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The Effect of the Engineering Design Process on the Critical Thinking Skills of High School Students

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ABSTRACT

The Effect of the Engineering Design Process on the
Critical Thinking Skills of High School Students

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The purpose of the research reported here was to determine the impact learning the engineering design process (EDP) would have on the critical thinking skills of high school physics students. An EDP unit was conducted with 5 classes of high school physics students in grades 10-12 over 1 month. The EDP unit's curriculum allowed for the gradual release of responsibility as students became more familiar with the EDP and more consistent in using it. The six steps used in this EDP unit were Ask, Imagine, Plan, Create, Test, and Improve. The Watson-Glaser Critical Thinking Appraisal was given as a pre- and post-test to measure the growth in critical thinking skills. By measured standards, qualitative analysis and observation, students showed an increase in critical thinking skills and in confidence to use them.

Keywords: active learning, critical thinking, critical thinking skills, EDP, engineering design process, engineering education high school, Heather Ure, high school, inquiry, problem based learning, students, Watson-Glaser Critical Thinking Appraisal

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1 INTRODUCTION

1.1 Background

The United States is struggling to produce the number of engineers it needs for its workforce (Augustine, 2005; Race to the Top: Kim Adams, 2008). There has been a huge push in K-12 educational institutions to promote engineering education through the use of engineering curriculum (i.e. Engineering is Elementary, Race to the Top, Project Lead the Way, etc). These programs are introducing engineering content in order to help increase K-12 students' interest in pursuing a college education in engineering. These efforts focus teaching about the different fields of engineering, and the skills, education, and attributes of engineers should possess. One such ability key to engineering is critical thinking.

Reed surveyed engineering professionals in an effort to determine the most important skills an engineer needs to possess. Over 98% of the respondents agreed/strongly agreed that engineers need critical thinking skills (2010). Nguyen's research supports these findings, suggesting that all engineers require the intellectual skills of logical thinking and problem solving (1998). If K-12 educators are going to try to help their students gain an interest in pursuing engineering careers, it will be necessary for their students to develop problem solving skills such as critical thinking.

The term critical thinking (CT) skills incorporates a wide variety of skills. R. Jay Kilby summarizes the work of many notable critical thinking experts; researchers "have identified numerous reasoning skills, such as focusing on a question, distinguishing relevant and irrelevant information, asking clarifying questions, judging the credibility of sources of information, and using deductive and inductive reasoning" (2004). Dr. Richard Paul, the Director of Research and Professional Development at the Center for Critical Thinking, describes critical thinking as

1. Ability to engage in reasoned discourse
2. Reasoning operated in the context of intellectual standards (clarity, accuracy, precision, relevance, depth, breadth, logic)
3. Involving analytic inferential skills (the ability to formulate and assess goals and purposes, questions and problems, information and data, concepts and theoretical constructions, assumptions and presuppositions, implications and consequences, point of view and frames of reference) (1997)

According to these definitions, the purpose of critical thinking skills is to "understand the mind and then training the intellect so that such 'errors', 'blunders', and 'distortions of thought' are minimized" (Paul, 1997). Accordingly, this research will use a comprehensive definition of CT that includes both analytical and logical skills used in evaluating and solving challenges to minimize errors as described above.

Although critical thinking skills are essential to the various engineering fields, several recently published reports indicate that many high school graduates are lacking in their abilities in this area. In 2008, the "U.S. Workforce Readiness Survey" was given to mid-size business owners who reported on the skill level of their recent high school graduate employees:

> Significant basic (reading comprehension, writing in English, mathematics) and applied skills (professionalism/work ethic, critical thinking/problem solving) deficiencies emerge among high school graduate entrants. (Casner-Lotto and Silvert)

In the same survey, "Critical Thinking/Problem Solving Skills" ranked as the 5th most deficient area in newly-hired graduates from both high school and college. This suggests that there is a certain need for these skills to be improved.

Additionally, the International Science Benchmark Report showed that the U.S. is significantly behind many other countries like Canada, China, Hong Kong, Japan and Singapore in cognitive skills such as knowing, applying and reasoning (Achieve Report, 2010). Many of the topics included in the study have a direct relationship to problem analysis and critical thinking skills.

At the ages of 15-17, students are refining their thinking skills. Many employers rate high school students' abilities "inadequate" upon graduation and in need of extra help to develop these sought-after skills (Casner-Lotto and Silver, 2008). The ability to think critically is one of the desired attributes of an employee (Casner-Lotto and Silvert, 2008). It would appear to be the K-12 teacher's responsibility to teach students crucial critical thinking skills that will help make them marketable in today's job market. However, according to Johnson, the "common approach to instruction will get students to memorize things and perform certain tasks but it will not lead to conceptual understanding, it will not help them think, nor enhance their ability to learn on their own" (1996). Youth do not inherently have critical thinking abilities but need to be taught how to think, step by step. Dr. Paul states "that the capacity of humans for good reasoning can be nurtured and developed by an educational process aimed directly at that end" (1997). CT skills can be cultivated through proper education. Teachers need to look for specific methods to help their students learn about CT skills and practice using them in real world applications.

As pointed out, the need to enhance critical thinking (CT) skills of high school students is great. Educators use several methods in their classrooms including, but certainly not limited to; explicit instruction, increasing rigor, problem-based learning, online discussions, peer-led team learning, and inquiry (Marin, 2011; McCollister, 2010; Kek, 2011; Szabo, 2011; Quitadamo, 2009; Burns, 2009). Each of these methods has been proven to be effective teaching methods and can be useful in specific instances. For example, explicit instruction does not work as well in history as inquiry does, and online discussions are relevant to educational psychology but not necessarily to science (Burns, 2009; Szabo, 2011). While there are many valuable teaching methods, most help students practice skills without necessarily focusing on developing critical thinking skills. The engineering design process, as described in the next section, may be an effective method for teaching students to think critically.

1.2 Overview of the EDP

One K-12 content area that focuses on teaching CT is technology education. The Technology for All Americans Project and the Standards for Technological Literacy (STL) outlines a curriculum opportunity of how to further promote an understanding and competency of technology in high school and junior high classrooms. The curriculum is largely based on the engineering design process (ITEA 2001, 2007). The design process "involves practical, real-world problem-solving methods, it teaches valuable abilities that can be applied to everyday life and provides tools essential for living in a technological environment" (ITEA, 2007). With the growing technological advances, our students need to be technologically literate. According to the STLs, technological literacy is the ability to interact with technology in the desired way and this "demands certain mental tools, such as problem solving, visual imaging, critical thinking, and reasoning" (ITEA, 2007). No matter the situation, being able to think critically by understanding the challenge, analyzing the situation, logically creating a plan, and testing that plan, which are all steps found in the engineering design process, are all life skills necessary for success (Johnson, 1996). Making good decisions comes from utilizing the human capacity to think in order to pick the best possible course of action. Engineers need that ability to perform their work on a daily basis. In order to train future engineers, we need to be helping them develop necessary CT skills.

The engineering design process (EDP) is a method of systematically identifying the problem, challenges, and limitations of a problem, analyzing and determining the best of the possible solutions, and testing the chosen solution. The results of the test are then analyzed and experimenters are able to then refine their solution by going through the cyclic pattern of the EDP. While there are many detailed versions of the EDP, the general concept is the same: thinking through the question and then systematically working out solutions to find the best possible option. Figure 1 illustrates the EDP used in this study.

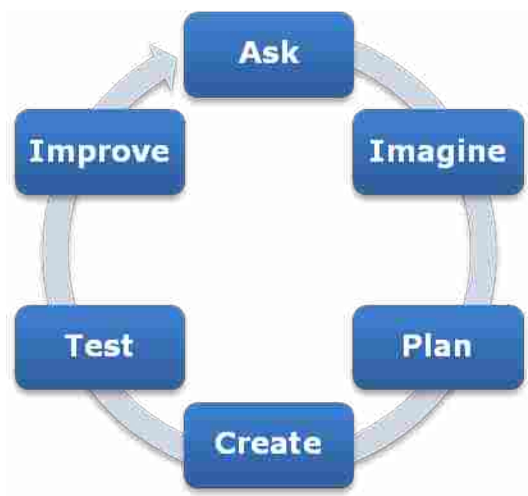

Figure 1 The EDP Cycle

The version of the EDP illustrated in Figure 1 was adapted from the Boston Museum of Science's Engineering is Elementary program (2010). This process shows the elements of the EDP: asking questions, imagining solutions through brainstorming, planning out a response to the challenge, creating the solution or prototype, testing the problem solution or prototype, and then seeking for ways to improve the solution by moving through the cycle again. It organizes the critical thinking though process into simple, manageable and specific steps that can be taught. The EDP may become an instinctive part of the person's natural thought process and increase the person's ability to think critically through challenges. This research will examine that relationship.

The EDP is a general problem solving process that can be used in any number of situations from academics to personal relationships to business decisions. The process of analyzing the problem, brainstorming solutions, and testing out the best option can be used throughout life (ITEA, 2007). People of all ages and dispositions can benefit from the use of EDP in their lives as it serves as an organizational tool aiding in making decisions and thinking analytically though challenges. Having better critical thinking skills should help individuals increase problem solving abilities and optimize the solutions to challenges.

At the Boston's Museum of Science *Engineering is Elementary Symposium* in June of 2010, many researchers and teachers from around the country presented their findings of the impact engineering units had on their students' standardized test scores and attitudes and dispositions towards engineering. These educators have been using the EDP in their classrooms to teach their state mandated curriculum. Their findings, although not formally published, suggest that the EDP is having a positive impact on how students not only perform better on standardized tests but are able to better think critically. Without published research in this area the evidence to encourage the use of the EDP is not getting out to K-12 educator.

1.3 Problem Statement

While there is an evident need for students to graduate with critical thinking skills and the EDP seems like a possible solution for promoting critical thinking, there has been no substantial data connecting the engineering design process to high school students and their ability to use critical thinking skills. This research will determine the effect of teaching the EDP in high school can have on student's critical thinking skills. In order to understand this effect, the following questions will guide the study:

- Do high school students develop greater CT skills by using the EDP on a regular basis?
- What type of students experience the most development in their CT skills after learning the EDP?
- How do students feel about the EDP and how do they see it as impacting their lives?
- What changes do teachers' observe in their students' behavior as students learn to embed the EDP in the classroom?

As part of this research, an EDP unit will be taught with a CT pre and post test to determine the relationship between students learning the EDP and their critical thinking abilities. A statistical evaluation t-test will help determine what types of students have the greatest improvement in the CT capacity and how much they were able to improve. In addition, surveys and formative assessments will be given to determine the students' attitudes towards the EDP and the impact they see it having in their own lives. While the EDP cannot be isolated from the labs, classroom environment, teacher influences, and yearlong progression, this study will be looking for general CT growth trends through the unit. By quantitatively and qualitatively measuring the change in CT skills and the development of the students, the groundwork is laid for future groups to expand this research to promote engineering education and actively teach critical thinking skills in classrooms by using the engineering design process.

2 LITERATURE REVIEW

Although engineering education is beginning to take hold on the country's education system, there is a relatively small amount of research relating K-12 education to engineering education. The benefits seem to be visible to those using engineering in the classroom, but little research has been published with the results. At the Engineering is Elementary Invited Symposium on June 3-4, 2010, current research, especially in elementary schools, relating to engineering education was presented and discussed. Few presenters at the conference have published research although many have done extensive action research, experimenting with engineering education privately in their own elementary school classes. In the profession of K-12 educators, there is very little motivation for publishing work even though personal, action research in the classroom is common. The need for critical thinking skills is evident through reports like the U.S. Workforce Readiness Survey but no substantial data connecting the engineering design process to high school students and their ability to use critical thinking skills has been found. This connection would give additional motivation for teachers to incorporate the EDP in their already busy classroom curriculums.

2.1 Work Importance of Critical Thinking Skills

It is commonly believed that the United States is not producing enough engineers for the future (Augustine, 2005; Race to the Top: Kim Adams, 2008). This is a huge challenge to solve but looking at the skills an engineer needs may help lead to possible solutions. The single most important skills needed by engineers to approach challenges are intellectual skills. These have been defined first and second as logical thinking and problem solving, respectively (Nguyen, 1998). These together can be defined as critical thinking skills. Critical thinking skills are one of the most important skills an engineer must have. Engineers by nature are problem solvers and in order to solve those problems, they must have the capacity to think through problems. In order to produce engineers, there must be students capable of thinking critically.

A significant study as background for this work is “New Graduates’ Workforce Readiness: The Mid-Market Perspective” by The Conference Board. This survey was done by a group of organizations trying to promote future business leaders. They gave the survey primarily to small to medium business owners in all fields (Casner-Lotto and Silvert, 2008). It reflects their attitudes towards different groups of employees they have hired. The human resource professionals ranked those recently employed as being excellent, adequate, or deficient in 20 different crucial areas. A surprising amount of high school graduates were considered deficient in various areas including those important to this study. Critical thinking/problem solving skills ranked as the 5th most deficient area at 69% deficient while creativity/innovation was 56% deficient. Critical thinking/problem solving skills were ranked the number 1 lowest in excellence at 0.0% (see Figure 2). If these skills are considered important by student’s future employees, there needs to be more done to help students acquire these skills. As stated in Chapter 1, this research hopes to prove that students can increase their critical thinking skills by learning the EDP in high school.

Rating Percentages for High School Graduates

Very few respondents rate skills of new entrants with a high school diploma as "excellent."

Deficient

Rank	Skill	%
	Basic skills	
1	Writing in English	72.8%
2	Foreign Languages	57.7
3	Mathematics	54.0
4	Science	44.8
5	Government/Economics	42.9
6	History/Geography	41.9
7	Reading Comprehension	36.7
8	Humanities/Arts	27.7
9	English Language	18.2
	Applied skills	
1	Written Communications	82.6
2	Professionalism/Work Ethic	73.7
3	Leadership	72.5
4	Critical Thinking/ Problem Solving	69.1
5	Lifelong Learning/ Self Direction	59.3
6	Creativity/Innovation	55.9
7	Oral Communications	51.6
8	Ethics/Social Responsibility	49.0
9	Teamwork/Collaboration	35.8
10	Diversity	29.3
11	Information Technology Application	23.0

Adequate

Rank	Skill	%
	Basic skills	
1	English Language	75.2%
2	Humanities/Arts	70.7
3	Reading Comprehension	60.4
4	History/Geography	57.0
5	Government/Economics	56.6
6	Science	54.7
7	Mathematics	44.4
8	Foreign Languages	41.8
9	Writing in English	26.4
	Applied skills	
1	Information Technology Application	62.1%
2	Diversity	61.6
3	Teamwork/Collaboration	59.3
4	Ethics/Social Responsibility	48.6
5	Oral Communications	46.3
6	Creativity/Innovation	42.0
7	Lifelong Learning/ Self Direction	39.0
8	Critical Thinking/ Problem Solving	30.9
9	Professionalism/Work Ethic	26.7
10	Leadership	25.1
11	Written Communications	16.9

Excellent

Rank	Skill	%
	Basic skills	
1	English Language	6.5%
2	Reading Comprehension	2.9
3	Mathematics	1.7
4	Humanities/Arts	1.6
5	History/Geography	1.1
6	Writing in English	0.8
7	Science	0.5
7	Foreign Languages	0.5
7	Government/Economics	0.5
	Applied skills	
1	Information Technology Application	14.8
2	Diversity	9.1
3	Teamwork/Collaboration	4.9
4	Ethics/Social Responsibility	2.5
5	Creativity/Innovation	2.1
6	Oral Communications	2.0
7	Lifelong Learning/ Self Direction	1.7
8	Professionalism/Work Ethic	1.2
9	Leadership	0.8
10	Written Communications	0.4
11	Critical Thinking/ Problem Solving	0.0

Number of respondents varied for each question, ranging from 165 to 247 for basic skills and 236 to 246 for applied skills.

Figure 2 New Graduate's Workforce Readiness: Rating Percentages for High School Graduates.

The International Science Benchmark Report shows that we are significantly behind many other countries like Canada, China, Hong Kong, Japan and Singapore (Achieve Report, 2010). This study involved the use of the Programme for International Student Assessment (PISA) and Trends in International Math and Science Study (TIMSS) tests which were administered across the world. Students from the United States came in much lower than expected. TIMSS ranked the USA students as #8 in fourth grade science and #11 in 8th grade science but, in the PISA scores, the USA students were even lower at 29th in Science Literacy. Areas that were tested included science literacy (i.e., identifying scientific issues, explaining phenomenon scientifically, and using scientific evidence) and cognitive domain skills such as knowing, applying, and reasoning. Many of these topics have a direct relationship to problem analysis and critical thinking skills. Although this study does not explicitly refer to critical thinking skills, the areas of scientific literacy fall under the definition of CT skills as stated in Chapter 1. Many of the areas tested are subcategories of critical thinking tests (Mental Measurements Yearbook with Tests in Print, 2011).

2.2 Engineering Design Process as an Instructional Strategy

The EDP is a method of solving problems that seems to fit with the innate nature of children to learn about their world with a hands-on approach. The EDP is closely related to inquiry and problem-based learning while focusing more on how to design appropriate solutions with forethought rather than just giving student opportunities to rush into a project with little forethought. This specific process has recently had an emphasis in numerous research studies and publications. While newly in the educational spotlight, this type of a process has always been used by engineers to help them step through a challenge and create an effective solution to that challenge.

As an engineering education researcher, Robert C. Wicklein, is a strong promoter not only of engineering education, but specifically of teaching engineering design as part of high school technology and engineering education (TEE) courses. In “Five Good Reasons for Engineering Design as the Focus for Technology Education” he states that many people discredit the need for TEE courses in general because they don’t fully understand or appreciate the impact TEE courses can have (2006). He gives the following five reasons for using engineering design in TEE courses:

1. Engineering design is more understood and valued than technology education by the general populace.
2. Engineering design elevates the field of technology education to higher academic and technological levels.
3. Engineering design provides a solid framework to design and organize curriculum.
4. Engineering design provides an ideal platform for integrating mathematics, science, and technology.
5. Engineering provides a focused curriculum that can lead to multiple career pathways for students.

These five reasons are focused primarily on the curriculum and education aspects of education but not necessarily on the student. In 2009, he continued his research with a Delphi study of engineering experts (Essential Concepts of Engineering Design Curriculum in Secondary Technology Education). In response to the question, "What aspects of the engineering design process best equip secondary students to understand, manage, and solve technological problems?" experts gave critical thinking a mean score of 5.23/6. The mean shift over the duration of the study was only 0.1% implying a high level of stability for that answer as a consistent need for future engineers and a strong uniformity within the field studied. Critical thinking skills developed as part of the EDP are considered crucial by experts as a technique to deal with technological problems, and yet no current research measures the connection between the two.

As a guideline for education, The Standards for Technological Literacy (STL) was created after four years of research under a National Science Foundation grant and is in response to the need the country has for technological literacy to compete in the world market (STL, 2007). The Standards were developed to serve as a guide for student learning in the ways that the researchers deem most appropriate through their research and expert opinions. The STLs cover a few main topics including general concepts of technology (1-3), technology and society

(4-7), design (8-10), abilities (11-13), and specific areas of technology (14-20). STLs 8-11 are specifically related to engineering design and the EDP:

Standard 8: The attributes of design Standard 9: Engineering design Standard 10: The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. Standard 11: Apply the design process

Figure 3 The STLs Relating to the EDP

The expertise and national accreditation of this study solidify the need students have to understand and use the EDP. This process is a valid tool that enables students to positively interact with and understand the processes of technology.

Another major publication, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, is produced by the National Research Council and the Committee on Conceptual Framework for the New K-12 Science Education (2011). This publication is intended to help with the application of the STLs into the daily science classroom. The expert authors condense all engineering, technology, and the application of science (ETS) into two core ideas: ETS1 is Engineering Design and ETS2 is to understand the relationship between the ETS fields. It states, "…that students should learn how science is utilized, in particular through the engineering design process…" (Framework, 2011). The Framework also relates back to the Standards for K-12 Engineering Education by the National Academy of Engineering and the Committee on Standards for K-12 Engineering Education in 2010 claiming "it affirmed the value of teaching engineering ideas, particularly engineering design, to young students." With so much current research on the need for the EDP and the value of it in our school systems, very little research has been done to measure the impacts of the EDP on various aspects with regards to the students. There is a clear need for this research to be done.

2.3 Engineering Education

While the Engineering Design Processes is needed in general education, there is some indication that it is specifically needed in engineering education to prepare future engineers for the challenges that will face them. The National Academy of Sciences put out a report called *The Engineer of 2020: Visions of Engineering in the New Century* which gives an idea of what engineering will look like in the near future. In the Executive Summary, they put forth a call "for us to educate engineers" and then "[*The Engineer of 2020*] takes the aspirations a step further by setting forth the attributes needed for the graduates of 2020. These include such traits as strong analytical skills, creativity, ingenuity, professionalism, and leadership" (2004). The first attributes listed are critical thinking skills. Little research has been done of how to develop these skills and yet teaching these analytical skills is necessary for the success of our future engineers. *The Engineer of 2020* suggests that "the engineering profession …must … transform engineering education to help achieve the vision" (2004). Using the EDP in K-12 education is part of that transformation that could revolutionize the quantity and quality of the engineers produced.

Once the National Academy of Sciences published *The Engineer of 2020,* they moved to Phase II of their project with *Educating the Engineer of 2020: Adapting Engineering Education to the New Century.* This new publication focused on the need for changes in university undergraduate and graduate level programs but also commented on the value of primary and secondary education in helping to prepare future engineers. K-12 education "can have an important but indirect effect on engineering in terms of encouraging secondary school students to consider an engineering education and preparing them intellectually so that an engineering education is accessible to them" (2005). Preparing them intellectually is developing the analytical and critical thinking skills described in *The Engineer of 2020*.

Educating the Engineer of 2020 even gives a recommendation for higher education programs to be involved in the community and K-12 education, stating, "The engineering education establishment should participate in efforts to improve public understanding of engineering and the technological literacy of the public and efforts to improve math, science, and engineering education at the K-12 level" (2005). Encouraging busy graduate and undergraduate programs to be involved shows the importance of K-12 education. This report also states that "The success of academic engineering research is undeniable. It helped shape this nation's industrial capabilities and continues to do so in an increasing degree" alluding to the impact of engineering on the nation's economy (2005).

The National Academy of Science's publications, *The Engineer of 2020* and *Educating the Engineer of 2020*, give perspective on the future of engineering, the attributes of future engineers, and the need to develop those attributes early on, in K-12 education, as well the need for research in engineering education. A connection between using the EDP and developing the sought after attribute of critical thinking skills, to better prepare future engineers who will "develop new technologies to address the problems faced by society" needs to be investigated (The Engineer of 2020 Executive Summary, 2004).

2.4 Critical Thinking Instrument

In order to address the key research questions of this study, a good assessment tool of critical thinking needs to be identified. Being both valid and reliable, a measuring instrument of critical thinking will provide good data that can be shared and used by others. After searching through dozens of different assessments using the Elton B. Stephens Company (EBSCO) database Mental Measurements Yearbook with Tests in Print and searching under "Critical Thinking" the possibilities were narrowed down to just a few options.

The California Critical Thinking Skills Test (CCTST) seemed to be an ideal test because of the attributes it measures. Although intended for the health sciences, it tests critical thinking, decision making, and problem solving skills and gives subscores in Inductive, Deductive, Analysis, Evaluation, and Inference skills. There are multiple forms and takes about 45 minutes to complete the 34 multiple choice test online or on paper. It has a .72 correlation to the Graduate Record Exam (GRE) and a Kuder-Richardson Formula 20 (KR-20) score of .8 proving its internal consistency. However, this test is intended for college students, graduates, or professionals, and it may not be best suited to test at a high school level.

The CCTST's younger sibling the Test of Everyday Reasoning (TER) may be more on pace with high school students. It is very similar to the CCTST but is adapted for a 4th grade reading level and is meant to be used with middle school to high school students. The TER has an internal reliability are between .72 and .89, and the CCTST and the TER have a correlation of .77. Unfortunately, that is all the validity support for the TER available as there is limited research done on this test. Little research has been done using the TER and there does not seem to be evidence of the test being commonly used. Without connections to other reliable tests or expert validations, this test lacks concrete evidence of its ability to accurately test CT skills. Without that evidence, this test was rejected as the best possible test for this research.

The Cornell Critical Thinking Test is also a very applicable test. It has been used since the 70s and has an emphasis on teaching evaluation. There is a test version for elementary through high school students and another one for advanced high school to college level students.

High school students do not really fit well into either group as they are right in the middle. It has a reliability of .76-.87 but has no test-retest data. This test is also a relevant test but does not provide the option of a pre and post test as needed in this proposed study.

Perhaps the most commonly used and recommended test for applications similar to the proposed research is the Watson-Glaser Critical Thinking Appraisal (WGCTA) which has been around since 1942. It has been a standard in the industry with almost 70 years and has a reliability of .81. With 80 multiple choice questions in 60 minutes or 40 questions in 30 minutes, this test focuses on inference, recognition of assumptions, deductive, interpretation, and evaluation skills. The standard deviation seems to be a little narrow causing some test-retest reliability instability, but it has two versions of the test. These two versions, Forms A and B, can be used as a pre- and post-test so the students do not become too familiar with a particular test. They test the students in several areas giving 5 subtest scores that can be used to better understand exactly where improvement takes place. The tests are intended for those with at least a 9^{th} grade education. This fits the students in this study and is a long tested assessment that can be effectively used for this research.

3 METHODOLOGY

This research was designed to investigate the effect of teaching the engineering design process (EDP) on the critical thinking skills of a sample of 10-12 grade students. In order to accomplish this, an EDP unit was taught to 147 students in 5 physics classes by the same teacher. Pre-and post-critical thinking tests were used to measure the change in CT abilities of the students. The data from these tests were analyzed according to a standard statistical analysis using a t-test. Qualitative data was also gathered from a voluntary concluding survey and formative assessments including observations, class discussions, and asking direct questions to students.

3.1 The Critical Thinking Test

One of the most important stages of the research was to find a test that measures exactly what is necessary to connect critical thinking skills to the engineering design process. As discussed in Chapter 2, the Watson-Glaser Critical Thinking Appraisal (WGCTA) was chosen as the most relevant and effective test for critical thinking skills in high school students. This test was administered online before the students were even familiar with the term EDP and then again, after they had a month long EDP unit. The Watson-Glaser test was given online, in a quiet computer lab. The students had 60 minutes to answer the 80 multiple choice questions. The tests were then scored by the Pearson Education company online and the overall scores and subtest scores were retrieved and compiled. The retake was done in exactly the same manner. Overall scores, subtest scores, and class averages were then analyzed.

Since the improvements made in critical thinking (CT) skills were being investigated, a pre- and post-test evaluation was sufficient. Regardless of what level the students started at, it was their progress that was valuable to measure and therefore, a control was not needed. It is assumed that students taking the same test would generate approximately the same test results one month later without any instruction. Instead of having a control, the pretest served as a baseline for the students and their final scores were compared to their initial ones to show the students' growth and progression from being taught the EDP.

The statistical analysis took place using standard statistical methods to study the effect, if any, of teaching the EDP on the students' critical thinking skills. Dr. Dennis L. Eggett in the BYU Statistics Department assisted this research by doing a t-test using SAS, a program to help create statistical data from the raw, original data. A paired, or repeated measures, t-test was chosen because of its ability to compare the test re-test data to eliminate compounding errors. This allows each student to be compared to his/her self without a comparison to other students. Each student was compared to themselves by measuring his/her increase. These scores were then averaging by calculating an overall mean and then the means of the pre- and post-test were compared. The means were then compared with student' GPA and gender. The results of these comparisons will be shown in Chapter 4. Each subtest score of the critical thinking skills test as described in Chapter 2 was also analyzed to see if the EDP unit increases one specific type of critical thinking skill. All raw data can be found in Appendix C: Watson-Glaser Critical Thinking Appraisal Raw Data and all statistical data can be found in Appendix D: Statistical Data produced by Dr. Eggett with SAS.

