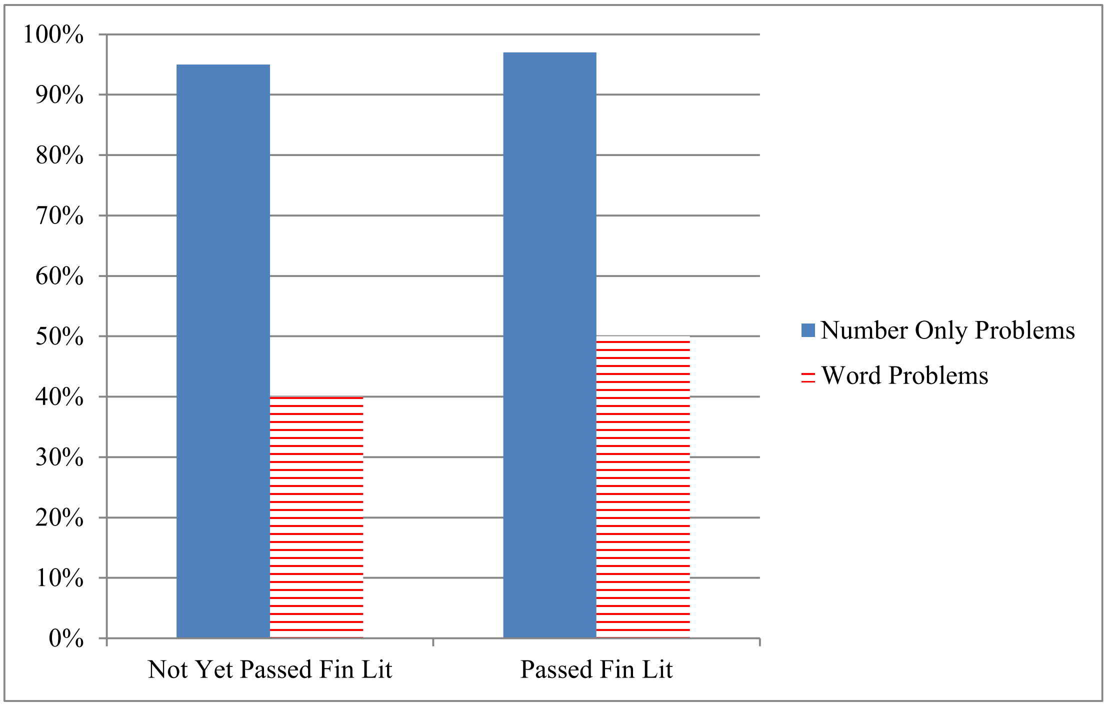

Figure 4-11: Percent Correct by Financial Literacy Class Status

The difference in number-only problems, 95% to 97% cannot be shown to be statistically significant with a $p > 0.05$. The difference in word problems is $p = 0.0385$ and averages going from 40% correct for those who have not had Financial Literacy to 50% for those who have as shown in Table 4-7.

Table 4-7: Percent Correct by Financial Literacy Class Status

	Not Yet Passed (n=111)		Passed (n=39)	
	Mean	Standard Deviation	Mean	Standard Deviation
Number-Only Problems	.9459	.1087	.9679	.0939
Word Problems	.3994	.3043	.5043	.3494

It is important to note, however, that 90% of the students who have passed Financial Literacy are in classes above regular Secondary 2 math while only 58% of those who have not passed Financial Literacy are in the higher math classes. Since math level does have a significant effect on the ability of the students to do the word problems, this may be skewing the Financial Literacy statistics.

In order to make a more accurate analysis, a comparison was done between the students who are in math classes above regular Secondary 2 who have and have not passed Financial Literacy. Using only students in Secondary 2 Honors and above yields 64 students who have not passed and 35 students who have passed Financial Literacy. Again the differences in number-only percentages correct are small, 96% and 97%, and $p > 0.05$ but the differences in word problem correct percentages are also very small, 51% to 55% correct and cannot be shown to be statistically significant with $p > 0.05$. Table 4-8 and Figure 4-12 shows how similar these results are.