3.2 The EDP Unit

The goal of the unit was to teach students the Engineering Design Process. This process is a standard in engineering and is used in any number of situations. While the specifics of the process vary, the general steps are the same (see Appendix A: Summary of the Engineering Design Method by Dr. Ronald Terry, BYU). The steps include: identify the problem, research the problem, develop possible solutions, select a solution, construct a prototype, test/ evaluate the solution and/or prototype, share the solution, and redesign (Mass. Dept. of Ed., 2006). For high school students, the simplified process as shown in Figure 1was used.

The unit consisted of a series of labs and write-ups. Each day class began with an explanation and review of the EDP and answering questions from previous activities. The students were then given a challenge and a worksheet to keep track of their progress as a group. The labs were not intended to include new material but to primarily test their ability to combine the material from the past year into creative solutions to the challenges given them, thus utilizing the engineering design process as a method aiding in the problem solving process and developing the students' abilities to think analytically.

The first labs were quite simple involving paper rockets and paper towers. Paper rockets gave the students the opportunity to work through an optimization process using the EDP. Students built paper rockets and then added or modified different aspects of the rocket over a class period. The emphasis here was the test and evaluation part of the EDP. At the end of the class, they entered their final rocket in a competition. With the paper towers, students tested different designs to see the strengths and weaknesses of each one and eventually coming to a conclusion on the best possible design. This lab's emphasis was on the design process including brainstorming and creativity. Both labs were completed with extensive worksheets guiding them through the EDP by asking specific, detailed questions.

Their next big lab was to maximize the power output of a self-designed windmill. Students worked in small groups to create windmills that lifted a mass. The power equation (mass*gravitational constant*height/time or mgh/t) that they have used in physics during this school year was used to determine the winner. Instead of focusing on just one aspect of the EDP, this challenge covered the entire process and gave the students a little more freedom. The increased freedom allowed the students to more fully use and incorporate the EDP into their thought processes.

The electronics labs were the only ‘new’ material with which the students worked with. Many of them should have had a basic introduction to electronics in middle school so this was mostly a review with an added component: the motor. The skills they learned here were necessary for a basic understanding of the electronics that they will use throughout their lives. Added onto the basic circuits material, was a challenge lab that prepared them to incorporate their electronics knowledge in their final Rube Goldberg Project. They were asked to use their knowledge of circuits to solve a real life problem. It stretched them to use their critical thinking skills to come up with an innovative solution. The EDP acted as a backbone to give them structure in their approach. At this point in the unit, they needed little guidance and had learned to rely on the EDP to help them solve problems.

The culminating project in this unit was a Rube Goldberg Project built by many classes together. A Rube Goldberg machine does a very simple task in a very complicated way using a chain of events (i.e. a ball rolls down a ramp, knocking over row of dominos, that pushes a car with a needle on the end to pop a balloon). Each class was formed into eight groups of four students each. Group 1 from each of the 5 classes built Rube Goldberg Machine #1 together. There were only 8 total Rube Goldberg projects made, each one worked on by a group from each of the 5 classes. The purpose of this prolonged lab was to focus on helping them recognize the communication side of the EDP and the necessity of staying organized and focused. Their workspace needed be clean, organized, and they were asked to carefully document the work they did each day. It would have been much easier to absent-mindedly begin the project each time where they left off, but this process required the students to mentally engage in the work. With this protocol, the students had to pause to think through the previous class' additions and paperwork. Those brief few minutes appeared to help them approach their own work with greater forethought and care. It prompted the use of the EDP to create a methodology instead of jumping in blindly. Secondly, it reduced the number of man hours each student had to work on the project. Lastly, this enabled them to use the space in the classroom better. Instead of trying to fit 40 projects into the classroom, there were only eight, giving them more space and more flexibility.

The skills intended to be developed throughout this project and the entire unit, are based on learning to understand the situations, creative solutions, effective communication, and proactively seeking improvements. These types of critical thinking skills are extremely advantageous in the workplace as discussed earlier in this thesis. Technology has made the work market wireless and enabled people from all over the world to work together in an effective 24-hour workday while communication, teamwork, and analytical skills become ever more important (Augustine, 2005). This final project, the Rube Goldberg challenge, was designed to mimic this world condition and allow students to develop these necessary skills. The purpose of this research was to determine how teaching the EDP would affect the students' skills in this area.

3.3 Teaching Practices and Classroom Environment

In order to teach this process effectively, standard good teaching practices must be used. While there is always some disagreement on what makes an effective teacher, there are some normal teaching techniques that were followed to promote the best teaching possible. Having the same teacher for all 5 sets of students helped promote uniformity in the lessons and reduce the teacher effect. Each class underwent a similar schedule of activities and worksheets although presentation tended to vary slightly from class to class as human interactions varied. The general material and teaching techniques of the teacher remained consistent. The classroom environment may have had some impact on the results of this study but cannot be separated from the EDP. This is one of the limitations of this study. Some of the teaching techniques and the resulting classroom atmosphere are explained below.

Some type of paper work had to be required to keep students on task and recording their actions. This served as a formative assessment to let the teacher know the level of understanding the students have as they work through the labs. Without this, there would have been little physical evidence of their comprehension throughout the unit and corrections of misconceptions or miscommunications could not have been made. These worksheets served as a progress report so that teaching practices could be adapted and issues addressed. (See Appendix B: Worksheets for the EDP unit)

Gradual release of responsibility was a much needed technique in this unit. Gradual release of responsibility, or scaffolding, means that the teacher starts the students off with a lot of direct guidance to show them how to do a task and then gradually allows them to take full control of the material. This method has been particularly effective with these classes already and will be familiar to the students. In order to use this method, the worksheets required for each of the labs contained a reducing number of guiding steps and questions. For example, in the “pick a solution” section of the EDP, the first worksheet asked 3 or 4 questions detailing how to pick a selection to help the students narrow down their options, while the last worksheet simply asked them to pick a solution and explain why they picked it. This gradual release of responsibility allowed the students to train their minds to ask their own questions as suggested previously. Without the same questions being asked, students were also free to ask additional questions helping them find the best solution possible.

Working in small groups is part of the design of the EDP as well as part of standard classroom protocol. The EDP is intended to be used in group situations. As the EDP is one form of problem-based learning the intention is to work in small groups to accomplish a common goal (Barrow, 1996). This collaborative group work helps to expand their understanding as they each add their perspectives and ideas to the groups’ collective thought process. As the students have been using small groups all year, this technique was comfortable and familiar to them, and they already knew how to work effectively with others. Continuity in the classroom is part of establishing an effective classroom behavior plan and would help to keep students on task without confusion.

The bulk of the unit consisted of challenge labs. Challenge labs are labs where very little direction is given but the students are given a challenge or task to perform. Typically the best student projects (furthest, fastest, most accurate etc.) were given extra credit as further motivation to excel in challenge labs. As the students have done challenge labs over the year, approximately 1-3 a month, they would be familiar with these types of assignments. Labs are the best way to allow students to use the EDP in a hands-on way (Bottomley et al, 2000). After given these challenges, students were required to work through the EDP to brainstorm ideas, test models, and present their optimum solution to the teacher, and possibly the class. While students may simply memorize the EDP, that doesn't give them time to practice using it. In order for the students to truly make it a part of their thought process, they have to use it. Giving them multiple opportunities to use the EDP with varying levels of guidance allowed them to incorporate this process into their thought process potentially increasing their critical thinking skills.

Formative assessments in the form of notes were also taken. Typically, as a teacher, mental notes are taken so that the lesson plan can be revised for later class periods or later days. These mental notes are invaluable sources as information about miscommunications and misconceptions and are used to edit the lessons in order to teach more effectively. While these notes are typically taken mentally, a physical record was taken for the purposes of this research. Direct quotes from students in the classroom were also taken. Questions such as "What do you like about the EDP thus far?" or "How has the EDP helped you in your daily life?" were asked to allow the teacher to evaluate depth of their understanding. These notes could be used in future studies to understand how the EDP can be better taught and how to alter future labs and worksheets used. They were also used to substantiate the quantitative statistical findings by conducting a brief qualitative analysis.

3.4 Voluntary Concluding Survey

After the post-test, a voluntary concluding survey was given to the students. The purpose of the survey was to get the students' perspectives of the EDP unit and how they felt they were impacted. As it was voluntary, only 88 out of 143 students took the survey. Students who did not take the survey could have offered either positive or negative comments, but without data, it is too uncertain to discern. While this does not give us concrete evidence for all students, the data collected was insightful to how some of the students felt about the EDP. Because it was anonymous, we can assume students felt more comfortable speaking their minds without fear of being judged or disliked by the teacher for their responses. This has the potential to allow for more open communication although it does not necessarily allow a connection between their test scores and their attitude to be formed. Some extra questions were asked about the class in general for the benefit of the teacher and are not included in this study. The questions in Figure 4 were specific to this unit; they were used to get an idea of how the students were affected by the teaching of the EDP and if they were able to internalize the EDP process.

1. What was the biggest challenge on the Rube Goldberg?
2. What was your favorite project we did?
3. What are your overall thoughts/comments on the EDP unit?
4. How much did you enjoy the Rube Goldberg Project?
5. Did you find the EDP useful in your everyday life?
6. How has learning the EDP helped you? What is the most useful part of the EDP?
7. Was the EDP a new concept for you? Explain.
8. After going through the EDP unit, was is your overall take-away? What did you learn? What will you use? What did you learn about yourself, physics engineering etc.?

Figure 4 Survey Questions

4 QUANTITATIVE AND QUALITATIVE DATA

Data for this study was collected both and quantitatively and through student reflections. The quantitative data was gathered in the form of pre and post scores on the Watson-Glaser Critical Thinking Appraisal as total score, total percentile, inference scores, recognition of assumption scores, deduction scores, interpretation scores, and evaluation of argument scores with connections to their gender, GPA, and grade level. The qualitative data was obtained by the teacher's informal questions, a review questionnaire, and observations.

4.1 Quantitative Data

The Watson-Glaser Critical Thinking Appraisal was chosen for its long standing reliability and critical thinking subtest scores. Pearson Education compared the student scores to a national database of test takers in each age group to give a percentile. This percentile gives an idea of the rank of the students compared to others of the same age group. Percentile data was used to compare the students overall growth as another way of equalizing the pre- and post-tests and raw scores were used to compare the subtests as they were only given as scores. Statistics concerning age, grade level and gender were also used in the comparison.

The Watson-Glaser Critical Think Appraisal has two forms that were used: A and B. These forms were created for test retest opportunities and the testing manual states "Users of the Critical Thinking Appraisal may regard Forms A and B as equivalent, alternate forms. Raw scores on one form of the test may be interpreted as having the same meaning as identical scores on the other form" (Watson and Glaser, 2008). This allows direct comparison of the two test scores of each student to show their growth. Each student score was reported with the total score, total percentile score, and each of the 5 categories' raw scores out of 16 possible points. This data was collected from the company and compiled by the author. It was then analyzed using SAS software by Dr. Dennis L. Eggett of the Brigham Young University Statistics department.

Means were found by averaging the scores in each category or subscore. The standard deviations (SD) were calculated to show the spread of the test scores. The narrower the SD, the more unified or convergent the scores were. T-tests were conducted between the two items to be compared. A positive t-value indicated a positive relationship while a negative t-test leads to a negative relationship. P-values are then calculated to determine if the data is significant. A p-value of less than 0.05 means the data is statistically significant while above 0.05 is not considered statistically significant. A statistical significant declaration denies the null of the statement, not necessarily guaranteeing an absolute connection; it narrows the probability that the alignment was by chance.

4.1.1 Overall Test Comparison Scores

The test scores were compared using the overall percentage as well as the individual test scores. The overall average for all of the classes was in the 61.17th percentile for the pre-test and 63.89 percentile for the post-test, with an overall gain of 2.72 percentiles. The standard deviation also increased for the post test showing a greater dispersion of scores. A grade level comparison will look closer at the reasons for that. A t-test was performed for the overall percentile gains and p value was determined to be .1473, which is not statistically significant. Therefore, while they did slightly increase, there was no significant growth in the overall average percentiles scored on the Watson-Glaser test throughout all of the classes.

Interestingly, when the overall gain score is evaluated instead of looking at the percentiles for each student, we see an improvement in statistical significance. The overall total gain percentage p-value was .0586, which is nearly significant. This means that out of 80 questions, on average, the students scored 1.11 questions higher on the post test than the pretest. While not extraordinarily significant, it does show the general trend. The difference in significance from the raw score compared to the percentile makes one question the value and accuracy of raw score verses percentile. The percentile scores are only available for the overall test and not for the subtest scores, so the subtest scores will only be evaluated with raw score data.

4.1.2 Grade Level Comparison

The grade level comparison data shows quite a bit of variance between the grade levels. For grades 10, 11, and 12 the p values found in a Least Squares Means test are, respectively, .0993, .0089, and .0419 showing the relationship between grade level and overall percentiles gains. Sophomores, or 10th grade students, could have been positively affected although not statistically significantly. Juniors, or 11th grade students, were certainly positively affected as they had an average 8.07 percentile increase after participating in the Engineering Design Process unit. Their gain is statistically significant and quite prominent.

The seniors, or 12th grade students, also had a statistically significant p value of .0419; however, it was in a negative direction. Senior students had a huge decrease in their test scores with an average -16.43 percentile drop. We could conclude that seniors' critical thinking skills were negatively affected by the unit which is a remote possibility. Upon further investigation, we realized that this test was given at the very end of the year, on one of the last days before graduation. Many of the students had to come in on their own time, during lunch or after school in less than ideal conditions, as it was also senior ditch day.   Senioritis, or a lack of concern for grades and educational practices, may have kicked in hard that last week and their test scores may be a result. While neither answer for the decline can be proven, experienced teachers know the impact of senioritis and will tend to accredit that as the reason. As a teacher, the author will take the liberty to make that assumption and look at the data in another way.

Of the 6 seniors, 5 of them, all female, decreased significantly in their raw test scores with declines of -3, -10, -17, -7, and -9 an average decline of 9.2 points or questions on the test and an average percentile drop of 30% (actual change in percentile were -10%, -10%, -35%, -35%, and -60% for the 5 senior girls). The one male senior had an increase of 1 point and 5 percent. Because of this statistical and logical anomaly with the seniors' scores, another analysis was done with only the 10th and 11th grade students' scores. This analysis showed an overall statistically significant increase in test scores. While the average pre-percentile score was lower without the seniors, 60.56 compared to 61.17, the post-percentile score increased, without the seniors being 64.47 and with them 63.89. (see Table 1)

Table 1 Overall Percentile Comparison With and Without Seniors

	With seniors (10th, 11th, and 12th grade students)	**Without seniors** (10th and 11th grades only)
Number of Students	142	136
Pre-Percentile Mean	61.2	60.6
Post- Percentile Mean	63.9	64.5
Gain Percentile	2.73	3.91
Gain Percentile P value	0.147	0.0361
Gain total score	1.11	1.49
Gain total score P value	0.0586	0.0110

By taking out the seniors' questionable data, the p value of the gain percentile was .0361 which is certainly statistically significant and the gain total score had a p value of 0.0110 which is also significant. This means that the students had an overall increase in their test scores on the Watson-Glaser Critical Thinking Analysis. Only six seniors took the pre and post test and by taking those six students out, we see a large increase in the statistical importance of the data for the other 136 students. 10^{th} and 11^{th} grade students who participated in the Engineering Design Process unit improved their critical thinking skills as measured by the WGCTA. The seniors may also have increased in their ability to think critically and solve problems, but the way they took the test may influence the data to eliminate all evidence of their growth. For the rest of the data analysis, both the data with and without the seniors will be considered.

4.1.3 GPA Comparison

Table 2 Comparison of GPA to WGCTA Gain Percentile

	t value	Pr>|t|
10, 11, 12 students' GPA	2.83	0.0054
10, 11 students' GPA	2.73	0.0071

GPA was also analyzed in comparison to gain percentile. In Table 2, we see that both with and without the seniors we have a statistically significant, positive connection. This means that the better the student, the more the increase in critical thinking skills they had from the Engineering Design Process unit. Interesting, even with the poor scoring seniors, the connection holds true. The p value with all three grades was 0.0054, and without seniors 0.0071, both showing a very strong connection between GPA and percent gain. All three grade levels had a statistically significant, positive connection between their GPA and their percent gain.

This data is interesting because so many of the high GPA students tend to be more grade oriented. By nature of the material, this unit was much less grade based and yet the over-achievers still learned the most. Students are then, perhaps, much more engaged by inquiry, hands-on material than we recognize and more intrinsically motivated rather than externally motivated by grades. Some possible reasons that the material could have been more effective for higher achieving students include but are not limited to: the material was more relevant to them; it was not as much of a shock for them as they possibly were used to using these type of thought processes and it was easily enhanced; it could have been at a more engaging and challenging level for them; the lower achieving students could have given up because of a particular teaching method or challenge; or perhaps, higher functioning students simply learn more from hands-on projects as it coordinates with the way they naturally learn. The reasons behind this statistic could benefit from further investigation.

4.1.4 Gender Comparison

Table 3 Gender Comparisons

	Mean Percentile Gain	P value
10, 11, 12 grade female students	-0.226	0.923
10, 11 grade female students	1.47	0.560
10, 11, 12 grade male students	8.33	0.0010
10, 11 grade male students	8.40	0.0011

We can see the impact of those 5 senior female students in the comparison between the data with the seniors and without. With the seniors, there was an overall mean decrease of -0.226, while without the questionable senior data; there is an overall increase of 1.47, neither one statistically significant. The males on the other hand, were hardly impacted by that 1 senior who barely increased on his test. With the senior, the boys had an increase percentile gain of 8.33 and without him, 8.4. The p-values for the same are, respectively, 0.0010 and 0.0011.

Table 4 Female Means and Standard Deviations

	10,11,12 Mean	10,11,12 SD	10,11 Mean	10,11 SD
Gain Percentile	-0.226	24.3	1.47	23.5
Pre-Percentile	62.8	22.3	62.3	22.6
Post Percentile	62.6	24.7	63.7	24.0

Table 5 Male Means and Standard Deviations

	10,11,12 Mean	10,11,12 SD	10,11 Mean	10,11 SD
Gain Percentile	8.33	16.6	8.40	16.7
Pre-Percentile	58.1	22.7	57.4	22.4
Post Percentile	66.4	22.8	65.8	22.7

The standard deviations shown in Table 4 and Table 5 have been included because of the evident differences between the male and female students. The female students have a SD around 24 while the male students' value is 16 or 17. The female students have a much wider distribution with SD of 24.3 and 23.5 for all female students and then just 10th and 11th grade female students. The male students are much closer together with only 17% variance. The male students started out lower than the females but ended in a higher percentile. A few possible inferences can come from this. The first is that some may argue that female students didn't really learn and use the EDP but by observation, they seemed to talk about it much more and seemed to really appreciate the process and incorporate it in their lives. Of course, in general, girls also talk more than boys, especially to female teachers. Another possible explanation is that the female students already had the EDP as part of their thought processes, as evident by their initially higher test scores, and so didn't gain nearly as much since it wasn't revolutionizing for them. The male students didn't use an EDP type process as much before and with the introduction of it, they had statistically significant gains. The latter is more indicative of the data and their attitudes and conversations in class. According to observation, the boys fought the structure and organization of the EDP initially but seemed to grow the most from using the EDP. Perhaps high school age boys do not typically think through things as much as their female counterparts because girls mature earlier. If this is the case, it could be more beneficial for girls to receive this type of education earlier to match the timing of their CT skills training with the development of their brains. With much speculation as to the reasons behind this data, these topics would greatly benefit from further investigation.

4.1.5 Individual Test Comparisons

While the Pearson Education company, who distributed the test, does not recommend looking solely at individual test scores to judge a person's critical thinking skills, the areas in general show the trends for the group as a whole. Individual test scores can experience a small shift because of the small quantity of questions for each section. Students were asked 16 questions in each of the five areas: Inference, Recognition of Assumptions, Deduction, Interpretation, and Evaluation of Arguments. These questions usually referred to a short paragraph or scenario they had just read. These scores are looked at as raw scores out of 16.

Table 6 Subtests for 10, 11, 12 Grade Students

Subtest	Mean Pre-test	Mean Post-test	Mean gain	Pr>|t|
Inference	7.27	7.09	-0.176	0.495
Recognition of Assumptions	9.94	10.5	0.570	0.0563
Deduction	10.4	9.93	-0.423	0.105
Interpretation	11.1	11.2	0.0986	0.638
Evaluation of Arguments	10.9	11.9	1.00	<.0001

Table 7 Subtests for 10, 11 Grade Students

Subtest	Mean Pre-test	Mean Post-test	Mean gain	Pr>|t|
Inference	7.31	7.00	-0.318	0.343
Recognition of Assumptions	9.84	10.5	0.691	0.0225
Deduction	10.3	9.97	-0.360	0.171
Interpretation	11.0	11.2	0.199	0.349
Evaluation of Arguments	10.9	11.9	1.03	<.0001

4.1.5.1 Inference

The inference section of the test is used to determine the students' abilities to discern truth from a given passage. The manual gives the following description of the inference section: "Discriminating among degrees of truth or falsity of inferences drawn from given data" (Watson and Glaser, 2008). This type of critical thinking skill is not directly addressed by the Engineering Design Process and therefore, the results are not surprising. The p value for all grades is 0.495 and without seniors, it is 0.343. This shows no statistical significance of the EDP unit on this portion of the test. There is not a direct connection (see Table 6 and Table 7)

4.1.5.2 Recognition of Assumptions

"Recognizing unstated assumptions or presuppositions in given statements or assertions" is the definition given of this subtest of the WGCTA (Watson and Glaser, 2008). As shown in Table 6 Subtests, in this subtest, students increased an average of 0.570 points out of the 16 possible points. This was nearly statistically significant with a P value of 0.0563. This is slightly above the cutoff of statistical significance which is 0.05. There was a positive relationship here with students averaging 0.57 questions more on this section of the WGCTA, but not of statistical significance.

When the data for just the 10th and 11th grade students is analyzed, the increase is certainly statistically significant. The mean gain is almost 7% with a p value of 0.0225 meaning that students who participated in the EDP unit increased in their ability to recognize assumptions. Asking questions was an area of emphasis in this unit and allowed the students to study out a problem presented before them and then check to see if the conclusions follow a logical thought pattern. Students were better able to separate out what they know and what they thought they knew from assumptions after participating in the EDP unit. (see Table 6 and Table 7)

4.1.5.3 Deduction

The Watson-Glaser Form A manual (2008), describes this test as "Determining whether certain conclusions necessarily follow from information in given statements or premises." On the deduction subtest section of the Appraisal, students had a mean of -0.423 with a P value of 0.1045 (see Table 6 Subtests). This negative relationship was not statistically significant. The data that did not contain the seniors' scores was very similar with a mean of -0.360 and a p value of 0.171, even less significant than with the seniors. (see Table 6 and Table 7)

Deduction was not one of the subtests that was statistically significantly affected by the EDP unit. Since, it is considered part of the engineering design process, it was emphasized in the unit. Taking away information from the big picture wasn't specifically addressed and is something most students struggle with normally. In a future study, it should be considered to make this a greater emphasis within the unit.

4.1.5.4 Interpretation

This subtest is described by the WGCTA Manual as such: "Weighing evidence and deciding if generalizations or conclusions based on the given data are warranted" (Watson and Glaser, 2008). These skills, according to the appraisal, were not significantly increased statistically. The students' pre-test mean scores were higher in this section than any other leaving less room for improvement. They started and ended with a mean value around of 11. With all students, the p value of 0.6379 and without the seniors, it was 0.349, both of which are not statistically significant. (See Table 6 and Table 7)

Again, this section was not heavily discussed or used in the EDP unit although there may still be some connection to the process itself. Creating generalized conclusions was not part of the students' asking, creating, building, and improving process, although it could have been emphasized better if they had been required to present their projects to the class with their final conclusions. This would be a better use of the EDP as several versions of the EDP have communication and presentation as the final step (see Appendix A: Summary of the Engineering Design Method by Dr. Ronald Terry, BYU) and it is considered an element of CT (Paul, 1997). With limited time, however, this was not integrated as a piece of the unit.

4.1.5.5 Evaluation of Arguments

This subtest had by far the greatest significance to the overall research. Students were asked to "distinguish between arguments that were strong and relevant and those that are weak and irrelevant to a particular question at issue" (Watson and Glaser, 2008). Starting out with a relatively high score of 10.94 and ending at 11.94, showing a 1.00 and 1.03 (without seniors) question increase in their ability to evaluate arguments. The p value for both with and without the seniors was <0.0001 showing a certain, positive relationship. Students who participated in the EDP unit increased their critical thinking skills in the area of evaluating arguments. (See Table 6 and Table 7)

The evaluation of arguments had by far the greatest connection to the EDP material covered in class. Determining if an argument is strong would involve asking questions and going deeper into the real question. As a class, the students very successfully learned this. To start a lab, the challenge would be stated in as few words as possible, after which, the students were then given time to ask as many questions as possible about it to really uncover the task and look beyond the surface. The students developed rapidly in this exercise as it was repeated with each lab. Students' questions quickly got deeper, more thought out, more specific and seeking greater understanding. They were frequently overheard asking questions to their peers about the project as a means to find an effective solution. In their qualitative survey, many of them stated this as the most useful part. One said,

> One of the best things you did, Miss Ure, was tell us as little as you possibly could at the beginning of class, and have us use the 'ask' step to figure out what the goal would be, and the supplies that we would be allowed to use. *

* All quotations from students were left in their original format to preserve the student's meaning and prevent the author from imposing her bias on the students' personal comments.

The challenge was stated as vague as possible so students had to stagger in the dark until they understood the challenge by asking questions. This mirrors real life and allowed them to dig deeper into the simple statement they were given to find the real meaning. It allowed them to take a good, hard look at the argument and evaluate it, learning yet another aspect of CT skills.

4.1.6 Quantitative Data Conclusions

The quantitative data evaluation leaves us with split information and many questions. Overall, students who participated in the Engineering Design Process did not statistically significantly improve in their percentile but nearly statistically significant in their raw overall score. Seniors had a statistically significant decrease in their test scores from beginning to end, probably due to it being the very end of their high school careers and their attitude about taking yet another test. By eliminating the possibly misleading and inaccurate data from 6 seniors, sophomores and juniors both had statistically significant improvements in their test scores. Male students had lower pre-test scores but had a much greater and statistically significant increase in their test scores. Female students started higher than their male counterparts but decreased insignificantly statistically. Students with a higher GPA had a greater gain than students with a lower GPA meaning that higher achieving students learned more from the EDP unit.

The subtest scores showed the specific areas where improvement happened. The only subtest with a statistically significant increase was the evaluation of arguments, which has an undeniable positive association. The EDP's cycle includes the following steps: Ask, Imagine, Plan, Create, Test, and Improve. The evaluation of arguments subsection could have been positively affected by the ask stage. Asking questions was part of the introduction to every challenge and was rated by students to be of prevalent value in the EDP (see 4.2.2 in the Qualitative Data analysis). The other subtests of the WGCTA, inference, recognition of assumptions, deduction, and interpretation don't seem to fit into the EDP quite as well. Recognition of Assumptions could also have been benefited by the "Ask" part of the EDP and it was statistically significant for the sophomores and juniors.

While this test did show some interesting trends, it may not have evaluated the idea of critical thinking relative to the EDP. The research's purpose was to determine if teaching the EDP could increase students' critical thinking skills. The challenging thing about this question is defining what critical thinking skills are exactly. The Watson-Glaser Manual quotes Dressel and Mayhew in defining critical thinking skills as the ability to "define a problem…select pertinent information for the solution of a problem…to recognize stated and unstated assumptions …formulate and select relevant and promising hypotheses… [and] draw valid conclusions and judge the validity of inferences" (Dressel and Mayhew 1954 quoted in Watson and Glaser, 2008). The WGCTA's has been validated in testing it's five subtests of inference, recognition of assumptions, deductions, interpretation and evaluation of arguments by Houle (1943) and Morse and McCune (1957); it does accurately test these 5 principles of critical thinking skills.

4.2 Qualitative Data

Qualitative data was gathered in a variety of ways. Informal observation of and questions to the students in each class were two of the ways to gather information. Attitudes, behaviors, and level of engagement were all observed casually by the teacher and without specific objectives. Because the teacher knew her students fairly well by the end of the year, these observations measured the changes from the EDP unit as they differ from the established norm of the class and students. Informal discussions and student evaluations of the unit were also collected. After the final WGCTA, an optional, short survey with very open ended questions was given. 92 out of the 142 students (64.8%) voluntarily participated giving anonymous and honest data. The open ended questions were designed to get a general feeling of the attitude of the students and what they were most drawn towards (See Appendix E: Survey Questions and Appendix F: Student Responses to Survey for full responses). This data was then organized and themes were pulled out to summarize the students' reflections of the unit. From the EDP itself, the ask, plan, and improve steps were the most popular to the students although all they wanted to do initially was create. Organization and taking time to process the challenge were aspects of the EDP that students also appreciated and felt they grew in. These themes will be presented in this chapter with input from observations, informal discussions, and the final survey.

4.2.1 New Process

The engineering design process itself was not received particularly well at first, probably due to its association with the worksheets given to the students. When students were first introduced to the process, they were confused and irritated that they were learning something new at the end of the year. One student even reminisced in the concluding survey:

> At first, I had no idea what you were getting us into and I didn't really like it. I was thinking I would rather do nothing, than do this. But it was actually pretty fun! And using the EDP within the labs really worked. I think that we had a better outcome from our projects because of it. We all sat down and really just thought and I think it saved us more time because there were less errors. Although it seems more time consuming to just sit down and think, it really helps limit your wasted time on stupid errors.

Their initial anxiety was generally overcome by their effective use of a new tool. Eventually, many students recognized it as a benefit to their thought process instead of hindering. While the EDP itself was a new name, it was not necessarily a new concept. 71% of students said they had used it before in life without the name and 11% said they have used it in a science class before but 17% said they had never heard of it at all before. (See Figure 5)

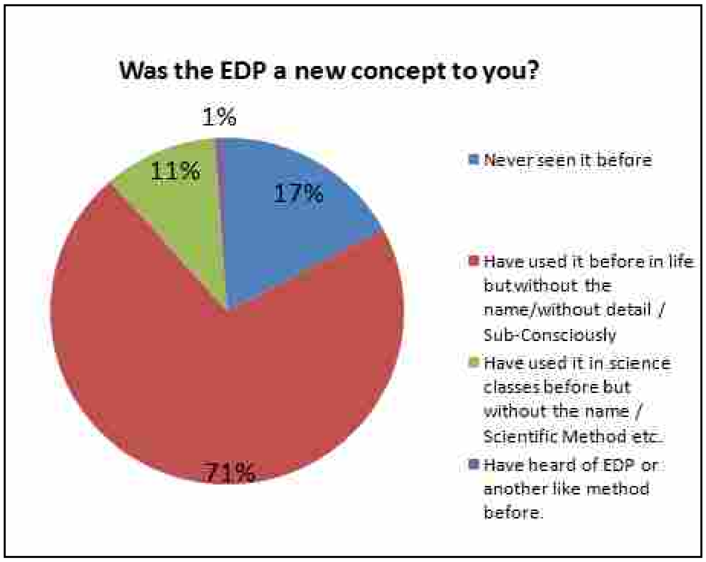

Figure 5 Was the EDP a New Concept to You?

It is interesting to note that the majority of students seemed to be familiar with the ideas but have rarely had structured guidance in using the EDP or anything similar including the scientific method. This method should have been taught in every science class since the students were young or even this year in physics. The scientific method is not sinking deeply into the students if they don't recognize it as related to the EDP process of asking questions, thinking through possible solutions, designing the experiment, trying it out, and refining their solutions. And yet, students see themselves using this process on their own. Table 8 is a simple comparison of the scientific method and the EDP. The scientific method is used by scientists to understand the world (biology, chemistry etc.) and the EDP is used by engineers to create new innovations. Although there are many similarities, the scientific method is for facts and the EDP is for creating. Using this creative process to come up with solutions to challenges allows students to develop greater CT skills.

Table 8 Scientific Method vs. Engineering Design Process

Scientific Method	**Engineering Design Process**
Problem	Ask questions
Hypothesis outcome	Imagine answers
Materials and apparatus	Plan solution
Procedure	Create
Data and work	Test
Evaluation of data	Improve
Conclusion	(presenting/sharing results)

Although students claimed they already used the ideas in the EDP, there was still a drastic change in attitude and direction from the beginning of the unit to the end. One student said, "Before I may have followed the EDP unconsciously, but now that I'm aware of it, I think about it faster and things make sense quicker." Students seemed to appreciate the direction and clarity the EDP gave to their current thought processes.

4.2.2 Asking Questions

A big change observed in the students was in their ability to ask questions. Initially, the students were given a very brief, simple statement about their task. For the first minute or so, they simply stared at the teacher before making really ineffective comments and questions. Students were then guided to the right questions with comments like, "Alright, if you don't have any questions, are you guys ready to go?" which merited an immediate, "No! Wait, what are we doing? What is the purpose? etc." Further ridiculous questions got them thinking, like, "Do you guys have any titanium for the rockets? That would be awesome!" to prompt them to think about material limits to the solution. Through this process, students began to ask their own questions and formulate a mental image of what they were doing. If the students had been released to work after the initial statement, which teachers, including the author, do quite often, they would have been completely confused and lost in the assignment. The asking questions stage allows students to internalize the challenge before getting to work.

Students really latched onto the asking stage. One student who wasn't necessarily partial to the entire EDP idea still said,

> The most useful would be asking questions…I will use the asking questions the most.

Another student said,

> I like the ask part of the EDP, because it makes you dig down and really figure out what's wrong, and what needs to be fixed.

Asking questions helped the students determine what the task was, what they needed to do, what limits they had, and what the final goal was. Students often start working on a project limited by their tunnel vision. They may work hard but miss the overall concept or challenge because they do not step back to see the big picture. The process of asking questions enables students to become mentally engaged in the assignment before physically engaged, so that when they do work hands on, they are focused and more efficiently, making fewer mistakes.

4.2.3 Organizations Skills/Plan Ahead

Just asking questions is not enough to help students create their solution but it does allow the thinker to become more organized and plan ahead. One student said,

> My overall take-away is to slow down, ask questions, prepare before hand, and break the bigger picture down into smaller pictures. Things like, "what is the goal?" "How can we accomplish it?" "What things can be changed?" and most importantly, "How does this apply to the real world, what have those real world engineers done to succeed in thier work, and how can I mimic those achivements on a smaller scale?" are the big questions I have learned to ask before even getting started.

This student vocalized the need to pause, to break down the challenge into manageable pieces before even beginning. The preparation changes seen were incredible. At first, students were not allowed to touch the supply table at all in the first 5 minutes of group work. Some would try but, reproved by the teacher, soon realized that they needed to brainstorm and anticipate some of the problems they would have. After a while, they did not have to be reminded to wait, they immediately started reading the last group's entry and sketching their own ideas, talking about plans and making assignments for each person. They would talk about ideas instead of just trying the first one the loudest person had. Another student wrote,

> I learned that sometimes I just need to take things slow instead of jumping right into them. That yes, it can help when I think things out or, in the Rube Goldberg project, read what the other group wrote.

This process of slowing down and pausing helped students to plan out their ideas and find mental clarity before trying to put ideas into action.

Another part of the planning phase is becoming organized. Students, like people in general, find it difficult to organize their thoughts. When coming in to talk about problems they are facing or challenges in the classroom, they describe the situation in such confusion that it is hard to follow. At this stage in life, many students are figuring out how to think for themselves and often do not have a firm mental structure in place for finding solutions to challenges. Using the EDP helped structure the way students thought to enable them a more efficient thought pattern and a clearer mind to discover new ideas. When asked what they learned, one student said, "organizing what you need to accomplish helps a lot." 18 out of the 88 students that responded to the optional survey listed organization and clarity in their free responses to questions like, "What was the most useful part of the EDP?" or "What are your overall thoughts/comments on the EDP unit?" I know the students enjoyed it as they excitedly got to work, but I was surprised how many of them mentioned skills like this instead of responding to the survey with "this was cool" or "this was lame." Their qualitative responses show their engagement instead of their usual passive, get-it-done-and-over-with type attitudes.

It was evident from the teacher's familiar associations with the students, that they gained an impressive clarity of direction by the end of the EDP unit. For example, the first day of the Rube Goldberg projects, the students sat there and stared at the teacher and then kind of argued with each other, but by the last few days, they were unified and organized in their direction. They came in and after our opening, they immediately got to work, assigning out tasks and working hard. It would be interesting to continue this study to compare the amount of time each student was engaged in EDP class work to an average class. With the EDP unit, each student knew what they needed to do and they went to work. When asked what they learned, a student said,

> I learned the importance of good planning. When you plan it all out and brainstorm before you start, you make less mistakes and have a lot less to worry about, as opposed to just putting ideas together as you go along and not knowing the result until it happens.

This student showed how important planning is to have clarity in the project. At first the time it took to plan was very irritating to the students, but eventually they came to value that time to reduce mistakes and allow clarity before working intensely.

Part of the organization process for students is writing their thoughts down. While students initially whined about writing down ideas, they seemed to have a positive attitude towards it after they tried it for a while. Clarity and organization followed. A student said, "

> I like the EDP because it helps me become more organized. I feel like my thought process is more clear. Before, I got confused with my own thinking because I never really thought through the whole process. After learning about the EDP, I realized how much I use it in my life without realizing. If I remembered to used the EDP more often, then it would make many of my decisions so much easier

> and less confusing. Especially the part where you write everything down. I can see everything more clearly.

The EDP helped this student organize his/her thoughts and bring clarity to the way he/she looked at life. Another student clarifies why the EDP helped so much:

> It helped me organize what things I knew were true, some things I assumed to be true, and things that weren't true.

This student used the EDP to organize his/her thoughts to identify truths about ideas or notions. This directly corresponds with the CT subskill of inference and recognition of assumptions. Separating truths from assumptions can allow a student to proceed in the right direction with fewer mistakes. Another student noted,

> The most significant part of the EDP is writing and drawing your ideas down. Without it, and not designing it there is absalutley no point in creating because you have no foundation to start from. Learning the EDP has helped me by expanding and understanding how the proccess works in a more clear point of view.

Organization and planning skills were some of the most recognized skills by the students both from their own comments and the author's observations. These skills allowed students to put organization and structure into their complex assignments so that they could work more efficiently and effectively to come up with better solutions. Organization skills are a necessary part of CT skills.

4.2.4 Opportunity to Improve

Although students found that the EDP helped them make fewer mistakes, many students also commented on the freedom the EDP gave them to make mistakes and learn from them. Typically, education focuses on what is right and wrong, condemning incorrect responses. In the EDP, 'wrong' solutions are on the path to better ones. One student commented on the EDP,

> I liked it a lot because it was more hands on and it was almost impossible to be wrong...you would just try again.

This is a much more real world outlook. Instead of being afraid of being wrong, students felt the liberty to test out their ideas with the comfort that they can try again and continually improve. This gives an increased confidence in their ability to work out a solution, not just the teacher's solution or the one right solution, but their solution. Another student commented on their newfound confidence in being able to solve problems:

> It has helped me solve problems in a more efficient manner, to look at both sides of the problem and think of ways on how I can solve it. I think the most useful part is the test/improve section. Instead of giving up on a project, you are able to brainstorm and come up with better ideas that can help solve the problem you are trying to fix.

The improve phase of the EDP is one that students found to be important and useful. It allows the problem solver an opportunity to move through the cycle again by continuing to ask questions, recognizing the imperfections of the current solution, and finalizing a better solution. Often, these few steps take little time but make the solution that much better. One student said,

> I think the most important step from the EDP I've learned is the improvement step. This helps me realize what I can improve on the project and different ways I can

During an informal mid-unit conversation, students also commented,

> You find the weak points and fix them.

> I like being able to test it more than once. So you can improve.

These students recognized the opportunities available after an initial solution was found. This process of continual refinement is helpful on a personal development level as well as in any area of life.

Along with improving comes the improvement of ideas. Group work was a huge part of this process. Because of the time set aside to plan, students had the time to hear everyone's ideas. With purposefully more time than needed, students who tended to be quieter were able to fill the gap by adding in their valuable, often unheard thoughts. In our group discussion, one student commented on group work,

> We can combine the ideas with other ones to make a better design.

This was a huge step for the students. Each person comes to the group with what they think is the best possible solution, but through the EDP they were able to combine ideas to come up with something better. They saw the value of group work. Their groups changed for every activity and while they rebelled at first, they came to appreciate the variety of insights other students had. A few students gave their overall reaction to the EDP as follows:

> I learned so much about teamwork, problem solving, and am starting to reconize it in my life. I enjoyed the projects and the creativeness that it brought. It also helped me see other group's members strengths and solve how we could implement their ideas and strenghts into the project

> …I've learned, more than anything, how to work in a group setting; that everyone has ideas, you just have to figure out the way to make someone voice them. I've learned how key communication is…

These students learned how valuable each student's ideas are and how important it is to listen to them. Group work is a major aspect of the working world and skills learned in this area are highly valuable. By using a team, group members' individual critical thinking skills are magnified as they learn to sort out other students' ideas and perspectives.

4.2.5 Beyond the Classroom

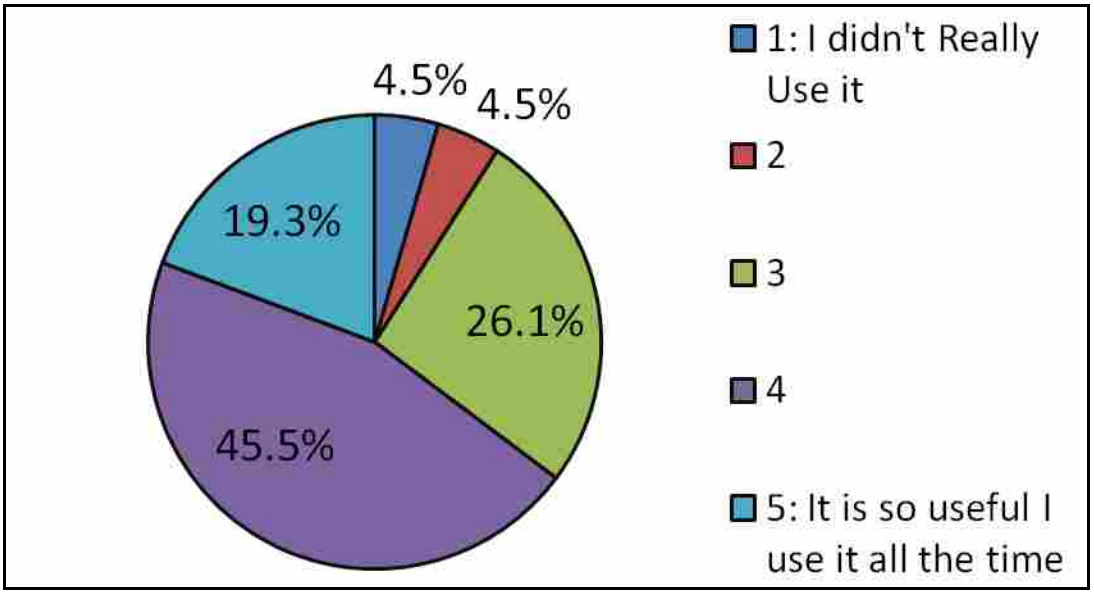

Figure 6 Did You Find the EDP Useful in Your Everyday Life?

One of the research questions was to see if the EDP could help students develop critical thinking skills that they could take beyond the classroom. Seeing the practical applications of their new critical thinking skills in their daily lives enabled students to adapt these CT skills across curriculum and in non-academic settings. Figure 6 above shows how students responded in a post-unit survey to the question “Did you find the EDP useful in your everyday life?” with 71.6% considering it useful or very useful. In order to encourage the EDP to further become part of their cognitive process, optional homework was assigned every night to use the EDP outside of class. As a warm-up and reminder of the process, the first 5-10 minutes of each class period were given to the students’ to share their experiences with the EDP outside of class. Students shared experiences from their personal lives such as arguments with parents, understanding emotions, dealing with sports teams, evaluating jobs and conflicts, and many more. The following is an excerpt of a typed conversation the author had outside of class with a student:

> Teacher: Has the EDP helped you outside of class at all?
>
> Student: actually it really has!! i know it has helped me in soccer... actually just yesterday i was playing a new postion on my team and i used it... i had to ask myself what was going to be hard and then i had to plan out how do succed and at half time i changed things that werent working and i fixed it! it really can apply to any situation that you are put into because every situation has questions to be asked and also different ways of sloving it. some ways work better then others and you just have to figure out what way works the best and that take lots of trying different things out! ☺ ….
>
> Student: it has been really helpful!
>
> Teacher: I'm so glad you used it! ...
>
> Student: I never have before because I just try to dive into things head first and take it all on at once, when in real life it is a lot easier if you take it step by step. i also realized that it is ok to not get it the first time as long as you improve the next times you try something

This student talked about how she was able to use the EDP to benefit her life outside of school. She was able to recognize how applicable the process was to any situation and how useful it was to improve the current conditions.

While the above student saw the tangible results of her use of the EDP, another student used it theoretically:

> I have had to make a lot of decisions lately and it has helped me choose the more beneficial one for me. The most useful part is testing to see how it works and then if it doesn't-changing it. Sometimes, it wasn't something I could literally test, so I had to go through the consequences and what could potentially go wrong/right in the situation and test it out there.

This student used her new critical thinking skills to solve a problem that could not be tested out physically. He/she was able to think through the impact of their actions before doing it. This is an important step in the critical thinking process to learn how to make better decisions. One student said,

> I thought that it really taught me how to thoroughly think. I have realized I have made better, and more wise decisions since this unit.

Another student saw the value of the EDP in other classes:

> I learned how to organize my ideas in everyday life. Not only can I use EDP in like Science and Math classes, but really in all subjects.

This next student took it a step further:

> I will use EDP to have better relationships with family and friends and figuring what is wrong for all things in my life like school to how to PARTY!

While this may seem a little extreme, it is valuable for students to be able to think through all aspects of their lives, from their social pursuits to their academic challenges.

The EDP can have an impact on the way students approach their academic studies as well. Reflecting on his/her educational practices, a student said,

> Before the EDP, I considered myself a smart student because I got good grades, but I was just memorizing what the teachers told me. I never really thought about what I was learning. When we did the EDP, I realized that I wasn't THINKING to get good grades, which is a problem.

It is interesting to see how this last student's definition of intelligence changed. Originally they thought that memorizing to get an A was 'smart' but now it is about thinking. That paradigm shift is important for the students, especially at an academically intense school. Intelligence is more about thinking through challenges and processing solutions than about regurgitating mindless a test that is quickly forgotten. It is those critical thinking skills that allow one to appropriately deal with any situation in life, education, and in future employment. The fact that even a single a student realized this was a highlight to the findings of this research. Many students found application for the EDP beyond this particular unit of challenges. Students learning to think critically in the classroom setting and outside the classroom gives one more reason it promote the implementation of the EDP into their curriculum.

4.2.6 Challenges to Implementing the EDP in the Classroom

This unit certainly did not come without its challenges. Although several have been discussed with regards to what the students have learned, it would not be fair not to present some of the other challenges encountered, both from the teacher's perspective, as well as the students'.

Unfortunately, not all students participated in the final survey. The missing students probably would have given more negative comments than is accurately represented in the qualitative data as they were unwilling to respond. There were some comments made by students that offered interesting insights into the challenges of the EDP unit. One comment showed the student's overall dislike for the EDP unit:

> It wasn't my favorite unit because I actually liked figuring physics stuff with math and not using it with edp.

This same student continued to say,

> I did like how we talked about making edp in our daily life.

One idea that could be taken away from these comments is that this student likes theoretical concepts instead of practical ones because they are easier and don't require as much thinking. Or, possibly that they appreciated the ability to think outside of class but really just wanted the grade in class. Perhaps these students like the right-and-wrong-type work because then they know for sure if they are right. This type of mentality may be common in the classroom although previous analysis leads to the notion that most students appreciate stepping outside of the black-and-white academic world into practical situations.

It is not always easy to use classroom material beyond the curriculum as another student commented,

> I think what the problem was, is trying to train yourself to use it. And to remember to use it. Because when your in a situation where you can use it you don't always do. Not because you don't want to, but because it's maybe just not the first thing you think of.

This provides a valid point that it takes time to ingrain this type of thinking into a person's brain after they have been doing it differently for so many years. Students picked up on the EDP at different rates. With the critical thinking grown seen in this study from only a month of EDP coursework, it would be interesting to study this relationship over a greater period of time or the relationship between how many years of EDP usage students have to the enhancement of their critical thinking skills.

Time is one challenge that is hard to get around. Using the EDP in class is more time consuming that simply lecturing at students. However, when done correctly, there is some positive return. Students who learn the EDP were much less likely to ask the teacher questions. One student said,

> I thought it was interesting to see how we all started thinking on our own and didn't immediately run for help as soon as we saw a problem.

This frees up the teacher's time to work with students who really need the help instead of every boisterous person who gets momentarily stuck. Overall, it appeared that much more of the class time was effectively used by engaging with the material compared to these classes' previous to the EDP unit. That connection with the material is where valuable learning takes place. While using the EDP does take more time, students are more engaged in the work and have greater motivation to do well. Teachers have very little time and, so much that they are required to teach, it can be a difficult balance. Embedding the EDP into existing curriculum would help the student learn valuable life skills as well as the material required.

From informal observations, students had a higher level of frustration in starting the EDP unit than in most other physic's units. All students had some level of frustration when there were no longer correct answers like they were used to. Here 'the system' was eliminated for the most part and their grade was based simply on participation. Grades were not a huge extrinsic motivation for doing the projects but the students seem to work diligently with fewer distractions than normally seen in this classroom. Where the extrinsic motivation decreased, the internal motivation increased. Students became passionate about their work and full of pride in their team and the team's project frequently calling the teacher over to show off their projects. Students who started out frustrated, were, for the most part, able to enjoy the process of building instead of just looking to get the grade. There were certainly still students who struggled with the project because of the lack on concrete answers. By informal observation, the majority of these students still frustrated with the project were female, which matches with the smaller growth percentiles they experienced compared to their male counterparts. While it may be frustrating for the teacher to help those frustrated students, it is also rewarding to see students figure it out themselves, become better at the EDP, and develop necessary critical thinking skills.

For the teacher, the EDP isn't the easiest thing to facilitate in your classroom. Hands on discovery activities that lend themselves to the EDP take time to develop and prepare for, as well as grade. It requires a shift in the way educators typically facilitate a classroom that, while worthwhile, requires effort to instate. It is much easier to follow the path that has been prepared for teachers by veteran co-workers as they generously donate their worksheets, presentations, and test materials. The result is that students get good grades by memorizing instead of thinking, as one student previously stated. Encouraging the students to think through something like the EDP takes effort from the students and teachers. The materials used for this EDP unit were primarily collected from a number of sources like expert teachers, university professors, professional organizations, internet searches etc. There is much more work for a teacher to do in order to organize these types of units. In general education, there are many requirements and a very small amount of time to teach them in. However, seeing the positive impact of the EDP on student behavior in the classroom is a motivating factor in using this process to teach CT skills to help students analyze situations and find effective solutions.

4.2.7 Qualitative Conclusions

The engineering design process was not entirely new to most students as many of them have been using similar concepts without as structured of an organization or formal names. The EDP clarified students own thought processes and allowed them to be more effective. One of the important steps that students enjoyed the most was the asking stage. Learning to ask questions to define the problem helped them to understand the challenges they faced and narrow in on the task. The plan step was very important to many who needed that time to get organized. High school students have the tendency to rush into a project without really thinking it through and when they were required to do this step initially, students became frustrated. Eventually the planning and organizing steps helped the students to work as a more efficient, cohesive group. Students realized the validity of others' ideas when they took the time to listen to everyone. Those ideas could then be merged into one, better idea that the entire group has a stake in. If that idea didn't work, the group was able to add to their previous list of ideas and try something new. In-class time was also more focused on the task in front of them than previously observed and students were able to stay productively focused with less help. The EDP allowed students to accept failures as a step towards success. Instead of giving up after the first try, students saw the room for growth in the improve step of the EDP. An increase of confidence in their ideas and abilities to successfully problem solve, as well as an increase in intrinsic motivation, was noticed. This confidence in a student's critical thinking skills penetrated deeper than just the physics classroom. Students gave numerous examples of using the EDP outside of class in other areas such as: other academics, personal relationships, family decisions, sports endeavors, and life decisions. Many students commented on the ability it gave them to make better decisions and have confidence in those decisions.

While there were many positive impacts of the EDP unit on these students, there were also some challenges that came with it. Teachers are required to put in extra effort in order to create and prepare for the hands-on experiments. Initially, students struggled with the new ideas and were unnerved by the lack of right and wrong answers. By the end of the unit, students were no longer as concerned with a grade as they were about accomplishing their task. Some students struggled to remember to use the EDP in their life but generally liked it. Other students did not like the thinking part of this unit and would have rather done theoretical calculations. Others simply disliked the building part of the EDP labs.

These challenges should not deter any teacher from using the EDP as the positive results far outweighed the struggles. Students increased in confidence, in group communication skills, in appreciating others' differing ideas, in organizational and planning skills, and in independent critical thinking skills to think through situations within and beyond the physics classroom. The qualitative data strongly supports that learning the EDP does increase critical thinking skills in high school students.

5 CONCLUSIONS

High school students have a need to develop and apply critical thinking skills as evident through reports like the U.S. Workforce Readiness Survey. The engineering design process has been promoted as an effective tool to be used to assist in teaching critical thinking skills but no substantial data connecting the engineering design process to high school students' ability to use critical thinking skills has been found. This research was developed to understand the effect of the EDP on the CT skills of high school students. Over one month, 5 classes of physics students participated in an engineering design process (EDP) unit and took the Watson-Glaser Critical Thinking Appraisal as a pre- and post-test to measure the impact being engaged in the EDP has on their critical thinking skills. There were 4 questions that were answered by this research. Each one will be discussed in this chapter.

5.1 The Research Questions Answered

The first question was "Do high school students develop greater CT skills by using the EDP on a regular basis?" The data from the WGCTA showed varying results. Six seniors who appeared to be suffering from a bad case of senioritis dropped an average of 16% which drastically altered the overall data. By removing this data, the results became more consistent with a smaller standard deviation and a better representation of the students' CT growth. Students statistically significantly gained in their overall CT test percentiles showing the positive relationship between the EDP unit and students' critical thinking skills. Students demonstrated statistically significant gains in the subtest areas of Recognition of Assumptions and Evaluation of Arguments, suggesting that their CT skills improved in these areas.

From the qualitative data, students were seen to improve in a variety of critical thinking domains such as: organization, asking questions, planning ahead, seeking opportunities to improve, effective communication, and analytically thinking about challenges. This was evident from in class and out of class conversations and observations, and an anonymous voluntary, survey. These characteristics are consistent with the description of attributes given in the first chapter by Paul, Kilby, and the researchers they cited including "reasoning skills", "focusing on a question," "asking clarifying questions," "distinguishing relevant… information", "engaging in reasoned discourse," "reasoning…[with] clarity, accuracy, …relevance, depth, breadth, [and] logic," and "analytic inference skills [such as] the ability to formulate and assess goals and purposes, questions and problems, information and data, concepts and theoretical constructions, assumptions and presuppositions, implications and consequences, point of view and frames of reference" (1997, 2004). The observations made from the qualitative data regarding these attributes suggest that there is a positive relationship between learning the EDP and gaining critical thinking skills.