Table 4-8: Percent Correct by Financial Literacy Class – Higher Math Classes Only

	Not Yet Passed (n=64)		Passed (n=35)	
	Mean	Standard Deviation	Mean	Standard Deviation
Number-Only Problems	.9609	.0700	.9714	.0914
Word Problems	.5104	.2968	.5476	.3347

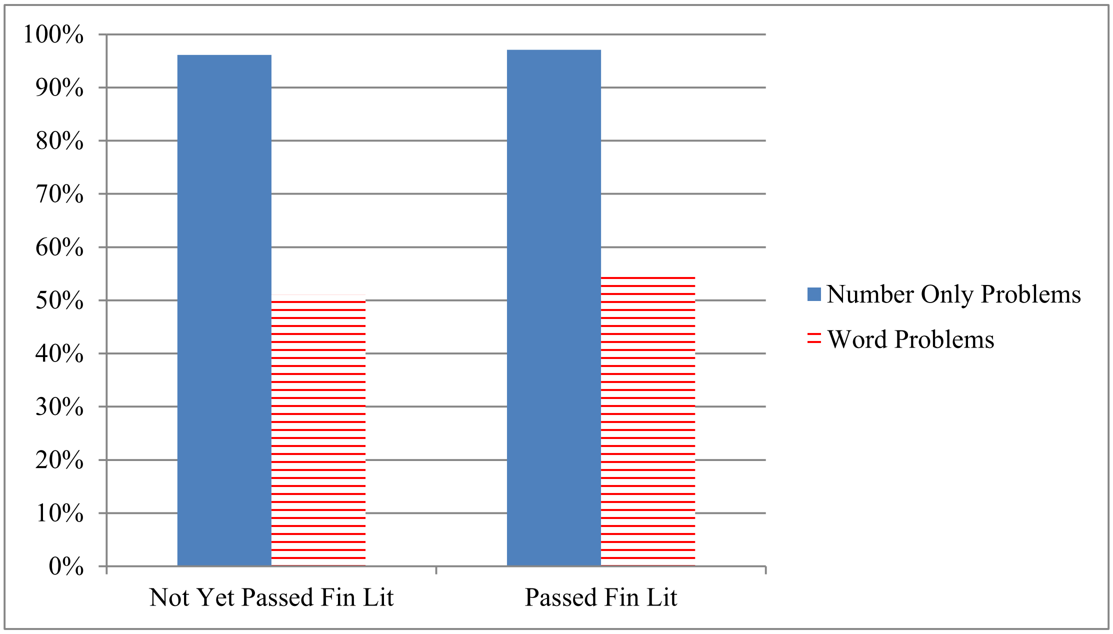

Figure 4-12: Percent Correct for Upper Level Math Students

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Research Questions Answered

The main question this study set out to answer was:

1. *Do the students have the ability to set up equations needed to work word problems and do the necessary math to determine energy costs?*

This is a compound question addressing both the ability to set up equations and the ability to do the mathematical computations. Both of these abilities are needed in order to determine the associated energy costs. The conclusion was that the students could not do all that was necessary in order to correctly determine the energy costs.

The two parts of the main question were assessed separately and the conclusions were addressed as answers to the other three research questions. Unfortunately, although the students were instructed to do so, many students did not write out the equations they used to solve the word problems. Because of this, it was not possible to have a complete understanding of all the difficulties the various students had. The information that could be extracted is discussed below.

2. *How well did the students correctly identify the relevant information in the word problems?*

Correctly identifying relevant information was noticed as a problem for students in several instances. Two of the common problems involved using the information given for miles per hour when they should have used the information for miles per gallon and incorrectly identifying that bulb wattage is in watts, not kilowatt hours.

3. *How well did the students correctly transfer the information from the word problems into mathematical expressions?*

So many students did not completely write out the mathematical expressions they used that it is not possible to fully analyze all the problems they had transferring information into correctly set-up their equations. Some of the problems that were identified involved multiplying numbers when they should have divided. Also, nine of the students did not seem to understand how to reduce 180 by 15% and so they simply subtracted 15 from 180 instead.