The second research question asked was "What type of students experience the most development in their CT skills after learning the EDP?" This question was answered from data resulting from the pre- and post-test data analysis. Male students gained an impressive average of 8.37%, which was calculated to be statistically significant, on their overall test percentages while all female students averaged a decrease in percentile scores of -0.226% which was calculated to be statistically insignificant. Senior girls in particular struggled in the post-test possibly due to senioritis as the differences in their pre- and post-test scores were extreme.

Without the seniors, female students still only gained 1.47%, which was calculated to be statistically insignificant.

When comparing the students' GPA with their change in pre- and post-test scores, it was evident that higher functioning students had a greater growth in CT skills. Juniors, or 11th grade students, grew the most with an average 8.07 percentile increase after participating in the Engineering Design Process unit. While it appears that high achieving, 11^{th} grade, male students seemed to benefit most from the EDP, it should be noted that most students benefited in some way from being taught the EDP

The third question was "How do students feel about the EDP and how do they see it as impacting their lives?" This question was answered from the qualitative data gathered through the online exit survey and direct student comments. While some students were frustrated and negative about the change from right and wrong schoolwork to exploratory learning using the EDP in the challenge labs, the majority of students expressed their appreciation for learning some part of the EDP. Many students offered their stories and experiences as they had used the EDP in a positive way to help solve challenges outside of class. In class, some students complained about the worksheets and paperwork required to teach them the EDP effectively. As the unit progressed, however, the students reported that the EDP became more natural and therefore, easier to use. Students did not complain as much when they saw the effectiveness of using the EDP. In the final survey, students shared how they feel about the EDP and why. Here are some of their comments:

> I love EDP! It really can help you through whatever-and has caused me to think about the world so differently. I even find myself going through the EDP process watching the news. I really think that if everyone learned this EDP process, the world would be a completely new place…

> [The EDP is] useful for mankind as a whole. Right now, it isn't completely beneficial for high school students because we haven't actually hit a part of our lives where we need such deep analytical skills.
>
> It organizes your thought process on dealing with issues in any aspect of life. Not only has it helped me with the projects in physics, but the EDP has also helped me in other classes (for studying) and at home. The most useful part of the EDP would be the improve part, because without that step nothing is going to get better.
>
> I will use the EDP in order to accomplish tasks. I learned that waiting just a few minutes in order to come up with a plan and ideas was much more useful and valuable than just jumping right in to the assignment…I learned that I had a lot more good ideas and plans/abilities than I thought I did, and this process really changed how I viewed physics, english, math, and my classes/homework in general.

One student did not see the need for analytical skills in his/her life at this point but conceded that it was beneficial eventually when such ‘deep analytical skills’ were needed. Students felt that the EDP helped them develop critical thinking skills by thinking about the world different, analyzing challenges, organizing thoughts, and slowing down to plan a course of action in many different areas of life.

The fourth and final research question was “What changes do teachers’ observe in their students’ behavior as students learn to embed the EDP in the classroom?” The teacher noticed an increase of time engaged in the material, pride in their work, intrinsic motivation instead of extrinsic motivation, and organized, independent thought. Learning the EDP enabled students to work more independently and increased the percentage of time focused on the material. It appeared that the EDP enabled students to think through challenges more thoroughly by asking good questions and then organizing their thoughts in the plan section. These two notions, asking good questions and organizing their thoughts, were important in giving students a clear vision of their goal and how they were going to accomplish it.

Students saw that each group member can be a valuable contributor in their prolonged planning sessions and as a result, each student became more organized and focused in his/her work to positively contribute during the challenge. Intrinsic motivation to accomplish the task was very high as everyone felt included and needed and demonstrated this as their individual group skills increased.

The improve section (see Figure 1) of the EDP helped students see that the first single solution that worked is not the best or the end product, and while students may have been frustrated, they stuck with it and found effective solutions to their challenges. Students appreciated the system's acceptance of failure as a step in the right direction: instead of being offended and giving up after the first try, they were able to see the mistakes and work to correct them. Effective critical thinking uses a continual refinement process to improve the solution to the problems.

5.2 Summary

The purpose of this research was to determine how teaching the EDP would develop workplace desired critical thinking skills in high school students. Overall, there was an evident growth in CT skills shown by the WGCTA statistical analysis, students displayed attributes of critical thinking as they worked more diligently and analytically in class, and students noted they used the EDP and the CT skills associated with it outside the classroom to solve real-world challenges. As a limitation of this study, the EDP process cannot be completely isolated from other variables such as the classroom environment, the teacher, a familiarity with the WGCTA, and other outside influences.

Students became more capable of solving challenges by asking questions, organizing their thoughts, recognizing assumptions, evaluating arguments, working efficiently in group situations, and re-evaluating possible solutions to find better ones. The test results, survey information, and observations suggest that teaching the EDP to high school students can improve their critical thinking skills. Additionally, students reported that they generally enjoyed the EDP unit because it helped them better analyze challenges and come up with solutions independently from the teacher. Regarding this, one student reflected:

> I thought it was interesting to see how we all started thinking on our own and didn't immediately run for help as soon as we saw a problem.

This ability for students to think on their own is a significant accomplishment that resulted from teaching the EDP unit. With greater CT skills our students will be more capable of solving challenges as they enter into the workforce. As students enhance their CT skills, they will become better prepared to become engineers and fill the need our economy has for them.

6 RECOMMENDATIONS FOR FUTURE STUDIES

While this study examined the relationship between the EDP and a development of critical thinking skills in high school students, it was in no way comprehensive or complete. It developed a basic relationship lacking many specifics. If anything, this research added a whole new list of questions to ask. To more fully see the benefits of implementing the EDP in the classroom, below are some recommendations for future studies:

- How does learning the EDP impact students in their overall academic success?
- How does the EDP change perceived success?
- What is the comparison of teacher-student interaction time for a regular classroom verses an EDP class?
- How does the EDP impact the student engagement time or the time the student actually spends focusing on the material?
- What impact does vagueness have on autonomy and creativity? How does asking open-ended questions impact autonomy and creativity?
- This study was done over a month, how would the EDP impact a student's critical thinking skills over a year? Over middle school years or elementary school years? Over their entire K-12 education? Would different results have been obtained in non-inquiry based classroom?
- Does the amount of time students are exposed to the EDP impact their CT skills growth? Is there an optimum number of years?

- Is there an optimal age to develop CT skills? Do male and female students develop them at different times? (See 4.1.4 Gender Comparison) How does this fit into Perry's model of cognitive development?
- What is the long term impact of teaching critical thinking skills on hiring rates and job success?
- Is there a better way to measure critical thinking skills relevant to the physics classroom?
- Are certain people more susceptible to the EDP because of the way their brains think or are all personality types as likely to grow from the EDP?

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APPENDIX A: SUMMARY OF THE ENGINEERING DESIGN METHOD BY DR. RONALD TERRY, BYU

"The" Engineering Design Method

MA State [1]	"Elementary" [2]	Dartmouth Design [3]	Cal State LA [4]	Designing Engineers [5]
Identify the problem	Ask	Define the Problem	Identify the need	Define the problem
Research the problem	Imagine	Restate the Problem	Define the problem	Development of a plan
Develop possible solutions	Plan	Develop Constraints and Criteria (specifications)	Gather information	Model formation (Analytical/ Experimental)
Select a solution	Create	Brainstorm ideas	Develop and evaluate alternative solutions	Application of physical principles/ Gathering data
Construct a prototype	Test	Research Alternatives	Conduct analysis	Computation
Test/ Evaluate solution	Improve	Analyze alternatives by a trade-off matrix	Make a decision	Checking
Share the solution		Identify a potential solution	Test and verify solution	Evaluation
Redesign		Research in detail the potential solution	Communicate the solution	Optimization
		Design a potential solution (prototype)		
		Construct a prototype		
		Evaluate prototype		
		Reiterate if necessary		
		Simplify if possible		

1. Massachusetts State Frameworks www.doe.mass.edu
2. Engineering is Elementary, Museum of Science www.mos.org/eie
3. Elsa Garmire "The Engineering Design Method," The Technology Teacher Dec/ Jan 2004
4. California State University, Los Angeles
5. Louis Bucciarelli, *Designing Engineers* (1994) Cambridge MA the MIT Press.

APPENDIX B: WORKSHEETS FOR THE EDP UNIT

Names:	________________
	________________
	________________
	________________
Class:	________________

Paper Rockets

For this challenge, you will be designing and testing paper rockets. They are easily made and should be fairly easy to design. If done correctly, they can really fly. Your job is to test and evaluate different rockets to produce the furthest flyer. You may test any number of prototypes as much as you would like but you only get one shot at the final launch. I recommend only changing one thing at a time so you can see the improvement or regression. Use the EDP! It will reduce the time you waste and will make your project more effective.

1. What is your goal?
2. Do you have any limits?
3. What types of ideas do you have?

4. What is your plan of action?

5. How many are you going to create? How many test runs?

6. What will they look like? See attachments
7. Who is doing what?
    a. Person 1:
    b. Person 2:
    c. Person 3:
    d. Person 4:
8. Test. Record your test results in the attachments section for each plane.

Reflection:

1. How much do you feel like you used the EDP?	1	2	3	4	5
2. Do you think it was useful?	1	2	3	4	5

3. Did this process help you design a better rocket?

4. How would you do things differently?

Design

Plane 1:

Describe its flight:

____

Why do you think this happened?

____

Distance traveled:

Plane 2:

Describe its flight:

____

Why do you think this happened?

____

Distance traveled:

Plane 3:

Describe its flight:

____

Why do you think this happened?

____

Distance traveled:

Plane 4:

Describe its flight:

____

Why do you think this happened?

____

Distance traveled:

Names: ________________
____
____
____
Class: ________________

Paper Towers

Challenge: Build a freestanding tower that will suspend a golf ball the highest possible. You get one piece of paper and 12 inches of tape.

Ask:

1. Define the Problem:
2. What is your goal?
3. Do you have any limits?
4. What types of ideas do you have?

Imagine:

5. What ideas do you have?
6. Possible structural ideas?

Plan

7. What is your plan of action?
8. Who is doing what?
   a. ____
   b. ____
   c. ____
   d. ____
9. What will they look like? Sketch on attached sheets.

Create:

10. Were there any unforeseen challenges?

Test. Record your test results in the attachments section for each plane.

11. What designs worked best?

Improve: Go again…

12. How are you going to improve?

Reflection:

1. How much do you feel like you used the EDP? 1 2 3 4 5
2. Do you think it was useful? 1 2 3 4 5
3. Did this process help you design a better tower?

4. How would you do things differently?

Design

Information to include about your designs:

- How tall did the ball reach?
- How stable was your structure?
- What was the strongest and weakest point?

Windmills

Names:______________
____
____
____

Ask

What are you trying to do?

What are the challenges you are facing?

Define the goal.

Imagine

What are some of the general concepts you are planning around?

What are some of your brainstorming ideas?

Plan

What are you going to test now?

Who is going to do what?

Create

What does it look like?

Test

What are the strengths and weaknesses of your creation?

What measurements of it did you make? Which one was best?

(This page repeated 3 times.)

Windmills

Names:______________

____

____

____

Improve →Ask

What needs to be improved?

What is the weakness?

Imagine

How can we improve the weakness?

Come up with 2-5 ideas on how to improve for each area of needed change:

Plan:

Which idea could probably work best?

What are you going to do?

How are you splitting up the work?

Create

New prototype sketches:

Test

Did if fix the problem?

How did it work? Measurement?

What is the next weakness that needs to be improved?

Electronics Challenges:

Challenge #1 Light the light bulb with a battery and one wire.	Challenge #2 Light 2 lights. Include a switch.
Challenge #3 Light 2 lights in a different way. Which one is brighter?	Challenge #4 Light up a light and a buzzer.

Challenge #5

- The "Drive Thru Family Laundry" is along a busy road.
- The facility is set back from the road so that it has a drive thru for customer convenience.
- The Store is designed so that it has two main sections: Office in front and Laundry in back
- Sometimes only one person is working in the store.
- The laundry is noisy and it is sometimes difficulty for workers to hear / see when customers arrive.
- Several customers have complained lately because they pull up to the drive thru and they have to wait because the workers do not know they are there.
- Workers have complained because they are busy and have to hurry back and forth between the laundry and office to see if customers are waiting.

Design an audio/visual alarm system that will alert the workers when someone **drives up** to the store

Common Schematic Symbols

Battery:

Wire connect:

Light Bulb:

Wire cross but not connect:

Switch:

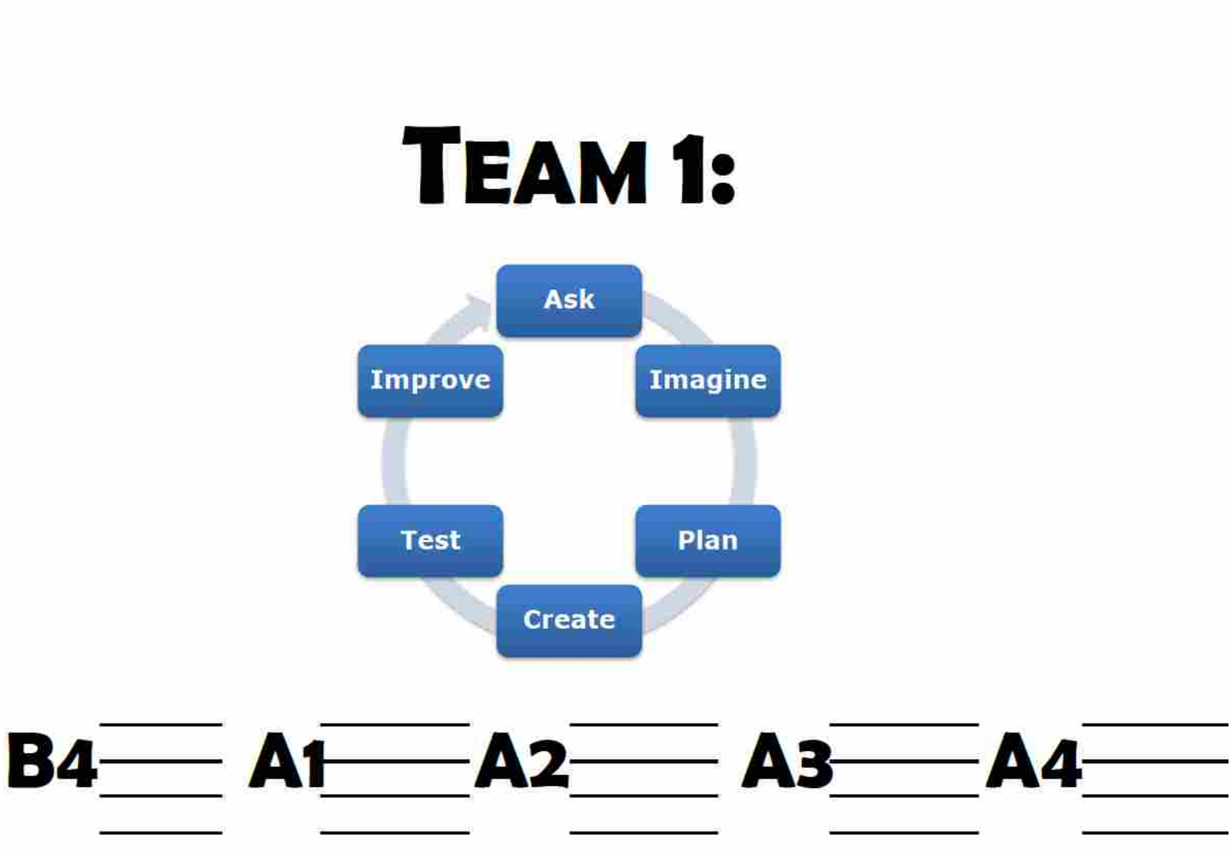
Buzzer:

Rube Goldberg Project Workbooks

These workbooks were made into legal size ledgers, landscape direction, bound with binding combs and laminated front and back covers. Students commented on how this made them feel important, like their records were valuable and the work there were doing was unique from the rest of their class work. They felt like legit engineers as the intended outcome.

Rube Goldberg Project Workbooks: Cover Page

Cover page with places for each periods' team members' names



Rube Goldberg Project Workbooks: Materials Log

Materials Log for members to record their donations in case they want the materials returned at the end.

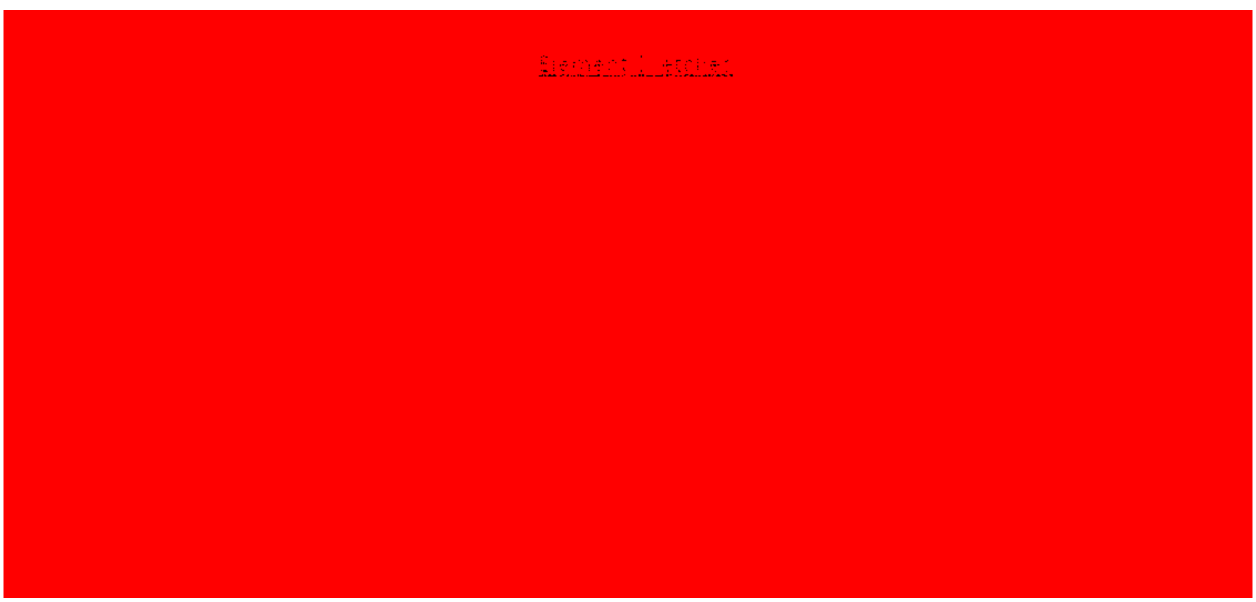
Materials Log

Name	**Material and Quantity**	**Description:** color, size, function, placement, etc.

Rube Goldberg Project Workbooks: Worksheets

This worksheet paired with the following blank sketch page were repeated ~10 times per ledger.

Date	ASK	IMAGINE	PLAN	CREATE	TEST / IMPROVE
	What is the problem? What are you trying to do? What are the challenges?	Brainstorm. What possible ideas could work? Which are the best ideas? Why?	Draw a picture! What needs to be done first? Who does what?	Go to work! Record what you do.	How did it do? What works? What doesn't? What could you do to make this better? →ASK



Rube Goldberg Project Workbooks: Rubric

Students were responsible for grading the previous group's work. A place for comments was included so students could understand their grade and how to improve. Having students grade other student's work was an eye-opener for what they needed to do in their own records.

Area	Explanation of Points – be honest	Points
Progress– appears that they worked hard and accomplished something – whether tweaking or creating new elements.		/5
Records– Clear, accurate records detailing actions of previous period, the new group understands the previous notes without question. Subtract points for corrections or questions you can to ask.		/5
EDP – follows the EDP as detailed in the workbook. Use the elements of EDP to enhance their records and their product. Deduct points if they fail to follow the EDP process or don't fill in each column.		/5
Organized – the workspace has been cleaned, excess material thrown away or put away. Workable space when you walked in the door.		/5

APPENDIX C: WATSON-GLASER CRITICAL THINKING APPRAISAL RAW DATA

pre total	post total	pre percent	post percent	Pre Inference	Post Inference	Pre Recognition of Assumptions	Post Recognition of Assumptions	Pre Deduction	Post Deduction	Pre Interpretation	Post Interpretation	Pre Evaluation of Arguments	Post Evaluation of Arguments	Grade	GPA	Gender
51	48	65	55	4	5	12	13	13	6	11	10	11	14	12	3.91	F
55	45	75	40	6	7	13	4	10	11	14	10	12	13	12	3.93	F
51	34	65	5	9	6	8	6	8	7	13	8	13	7	12	3.79	F
67	60	95	85	12	9	13	13	12	9	16	14	14	15	12	3.98	F
50	41	60	25	6	3	13	10	12	8	12	10	7	10	12	3.5	F
64	65	90	95	12	9	15	15	10	13	14	15	13	13	12	3.92	M
45	30	45	3	6	2	5	5	12	9	14	6	8	8	11	3.48	F
43	41	35	30	5	2	6	9	9	9	13	8	10	13	11	3.68	F
50	60	60	90	7	7	13	12	8	15	12	12	10	14	11	3.98	F
50	43	60	35	7	4	13	12	9	8	12	8	9	11	11	3.27	F
45	48	55	55	5	10	7	8	12	9	9	8	15	13	11	4	F
38	50	15	60	6	10	4	12	9	7	11	9	8	12	11	3.25	F
48	43	55	35	7	4	13	12	9	9	10	10	9	8	11	2.6	F
52	53	75	70	6	7	12	14	10	6	10	10	14	13	11	3.5	F
50	52	60	65	6	8	12	12	9	13	11	12	12	7	11	2.83	F
60	61	90	90	14	12	5	7	12	14	14	13	15	15	11	3.99	F
53	52	70	65	10	4	11	11	7	12	13	13	12	12	11	4	F
51	55	65	75	12	9	10	10	8	12	11	11	10	13	11	3.99	F
65	57	95	80	7	6	14	14	15	11	14	13	15	13	11	4	F
46	56	45	80	6	5	15	13	9	14	9	11	7	13	11	3.86	F
43	62	35	90	4	10	5	16	9	10	12	13	13	13	11	4	F
39	48	20	55	6	8	7	11	7	10	8	11	11	8	11	3.58	F
52	43	65	35	8	5	14	9	10	6	8	8	12	15	11	3.86	F
41	54	30	75	8	9	2	13	11	9	13	10	7	13	11	3.79	F
44	38	40	15	6	5	9	10	13	4	6	12	10	7	11	3.89	F
45	54	45	75	8	9	7	8	12	14	8	11	10	12	11	3.97	F
48	48	55	55	6	6	8	8	8	10	12	10	14	14	11	3.87	F
36	41	10	30	5	3	6	3	8	10	8	13	9	12	11	3.35	F
54	58	75	85	7	10	10	13	10	14	13	12	14	9	11	3.74	F

pre total	post total	pre percent	post percent	Pre Inference	Post Inference	Pre Recognition of Assumptions	Post Recognition of Assumptions	Pre Deduction	Post Deduction	Pre Interpretation	Post Interpretation	Pre Evaluation of Arguments	Post Evaluation of Arguments	Grade	GPA	Gender
42	47	30	50	6	5	9	8	9	9	8	11	10	14	11	3.73	F
48	45	55	45	7	7	12	9	9	9	8	7	12	13	11	3.96	F
48	47	55	50	9	8	7	7	10	11	11	10	11	11	11	3.16	F
52	56	65	80	7	9	11	12	12	11	9	12	13	12	11	3.97	F
69	64	97	95	13	7	16	15	14	16	15	15	11	11	11	3.74	F
55	59	75	85	13	7	6	12	10	11	13	14	13	15	11	3.99	F
54	47	70	50	10	6	14	7	11	8	10	12	9	14	11	3.39	F
54	58	75	85	9	7	13	12	10	11	11	12	11	16	11	4	F
43	56	35	80	8	8	2	12	9	11	10	14	14	11	11	3.76	M
45	49	45	55	8	4	6	9	9	14	11	12	11	10	11	4	M
65	63	95	90	11	8	14	13	14	13	13	14	13	15	11	3.87	M
52	57	65	80	12	7	7	14	10	12	15	13	8	11	11	3.25	M
43	47	35	50	4	5	13	8	9	12	7	11	10	11	11	3.8	M
45	47	45	50	6	4	12	13	10	11	8	9	9	10	11	2.99	M
46	55	45	75	7	9	6	14	10	7	12	10	11	15	11	3.16	M
50	58	60	90	11	7	4	11	10	14	12	12	13	14	11	3.94	M
45	45	45	45	10	6	8	10	9	7	9	10	9	12	11	3.65	M
41	42	35	30	7	3	8	10	10	10	9	9	7	10	11	2.12	M
56	60	80	90	7	6	11	15	13	13	12	13	13	13	11	2.39	M
37	35	15	10	4	4	8	9	10	9	10	5	5	8	11	3.17	M
50	55	60	75	8	8	11	13	9	7	13	13	9	14	11	3.61	M
35	42	10	30	0	4	9	10	10	7	7	10	9	11	11	2.96	M
54	64	75	95	7	8	13	14	10	14	13	13	11	15	11	3.56	M
54	63	80	95	10	12	12	14	9	12	11	13	12	12	10	3.96	F
39	47	25	60	5	4	6	10	8	11	11	10	9	12	10	3.93	F
53	59	80	90	5	9	12	12	10	12	14	13	12	13	10	4	F
45	43	50	45	4	6	9	7	9	10	10	10	13	10	10	3.93	F
55	62	85	95	8	11	13	12	12	16	12	10	10	13	10	4	F
48	39	60	25	4	3	8	9	13	6	12	7	11	14	10	3.82	F
51	46	70	55	13	8	4	8	12	9	13	10	9	11	10	3.91	F
59	68	90	97	8	14	13	15	10	12	14	13	14	14	10	3.97	F
32	47	5	60	5	9	4	10	7	9	7	9	9	10	10	3.88	F
49	49	65	65	9	7	7	12	13	8	11	12	9	10	10	3.95	F
58	64	90	95	10	12	14	15	12	13	9	12	13	12	10	4	F
55	60	85	90	5	9	15	14	10	11	12	12	13	14	10	3.97	F

pre total	post total	pre percent	post percent	Pre Inference	Post Inference	Pre Recognition of Assumptions	Post Recognition of Assumptions	Pre Deduction	Post Deduction	Pre Interpretation	Post Interpretation	Pre Evaluation of Arguments	Post Evaluation of Arguments	Grade	GPA	Gender
47	49	60	65	5	8	8	8	10	10	10	10	14	13	10	4	F
51	42	70	40	10	3	13	10	8	10	8	9	12	10	10	3.38	F
55	48	85	60	10	9	6	4	12	11	14	11	13	13	10	3.89	F
36	42	15	40	6	4	4	6	8	9	8	12	10	11	10	3.95	F
41	56	35	85	4	11	7	13	13	8	9	13	8	11	10	3.9	F
48	44	60	45	5	9	15	7	12	6	7	12	9	10	10	3.94	F
50	47	70	60	7	4	11	14	10	12	10	10	12	7	10	3.99	F
57	57	85	85	10	11	13	12	12	8	13	13	9	13	10	2.48	F
50	57	70	85	7	6	11	10	9	12	11	14	12	15	10	3.98	F
52	58	75	91	8	10	11	15	9	10	11	11	13	12	10	3.93	F
52	50	75	70	6	5	15	11	8	11	10	11	13	12	10	4	F
45	55	50	85	5	5	7	13	11	10	8	13	14	14	10	3.99	F
59	59	90	90	7	9	15	15	10	13	14	11	13	11	10	4	F
49	58	65	90	10	8	10	13	8	11	11	13	10	13	10	4	F
53	46	70	55	7	6	10	7	10	10	12	10	14	13	10	4	F
52	54	75	80	8	10	13	11	8	8	11	12	12	13	10	4	F
57	59	85	90	6	6	12	13	14	13	15	12	10	15	10	3.87	F
58	50	91	70	6	3	15	13	11	10	14	14	12	10	10	3.98	F
35	40	15	30	3	5	6	8	10	7	9	8	7	12	10	3.64	F
47	55	60	85	9	7	8	12	10	12	11	11	9	13	10	3.99	F
55	59	85	90	8	10	11	12	11	11	13	14	12	12	10	4	F
61	62	95	95	13	13	12	14	12	13	13	9	11	13	10	3.94	F
52	58	75	90	11	6	9	12	11	12	12	15	9	13	10	3.95	F
50	44	70	45	7	3	9	13	13	9	10	9	11	10	10	3.91	F
51	45	70	50	5	8	13	7	10	7	11	12	11	11	10	4	F
51	48	70	60	9	5	13	12	7	9	10	11	12	11	10	3.97	F
44	51	45	70	6	9	6	11	10	8	12	15	10	8	10	4	F
52	64	75	95	9	8	6	12	12	15	12	15	13	14	10	3.96	F
53	51	80	70	10	7	5	3	15	14	12	13	11	14	10	3.99	F
66	67	97	97	16	12	13	12	12	14	13	14	12	15	10	4	F
35	38	15	25	1	2	7	6	10	11	8	9	9	10	10	3.28	F
47	48	60	60	7	7	11	11	9	7	11	10	9	13	10	4	F
44	27	45	1	2	3	12	5	9	7	10	7	11	5	10	3.63	F
54	50	80	70	6	6	5	2	15	16	15	12	13	14	10	4	F
50	50	70	70	2	6	14	11	12	7	11	13	11	13	10	3.92	F

pre total	post total	pre percent	post percent	Pre Inference	Post Inference	Pre Recognition of Assumptions	Post Recognition of Assumptions	Pre Deduction	Post Deduction	Pre Interpretation	Post Interpretation	Pre Evaluation of Arguments	Post Evaluation of Arguments	Grade	GPA	Gender
53	44	80	45	8	5	13	5	11	8	12	13	9	13	10	3.83	F
47	45	60	50	9	5	7	10	8	9	9	11	14	10	10	3.54	F
49	46	65	55	8	5	10	12	8	8	11	10	12	11	10	3.89	F
46	43	55	45	7	6	11	12	10	7	9	8	9	10	10	3.9	F
44	47	45	60	5	5	12	13	8	8	11	9	8	12	10	4	F
53	55	80	85	3	9	14	12	11	11	14	11	11	12	10	3.97	F
37	41	15	30	6	7	7	10	9	6	9	7	6	11	10	3.67	F
53	35	80	15	8	4	9	5	11	7	11	9	14	10	10	3.78	F
50	44	70	45	5	5	12	12	13	7	9	10	11	10	10	3.9	F
58	40	90	30	11	5	11	8	14	6	13	11	9	10	10	3.97	F
38	43	25	45	2	6	12	10	6	9	7	8	11	10	10	2.45	M
47	52	60	75	3	9	7	13	10	9	12	10	15	11	10	3.5	M
65	64	97	95	14	11	16	15	13	12	11	11	11	15	10	3.98	M
67	63	95	95	11	13	15	14	15	11	13	12	13	13	10	4	M
72	71	99	99	14	10	15	15	13	15	16	15	14	16	10	3.94	M
47	43	60	45	7	8	7	7	11	9	11	11	11	8	10	4	M
44	43	45	45	7	8	12	10	10	5	8	11	7	9	10	3.93	M
41	39	40	25	8	4	8	7	8	5	6	11	12	12	10	3.82	M
50	48	70	60	5	9	14	9	11	8	11	13	9	9	10	3.87	M
56	59	85	90	5	11	9	9	14	11	14	15	14	13	10	3.83	M
44	54	45	80	7	7	7	11	12	10	12	14	6	12	10	3.75	M
44	48	45	60	5	9	6	6	10	10	15	9	8	14	10	2.85	M
41	44	35	45	7	6	10	12	10	9	9	9	5	8	10	3.13	M
59	63	90	95	9	9	12	13	14	11	12	14	12	16	10	3.96	M
44	51	45	70	7	7	5	8	10	12	11	12	11	12	10	3.84	M
61	55	95	85	11	8	16	14	10	9	12	11	12	13	10	4	M
46	59	55	90	7	8	10	12	9	12	10	14	10	13	10	4	M
43	50	45	70	8	6	11	12	8	13	8	9	8	10	10	3.33	M
57	57	85	85	9	12	8	8	13	11	15	13	12	13	10	4	M
49	43	65	45	7	6	14	9	11	10	10	9	7	9	10	3.96	M
47	48	60	60	5	6	8	6	11	9	10	14	13	13	10	3.75	M
43	46	45	55	5	11	9	7	11	7	10	8	8	13	10	3.71	M
46	46	55	55	7	5	8	9	10	6	8	12	13	14	10	3.75	M
45	53	50	80	6	11	5	12	12	7	8	12	14	11	10	4	M
51	42	70	40	11	9	5	8	11	6	10	7	14	12	10	3.92	M

pre total	post total	pre percent	post percent	Pre Inference	Post Inference	Pre Recognition of Assumptions	Post Recognition of Assumptions	Pre Deduction	Post Deduction	Pre Interpretation	Post Interpretation	Pre Evaluation of Arguments	Post Evaluation of Arguments	Grade	GPA	Gender
55	55	85	85	6	8	12	12	12	11	9	13	16	11	10	3.98	M
48	45	60	50	6	5	12	10	7	8	11	11	12	11	10	3.86	M
39	38	25	25	2	1	12	12	7	7	8	7	10	11	10	1.46	M
41	55	35	85	6	9	11	9	5	10	12	14	7	13	10	3.67	M
43	46	45	55	3	5	11	11	7	9	11	7	11	14	10	3.19	M
47	57	60	85	8	12	7	10	10	10	13	13	9	12	10	3.97	M
57	53	85	80	4	7	12	13	12	4	15	14	14	15	10	3.59	M
46	47	55	60	8	6	5	5	10	12	13	12	10	12	10	3.77	M

APPENDIX D: STATISTICAL DATA PRODUCED BY DR. EGGETT WITH SAS

Data taking into account 146 students is all grades together while data with only 136 students is without all 6 seniors, comprising of only sophomores and juniors in high school.

The SAS System 1
Analysis for percent
10:07 Wednesday, July 20, 2011

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_percent		142	2.7253521	22.2851108	1.46	0.1473
pre_percent	pre percent	142	61.1690141	22.4429843	32.48	<.0001
post_percent	post percent	142	63.8943662	24.0524568	31.66	<.0001

The SAS System 2
Analysis for percent
10:07 Wednesday, July 20, 2011

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_percent		136	3.9117647	21.5549154	2.12	0.0361
pre_percent	pre percent	136	60.5588235	22.5703065	31.29	<.0001
post_percent	post percent	136	64.4705882	23.4886706	32.01	<.0001

The SAS System 3
Analysis for percent
10:07 Wednesday, July 20, 2011

------------------------------- Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_percent		93	-0.2258065	24.3212776	-0.09	0.9289
pre_percent	pre percent	93	62.7956989	22.2625437	27.20	<.0001
post_percent	post percent	93	62.5698925	24.6860275	24.44	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_percent		49	8.3265306	16.6187491	3.51	0.0010
pre_percent	pre percent	49	58.0816327	22.6888709	17.92	<.0001
post_percent	post percent	49	66.4081633	22.8372123	20.36	<.0001

The SAS System 4
Analysis for percent
10:07 Wednesday, July 20, 2011

------------------------------- Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_percent		88	1.4659091	23.4853581	0.59	0.5597
pre_percent	pre percent	88	62.2727273	22.5830408	25.87	<.0001
post_percent	post percent	88	63.7386364	24.0088558	24.90	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_percent		48	8.3958333	16.7874568	3.46	0.0011
pre_percent	pre percent	48	57.4166667	22.4412551	17.73	<.0001
post_percent	post percent	48	65.8125000	22.6909451	20.09	<.0001

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_percent
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	3	10 11 12
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	8
Columns in Z	0
Subjects	1
Max Obs Per Subject	142

Number of Observations

Number of Observations Read	142
Number of Observations Used	142
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	370.89

Fit Statistics

-2 Res Log Likelihood	1218.1
AIC (smaller is better)	1220.1
AICC (smaller is better)	1220.2
BIC (smaller is better)	1223.1

The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			-31.3666	17.2993	136	-1.81	0.0720
pre_percent			-0.4406	0.07923	136	-5.56	<.0001
GPA			12.4333	4.4011	136	2.83	0.0054
Grade		10	19.9024	8.1886	136	2.43	0.0164
Grade		11	24.4994	8.5304	136	2.87	0.0047
Grade		12	0	.	.	.	.
Gender	Female		-8.9798	3.5703	136	-2.52	0.0131
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
pre_percent	1	136	30.92	<.0001
GPA	1	136	7.98	0.0054
Grade	2	136	4.20	0.0169
Gender	1	136	6.33	0.0131

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	3.4683	2.0900	136	1.66	0.0993
Grade		11	8.0654	3.0366	136	2.66	0.0089
Grade		12	-16.4340	7.9999	136	-2.05	0.0419
Gender	Female		-6.1233	3.0576	136	-2.00	0.0472
Gender	Male		2.8565	3.8344	136	0.74	0.4576

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard F	DF	t Value
Grade		10		11	-4.5970	3.6599	136	-1.26
Grade		10		12	19.9024	8.1886	136	2.43
Grade		11		12	24.4994	8.5304	136	2.87
Gender	Female		Male		-8.9798	3.5703	136	-2.52

The SAS System 7
Analysis for percent
10:07 Wednesday, July 20, 2011

The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.2113
Grade		10		12	0.0164
Grade		11		12	0.0047
Gender	Female		Male		0.0131

The SAS System 8

Analysis for percent

10:07 Wednesday, July 20, 2011

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_percent
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	2	10 11
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	7
Columns in Z	0
Subjects	1
Max Obs Per Subject	136

Number of Observations

Number of Observations Read	136
Number of Observations Used	136
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	361.14

Fit Statistics

-2 Res Log Likelihood	1169.0
AIC (smaller is better)	1171.0
AICC (smaller is better)	1171.1
BIC (smaller is better)	1173.9

The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			-4.7018	14.5663	131	-0.32	0.7474
pre_percent			-0.4603	0.07872	131	-5.85	<.0001
GPA			11.9129	4.3579	131	2.73	0.0071
Grade		10	-4.2309	3.6154	131	-1.17	0.2440
Grade		11	0	.	.	.	.
Gender	Female		-7.8603	3.5799	131	-2.20	0.0299
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
pre_percent	1	131	34.19	<.0001
GPA	1	131	7.47	0.0071
Grade	1	131	1.37	0.2440
Gender	1	131	4.82	0.0299

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	3.6367	2.0677	131	1.76	0.0809
Grade		11	7.8675	2.9926	131	2.63	0.0096
Gender	Female		1.8220	2.1021	131	0.87	0.3877
Gender	Male		9.6822	2.9469	131	3.29	0.0013

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-4.2309	3.6154	131	-1.17
Gender	Female		Male		-7.8603	3.5799	131	-2.20

The SAS System 10
Analysis for percent
10:07 Wednesday, July 20, 2011

The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.2440
Gender	Female		Male		0.0299

The SAS System 11
Analysis for total
10:07 Wednesday, July 20, 2011

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_total		142	1.1126761	6.9528285	1.91	0.0586
pre_total	pre total	142	49.5422535	7.4990526	78.73	<.0001
post_total	post total	142	50.6549296	8.2942737	72.78	<.0001

The SAS System 12
Analysis for total
10:07 Wednesday, July 20, 2011

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_total		136	1.4926471	6.7549667	2.58	0.0110
pre_total	pre total	136	49.2426471	7.3881751	77.73	<.0001
post_total	post total	136	50.7352941	8.1633647	72.48	<.0001

The SAS System 13
Analysis for total
10:07 Wednesday, July 20, 2011

------------------------------- Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_total		93	0.3440860	7.6164790	0.44	0.6641
pre_total	pre total	93	49.9032258	7.0279945	68.48	<.0001
post_total	post total	93	50.2473118	8.3830262	57.80	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_total		49	2.5714286	5.2440442	3.43	0.0012
pre_total	pre total	49	48.8571429	8.3541407	40.94	<.0001
post_total	post total	49	51.4285714	8.1521981	44.16	<.0001

The SAS System 14
Analysis for total
10:07 Wednesday, July 20, 2011

------------------------------- Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_total		88	0.8863636	7.3896974	1.13	0.2636
pre_total	pre total	88	49.6250000	6.9618212	66.87	<.0001
post_total	post total	88	50.5113636	8.2920739	57.14	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N	Mean	Std Dev	t Value	Pr > |t|
gain_total		48	2.6041667	5.2944756	3.41	0.0014
pre_total	pre total	48	48.5416667	8.1422417	41.30	<.0001
post_total	post total	48	51.1458333	7.9919896	44.34	<.0001

The SAS System 15
Analysis for total
10:07 Wednesday, July 20, 2011
The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_total
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	3	10 11 12
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	8
Columns in Z	0
Subjects	1
Max Obs Per Subject	142

Number of Observations

Number of Observations Read	142
Number of Observations Used	142
Number of Observations Not Used	0

Covariance Parameter
Estimates

Cov Parm	Estimate
Residual	39.4774

Fit Statistics

-2 Res Log Likelihood	911.3
AIC (smaller is better)	913.3
AICC (smaller is better)	913.4
BIC (smaller is better)	916.2

The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			-0.1313	6.2203	136	-0.02	0.9832
pre_total			-0.3254	0.07592	136	-4.29	<.0001
GPA			3.4160	1.4304	136	2.39	0.0183
Grade		10	5.8932	2.7048	136	2.18	0.0311
Grade		11	7.9618	2.7933	136	2.85	0.0050
Grade		12	0	.	.	.	.
Gender	Female		-2.5828	1.1657	136	-2.22	0.0284
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
pre_total	1	136	18.36	<.0001
GPA	1	136	5.70	0.0183
Grade	2	136	4.54	0.0123
Gender	1	136	4.91	0.0284

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	1.0917	0.6807	136	1.60	0.1111
Grade		11	3.1603	0.9826	136	3.22	0.0016
Grade		12	-4.8015	2.6366	136	-1.82	0.0708
Gender	Female		-1.4745	1.0029	136	-1.47	0.1438
Gender	Male		1.1082	1.2611	136	0.88	0.3811

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-2.0686	1.1819	136	-1.75
Grade		10		12	5.8932	2.7048	136	2.18
Grade		11		12	7.9618	2.7933	136	2.85
Gender	Female		Male		-2.5828	1.1657	136	-2.22

The SAS System 17

Analysis for total

10:07 Wednesday, July 20, 2011

The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.0823
Grade		10		12	0.0311
Grade		11		12	0.0050
Gender	Female		Male		0.0284

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_total
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	2	10 11
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	7
Columns in Z	0
Subjects	1
Max Obs Per Subject	136

Number of Observations

Number of Observations Read	136
Number of Observations Used	136
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	39.2351

Fit Statistics

-2 Res Log Likelihood	876.1
AIC (smaller is better)	878.1
AICC (smaller is better)	878.1
BIC (smaller is better)	881.0

The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			9.0344	5.2780	131	1.71	0.0893
pre_total			-0.3478	0.07696	131	-4.52	<.0001
GPA			3.3219	1.4307	131	2.32	0.0218
Grade		10	-2.0065	1.1789	131	-1.70	0.0911
Grade		11	0	.	.	.	.
Gender	Female		-2.2566	1.1801	131	-1.91	0.0580
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
pre_total	1	131	20.42	<.0001
GPA	1	131	5.39	0.0218
Grade	1	131	2.90	0.0911
Gender	1	131	3.66	0.0580

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	1.1458	0.6792	131	1.69	0.0940
Grade		11	3.1524	0.9793	131	3.22	0.0016
Gender	Female		1.0208	0.6926	131	1.47	0.1429
Gender	Male		3.2774	0.9706	131	3.38	0.0010

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-2.0065	1.1789	131	-1.70
Gender	Female		Male		-2.2566	1.1801	131	-1.91

The SAS System 20

Analysis for total

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The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.0911
Gender	Female		Male		0.0580

The SAS System 21

Analysis for Inference

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The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Inference		142	-0.1760563	3.0696392	-0.68
Pre_Inference	Pre Inference	142	7.2676056	2.8407258	30.49
Post_Inference	Post Inference	142	7.0915493	2.6602003	31.77

Variable	Label	Pr > |t|
gain_Inference		0.4954
Pre_Inference	Pre Inference	<.0001
Post_Inference	Post Inference	<.0001

Analysis for Inference

10:07 Wednesday, July 20, 2011

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Inference		136	-0.1102941	3.0952121	-0.42
Pre_Inference	Pre Inference	136	7.2279412	2.8230976	29.86
Post_Inference	Post Inference	136	7.1176471	2.6779174	31.00

Variable	Label	Pr > |t|
gain_Inference		0.6784
Pre_Inference	Pre Inference	<.0001
Post_Inference	Post Inference	<.0001

------------------------------- Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Inference		93	-0.3763441	3.0854285	-1.18
Pre_Inference	Pre Inference	93	7.3118280	2.7661718	25.49
Post_Inference	Post Inference	93	6.9354839	2.7139192	24.64

Variable	Label	Pr > |t|
gain_Inference		0.2425
Pre_Inference	Pre Inference	<.0001
Post_Inference	Post Inference	<.0001

------------------------------- Gender=Male -------------------------------

Variable	Label	N	Mean	Std Dev	t Value
gain_Inference		49	0.2040816	3.0343835	0.47
Pre_Inference	Pre Inference	49	7.1836735	3.0046732	16.74
Post_Inference	Post Inference	49	7.3877551	2.5561717	20.23

Variable	Label	Pr > |t|
gain_Inference		0.6399
Pre_Inference	Pre Inference	<.0001
Post_Inference	Post Inference	<.0001

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The SAS System 24

Analysis for Inference

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------------------------------ Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Inference		88	-0.3181818	3.1277235	-0.95
Pre_Inference	Pre Inference	88	7.3068182	2.7641297	24.80
Post_Inference	Post Inference	88	6.9886364	2.7396380	23.93

Variable	Label	Pr > |t|
gain_Inference		0.3426
Pre_Inference	Pre Inference	<.0001
Post_Inference	Post Inference	<.0001

------------------------------ Gender=Male -------------------------------

Variable	Label	N	Mean	Std Dev	t Value
gain_Inference		48	0.2708333	3.0299188	0.62
Pre_Inference	Pre Inference	48	7.0833333	2.9523401	16.62
Post_Inference	Post Inference	48	7.3541667	2.5722710	19.81

Variable	Label	Pr > |t|
gain_Inference		0.5387
Pre_Inference	Pre Inference	<.0001
Post_Inference	Post Inference	<.0001

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Inference
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	3	10 11 12
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	8
Columns in Z	0
Subjects	1
Max Obs Per Subject	142

Number of Observations

Number of Observations Read	142
Number of Observations Used	142
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	5.6275

Fit Statistics

-2 Res Log Likelihood	644.5
AIC (smaller is better)	646.5
AICC (smaller is better)	646.5
BIC (smaller is better)	649.4

The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			-1.3565	2.1299	136	-0.64	0.5253
Pre_Inference			-0.6941	0.07423	136	-9.35	<.0001
GPA			1.5747	0.5395	136	2.92	0.0041
Grade		10	1.1304	1.0071	136	1.12	0.2636
Grade		11	0.5394	1.0380	136	0.52	0.6042
Grade		12	0	.	.	.	.
Gender	Female		-0.8231	0.4412	136	-1.87	0.0643
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Inference	1	136	87.45	<.0001
GPA	1	136	8.52	0.0041
Grade	2	136	1.29	0.2788
Gender	1	136	3.48	0.0643

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	0.1907	0.2578	136	0.74	0.4607
Grade		11	-0.4003	0.3743	136	-1.07	0.2867
Grade		12	-0.9397	0.9805	136	-0.96	0.3396
Gender	Female		-0.7947	0.3757	136	-2.12	0.0362
Gender	Male		0.02842	0.4739	136	0.06	0.9523

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	0.5910	0.4518	136	1.31
Grade		10		12	1.1304	1.0071	136	1.12
Grade		11		12	0.5394	1.0380	136	0.52
Gender	Female		Male		-0.8231	0.4412	136	-1.87

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Analysis for Inference
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The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.1930
Grade		10		12	0.2636
Grade		11		12	0.6042
Gender	Female		Male		0.0643

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Inference
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	2	10 11
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	7
Columns in Z	0
Subjects	1
Max Obs Per Subject	136

Number of Observations

Number of Observations Read	136
Number of Observations Used	136
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	5.7789

Fit Statistics

-2 Res Log Likelihood	623.3
AIC (smaller is better)	625.3
AICC (smaller is better)	625.3
BIC (smaller is better)	628.1

The SAS System 29
Analysis for Inference
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The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			-0.6341	1.8406	131	-0.34	0.7310
Pre_Inference			-0.7012	0.07714	131	-9.09	<.0001
GPA			1.5330	0.5494	131	2.79	0.0060
Grade		10	0.5982	0.4581	131	1.31	0.1939
Grade		11	0	.	.	.	.
Gender	Female		-0.7942	0.4536	131	-1.75	0.0823
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Inference	1	131	82.63	<.0001
GPA	1	131	7.79	0.0060
Grade	1	131	1.71	0.1939
Gender	1	131	3.07	0.0823

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	0.2088	0.2615	131	0.80	0.4259
Grade		11	-0.3894	0.3794	131	-1.03	0.3066
Gender	Female		-0.4874	0.2658	131	-1.83	0.0690
Gender	Male		0.3068	0.3736	131	0.82	0.4130

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	0.5982	0.4581	131	1.31
Gender	Female		Male		-0.7942	0.4536	131	-1.75

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Analysis for Inference
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The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.1939
Gender	Female		Male		0.0823

The MEANS Procedure

Variable	Label	N
gain_Recognition_of_Assumptions		142
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	142
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	142

Variable	Label	Mean
gain_Recognition_of_Assumptions		0.5704225
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	9.9436620
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	10.5140845

Variable	Label	Std Dev
gain_Recognition_of_Assumptions		3.5318167
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	3.3995716
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	3.0076402

Variable	Label	t Value
gain_Recognition_of_Assumptions		1.92
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	34.86
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	41.66

Variable	Label	Pr > |t|
gain_Recognition_of_Assumptions		0.0563
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	<.0001
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	<.0001

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Analysis for Recognition_of_Assumptions

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The MEANS Procedure

Variable	Label	N
gain_Recognition_of_Assumptions		136
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	136
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	136

Variable	Label	Mean
gain_Recognition_of_Assumptions		0.6911765
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	9.8382353
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	10.5294118

Variable	Label	Std Dev
gain_Recognition_of_Assumptions		3.4907597
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	3.4063570
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	2.9563270

Variable	Label	t Value
gain_Recognition_of_Assumptions		2.31
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	33.68
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	41.54

Variable	Label	Pr > |t|
gain_Recognition_of_Assumptions		0.0225
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	<.0001
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	<.0001

-------------------------------- Gender=Female --------------------------------

The MEANS Procedure

Variable	Label	N
gain_Recognition_of_Assumptions		93
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	93
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	93

Variable	Label	Mean
gain_Recognition_of_Assumptions		0.3333333
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	10.0430108
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	10.3763441

Variable	Label	Std Dev
gain_Recognition_of_Assumptions		3.6781769
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	3.3876822
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	3.1757025

Variable	Label	t Value
gain_Recognition_of_Assumptions		0.87
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	28.59
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	31.51

Variable	Label	Pr > |t|
gain_Recognition_of_Assumptions		0.3844
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	<.0001
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N
gain_Recognition_of_Assumptions		49
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	49
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	49

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Analysis for Recognition_of_Assumptions
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-------------------------------- Gender=Male ---------------------------------

The MEANS Procedure

Variable	Label	Mean
gain_Recognition_of_Assumptions		1.0204082
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	9.7551020
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	10.7755102

Variable	Label	Std Dev
gain_Recognition_of_Assumptions		3.2241911
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	3.4492186
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	2.6713394

Variable	Label	t Value
gain_Recognition_of_Assumptions		2.22
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	19.80
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	28.24

Variable	Label	Pr > |t|
gain_Recognition_of_Assumptions		0.0315
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	<.0001
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	<.0001

```
                The SAS System                    35
         Analysis for Recognition_of_Assumptions
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------------------------------ Gender=Female -------------------------------
               The MEANS Procedure
  Variable                   Label                     N
  -------------------------------------------------------------------
  gain_Recognition_of_Assumptions                              88
  Pre_Recognition_of_Assumptions   Pre Recognition of Assumptions    88
  Post_Recognition_of_Assumptions  Post Recognition of Assumptions   88
  -------------------------------------------------------------------
Variable                   Label                          Mean
-----------------------------------------------------------------------------
gain_Recognition_of_Assumptions                              0.5000000
Pre_Recognition_of_Assumptions   Pre Recognition of Assumptions
9.9431818
Post_Recognition_of_Assumptions  Post Recognition of Assumptions
10.4431818
-----------------------------------------------------------------------------
Variable                   Label                        Std Dev
-----------------------------------------------------------------------------
gain_Recognition_of_Assumptions                              3.6166918
Pre_Recognition_of_Assumptions   Pre Recognition of Assumptions
3.4252543
Post_Recognition_of_Assumptions  Post Recognition of Assumptions
3.1325431
-----------------------------------------------------------------------------
 Variable                   Label                      t Value
 -----------------------------------------------------------------------
 gain_Recognition_of_Assumptions                              1.30
 Pre_Recognition_of_Assumptions   Pre Recognition of Assumptions     27.23
 Post_Recognition_of_Assumptions  Post Recognition of Assumptions    31.27
 -----------------------------------------------------------------------
 Variable                   Label                      Pr > |t|
 ------------------------------------------------------------------------
 gain_Recognition_of_Assumptions                            0.1981
 Pre_Recognition_of_Assumptions   Pre Recognition of Assumptions     <.0001
 Post_Recognition_of_Assumptions  Post Recognition of Assumptions    <.0001
------------------------------- Gender=Male -------------------------------
  Variable                   Label                     N
  -------------------------------------------------------------------
  gain_Recognition_of_Assumptions                              48
  Pre_Recognition_of_Assumptions   Pre Recognition of Assumptions    48
  Post_Recognition_of_Assumptions  Post Recognition of Assumptions   48
  -------------------------------------------------------------------
```

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Analysis for Recognition_of_Assumptions
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-------------------------------- Gender=Male --------------------------------

The MEANS Procedure

Variable	Label	Mean
gain_Recognition_of_Assumptions		1.0416667
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	9.6458333
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	10.6875000

Variable	Label	Std Dev
gain_Recognition_of_Assumptions		3.2548382
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	3.3989334
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	2.6268357

Variable	Label	t Value
gain_Recognition_of_Assumptions		2.22
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	19.66
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	28.19

Variable	Label	Pr > |t|
gain_Recognition_of_Assumptions		0.0315
Pre_Recognition_of_Assumptions	Pre Recognition of Assumptions	<.0001
Post_Recognition_of_Assumptions	Post Recognition of Assumptions	<.0001

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Recognition_of_Assumptions
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	3	10 11 12
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	8
Columns in Z	0
Subjects	1
Max Obs Per Subject	142

Number of Observations

Number of Observations Read	142
Number of Observations Used	142
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	7.6176

Fit Statistics

-2 Res Log Likelihood	686.1
AIC (smaller is better)	688.1
AICC (smaller is better)	688.1

The Mixed Procedure

Fit Statistics

BIC (smaller is better) 691.0

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF
Intercept			4.6729	2.6322	136
Pre_Recognition_of_A			-0.6219	0.06962	136
GPA			0.3433	0.5978	136
Grade		10	0.9368	1.1776	136
Grade		11	1.8222	1.2259	136
Grade		12	0	.	.
Gender	Female		-0.5849	0.5120	136
Gender	Male		0	.	.