4. *How well did the students correctly perform the mathematical operations associated with the mathematical expressions they created?*

For students who did fully write our correct mathematical expressions using the right relevant information, virtually no errors were noticed in their calculations. This agrees with the results from the number-only section of the assessment which found that 95% of those questions were answered correctly.

5.2 Conclusions Compared to Prior Research

This study produced many of the same results that previous studies have shown. It confirmed that the majority of students do have a hard time solving word problems. Like the Australian nursing students and the construction management students, the CTE students in the study found even basic mathematical calculations difficult to implement in real-world situations. (Eastwood, et al. 2011, 815-818; Davis, 2011) Power bill questions involving kilowatt hour costs were also shown to have challenges similar to those DeWaters, Southwell and others found with students and American consumers. (DeWaters and Powers 2011, 1699-1710; Southwell et al 2012)

Tariq's study dealt with college students while this study dealt with high school students. Both studies found that abstract questions were much easier for students than were word problems. Although the problems in this study required no more than sixth grade math, the average word problem score was less than 45% correct. This is in comparison to 95% correct on the number-only problems. This agrees with Tariq's conclusions that students perform poorly in "contextualized mathematical content." It also helps confirm that the difficulties students have with real-life problems are there even when the necessary math is rather basic. (Tariq 2008, 889-904)

Unrealistic answers were also common in this study just as they were in the studies by Wyndhamn and Säljö and others as described in section 2.6 of this thesis. (Wyndhamn and Säljö 1997, 361-382; Greer 1997, 293-307; Reusser and Stebler 1997, 309-327) Even when the students were given the miles per gallon estimates for a car, over 40% did not know how to use them to correctly find commuting costs resulting in answers with unrealistically high expectations of how much it would cost to go to and from work on a daily basis. (Verschaffel, De Corte, and Lasure 1994, 273-294) How can we expect students to recognize realistic ways to save energy if they cannot accurately set up the problem to calculate gas usage for a daily commute or electricity used in a single light bulb?

5.3 Discussion of the Importance of this Study

While this study is informative to help understand why students struggle with word problems, it is especially applicable as the efficacy of financial literacy and the push for higher math education in public school is evaluated. These results show that the students specifically can do the math calculations necessary for basic energy cost problems. They don't need higher levels of math or more practice with the algorithms associated with high school math. They can do the calculations in abstract form. What they lack is the ability to apply even the basic math skills they do have to real-world problems.

Perhaps part of the problem is that, because the students can do the calculations required in high school math classes, it is assumed that they can also apply those concepts. Tests are given based on math level. The overall scores for different student race, gender and other demographics are thoroughly studied and reported, yet no information is given as to the scores on the different types of questions. There is no breakdown of which, if any, types of word problems are included in the tests. There are not even any sub-scores for number-only vs. word problems.

One of the things this study does is emphasize the need to evaluate which types of problems are assessed on standardized tests and to evaluate the results for each of those types of questions. If a standardized test had sub-scores for abstract and word-problems similar to this study (95% and 43% respectively) with 60% of the questions being abstract, the overall score would be 74%. That result may be considered passing and not reflect the inability of students to apply the given math in their lives. As Rolf Olsen notes in his paper, *Achievement Tests from an Item Perspective*, "the major portion of information from a typical test is thrown away when only the overall score is analysed." (Olsen, 2005)

Another important finding from this study is that the group of students who had passed the required Financial Literacy class still scored below 60% on the word problems. It demonstrates that passing Financial Literacy does not guarantee students will do well at solving even basic financial calculations needed for energy cost decisions. Clearly there is a need for an assessment to measure the usefulness and benefits of this class in this area. (Hales and Shumway 2013) This study shows that such an assessment should involve not just vocabulary and general questions but specific, energy cost and other related word problems as well. Assessments that measure how confident students feel with financial decisions are not an accurate measure of their abilities to make financial decisions. Confidence without competence may lead to worse decisions as Will and Frazier discussed and as demonstrated by some of the answers given by the students in this study. (Willis, 2008; Frazier, 2008) It may be difficult for students to evaluate the benefits of particular careers if they expect the costs to commute to be hundreds of dollars per day.