Solution for Fixed Effects

Effect	Gender	Grade	t Value	Pr > |t|
Intercept			1.78	0.0781
Pre_Recognition_of_A			-8.93	<.0001
GPA			0.57	0.5668
Grade		10	0.80	0.4277
Grade		11	1.49	0.1395
Grade		12	.	.
Gender	Female		-1.14	0.2553
Gender	Male		.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Recognition_of_A	1	136	79.79	<.0001
GPA	1	136	0.33	0.5668
Grade	2	136	1.96	0.1455
Gender	1	136	1.30	0.2553

The Mixed Procedure

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	0.4138	0.2991	136	1.38	0.1688
Grade		11	1.2992	0.4345	136	2.99	0.0033
Grade		12	-0.5230	1.1499	136	-0.45	0.6500
Gender	Female		0.1042	0.4398	136	0.24	0.8130
Gender	Male		0.6891	0.5495	136	1.25	0.2119

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-0.8854	0.5226	136	-1.69
Grade		10		12	0.9368	1.1776	136	0.80
Grade		11		12	1.8222	1.2259	136	1.49
Gender	Female		Male		-0.5849	0.5120	136	-1.14

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.0925
Grade		10		12	0.4277
Grade		11		12	0.1395
Gender	Female		Male		0.2553

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Recognition_of_Assumptions
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	2	10 11
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	7
Columns in Z	0
Subjects	1
Max Obs Per Subject	136

Number of Observations

Number of Observations Read	136
Number of Observations Used	136
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	7.3441

Fit Statistics

-2 Res Log Likelihood	655.1
AIC (smaller is better)	657.1
AICC (smaller is better)	657.1

Analysis for Recognition_of_Assumptions
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The Mixed Procedure

Fit Statistics

BIC (smaller is better)	660.0

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF
Intercept			6.7470	2.1832	131
Pre_Recognition_of_A			-0.6329	0.06901	131
GPA			0.2777	0.5906	131
Grade		10	-0.8569	0.5136	131
Grade		11	0	.	.
Gender	Female		-0.4574	0.5111	131
Gender	Male		0	.	.

Solution for Fixed Effects

Effect	Gender	Grade	t Value	Pr > |t|
Intercept			3.09	0.0024
Pre_Recognition_of_A			-9.17	<.0001
GPA			0.47	0.6390
Grade		10	-1.67	0.0976
Grade		11	.	.
Gender	Female		-0.89	0.3725
Gender	Male		.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Recognition_of_A	1	131	84.12	<.0001
GPA	1	131	0.22	0.6390
Grade	1	131	2.78	0.0976
Gender	1	131	0.80	0.3725

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	0.4686	0.2943	131	1.59	0.1138
Grade		11	1.3255	0.4259	131	3.11	0.0023

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Analysis for Recognition_of_Assumptions
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The Mixed Procedure
Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Gender	Female		0.6684	0.2996	131	2.23	0.0274
Gender	Male		1.1258	0.4207	131	2.68	0.0084

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-0.8569	0.5136	131	-1.67
Gender	Female		Male		-0.4574	0.5111	131	-0.89

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.0976
Gender	Female		Male		0.3725

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Analysis for Deduction_
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The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Deduction_		142	-0.4225352	3.0812265	-1.63
Pre_Deduction_	Pre Deduction	142	10.3521127	2.0042408	61.55
Post_Deduction_	Post Deduction	142	9.9295775	2.6380949	44.85

Variable	Label	Pr > |t|
gain_Deduction_		0.1045
Pre_Deduction_	Pre Deduction	<.0001
Post_Deduction_	Post Deduction	<.0001

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Analysis for Deduction_

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The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Deduction_		136	-0.3602941	3.0566813	-1.37
Pre_Deduction_	Pre Deduction	136	10.3308824	2.0149631	59.79
Post_Deduction_	Post Deduction	136	9.9705882	2.6413834	44.02

Variable	Label	Pr > |t|
gain_Deduction_		0.1715
Pre_Deduction_	Pre Deduction	<.0001
Post_Deduction_	Post Deduction	<.0001

------------------------------ Gender=Female ------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Deduction_		93	-0.3870968	3.1416980	-1.19
Pre_Deduction_	Pre Deduction	93	10.3763441	1.9721649	50.74
Post_Deduction_	Post Deduction	93	9.9892473	2.6477826	36.38

Variable	Label	Pr > |t|
gain_Deduction_		0.2378
Pre_Deduction_	Pre Deduction	<.0001
Post_Deduction_	Post Deduction	<.0001

------------------------------ Gender=Male ------------------------------

Variable	Label	N	Mean	Std Dev	t Value
gain_Deduction_		49	-0.4897959	2.9938997	-1.15
Pre_Deduction_	Pre Deduction	49	10.3061224	2.0837074	34.62
Post_Deduction_	Post Deduction	49	9.8163265	2.6431789	26.00

Variable	Label	Pr > |t|
gain_Deduction_		0.2578
Pre_Deduction_	Pre Deduction	<.0001
Post_Deduction_	Post Deduction	<.0001

------------------------------- Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	t Value
gain_Deduction_		88	-0.2500000	3.1082020	-0.75
Pre_Deduction_	Pre Deduction	88	10.3409091	1.9762170	49.09
Post_Deduction_	Post Deduction	88	10.0909091	2.6550163	35.65

Variable	Label	Pr > |t|
gain_Deduction_		0.4526
Pre_Deduction_	Pre Deduction	<.0001
Post_Deduction_	Post Deduction	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N	Mean	Std Dev	t Value
gain_Deduction_		48	-0.5625000	2.9815479	-1.31
Pre_Deduction_	Pre Deduction	48	10.3125000	2.1052745	33.94
Post_Deduction_	Post Deduction	48	9.7500000	2.6296185	25.69

Variable	Label	Pr > |t|
gain_Deduction_		0.1975
Pre_Deduction_	Pre Deduction	<.0001
Post_Deduction_	Post Deduction	<.0001

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Deduction_
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	3	10 11 12
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	8
Columns in Z	0
Subjects	1
Max Obs Per Subject	142

Number of Observations

Number of Observations Read	142
Number of Observations Used	142
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	6.6629

Fit Statistics

-2 Res Log Likelihood	666.8
AIC (smaller is better)	668.8
AICC (smaller is better)	668.8
BIC (smaller is better)	671.7

The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			2.9753	2.4386	136	1.22	0.2245
Pre_Deduction_			-0.8401	0.1117	136	-7.52	<.0001
GPA			1.1447	0.5723	136	2.00	0.0475
Grade		10	0.7904	1.0930	136	0.72	0.4708
Grade		11	1.8784	1.1309	136	1.66	0.0990
Grade		12	0	.	.	.	.
Gender	Female		-0.1217	0.4791	136	-0.25	0.7998
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Deduction_	1	136	56.59	<.0001
GPA	1	136	4.00	0.0475
Grade	2	136	3.06	0.0500
Gender	1	136	0.06	0.7998

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	-0.7227	0.2797	136	-2.58	0.0108
Grade		11	0.3652	0.4038	136	0.90	0.3673
Grade		12	-1.5131	1.0659	136	-1.42	0.1580
Gender	Female		-0.6844	0.4086	136	-1.67	0.0962
Gender	Male		-0.5627	0.5138	136	-1.10	0.2754

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-1.0879	0.4858	136	-2.24
Grade		10		12	0.7904	1.0930	136	0.72
Grade		11		12	1.8784	1.1309	136	1.66
Gender	Female		Male		-0.1217	0.4791	136	-0.25

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The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.0268
Grade		10		12	0.4708
Grade		11		12	0.0990
Gender	Female		Male		0.7998

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Deduction_
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	2	10 11
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	7
Columns in Z	0
Subjects	1
Max Obs Per Subject	136

Number of Observations

Number of Observations Read	136
Number of Observations Used	136
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	6.6494

Fit Statistics

-2 Res Log Likelihood	641.0
AIC (smaller is better)	643.0
AICC (smaller is better)	643.0
BIC (smaller is better)	645.9

The SAS System 51

Analysis for Deduction_

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The Mixed Procedure

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			4.8884	2.0963	131	2.33	0.0212
Pre_Deduction_			-0.8186	0.1135	131	-7.22	<.0001
GPA			1.0460	0.5761	131	1.82	0.0717
Grade		10	-1.0687	0.4856	131	-2.20	0.0295
Grade		11	0	.	.	.	.
Gender	Female		0.03008	0.4865	131	0.06	0.9508
Gender	Male		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Deduction_	1	131	52.06	<.0001
GPA	1	131	3.30	0.0717
Grade	1	131	4.84	0.0295
Gender	1	131	0.00	0.9508

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	-0.7262	0.2798	131	-2.60	0.0105
Grade		11	0.3425	0.4032	131	0.85	0.3972
Gender	Female		-0.1768	0.2854	131	-0.62	0.5366
Gender	Male		-0.2069	0.3998	131	-0.52	0.6057

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-1.0687	0.4856	131	-2.20
Gender	Female		Male		0.03008	0.4865	131	0.06

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Analysis for Deduction_
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The Mixed Procedure

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.0295
Gender	Female		Male		0.9508

The SAS System 53
Analysis for Interpretation
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The MEANS Procedure

Variable	Label	N	Mean	Std Dev
gain_Interpretation		0	.	.
pre_Interpretation		0	.	.
Post_Interpretation	Post Interpretation	142	11.1619718	2.1981208

Variable	Label	t Value	Pr > |t|
gain_Interpretation		.	.
pre_Interpretation		.	.
Post_Interpretation	Post Interpretation	60.51	<.0001

The SAS System 54

Analysis for Interpretation

10:07 Wednesday, July 20, 2011

The MEANS Procedure

Variable	Label	N	Mean	Std Dev
gain_Interpretation		0	.	.
pre_Interpretation		0	.	.
Post_Interpretation	Post Interpretation	136	11.1617647	2.1848657

Variable	Label	t Value	Pr > |t|
gain_Interpretation		.	.
pre_Interpretation		.	.
Post_Interpretation	Post Interpretation	59.58	<.0001

The SAS System 55
Analysis for Interpretation
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------------------------------- Gender=Female --------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev
gain_Interpretation		0	.	.
pre_Interpretation		0	.	.
Post_Interpretation	Post Interpretation	93	11.0430108	2.0742415

Variable	Label	t Value	Pr > |t|
gain_Interpretation		.	.
pre_Interpretation		.	.
Post_Interpretation	Post Interpretation	51.34	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N	Mean	Std Dev
gain_Interpretation		0	.	.
pre_Interpretation		0	.	.
Post_Interpretation	Post Interpretation	49	11.3877551	2.4222607

Variable	Label	t Value	Pr > |t|
gain_Interpretation		.	.
pre_Interpretation		.	.
Post_Interpretation	Post Interpretation	32.91	<.0001

------------------------------- Gender=Female --------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev
gain_Interpretation		0	.	.
pre_Interpretation		0	.	.
Post_Interpretation	Post Interpretation	88	11.0795455	2.0745950

Variable	Label	t Value	Pr > |t|
gain_Interpretation		.	.
pre_Interpretation		.	.
Post_Interpretation	Post Interpretation	50.10	<.0001

-------------------------------- Gender=Male --------------------------------

Variable	Label	N	Mean	Std Dev
gain_Interpretation		0	.	.
pre_Interpretation		0	.	.
Post_Interpretation	Post Interpretation	48	11.3125000	2.3893046

Variable	Label	t Value	Pr > |t|
gain_Interpretation		.	.
pre_Interpretation		.	.
Post_Interpretation	Post Interpretation	32.80	<.0001

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Analysis for Interpretation
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The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Interpretation

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Analysis for Interpretation
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The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Interpretation

The SAS System 59
Analysis for Evaluation_of_Arguments
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The MEANS Procedure

Variable	Label	N	Mean
gain_Evaluation_of_Arguments		142	1.0000000
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	142	10.9366197
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	142	11.9366197

Variable	Label	Std Dev
gain_Evaluation_of_Arguments		2.6816952
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	2.3253606
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	2.1477839

Variable	Label	t Value	Pr > |t|
gain_Evaluation_of_Arguments		4.44	<.0001
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	56.05	<.0001
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	66.23	<.0001

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Analysis for Evaluation_of_Arguments
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The MEANS Procedure

Variable	Label	N	Mean
gain_Evaluation_of_Arguments		136	1.0294118
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	136	10.9044118
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	136	11.9338235

Variable	Label	Std Dev
gain_Evaluation_of_Arguments		2.6609416
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	2.3218086
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	2.1194066

Variable	Label	t Value	Pr > |t|
gain_Evaluation_of_Arguments		4.51	<.0001
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	54.77	<.0001
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	65.67	<.0001

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Analysis for Evaluation_of_Arguments

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------------------------------ Gender=Female -------------------------------

The MEANS Procedure

Variable	Label	N	Mean
gain_Evaluation_of_Arguments		93	0.8064516
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	93	11.0645161
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	93	11.8709677

Variable	Label	Std Dev
gain_Evaluation_of_Arguments		2.7356665
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	2.1100507
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	2.1830663

Variable	Label	t Value	Pr > |t|
gain_Evaluation_of_Arguments		2.84	0.0055
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	50.57	<.0001
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	52.44	<.0001

------------------------------ Gender=Male -------------------------------

Variable	Label	N	Mean
gain_Evaluation_of_Arguments		49	1.3673469
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	49	10.6938776
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	49	12.0612245

Variable	Label	Std Dev
gain_Evaluation_of_Arguments		2.5633139
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	2.6941610
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	2.0957115

Variable	Label	t Value	Pr > |t|
gain_Evaluation_of_Arguments		3.73	0.0005
Pre_Evaluation_of_Arguments	Pre Evaluation of Arguments	27.78	<.0001
Post_Evaluation_of_Arguments	Post Evaluation of Arguments	40.29	<.0001

```
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             Analysis for Evaluation_of_Arguments
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------------------------------ Gender=Female ------------------------------
                   The MEANS Procedure

Variable                 Label                    N        Mean
--------------------------------------------------------------------------
gain_Evaluation_of_Arguments                      88     0.8295455
Pre_Evaluation_of_Arguments   Pre Evaluation of Arguments    88    11.0454545
Post_Evaluation_of_Arguments  Post Evaluation of Arguments   88    11.8750000
--------------------------------------------------------------------------
  Variable                 Label                    Std Dev
  ----------------------------------------------------------------------
  gain_Evaluation_of_Arguments                      2.6961940
  Pre_Evaluation_of_Arguments   Pre Evaluation of Arguments      2.0894320
  Post_Evaluation_of_Arguments  Post Evaluation of Arguments     2.1324666
  ----------------------------------------------------------------------
Variable                 Label                  t Value  Pr > |t|
--------------------------------------------------------------------------
gain_Evaluation_of_Arguments                      2.89    0.0049
Pre_Evaluation_of_Arguments   Pre Evaluation of Arguments     49.59    <.0001
Post_Evaluation_of_Arguments  Post Evaluation of Arguments    52.24    <.0001
--------------------------------------------------------------------------

------------------------------- Gender=Male -------------------------------
Variable                 Label                    N        Mean
--------------------------------------------------------------------------
gain_Evaluation_of_Arguments                                48     1.3958333
Pre_Evaluation_of_Arguments   Pre Evaluation of Arguments    48    10.6458333
Post_Evaluation_of_Arguments  Post Evaluation of Arguments   48    12.0416667
--------------------------------------------------------------------------
  Variable                 Label                    Std Dev
  ----------------------------------------------------------------------
  gain_Evaluation_of_Arguments                                2.5825897
  Pre_Evaluation_of_Arguments   Pre Evaluation of Arguments      2.7013754
  Post_Evaluation_of_Arguments  Post Evaluation of Arguments     2.1133651
  ----------------------------------------------------------------------
Variable                 Label                  t Value  Pr > |t|
--------------------------------------------------------------------------
gain_Evaluation_of_Arguments                      3.74    0.0005
Pre_Evaluation_of_Arguments   Pre Evaluation of Arguments     27.30    <.0001
Post_Evaluation_of_Arguments  Post Evaluation of Arguments    39.48    <.0001
--------------------------------------------------------------------------
```

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Analysis for Evaluation_of_Arguments
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The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Evaluation_ of_Arguments
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	3	10 11 12
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	8
Columns in Z	0
Subjects	1
Max Obs Per Subject	142

Number of Observations

Number of Observations Read	142
Number of Observations Used	142
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	4.1933

Fit Statistics

-2 Res Log Likelihood	604.1
AIC (smaller is better)	606.1
AICC (smaller is better)	606.1

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Analysis for Evaluation_of_Arguments
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The Mixed Procedure

Fit Statistics

BIC (smaller is better)	609.0

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value
Intercept			5.7300	1.8805	136	3.05
Pre_Evaluation_of_Ar			-0.7858	0.07797	136	-10.08
GPA			1.1027	0.4637	136	2.38
Grade		10	-0.03963	0.8679	136	-0.05
Grade		11	0.4303	0.8967	136	0.48
Grade		12	0	.	.	.
Gender	Female		-0.5536	0.3797	136	-1.46
Gender	Male		0	.	.	.

Solution for Fixed Effects

Effect	Gender	Grade	Pr > |t|
Intercept			0.0028
Pre_Evaluation_of_Ar			<.0001
GPA			0.0188
Grade		10	0.9636
Grade		11	0.6320
Grade		12	.
Gender	Female		0.1471
Gender	Male		.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Evaluation_of_Ar	1	136	101.57	<.0001
GPA	1	136	5.66	0.0188
Grade	2	136	0.75	0.4733
Gender	1	136	2.13	0.1471

Analysis for Evaluation_of_Arguments

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The Mixed Procedure

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	0.9319	0.2219	136	4.20	<.0001
Grade		11	1.4018	0.3204	136	4.38	<.0001
Grade		12	0.9715	0.8459	136	1.15	0.2528
Gender	Female		0.8249	0.3244	136	2.54	0.0121
Gender	Male		1.3785	0.4075	136	3.38	0.0009

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-0.4700	0.3855	136	-1.22
Grade		10		12	-0.03963	0.8679	136	-0.05
Grade		11		12	0.4303	0.8967	136	0.48
Gender	Female		Male		-0.5536	0.3797	136	-1.46

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.2249
Grade		10		12	0.9636
Grade		11		12	0.6320
Gender	Female		Male		0.1471

The Mixed Procedure

Model Information

Data Set	WORK.TEMP
Dependent Variable	gain_Evaluation_ of_Arguments
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
Grade	2	10 11
Gender	2	Female Male

Dimensions

Covariance Parameters	1
Columns in X	7
Columns in Z	0
Subjects	1
Max Obs Per Subject	136

Number of Observations

Number of Observations Read	136
Number of Observations Used	136
Number of Observations Not Used	0

Covariance Parameter Estimates

Cov Parm	Estimate
Residual	4.0616

Fit Statistics

-2 Res Log Likelihood	576.7
AIC (smaller is better)	578.7
AICC (smaller is better)	578.7

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The Mixed Procedure

Fit Statistics

BIC (smaller is better)	581.6

Solution for Fixed Effects

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value
Intercept			6.3204	1.5900	131	3.98
Pre_Evaluation_of_Ar			-0.7839	0.07818	131	-10.03
GPA			1.0487	0.4575	131	2.29
Grade		10	-0.4577	0.3796	131	-1.21
Grade		11	0	.	.	.
Gender	Female		-0.5351	0.3796	131	-1.41
Gender	Male		0	.	.	.

Solution for Fixed Effects

Effect	Gender	Grade	Pr > |t|
Intercept			0.0001
Pre_Evaluation_of_Ar			<.0001
GPA			0.0235
Grade		10	0.2300
Grade		11	.
Gender	Female		0.1610
Gender	Male		.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Pre_Evaluation_of_Ar	1	131	100.55	<.0001
GPA	1	131	5.25	0.0235
Grade	1	131	1.45	0.2300
Gender	1	131	1.99	0.1610

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Grade		10	0.9533	0.2186	131	4.36	<.0001
Grade		11	1.4110	0.3152	131	4.48	<.0001

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Analysis for Evaluation_of_Arguments
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The Mixed Procedure

Least Squares Means

Effect	Gender	Grade	Estimate	Standard Error	DF	t Value	Pr > |t|
Gender	Female		0.9146	0.2228	131	4.10	<.0001
Gender	Male		1.4497	0.3123	131	4.64	<.0001

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Estimate	Standard Error	DF	t Value
Grade		10		11	-0.4577	0.3796	131	-1.21
Gender	Female		Male		-0.5351	0.3796	131	-1.41

Differences of Least Squares Means

Effect	Gender	Grade	Gender	Grade	Pr > |t|
Grade		10		11	0.2300
Gender	Female		Male		0.1610

APPENDIX E: SURVEY QUESTIONS

1. What was the biggest challenge on the Rube Goldberg?
2. Which was your favorite project we did?
3. What are your overall thoughts/comments on the EDP unit?
4. How much did you enjoy the Rube Goldberg Project?
5. Did you find the EDP useful in your everyday life?
6. How has learning the EDP helped you? What is the most useful part about the EDP?
7. Was the EDP a new concept for you? Explain
8. After going through the EDP unit, what is your overall take-away? What did you learn? What will you use? What did you learn about yourself, physics, engineering etc.?

APPENDIX F: STUDENT RESPONSES TO SURVEY

Question 1: What was the biggest challenge on the Rube Goldberg?

Student #	Response:
1	Getting everything to work perfectly every time.
2	Trying to fix what the other group had done. We would get it perfect and come back and it wouldnt workd or be totally different.
3	Trying to work with other groups and classes, they kept taking down our ideas and changing everything. But it all worked out in the end.
4	Working with people from diffrent class periods. If they didn't explain something well enough, we didn't know what to do, so we would have to redo it for them. That was really hard, but it made it fun.
5	I think that the biggest challenge on the Rube Goldberg was working with the other classes.
6	trying to improve and fix things the other groups changed in our overall idea.
7	Communicating well with the other groups and understanding what they were trying to tell you.
8	Working with other groups in different classes other than your own group in your class. It was hard because with your group you have your own plan that you want to carry out. It doesn't always work that way when you have six other classes with tons of new and different ideas and plans. I think that was the hardest part. But, in the end the other groups contributed really good ideas and plans that in the end really improved the project and gave it better results.
9	working with the other groups. we would have something that worked fine or just needed to be tweaked because it got bumped or something and they would completely change it into something that didn't work as well as what was there before.
10	Working with the other groups. Understanding what they were trying to do became our main challenge.
11	The limited amount of time we had.
12	It was hard to work with the other classes because some of the ideas we had were too hard to communicate and we just needed to do them by ourselves, but by the time we got around to doing our idea, the other classes did something else that ruined our opportunity. Communication was the hardest thing because writing is just not the most effective form. It would've been easier if we all could've met face to face every time to explain our new ideas.
13	The biggest challenge was working with groups other than my own. It was hard, because my group would come up with a plan that we thought was good, and then the next class period we would discover that the groups previous to our own had changed everything! Also, sometimes the notes of other groups were unclear and/or hard to understand.
14	Having a difficult group.
15	Team work with the other classes. aka communication.
16	The biggest challenge was when a different group would change everything that worked to something else that didn't work at all. That was very frustrating.
17	The biggest challenge was when a different group would change everything that worked to something else that didn't work at all. That was very frustrating.
18	The others groups were a bunch of unintellectual nincompoops who kept messing up all the work that we did. They were completely unfocused on finishing the project and only

Student #	Response:
	cared about making it look cooler than everyone else.
19	working together with other classmates and classes
20	Trying to figure out what the other classes did when we went back.
21	communication with the other class periods, it was hard getting ideas across to them on written paper.
22	Getting everything to work out exactly right.
23	Communication and know what the other groups were thinking.
24	Trying to communicate with the other classes.
25	Increasing your chance of success.
26	I was at an AP test on that day
27	When something went wrong, we had to try and figuare out how to fix it without messing up or ruining all the other steps before it. And also finding the right materials to use, and measuring out distances, and measurements, and weights.
28	Getting group members to work together in the beginning, but at the same time, letting each other work on their part of the project and to let people be independent and to not micromanage each other every second of the process.
29	The biggest challenge was communicating with the other groups. We would tell them what they had to do and they just still couldn't understand what they were suppose to do.
30	Having to work with the other groups. As rude as this is, one group we worked with wasn't the most bright. They couldn't figure out how to set up dominoes in a straight line and they expected us to figure out everything and solve every problem in one class period.
31	simply communication, it was stressful to have groups before and after you who did fully understand or even read what you did to contribute. This made it a little frustrating because we wanted to make it cool but other groups shortcomings prevented us from adding new stuff each time.
32	I think the biggest challenge was communicating as a big group.
33	Communication. Sometimes it was hard to understand what the other periods were trying to do with it. Also, it would get annoying because things weren't always accurate. It was also sometimes annoying when you would work so hard on something and then you come back and the other periods have completely destroyed it.
34	Working with people that you never saw was difficult for me. I work best when I can talk with everyone and we all work together, but it was good to learn how to communicate with others this way.
35	Getting the obstacle to work every time with a 100% accuracy rate.
36	The other groups didn't always listen to our suggestions, and they apart what we had made. It was hard to communicate with them and It seemed like they would build a lot, and we would spend most ofo ur class period fixing what they had made because it didn't work every time.
37	making the flag wave. also working with people that weren't actually there. its difficult to work together when you aren't with them and can't discuss problems verbally.
38	You'd come into class the next day, and part of the course would be changed, or gone completely.
39	Getting the other groups to understand what we were trying to do with a certain step, or trying to understand what they other groups were trying to get us to do.
40	The biggest challenge was trying to make things work. Sometimes, I couldnt figure out how to fix a part of it and had to really think and test different methods at that one part, but when I did figure out how to make it better, I was really excited. :)
41	communicating with the other groups.
42	Definitely working with the other groups. There wasn't a direct line of communication between us, so it was difficult to continue steps that we started because they would deem them unusable. Much of our time was spent fixing problems presented by the other groups.
43	I think the biggest challege was that we were working with different classes, who didn't always respond or coroporate exactly how we wanted them to.

Student #	Response:
44	Getting everything to flow well. Working with other classes was fun and made things more interesting. But, it was also a little more challenging because if a different period set something up and didn't note it very well, it was sometimes confusing trying to figure out how to work it.
45	getting everything working the way you wanted them to and then thinking up new steps that would lead you to the end and only using the materials that you already had.
46	Having the next group completely disregard the plans you made and make something that is unreliable.
47	The biggest challenge was working with y teammates. It seemed like we all had a different idea in mind. another challenge was that something would work really well one day, and the next it wouldn't work. We would try to adjust it but sometimes it would make it worse. It was difficult to tell a teammate not to touch something because you had a different way of thinking it. Another challenge was having other teams mess with things and make them worse. Overall, it was a really fun project and it went well in the end.
48	The biggest challenge was trying to pick up where the other classes left off. Sometimes we would come in and it was completely different than how we left it and we didn't know what the previous classes where thinking of doing.
49	The biggest challenge for me was to not get frusterated at my group. I wanted to do it all just to get it right, but I had to let them do their thing so they could participate.
50	Making something and then finding out it doesn't work every time. Also communicating with the other groups because sometimes it was hard to figure out what they wanted us to do.
51	Getting the flag to wave.
52	Trying to get everyone to focus on the task at hand.
53	problem solving when something didn't work (patience)
54	working with people within own class period group
55	Fixing everything so that it flowed smoothly and did not stop.
56	Gettig everthing to work consecuatively.
57	Getting everything to work, and run smoothly.
58	Making sure it all worked consistently was the greatest challenge.
59	Getting it all to work at the time of being graded on it.
60	getting everything to work the way you wanted
61	The biggest challenge was communicating with the other classes. Some days we would make a lot of progress, but the other classes either didn't understand or didn't like where it was going, so they would undo all of our hard work. It was also tricky to get consistent result with so many variables. If even just one of the components didn't work right it would effect all of the steps after it.
62	Probably working with the other students in the different classes. It was confusing because they would do things to it that we thought were unnessesary or we thought there was an easier way.
63	Probably brainstorming what we could use. So many options lead to confusion on occasion. I also usually like working alone on things, but that's more of my personality. I also think brainstorming the ideas of how it would all connect
64	Probably coming up with new ways to create chain reactions that were inventive. I found myself, while creative in other aspects of life, returning back to the old dominoes and a marble track. Some of the pully systems and electronic things that the other groups did blew my mind. I would have never come up with them on my own. This could possibly be remidied by showing the videos you took from our year to next year's classes. This might get the ball rolling for the groups you will have in the future to create some really cool ideas.
65	What should come next?
66	Making everything work together.
67	Getting our communication thru with the others classes in our groups.
68	trying to understand what the other classes were doing and fixing things that couldn't seem to be fixed. It was also frustrating when it worked all the time but then it didn't when you

Student #	Response:
	graded.
69	Probably the beginning of the entire project, getting the ideas flowing and trying to see how it would work, and how we could incorporate what we had learned into the project. In addition, the working with the other classes was cool, but difficult at times.
70	communi cating with the other groups at times
71	Communicating. I really need to work on that.
72	The biggest challenge for me was creating and making everything work together perfectly so nothing went wrong.
73	making sure everything was perfect so it wouldn't misfire after everything else worked.
74	Trying to make everything work together.
75	Communicating with the other classes. It was sometimes hard to understand what their vision for the project was when compared to ours through pictures and written explainations, versus talking or showing them in person.
76	It wasn't hard to think of ideas, it was just hard to execute them with such basic materials and knowledge.
77	Once we figured out what the problem was we didn't know how to fix it. Also deciding what to add on.
78	Figuring out what exactly was the problem and how i could fix it efficiently and securely.
79	For me i would say it was the fact that the other people in our group were in different classes. Sometimes it was hard to figure out what they were trying to say and or do with the project.
80	The biggest challenge was understanding and working with the other classes. Sometimes it was dufficult to understand what they were going for in their design and because I did not know who was in the other periods I could not communicate with them.
81	The biggest challenge was bridging the gap between different class periods. Sometimes we had a hard time figuring out what previous classes had done, what needed to be fixed, and communicating what we wanted the next classes to do.
82	It was frustrating when we couldn'nt understand what happened while we were away from the project. It was also frustrating when something worked a few times, and then stopped working and we had to start the process all over agian.
83	Fixing all the problems and thinking of ideas of what to add.
84	The biggest challenge for me was making it perfected. It was so annoying when it would work one time through and then choke the next time. It took asking a lot of questions and alot of redoing to make it right.
85	Working with the other class periods. Sometimes it was hard to follow the notes they left for us, and a lot of the time their steps in the project didn't work, so we had to go back and fix their mistakes, which prevented us from creating new steps to our project because it took up a lot of time. It was hard to understand their way of thinking because they weren't here to tell it to us. Sometimes, the way certain class periods put together the project was very sloppy, and it frustrated my group because we would have liked to do it differently.
86	Tying to figure out how to work the system. The students before us weren't very specific and it made it hard to see what their plan was for making the system work. Also, having people work on it who you can't communicate with affectively.
87	The biggest challenge of the Rube Goldberg was figuring out what to invent in order to add it to the final project. Once you have discovered what you want to be part of the mechanics, you may then devolope them and improve on the design until it works flawlesly.
88	Getting every part of the project to work together flawlessly: it was easy to get one or two aspects of the machine to work perfectly, but it was a whole different story trying to get the whole project to work together in a smooth way.
89	Just getting everything to work together and coming up with ideas for new steps. It was tough but so much fun.

Question 2: Which was your favorite project we did?

Student #	Response:
1	Rube Goldberg
2	Rube Goldberg
3	Rube Goldberg
4	Rube Goldberg
5	Rube Goldberg
6	Rube Goldberg
7	Windmills, Rube Goldberg
8	Rube Goldberg
9	Rube Goldberg
10	Rube Goldberg
11	Rube Goldberg
12	Rube Goldberg
13	Rube Goldberg
14	Rube Goldberg
15	Paper Rockets (A day only)
16	Rube Goldberg
17	Rube Goldberg
18	Paper Rockets (A day only)
19	Windmills, Rube Goldberg
20	Rube Goldberg
21	Rube Goldberg
22	Rube Goldberg
23	Windmills, Rube Goldberg
24	Rube Goldberg
25	Rube Goldberg
26	Paper Rockets (A day only)
27	Rube Goldberg
28	Windmills
29	Rube Goldberg
30	Rube Goldberg
31	Electronics
32	Paper Towers, Rube Goldberg
33	Rube Goldberg
34	Rube Goldberg
35	Paper Rockets (A day only)
36	Rube Goldberg
37	Rube Goldberg
38	Rube Goldberg
39	Rube Goldberg
40	Paper Rockets (A day only), Rube Goldberg
41	Paper Rockets (A day only), Rube Goldberg
42	Electronics, Rube Goldberg
43	Paper Rockets (A day only), Rube Goldberg
44	Rube Goldberg
45	Paper Rockets (A day only), Rube Goldberg
46	Rube Goldberg
47	Paper Towers, Rube Goldberg
48	Rube Goldberg
49	Rube Goldberg
50	Rube Goldberg
51	Windmills

Student #	Response:
52	Rube Goldberg
53	Rube Goldberg
54	Paper Rockets (A day only)
55	Rube Goldberg
56	Rube Goldberg
57	Rube Goldberg
58	Rube Goldberg
59	Rube Goldberg
60	Rube Goldberg
61	Rube Goldberg
62	Electronics, Rube Goldberg
63	Electronics, Rube Goldberg
64	Rube Goldberg
65	Rube Goldberg
66	Rube Goldberg
67	Rube Goldberg
68	Rube Goldberg
69	Rube Goldberg
70	Rube Goldberg
71	Rube Goldberg
72	Rube Goldberg
73	Rube Goldberg
74	Rube Goldberg
75	Rube Goldberg
76	Paper Rockets (A day only), Paper Towers, Windmills, Rube Goldberg
77	Paper Towers, Rube Goldberg
78	Rube Goldberg
79	Paper Towers, Windmills, Rube Goldberg
80	Rube Goldberg
81	Rube Goldberg
82	Rube Goldberg
83	Electronics, Rube Goldberg
84	Rube Goldberg
85	Rube Goldberg
86	Windmills
87	Rube Goldberg
88	Rube Goldberg
89	Rube Goldberg

Question 3: What are your overall thoughts/comments on the EDP unit?

Student #	Response:
1	It was by far the best unit because we were able to have more hands on projects.
2	It was a great thing to learn but over all in my every day life when I come up with a problem this isnt the first thing that comes to mind to do.
3	It was fun, would of been better with more examples.
4	I think it is helpful to use in alot of situations.
5	I think that the EDP unit was very fun and I also think that it is very useful for kids in high school to learn. It is probably more useful learning how to work together and make solutions then plugging numbers into a formula.
6	i feel like it's nice and i use it without thinking about it, but the whole concept of doing it in school seems pointless.
7	When mastered, this process can be really useful in your everyday life.
8	I really enjoyed using it with projects and experiments. Doing it this way has shown how it really works and how you and your situation can be improved when you use the EDP process. I think that it was a very successfull unit and that it should be taught again next year.
9	I think it helps a lot to plan ahead and ask yourself what you need to change and what you can do better when you finish.
10	When doing school or goal related things it really helps me choose the best option for myself.
11	I liked it. The hands-on portion of it really helped me to remember it better.
12	It was fun to work through experiments using it and it helped keep things organized and running smoothly.
13	I thought it was interesting and really helped change how I think about things.
14	I think it was fun and good lesson to learn.
15	It was a good process to make my decisions.
16	I love EDP! It really can help you through whatever-and has caused me to think about the world so differently. I even find myself going through the EDP process watching the news. I really think that if everyone learned this EDP process, the world would be a completely new place. There would be less wars, less court trials, less fighting, less judgment,more research, more education, more love, and a better understanding for all things.
17	I love EDP! It really can help you through whatever-and has caused me to think about the world so differently. I even find myself going through the EDP process watching the news. I really think that if everyone learned this EDP process, the world would be a completely new place. There would be less wars, less court trials, less fighting, less judgment,more research, more education, more love, and a better understanding for all things.
18	Pretty good, useful for mankind as a whole. Right now, it isn't completely beneficial for high school students because we haven't actually hit a part of our lives where we need such deep analytical skills.
19	I liked it a lot because it was more hands on and it was almost impossible to be wrong...you would just try again.
20	I think it helps me to slow down and see what needs help and see what I need to be doing differently.
21	I use the concept, but not the each step, but the concept of asking myself what i need to fix and improve helps.
22	I liked it a lot. I like science but making it hands on always clicks better. It makes more sense to me to see something happening rather than reading a text book or a packet. Putting it into life situations and tangible things makes it more understandable.
23	I thought it was fun. I thought the edp process was just ok.
24	It was really good, and useful. I learned a lot about the way things work, and what

Student #	Response:
	affects them.
25	It was alot of fun, and i learned alot about physics.
26	It was good, I really like the transfer of motion/energy project where we had to build the tracks. It was way fun
27	I think it is very useful in life, however i dont use it as much, but after learning about it i want to start using it everyday. I think it is wonderful, and i am glad that i have learned about it so i can use it in my future.
28	Using the EDP in everyday life is inefficient. It would be helpful in solving larger problems, or working on projects (like the Rube-Goldberg) but would only be efficient if the person using it had lots of practice with it. Otherwise, it would just waste time.
29	It was interesting to see how much i use the EDP process without realizing that i use it.
30	I think it can take up to much time if you use it in place of common sense every single time you're making a decision. However, it was helpful under certain circumstances.
31	I liked it, I liked that we got to learn something we can actually use in our lives and really works and it is easy to see results. I also liked the challenges and how they really tested group work, problem solving, and creative and scientific abilities.
32	I think it was useful when I thought of actually using it. Other times I found myself not solving things like I could be.
33	I thought it was pretty good. It was interesting and I think it required all of us to concentrate more on the project and participate. I liked that it required everyone to participate so it wasn't just one person doing the project and everyone else standing around.
34	I liked it very much and I think that it was the perfect way to end the year.
35	It was good, I wished that we would have went over it more.
36	Sometimes it is annoying to have to do, but after you go through the process it is really helpful, and It is a good thing to use.
37	i liked learning about it. and i loved doing the labs that gave us examples of what it was and how to use it to solve problems.
38	It was super fun. It was relaxed and super chill, and it was a good way of helping us use the EDP. I think interaction is a better way of learning, than studying concepts on a sheet of paper.
39	It could be used earlier in the year so students can focus on using it the entire school year.
40	I liked doing all of the experiments in the EDP unit. I love working with my hands and making things. I also like to go through and figure out what I did wrong and try to fix it. I've always kind of been a person who likes to build and test things out, so I thought this unit was really fun.
41	i thought it was a really good unit
42	I think others will find it very helpful if they actually use it during the unit. It will probably prove to be an extremely important life skill.
43	I liked it a lot. It was really easy to understand and work with. It was also really fun and interesting.
44	I thought it was fun! I felt like we did that without knowing it throughout the whole year (lab reports). But I really enjoyed the last project (RG). I loved it!
45	i really liked it, the projects were alot of fun and they made me be thinking constantly.
46	This is something I will use even after I leave Ms.Ure's class.
47	At first, I had no idea what you were getting us into and I didn't really like it. I was thinking I would rather do nothing, than do this. But it was actually pretty fun! And using the EDP within the labs really worked. I think that we had a better outcome from our projects because of it. We all sat down and really just thought and I think

Student #	Response:
	it saved us more time because there were less errors. Although it seems more time consuming to just sit down and think, it really helps limit your wasted time on stupid errors.
48	I think it was okay. I just though of it as another assignment. It was sort of fun, but I didn't enjoy it.
49	I had a good time learning about the EDP and trying it out in my own life. I also enjoyed the multiple labs we did while using the EDP process. It was a great way to introduce EDP.
50	It was something new and different for me. I loved doing the project to get the flag to wave because it was so fun to actually see my plans work out and have a group analyzing why different aspects weren't working. The EDP unit let me create the type of situation I wanted.
51	I thought it was very interesting. I enjoyed that it gave us a chance to apply some of the concepts we had learned in physics to projects.
52	I wish that all physics students got the oppurtunity to learn about this. It is very fun and informative and applies to other things than just school.
53	I learned so much about teamwork, problem solving, and am starting to reconize it in my life. I enjoyed the projects and the creativeness that it brought. It also helped me see other group's members strengths and solve how we could implement their ideas and strenghts into the project.
54	fun building the goldberg machines. good process from group projects, not really useful for life
55	It was the most useful in real life of anything we learned this school year.
56	Useful.
57	I like it!! It makes you think, and its a better way to solve problems instead of overthinking everything.
58	This was a fun unit. I enjoyed all the projects we did.
59	I liked it but I don't think it helped me that much.
60	It was a good unit to learn and I think it will help me in my everyday life
61	I thought it was a lot of fun! It was nice to learn something that I can actually take with me after High School. I feel like it was very useful to learn this unit.
62	BEST UNIT EVER! It's was sooo great, I hope that schools put EDP in all subjects in all school so that we can learn to think and not just memorize.
63	good for organization, I subcontiously used this in my Physics and Calculus classes
64	I believe that the EDP is a usefull skill for any person to learn, but especially adolecents. Through the projects that we did, I have learned a great deal about communication with others, and ways to aproach problems. In most other circumstances, I would have never thought to ask questions about challenges that we might face, or to plan everything out and assign jobs to everyone before we got started. I tend to rush headlong into things, and this prevented me from doing that, something I am grateful for. One of the best things you did, Miss Ure, was tell us as little as you possibly could at the beginning of class, and have us use the 'ask' step to figure out what the goal would be, and the supplies that we would be allowed to use. I also thout that having a different person be the scribe every day during the Rube Goldberg project was really constructive to my group. But I think my partner and I noticed, when the boys in our group were gone, that assigning everyone to a job and then have them fill out the book on their own, like a community log, was a helpful way to keep both of us working; instead of having one working while the other furiously tried to scribble down everything that had happened since we arrived at our station.
65	It will help you make better decisions.
66	I really liked it. Hands on. Smooth stuff.
67	It is a good technique

Student #	Response:
68	I liked thinking and building everything but i would have rather been with a group of people i knew and could feel more comfortable talking with and discussing what was happening
69	It was cool! And the activities we did were really out of my comfort zone, because I don't always do as good on the hands-on sort of stuff- I think it helped me with that.
70	i like the whole unit and everything we did in it. it really helps me in my life
71	I thought it was a very fun unit. I enjoyed working with my hands and thinking through out situations a little more.
72	Overall I liked it, but there were some things that I didn't like, like writing everything down. Another thing that was a little bit difficult was planning. The more I did it though, the better I got at it. It was a fun unit. I liked finding the creativity I thought I didn't have.
73	It was good but i didnt think it helped with the test we just took. I didnt see how i could use the process on this test.
74	I really like it because it is a great way to solve problems.
75	I really enjoyed the unit. It was nice to be able to analyze things for myself and actually use the EDP process to build something that could be successful.
76	It's helpful, like if you get into a fight or a bad situation or whatever, the only problem is remembering to use the steps and actually think to use it when you're in a situation. Usually I'd just forget about it in the heat of the moment.
77	It wasn't my favorite unit because I actually liked figuring physics stuff with math and not using it with edp. I did like how we talked about making edp in our daily life.
78	Personally it helped me alot to think through different things more thoroughly and be able to fix them quicker rather than just doing the same thing over and over hoping it would work the next time.
79	I really enjoyed it. I really like the hands on part about it all. It is something i am sure i will always use!
80	I thought that it was a useful unit and although it was annoying to take the time to sit down and think through the steps, it proved helpful on several occasions.
81	I thought it was interesting to see how we all started thinking on our own and didn't immediately run for help as soon as we saw a problem.
82	I really liked it. I learned a lot doing it, and I think I am better at critical thinking now.
83	It was a different and fun way to learn. It is a helpful thing to know in my life.
84	I loved it! It's really opened my eyes to simple mind process i've just never thought about before and hasn't just helped me in school stuff but at home and other situations as well
85	I enjoyed it. I like how we were able to ask our own questions and to find solutions to our problems in a creative, effective way. We were able to think of different ideas and test each idea to come up with the best result. I really enjoyed the hands on work rather than taking notes and learning in our desks.
86	I think that it's something that could be really helpful in my life. I use with my family when we start to get hot heads and I just have to step back and use the EDP. It'll be fun to see what kinds of things it will help me with and I'm sure I'll use it in the future.
87	I loved the EDP unit! It is one of my absalute favorites to create, invent, which shows you of what your capable of and how you can improve your very own creative mind.
88	It was an interesting unit. I really enjoyed the Rube Goldberg assignment.
89	It was a lot of fun. I liked doing all the group projects. it was cool to use a new and effective process to work on them.

Question 4: How much did you enjoy the Rube Goldberg Project?

Student#	Out of 5
1	4
2	4
3	5
4	4
5	5
6	5
7	4
8	5
9	5
10	5
11	4
12	5
13	4
14	4
15	5
16	5
17	5
18	4
19	5
20	4
21	5
22	5
23	5
24	4
25	5
26	2
27	4
28	4
29	5
30	5

Student#	Out of 5
31	3
32	5
33	4
34	5
35	4
36	3
37	5
38	5
39	4
40	5
41	5
42	5
43	5
44	5
45	5
46	5
47	4
48	3
49	3
50	5
51	5
52	5
53	5
54	3
55	5
56	4
57	5
58	5
59	5
60	5

Student#	Out of 5
61	5
62	5
63	3
64	5
65	5
66	5
67	4
68	4
69	4
70	5
71	5
72	5
73	5
74	5
75	5
76	5
77	3
78	4
79	4
80	4
81	3
82	3
83	4
84	5
85	4
86	4
87	5
88	5
89	5

Question 5: Did you find the EDP useful in your everyday life?

Student#	Out of 5	Student#	Out of 5	Student#	Out of 5
1	3	31	5	61	2
2	3	32	4	62	4
3	4	33	4	63	4
4	4	34	5	64	4
5	4	35	4	65	3
6	3	36	4	66	3
7	4	37	5	67	2
8	4	38	4	68	3
9	3	39	4	69	5
10	3	40	5	70	4
11	4	41	2	71	4
12	4	42	4	72	4
13	4	43	4	73	3
14	5	44	4	74	5
15	4	45	4	75	3
16	5	46	4	76	3
17	5	47	4	77	3
18	4	48	4	78	4
19	4	49	3	79	5
20	3	50	5	80	3
21	2	51	5	81	1
22	5	52	4	82	4
23	1	53	4	83	5
24	4	54	1	84	5
25	3	55	3	85	5
26	4	56	3	86	3
27	4	57	4	87	5
28	1	58	4	88	3
29	5	59	3	89	3
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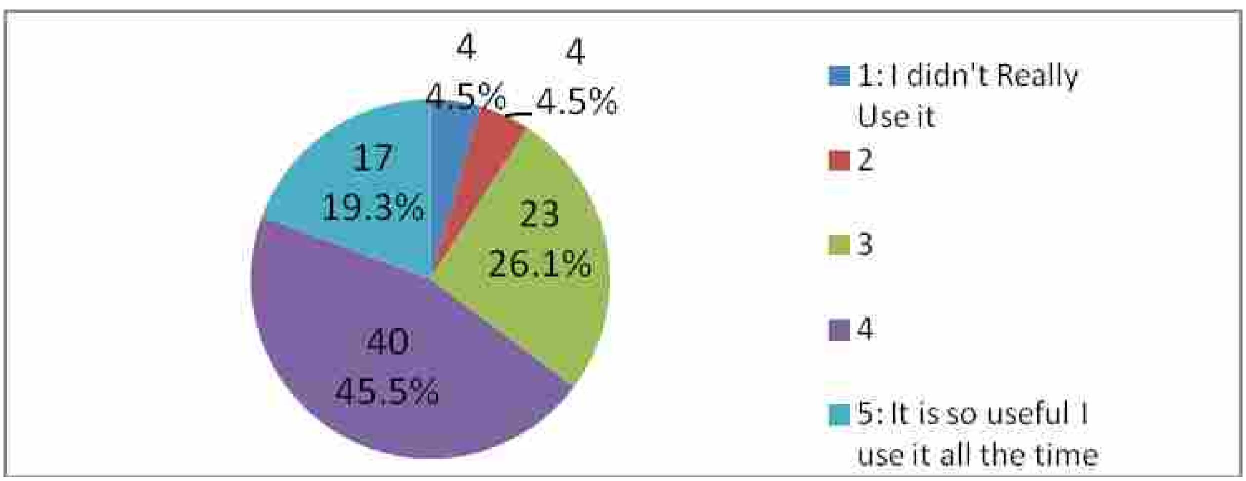

Question 6: How has learning the EDP helped you? What is the most useful part about the EDP?

Student #	Response:
1	
2	It helped me in my everyday life. It made me stop and think of a better way I could do things instead of just jumping right into them.
3	Probably the imagine, thinking of all the possiblities.
4	
5	
6	
7	The "Ask" step was good, since it slows you down and makes you think out what you're trying to do clearly.
8	I think that the EDP process has helped me a lot. After learing about it I have found that when I have a problem that I need to be solved, then I use the EDP process to help me out. I like the test and improve part of the EDP process. I think that when you do exeriment different ways for your problems then your solution will turn out better in the end of it all.
9	the most useful part of the EDP process is planning out before you start working, and that has helped me solve problems with less stress because I already know what I want to do
10	If I have a problem it gives me the opportunity to think about what I did wrong and then do it correct the next time.
11	It has helped me by expanding my knowledge on how to effectivly work out problems in my own life.
12	It has helped me be more careful before acting. The most useful part is that I don't rush decisions. I think of the best ways and test them to see what works. I remember what works and use it next time I have a similar situation.
13	It has helped me to analyze things and to think about something all the way through before acting. I think that the most useful part of EDP was the planning part, so I wouldn't just jump right in to a task without knowing what I was doing.
14	It helps me plan things better.
15	Looking at all the options and imagining all the possibilities.
16	Learning EDP has benefited me so much and I will continue to use it for the rest of my life. I even want to teach it to my future kids when they're young-because it really does make life so much easier when you follow it, and makes any problem solvable. Before we learned about EDP, I had a close friend who was experiencing depression and anxiety. Before this unit, I would always get on her case for acting the way she did, watching TV all the time, crying every day about her problems, and wanting to control everything. After I learned about EDP, I decided to look at the situation and find a way to solve my problems with her. Before EDP, I never thought about the chemistry going on in my friend's body. She really can't control the way she acts and it is good for her to be able to express the way she feels. She needs a lot of attention right now, and because of EDP I have been able to find better ways to spend time with her, and improve my relationship with her. I love the improve part, because there is always room for improvement, and I just try to be better than I was yesterday. That's all that really matters. So many times we compare ourselves to others, but really you just need to improve from yourself yesterday!
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Student #	Response:
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18	It helps because it teaches somebody how to stop and think about a situation before just jumping into it. It is most useful in that you can get things done quicker overall, whereas simpling leaping into a problem results in more problems that must be corrected later on.
19	it isn't just used in math or physics...it is used in every problem.
20	I think fixing the problem and recognizing the problem is the most useful part.
21	
22	It organizes your thought process on dealing with issues in any aspect of life.
23	Im not sure it really has, i don't think its really made a difference. The most useful would be asking questions.
24	It helps isolate problems, and then create the most useful solution
25	Helps in making decisions.
26	It organizes my thinking. Before I may have followed EDP unconsciously, but now that I'm aware of it, I think about it faster and things make sense quicker.
27	Instead of just guessing and rushing through the answers, i learned to take it step by step and realize that the outcome is much better. It helps me make more correct choces and decicions than wrong ones.
28	
29	The EDP process has helped me think about all the options that i have to consider before making a decision.
30	It is just good when you have to make a choice. I used it when deciding what topic o speak on for a speech in English and it really helped.
31	it really improves problem solving skills in any situation and dramatically affects how you look at a problem and how you will face it.
32	
33	It has just helped me learn to plan every part of whatever it is I'm doing and make sure I understand what it is saying. It has also helped me with my communication skills as we had to tell the period after us the new things that we added to our projects.
34	Learning about the EDP has helped me to think through things before I act on them. The most useful part for me was the "Plan" step. I now plan things out all the time.
35	It helps you devoure the situatuion and take a look at it from angles and figure out possible outcomes and solutions to your situation.
36	We use the EDP process a lot in our lives without knowing it, so learning about it has helped me to recognize when I use it.
37	it helps solving problems and figuring out how to fix things and make them better, or even decision making problems
38	You can always be making improvements in every facet of your life. Using the EDP is a way to help you figure out how to improve. I like the ask part of the EDP, because it makes you dig down and really figure out what's wrong, and what needs to be fixed.
39	Not only has it helped me with the projects in physics, but the EDP has also helped me in other classes (for studying) and at home. The most useful part of the EDP would be the improve part, because without that step nothing is going to get better.
40	I think learning about the specific steps has helped me to organize my thoughts better. Instead of just quickly going through the first parts of the steps, I stopped and thought about all the possiblities of what I could do more.
41	choosing what soccer team i wanted to play for. i thought out who would be the bettter team where would i have more fun playing.
42	The preparation period (planning and idea collection). Throwing out random ideas that

Student #	Response:
	probably won't work is a good way to decide what will work.
43	Yes it has helped me quite a few times. I think what the problem was, is trying to train yourself to use it. And to remember to use it. Because when your in a situation where you can use it you don't always do. Not because you don't want to, but because it's maybe just not the first thing you think of.
44	I have had to make a lot of decisions lately and it has helped me choose the more beneficial one for me. The most useful part is testing to see how it works and then if it doesn't-changing it. Sometimes, it wasn't something I could literally test, so I had to go through the consequences and what could potentially go wrong/right in the situation and test it out there.
45	It has helped me understand the way things work. So when I look at something I know what it's action will be and i can predict.
46	The planning before the building or acting process helps me to choose the best option. Communication was also a vital part in the building of the Rube Goldberg machines.
47	I like the EDP because it helps me become more organized. I feel like my thought process is more clear. Before, I got confused with my own thinking because I never really thought through the whole process. After learning about the EDP, I realized how much I use it in my life without realizing. If I remembered to used the EDP more often than it would make many of my decisions so much easier and less confusing. Especially the part where you write everything down. I can see everything more clearly.
48	
49	I think the part that has helped me the most is the asking. I ask myself long term question to help decide which choices and decisions I make will benifit me for the better.
50	I learned to analyze and ask questions like why is this happening? What is really going on in the situation? I use it all the time now in relationships I have with my family and especially friends. When my sister was mad at me, I found myself asking, ok what really happened to make her mad and then try to fix it.
51	EDP has helped me look at situations differently and come up with different ways to slove everyday problems.
52	It has made dealing with daily situations much simpler to solve. For me the most useful part is the brainstorming part. It makes you think more than just one narrow view.
53	It has helped me solve problems in a more efficient manner, to look at both sides of the problem and think of ways on how I can solve it. I think the most useful part is the test/improve section. Instead of giving up on a project, you are able to brainstorm and come up with better ideas that can help solve the problem you are trying to fix.
54	how to continually improve projects and findig ways to organize and communicate problems
55	Its helped me to think things through. The imagine has helped me think of more courses of action I can take in making decisions.
56	I actually use EDP alot cause im a mechanic and i use something similar to the EDP to solve whats damaged.
57	Yes it is. I think it would be, pin pointing the problem.
58	It has helped me a lot in certain games that require strategy.
59	It would say it helped me while building things or trying to fix things but not exactly make decisions.Asking how you can make it better...
60	It's easier to problem solve. The plan step, it reminds me to plan before I jump into a project.
61	The most helpful aspect of the EDP was definitely just learning how to organize and plan. Asking what can be improved and using the steps over and over also helped to get things done in a more efficient way.
62	It's helped my organize my thoughts so I can think about things more deeply and clearly. I think the EDP is just useful in general, I can imagine using it at home and at school, even for the rest of my life.
63	organization, brainstorming. Basic logical skills that help not only in math problems, but