5.4 Recommendations

The results of this study lead to more questions including how much actual time math teachers spend teaching students how to apply abstract concepts, particularly with scenarios with which the students can relate. It would also be informative to see how many of the problems given in the current math textbooks are word problems, what type of word problems they are, how many of them the teachers actually assign the students and how many of those assigned the students actually do. (Ding and Li 2010, 146-180) An analysis of the number and type of word problems used and answered correctly in standardized tests would also be very informative.

Finally, it cannot be shown that passing Financial Literacy made a significant difference in the ability of the students in this study to answer real life energy cost word problems. This correlates with the 2008 study JumpStart and with the article by Lauren Willis. (Jumpstart 2008; Willis 2008, 197) Since these types of problems are the kind that will likely impact the finances of these students, it is very disappointing that their scores are so low even after passing the Financial Literacy class. The Financial and Economic Literacy Taskforce Report was prepared in 2013 by Brenda Hales and Mary Shumway of the Utah State Office of Career, Technical and Adult Education. It specifically recommends that an “end-of-course exam should be implemented to provide data and accountability” for the Utah Financial Literacy class. The results of this thesis are evidence that this type of accountability exam is needed but that the assessment should focus on financial problems the students will really encounter rather than simply their understanding of vocabulary or concepts or an assessment of their feelings of financial confidence. (Hales and Shumway 2013)

Word Problems are not just a part of math curriculum. The ability to do word problems does not just affect grades and test scores. Rather, they are the substance of the decisions that we need to make on a daily basis. They affect our physical health, our current and future financial well-being, and the future of our environment. It is important that we look more closely at the ability of our students to do real-life word problems.

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APPENDIX A: ASSESMENT

Name:____

□ Sophomore □ Junior □ Senior Have you passed the Financial Literacy class? □ yes □no

What math class are you in this year? ____

SHOW ALL THE EQUATIONS & STEPS YOU USE!!

#1 $(15 \times 0.62) + (148.4 + 0.56) =$

#2 $4.2 + \frac{(25 \times 7 \times 0.23 \times 181)}{500} =$

#3 $\frac{3 \times 15}{18} =$

Use this table for questions #4 and #5

Route	Distance from Mark's house to work (one way)	Average Speed	Average miles per gallon (MPG)
Through the city	15 miles	25 miles/hour	16 MPG
On the freeway	21 miles	58 miles/hour	24 MPG

#4 How many gallons of gas will Mark use going to and from work in a typical day driving the city route?

#5 If a gallon of gas costs $3.60, how much does it cost Mark in gas to go to and from work on the freeway route?

#6 (1 – 35%) x 340 =

#7 290 – 164.72 =

#8 (0.11 x 262.8) + (4 x 0.85) =

Use this information for questions #9 - #11: Jim's gas bill for December was $180.00. In January he lowered his thermostat by 3 ℉ and his gas bill was 15% lower. In order to stay warm, he wore a sweater and ran a 1500 watt electric portable space heater for an average of 4 hours per day every day in January. Electricity in his area is $0.11 per kilowatt hour (kWh).

#9 How much was Jim's gas bill in January?

#10 How many kilowatt hours (kWh) did Jim's space heater use during January?

#11 Overall how much more (or less) did it cost Jim to stay warm in January?

#12 2.25 x 8.6 =

Use this table for questions #13 and #14

Type of Bulb	Watts used per hour	Bulb life if used 12 hours per day	Cost of each bulb
Standard incandescent	60	3 months	$0.85
Compact fluorescent	15	1 year	$3.90
Cost of electricity is $0.11 per kWh			

#13 Ann has a porch light she leaves on 12 hours each night. It currently has one standard incandescent bulb in it. What is her total cost in electricity and bulbs to light her porch for 1 year?

#14 What would be her cost be to light her porch for 1 year (including the cost of the bulb) if she replaced her incandescent bulb with a compact fluorescent bulb?

#15 357 + (148 x 0.22) =