Student #	Response:
	real life. If I was really confused about something happening in my life, I would use the EDP and it helped me organize what things I knew were true, some things I assumed to be true, and things that weren't true.
64	I think that it helped my groups get more work done through more effective communication and a more organized approach to the job we had to accomplish. The 'ask' step prevented us from rushing headlong into the problem without an in-depth understanding of what we had to face and what problems we would encounter along the way. The 'imagine' step allowed us all to voice opinions that I fully believe would not have surfaced out of students' general fear of being brushed aside. The most useful part of the EDP is the structured apprach to solving a problem. It grants the users an ability to think, talk, and organize that I believe many would not necessarily come up with on their own.
65	It has made me make better decisions in my life.
66	Yeah it has..... And probably just the thinkin through part.
67	It opened my mind a little
68	
69	I am able to rely on facts and what is really going on more than just emotions or what I think is going on at the moment.
70	yes, because now when things come up i can actually use my brain and reasoning and see why and waht really is going on.
71	I think through my situations a lot more. Instead of just blurting things out and getting upset I take a step back and think, hey wait a second, why did this happen? It helps prevent a lot of trouble later.
72	It's helped me with my communication skills and being able to find out what things are upsetting me or what things are upsetting my family or friends. For me the most useful part of the EDP process was the asking part.
73	It helped me recognize where the the cause of the problem was instead of the affect of the problem
74	I think it helped me more understand why people do the things they do. To really hink threw why things happen.
75	It has helped me to analyze a problem before I jump right into it. I really like the asking questions part, which helps me to figure out what is truly going on, rather than assume what is going on.
76	Yes, I certainly haven't mastered it or trained myself to think that way automatically yet, but it's useful to know and for future reference.
77	It has taught me to try to understand what is going on that just making a statement. The most useful was being able to see what the problem is and what I can do to fix it.
78	It has helped me to assess why things might be happening in a more logical way. Before i just thought they happened because of a shallow, surface reason. I didn't look deep to see exactly what might have lead up to it. I use this strategy alot now when having problems with the people i am constantly around.
79	Well, I have used it when i am in a fight with my sister, mom, dad, or even a friend. I really think about what they are going through and why they would be acting that way and i try to figure out what i need to do to help them.
80	It has helped me the most in relationships with others.
81	I think the most helpful thing that's come of it is that I don't just immediately say "I don't know how. I can't do it." If I break a situation down, I can begin to see where a problem lies and figure out what I need to do to fix it.
82	I"ve actually used it a lot when people are mad or fighting, and it really helps me to understand the situation better. I have also used it for general problem solving and to come up with plans and ideas. It has helped me to think through things better. My favorite part of it is that it makes me think through things instead of just worrying or not caring.
83	It has helped me in my daily life; I am able to work through problems or situations more

Student #	Response:
	effectively. I can find the most beneficial results to problems instead of the testing and checking which does not give me the best answer. It helps me with my social relationships. I have also been able toexpand and improve my thinking process.
84	It's helped me sort through lots of random personal problems that might come up through my day. They might seem complex but then when the problem is literally broken down, questions are asked, and i take a broader look at the whole situation through EDP then it's clear to see that the problem is a whole lot simpler than it initially looked to be. The most useful part is the end and asking questions. And mostly just asking what could make the situation better
85	It has helped me to learn to communicate better with others and to process my thinking in a more efficient way to understand why things are the way that they are. I think the most useful part about the EDP is knowing that you don't just use it in science. It is something you can take and apply into your own life.
86	If you are working on a project or relationship or anything like that, you can just step back and think about EDP. What is my problem, what are some things that I can do to fix it, etc. Using the EDP is really helpful if you have a problem and you don't know how to figure it out.
87	The most significant part of the EDP is writing and drawing your ideas down. Without it, and not designing it there is absalutley no point in creating because you have no foundation to start from. Learning the EDP has helped me by expanding and understanding how the proccess works in a more clear point of view.
88	I think the most useful aspect of the EDP is the way I think through all my actions now. I look for the source of problems, instead of the results of them.
89	

Question 7: Was the EDP a new concept for you? Explain

Student #	Response:
1	I think that learning about it was new but it seemed like a lot of it is used without even knowing.
2	Yeah, I had never heard of it before. I didnt realize that I already used It alot though.
3	Not really, I kind of all ready did it in my mind without thinking about it, but it was the first time i saw it on paper.
4	Yes, I hadn't heard about it before, so it was really helpful!
5	I wouldn't say that it was a new concept but I think that it was the first time that I recognized the process with specific steps.
6	yes. i've never heard of the concept before.
7	Yes. I had heard of different aspects of it, but not the specific method.
8	Yes. I dont think that I have ever heard about EDP before. So, it was brand new this year. I have heard of other ways to do things like this. But, the EDP process has been more affective and has improved my situations better.
9	No it wasn't a new concept, just the first time I had actually talked about it. I always try to think things out before doing them.
10	Yes. I had been taught to think about what actions to take to make the right decision, but I had never been taught the specific steps.
11	Kinda, I have learned similar concepts in problem solving but none as specific as this.
12	In a way. I think I usually use the process of thinking through things, but I didn't really realize it. It was good to see how I think and why I think and act the way I do.
13	No, I have used this process before in order to complete projects and asses certain situations.
14	Yes and no. I use it in my life a lot but it helped me to do it more.
15	I think that everyone has developed some sort of concept like this before but it was a good thing to exercise it.
16	It was to some extent. Some of the steps that I go into for problem making were the same, but the EDP really increased my knowledge for better ways to problem solve. I love how it is so direct and precise and easy to understand and follow. I love the steps because they work! It is so nice to be able to learn from my previous experiences, improve things I need to work on, and come up with new ideas to help me complete a goal, or project. Learning the exact steps though, really helped me solve my problems more efficiently.
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18	Kind of. I used my own way solving problems analytically, except my way never involved detailed steps like unto the EDP.
19	no, but it was a different format.
20	Ummm... Kind of I've used it in other science classes before.
21	the concept wasn't new, but each individual step was
22	No. It was new to learn the process fully. But after learning it I noticed that I have used this since I was a little tyke. I think it is because my dad is an engineer, so this is how we have been raised to deal with problems.
23	Yes i never learned it, but everyday desicions seem to use it. So i feel like ive used it and learned it, but it was new to me
24	Yes and no. I had been doing the EDP without knowing it previously, but I gained greater insight and information about it through the unit.
25	Not really, it's just a way you think about things.

Student #	Response:
26	Sort of, it was like the sibling concept of the scientific process so it was helpful, but not 100% fresh
27	Well no, I make assumsions and judgment like that everyday, just not as big and complex as the ones that were asked.
28	Not really. I have learned similar concepts in problem-solving in courses like Math and English.
29	No i use it everyday in my life. Going through this process just made me realize how much i use it.
30	Kind of. It was explained more to me, but I already used it subconsciously. I just didn't know there was an actual term and process for it.
31	no I have really used it very often but I didnt necessarily recognize there were specific steps and a name for it all.
32	Not really, I might have been using it before but just not knowing what it was called
33	Kind of. After learning about the process I realized that I used it in my life, without even knowing. But I did not know all the steps and outline of it. I also didn't realize that you could apply it to so much of your life.
34	Yes. I had never really thought about how I think until this unit. It was eye-opening and I believe that I will continue to use it in my everyday life.
35	No, because we use it in everyday situations, we just dont think about it as a process
36	Yes, I noticed that I have been using EDP in my life, but never really knew what it was called.
37	using the process wasn't new to my everyday life. i use it everyday without even noticing. but learning about EDP and the actual steps was all new to me.
38	Yeah it was.. But when we went over it in class, I realized that I use the EDP almost every single day.
39	I was familiar with the concept, but I'd never really used it before until this unit.
40	Not a really new concept. I usually go through the same basic process, I just never realized I was doing it before.
41	it was the proccess of planing out and thinking before you do anything. then you test it and fix the problems
42	No. I just realized that I have been using it for a lot of things before the unit.
43	Not really. I understood it pretty well but I don't remember working with it before.
44	It was something that I had done before but I wasn't aware that it was called anything. This just gave me a name to the problem solving process and also helped me in my problem solving. But, it mostly just gave a title.
45	kind of, I used it before but i didn't really know what it was or what it meant. so the concept wasn't new but now i just know what to call it.
46	Yes, I have used it before but I never knew what it was
47	yes ma'am! I had never really had a process of thinking, I just did it.
48	No, I have had to use it with other assignments and I use it when I write through editing my writing. I read through my writing and think how can I change it to make it better.
49	Yes, I learned a lot a lot of new concepts in this unit. I learned the steps of the EDP process and how to apply them in my own life.
50	Yes. At first it seemed really tedious and unimportant to sit down and actually think through situations, deciding if a conclusion followed or not. Usually I just make decisions or don't make a decision at all so having to think through the problem was something that took me out of my normal way of thinking.
51	Yes. The exact steps in order where a new idea, however the problem solving system by looking for new ways to do things was not new.
52	No, because a few years ago one of my science teachers briefly talked about the components of it.
53	No, although I never used the term "EDP" process, I think that this process is used in my everyday life whether I reconize it our not. Through school work, afterschool activities, goal setting, and I practice it everyday.

Student #	Response:
54	no, i have been introduced to thoought procces exercises before
55	Yes, I didnt think about how I thought about things before and the process used.
56	Yes it was. It was some interseting questions that i really had to think about .
57	Yes it was. Even though i kinda think that way already, it pointed it out for me.
58	In some ways, it was new, but I had already taught myself some of the concepts.
59	Yes, I kind of knew a little bit because of doing a Science Project in Elementary School.
60	no. I had learned it before, but this elaborated more and made the material easier to understand
61	Not completely new. I've always used these problem solving steps in my life, but never organized quite like this. I've also never recognized the process as different steps to solving problems.
62	Heck yes. Most classes tell you how you should think and do things, but the EDP was really cool because for once we got to do stuff our way and figure things out on our own. Before the EDP, I considered myself a smart student because I got good grades, but I was just memorizing what the teachers told me. I never really thought about what I was learning. When we did the EDP, I realized that I wasn't THINKING to get good grades, which is a problem.
63	Not nessisarily. It seemed like common sense, althought it was nice to have an organized way of dealing things. In my own life I found that I would use the EDP method, but I wouldn't follow it perfectly- I would skip steps
64	This was a new concept for me in the terms of applying it to science, but the basic process is similar to that of the decision making process that we learn in Health classes. In that we also evaluate options, but there is no room for testing and improving upon the decision made.
65	Yes, some things on it I wanted to think of as true or false answers not is it related to the situation.
66	Not really. I thought through most situations on my own.
67	Yes it was pretty new. But I learned something like it in Drivers Ed
68	it means thinking of more ways to fix a problem and doing it successfully
69	Yes. I had not learned anything like that in school before. It was cool
70	Yes. well the name was a new concept to me, but now that i have learned waht it is, i have used it before.
71	It was new in the way that it was given a name and expanded. I think I already used the process without ever realizing it.
72	Yes. I never heard the process so it was nice to learn a new concept that can better prepare me for life after I graduate high school.
73	yes it was. the actual steps are new but the process of recognizing them all wasnt there
74	Yes and No, because I didn't really think that you could apply the EDP process to everything. I have used it sometimes in problem solving but didn't really think to apply it to more things.
75	Somewhat. I have unconciously used parts of the EDP in my life, but the actual organized steps were a new concept.
76	Sort of. I mean, critical thinking and analyzing aren't a new thing, I've known the basics for a while. But there's never been the whole process and steps outlined for me before.
77	Yes and no. I used it for school to figure things out but not in day to day life time activtites.
78	In a way, yes. I'm more of the kind of person to try things out a bunch of different ways; but sometimes don't stop to think through what the problem was exactly and what i can do to improve. I also found myself looking at the broader perspective and connecting what was happening with why it might be happening.
79	Yes and No. I have been using the EDP a lot even before we started to learn it in class. But it wasn't untill this class i used it to this magnitued. I really liked it. It was really

Student #	Response:
	helpful. Not only in school but in my life. :)
80	EDP was not completely a new process, but i did learn new ways of thinking. In the past i have been able to use problem solving skills, but EDP made me really think about what affects i would have depending on my choices.
81	Not exactly. We've been taught the scientific method since elementary school, which teaches us to think of possible answers to a problem, test it out, and evaluate. However, this seemed more focused on using in everyday life.
82	Mostly. I never used that many steps when I problem solved before, but now I think through all the steps and am able to get better results.
83	Somewhat. Although I had never heard of the process or the steps, I have been using it without knowing.
84	Kind of! I had never heard of it in this structured outline but i've come to see that I usually try to solve my problems this way without knowing it. But now that i know what it is, i realize that I've sort of done it my whole life. But now i have an outline in my head to go through.
85	Yes and no. I have always thought of a similar thinking process like the EDP, but I never knew there was an actual name to this thinking process. I also didn't know that there were certain steps to follow.
86	Yes. I have never thought about solving a problem in that way. I always kind of thought that my way on making a decision was always the best, but then I would think about EDP and it would change my decision.
87	NO, it wasn't exactly a new concept for me. This proccess has been natural to me in my life, it might have given me new insite to my knowledge but created little influence.
88	Yes. I've never had to go into so much detail with questions, and thinking about my thought processes.
89	Yep. I've never done the whole process before at the beginning of a problem. It was cool!

Question 8: After going through the EDP unit, what is your overall take-away? What did you learn? What will you use? What did you learn about yourself, physics, engineering etc.?

Student #	Response:
1	I learned that you have the ability to look at a situation in many different ways. I don't know that I'll stop and think about EDP in a situation but like I said before a lot of it is subconscious.
2	I learned that some times I just need to take things slow instead of jumping right into them. That yes, it can help when I think things out or ,in the rube goldberg project, read what the other group wrote.
3	Next time there is a problem think of all the possible solutions not just a couple, it will help.
4	I learned how to solve a problem in hard situations. I will use all of it.
5	I learned from the EDP unit that there is always a solution.
6	I think the EDP unit was helpful for engineering and physics but i don't feel like i will use it a lot in my own life because i don't like the long and repetative process in my life.
7	My overall take-away was to slow down and figure out the problem first.
8	I think that after the EDP unit I will continue to use it in my everyday life. I love it when you find a solution to a problem and that you have to ideas on how to work it out and make it a better situation. Using the EDP I think that I have learned that I can think of great ideas as solutions and that I can figure out problems all by myself if I would only stop and think about what I am really trying to accomplish.
9	I will always try to plan things out better before I get started and then figure out what I can fix or improve once I'm finished.
10	I'm taking away a better way to problem solve. I learned that it can be very useful when dealing with school or personal goals. I will use the last step to improve myself and the decision I will have to make. I learned physics can be more than just math and science. It's a new way to solve problems.
11	I learned to always pick people in your group with the same brainpower as you or else.
12	It is important to think through how you are going to solve a problem instead of just jumping in head first and hoping it works. I learned not to act on an impulse, but to really think through what the chain reaction would be like.
13	I will use the EDP in order to accomplish tasks. I learned that waiting just a few minutes in order to come up with a plan and ideas was much more useful and valuable than just jumping right in to the assignment. It as also useful because the people in all my groups had a specific job to do, so no one was slacking off. I learned that I had a lot more good ideas and plans/abilities than I thought I did, and this process really changed how I viewed physics, english, math, and my classes/homework in general.
14	If I use the EDP process it helps me do more things correctly.
15	Theres a lot more to deciding than i thought.
16	I learned that I decide how I react no matter what the situation is. I only have control over me, I can't control everything, but I can improve it! :) I love learning how things work and will quite often find myself in the car calculating how fast I heard a noise, how long something will take, etc. etc. It is amazing how much I have expanded in my learning and critical thinking.
17	I learned that I decide how I react no matter what the situation is. I only have control over me, I can't control everything, but I can improve it! :) I love learning how things work and will quite often find myself in the car calculating how fast I heard a noise, how long something will take, etc. etc. It is amazing how much I have expanded in my learning and critical thinking.
18	Nothing much changed for me really. Maybe for others, but generally I have stayed the same.
19	i learned a lot!

Student #	Response:
20	That I need to slow down and evaluate everything.
21	I think the most important step from the EDP I've learned is the improvement step. This helps me realize what I can improve on the project and different ways I can.
22	The process overall just will help me in life. It helped me further understand the science field of work and what they do.
23	I will use the asking questions the most. I learned i am not that good at physics or doing anything like that
24	I learned that I really like creating things that work, and bring about a successful result.
25	I will use it in life.
26	I learned how to organize my ideas in every day life. Not only can I use EDP in like Science and Math classes, but really in all subjects.
27	I have learned to think through everything before I make a conclusion, because it will gaurentee me a better answer.
28	I learned that the EDP can be used in engineering.
29	I learned that you have to look at the situation first and think what are the problems that i see. Then you have to ask yourself how can i make this better. You don't just look at the problem and try to fix it the easiest way that you can think of.
30	I will probably ask more questions. I never really ask questions, I just go for it, so this will be helpful to me. Also, testing was very helpful in getting the job done right. I learned a lot about continuous circuits and having to keep them connected.
31	Just when I'm approaching a problem to really imagine the possiblilites, state the limitation, etc. and really approach life in a positive problem solving sort of way.
32	I learned how to solve problems better.
33	Probably just to ask more questions so that I really know what it is I am supposed to be doing. Also, the planning and assigning people to do certain tasks was really helpful.
34	The EDP unit taught me to really think about things. I learned how to plan out my actions in order to get the most effective and best results. I will continue to use the EDP process throughout my life- especially through the rest of high school. The EDP process made me appreciate engineers and scientists who plan things out very precisely.
35	I think I will use this when I go to do large projects agian, or I am struggling with a sistuation with a family member or friend. I learned that there are other ways of thinking about things.
36	The EDP unit has taught me to stop and think about things before I go ahead and begin whatever I am doing. It has helped me imagine and think of different possibilities before I use the first idea that comes to my mind.
37	EDP is the process of problem solving. and i better learned about it and the steps of how to do it. and it was effective when doing our labs, especially the Rube Goldberg lab.(which i loved, it was way better than math!)
38	I've learned to look at things how they are, instead of how they could be. I've become more realistic, and now instead of living inside my head, I'm using the things in my brain to contribute to things outside of myself.
39	I've always been very spontaneous, skipping straight to the build part of the EDP, and improving it without asking what may be wrong. After the EDP unit, I found myself slowing down and thinking about each step I performed, in and out of class.
40	Ummm... I learned that I should think about all the possiblities of what to improve on and how to improve. About myself, I figured out that I really enjoy doing the EDP process.
41	i learned that i need to question more ask what i can do to fix it and what i can do better
42	While I didn't learn very much, I decided that I knew how to use it in my life and have been doing so since. Becoming aware of the system that I was using helped me identify exactly what I needed to do next.
43	If you use this process and think things through you understand a lot better in a lot of different subjects and situations. and once you do it a few times your brain starts thinking like that which gives you more perspective.

Student #	Response:
44	I thought that it really taught me how to thoroughly think. I have realized I have made better, and more wise decisions since this unit.
45	i really want to do it again constantly. even though i already do i am able to recognize them now. on the rube goldberg project i am planning on doing it again on my own time during the summer just for fun.
46	I have learned not to be impulsive when making decisions. I tend to make last-minute decisions without analyzing the consequences. Physics seemed easier to understand once I started asking why things happen. I also realized that as much as I loved this unit, I don't want to be an engineer.
47	I learned that by using the EDP process, it really improves the outcome of things. It makes you think more about things you wouldn't normally think about.
48	I will be able to use EDP in my everyday life to improve my school work and driving. I learned that I don't really like engineering or physics.
49	I learned that asking is crucial in this process. If you ask before you begin then you will come away with the best result. I also learned to test, test, test until things are perfect and working how you want them to work.
50	I learned that I have been using the EDP process my whole life but not realizing it. I can now use it more effectively because I know what is really going on. I learned that maybe I should think through the decisions I make more. When I analyze what is really going on, I am able to make better decisions. With the classes I am taking next year I was indecisive to the point of just leaving some periods blank. But when I finally sat down and asked myself what do I really need, want, and what can I handle then I was able to decide. I found out that I am not that great at making decisions. But the EDP process has helped me.
51	I think that because of EDP I will take away a new thought process and a way to look at things. I learned that their are multiple solutions to any problem and there are many different ways to get them. I learned that physics concepts are everywhere.
52	I learned that I think engineering would be a great occupational choice. Also that before you go ahead and choose something arbitrarily, that you should think it through and then decide.
53	I learned that my strengths come through leadership and planning. I also learned that taking other's group members ideas is important and by combining everyones ideas, you are able to create a more sucessful project.
54	how to communicate problems with people. organizing what you need to accomplish helps a lot
55	I learned to think things through more and think about possible outcomes: to identify all of the possibilities.
56	I had a review of what i know about engineering and components and systems of vehichles.
57	I learned how to solve my problems properly.
58	I've learned that physics will always be here. No matter what you do, physics will be involved.
59	I think that I will use this in building/fixing things. I learned even if you think it is perfect, you can always make perfect, more perfect.
60	I think I will take problem-solving skills away from this. I learned how to plan before I start and how to utilize other group members' strengths. I will use the entire process to always make sure that I come out with the best possible solution.
61	I learned the importance of good planning. When you plan it all out and brainstorm before you start, you make less mistakes and have a lot less to worry about, as opposed to just putting ideas together as you go along and not knowing the result until it happens.
62	The EDP, of course! I learned that its isn' that hard to think about the really hard things if you just organize your thoughts.
63	I like engineering a lot more than I thought I would. I enjoied having a problem, and

Student #	Response:
	brainstorming ideas about how to solve it. It let's me think about the problem more than I initially would.
64	My overall take-away is to slow down, ask questions, prepare before hand, and break the bigger picture down into smaller pictures. Things like, "what is the goal?" "How can we accomplish it?" "What things can be changed?" and most importantly, "How does this apply to the real world, what have those real world engineers done to succeed in thier work, and how can I mimic those achivements on a smaller scale?" are the big questions I have learned to ask before even getting started. I will most likely use this in any large project, as well as in life in general. I've learned, more than anything, how to work in a group setting; that everyone has ideas, you just have to figure out the way to make someone voice them. I've learned how key communication is, and I've learned it through hands on experiences, in a way using the EDP. Creating sentences, seeing how those spoken words affected the people around me, and changing them to get better responses, and more stable emotional platfoms. The cool thing is, it changes group to group. I can start with the last test and results from my last group, but every person, every group, is different, and I sometimes had to go back to a communication technique that didn't work for one person to get a good reation from another. I'm getting faster at evaluating a person's responses so I can reach the best style faster.
65	I learned alot about physics and different ways to think of things.
66	That I need to think through stuff more logically.
67	It made me smarter
68	I think i realized that i do use it a lot i just don't think about as in depth as we do in class it is pretty much automatic.
69	I think I will take away a lot, and I am already applying the EDP into my life. I use it when I am freaking out or stressed to calm myself down when I don't feel in control of a situation, and it really helps me recognize the control I do have, and it is really helpful and calming and it makes me feel smart :)
70	that if i just look and p0lan and think i an really accomplish anything
71	I learned that there are ways to handle situations a lot better. Any situations. Whether school, friends, family... I learned that I can deal with a situation without getting overworked or stressed about it. I just need to take and step back and actually think.
72	I learned how to communicate better with family memebers and learned that I should try to understand what is going on in someone's life that is making them lash out in anger. While doing this unit I learned that I actually do have creativity, I just need to use it more often.
73	slow down and look at what the problem is, what caused it, then what the problem is afffecting
74	I learned a lot about my friends and fasily and my own shelf.
75	I learned not to assume things, about life or people in general, and that before I make a conclusion, I need to ask questions and analyze the situation before I try to solve it.
76	I think I can use it in my everyday life, and I think it'll be helpful for test-taking, maybe even the ACT.
77	I learned that there is always a better way to do things and work it out. I will use EDP to have better relationships with family and friends and figuring what is wrong for all things in my life like school to how to PARTY! I learned that we all react to things different.
78	I learned how to fix problems more efficiently by taking the time to think of possible problems and how i could fix them. I use this method alot with my friends now. It helps me to see a broader picture and know that what is going on isn't just for shallow reasons, rather many small events linked and added up to one. Also in physics i can mend and fix things faster by quickly thinking things through.
79	It is hard. It is hard to not just jump into a problem and just go for it. It is hard to stop and think about what to do before you do it. I am positive that i will use this most likely everyday.
80	What I will take away from EDP is the skill involved with sitting down, thinking, and truly

Student #	Response:
	analyzing the situation. Sometimes I tend to jump to conclusions, so this will be helpful.
81	Hopefully, I will start trying a bit harder to solve problems on my own where possible. I kind of have developed a bad habit of running for help as soon as the smallest problem arises that I could fix on my own if I gave it a little more thought.
82	My overall take-away is that problems don't have to be so intimidating. They can be taken step by step. I learned that I can problem solve and get through frustrating things. I think I will use it mostly with problems with other people. That is where it has come in handy the most so far.
83	I learned that asking questions is very important and very beneficial. It taught me to step back and look at the big picture and asess a situation before I act. I will use it in any situation (if I remember it) to help me gain a better understanding of what is going on. I learned that I am very quick to make inferences about others and that a lot of the time I am correct. I learned that I have a very good memory about people which aids my understanding on them. I learned that asking questions is beneficial in physics, engineering, and every aspect of life.
84	I learned that life makes so much more sence when you really think about something! because there really is a reason or answer to every problem, it just might not be evident until you truly break it down to get an answer.
85	I think overal, I will take this process and use it in my life as a way to think and solve problems non-science related. I learned to stop and think for a minute and ask why something is happening, or why someone is acting the way they are rather than just asume someone is mad at me, or other situations like that.
86	I learned that if you have a problem, ask why is there a problem. Figure that out and then use your imagination to figure out possible solutions. By doing this, it makes a much easier, more organized, and less caotic way of solving a problem.
87	After going throw the proccess it has influenced me to increase my knowledge and creativity in inventing rather than discuragment. My strength is hands on, designing and inventing the mechanical components in order for it to work. I love engineering, especially in the field of areonautics propulsion systems.
88	It sounds a bit cliche, but I think that from that unit, I learned that every thing that we do, every action that we take affects one another.
89	When there is a problem, I have to ask questions that will help me solve it. I need to try methods. And if they don't work, I have to question why and try to improve them and try again.

APPENDIX G: IRB ACCEPTANCE FORMS

Institutional Review Board
for Human Subjects

Brigham Young University
A-285 ASB Provo, Utah 84602
(801) 422-3841 / Fax: (801) 422-0620

April 15, 2011

Heather Ure
621 E 420 N #201
Provo, UT 84606

Re: Critical thinking and problem solving skills can be improved by learning the engineering design process

Dear Heather Ure

This is to inform you that Brigham Young University's IRB has approved the above research study.

The approval period is from 4-15-2011 to 4-14-2012. Your study number is E110167. Please be sure to reference this number in any correspondence with the IRB.

Continued approval is conditional upon your compliance with the following requirements.

All protocol amendments and changes to approved research must be submitted to the IRB and not be implemented until approved by the IRB.

A few months before this date we will send out a continuing review form. There will only be two reminders. Please fill this form out in a timely manner to ensure that there is not a lapse in your approval.

If you have any questions, please do not hesitate to call me.

Sincerely,

Lane Fischer, Ph.D., Chair
Sandee M.P. Munoz, Administrator
Institutional Review Board for Human Subjects