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*Brigham Young University - Provo*

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An Investigation of the ASIT Problem-Solving Method on  
Middle School Technology Education Students'  
Ability to Produce Inventive Solutions

Jared Merrill

A thesis submitted to the faculty of  
Brigham Young University  
in partial fulfillment of the requirements for the degree of

Master of Science

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December 2013

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## ABSTRACT

### An Investigation of the ASIT Problem-Solving Method on Middle School Technology Education Students' Ability to Produce Inventive Solutions.

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This study compared two groups of students being instructed in various methods of problem solving over a two-week period. The control group was instructed using the standard Career and Technology Education (CTE) Introduction curriculum on using brainstorming to solve problems. The treatment group was instructed using a structured problem solving method developed to help focus problem solving on finding a solution that satisfies the conditions.

Students were selected from 7<sup>th</sup> grade students at a suburban middle school in Utah. The independent variable in this study was the type of problem solving instruction received. The dependent variables of interest were the fluency of producing solutions (S), number of inventive solutions (I) produced while problem solving. Additional variables of interest include student's perceived competence (c) while problem solving and students' perceived usefulness (u) of problem solving in their lives.

A pre-test and a post-test consisting of open-ended problems were utilized to assess the fluency of solutions (S) and the number of inventive solutions (I). A modified Fennema-Sherman attitude questionnaire was utilized to assess student's perceived competence (c) and perceived usefulness (u).

The findings indicated that students who are taught a structured problem solving method produce a statistically significant (p-value of .033) greater number of inventive solutions when compared to students not instructed in this method. These students also appear to focus their problem solving by producing less total solutions (s) but a greater portion of these solutions is inventive.

Other findings include data that supports the idea that dedicated problem solving instruction increases students perceptions of their own abilities to problem solving. Both control and treatment groups experience a statistically significant increase in their perceived competence in problem solving (p-value of .430 and .382 respectively).

**Keywords: problem solving, ASIT method, inventive solutions**

## ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to those who have helped in the completion of this thesis paper. My committee members Dr. Steve Shumway, Dr. Kip Christensen, and Dr. Geoff Wright spent many hours providing valuable feedback and guidance throughout the planning and writing process. Dr. Steve Shumway as my chair was particularly indispensable with his patience and guidance as we slogged through two and a half years of work. Dr. Dennis Eggett was invaluable with his instruction and help with statistics.

Thanks are owed to the valuable support that I received at Centennial Middle School. My principal and co-workers were extremely supportive and encouraging throughout the entire process. Thanks is also due to my wonderful students, who participated in the study without complaint and with much enthusiasm.

Finally, I would like to thank my family for their support in my pursuit of a master's degree. I am especially appreciative of my wife, Megan, who has been there for me through all the long nights and weekends. I cannot thank her enough for her patience with me while she managed to take care of our lovely children, housework, and keeping our family sane. Thank you for all that you sacrifice for me.

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# **1 INTRODUCTION**

## **1.1 Creativity and Problem Solving**

Creativity is a broad topic that has been the subject of research in fields as diverse as medicine and engineering (Sternberg and Lubart 1996). Barak (2009), referencing Guilford (1967), states creativity as “the ability to produce ideas, processes or products that are novel (original, unexpected, imaginative) and useful (appropriate or adaptive regarding task constraints)”. Given that creativity is such a universal topic that is required for a multitude of different disciplines and aspects of life, it appears to be a very valuable quality that the education system should understand and engage with (Barak and Goffer 2002).

In recent years, creativity has been closely associated to the process of problem solving (Barak and Mesika 2007). There have been numerous methods proposed of “disordered thinking” or free flow of thought to problem solve, including brainstorming and other forms of idea generation (Barak 2004). Alex F. Osborn in the late 1930s first proposed the idea of brainstorming as a heuristic for solving a problem (Osborn 1953). In essence, brainstorming is the process of generating a large number of ideas or solutions without any initial pre-judgment (Simonton 1988).

As more research has been conducted, an increased number of researchers are becoming aware that these forms of “disordered thinking” may not be as productive as previously predicted (Stroebe and Diehl 1994). Methods that involve “ordered thinking” or structured problem solving have gained awareness as ways to not only generate ideas but to produce creative results.

As Barak and Mesika (2007) state, “creative individuals do not produce new ideas de novo, rather these ideas arise from a large set of well-developed, problem-solving skills and a rich body of domain-relevant knowledge.”

## **1.2 Structured Problem-Solving**

TRIZ (Teoriya Resheniya Izobreatatelskikh Zadatch), interpreted as “Theory of Inventive Problem-solving”, is a well-known method of structured problem solving. It was developed by Genrich Altschuller in the Soviet Union in the 1940s (Altschuller 1984). The purpose of TRIZ was to define a process for inventive problem solving by looking at the methods that inventors used to develop new inventions and identify what connections could be made. Altschuller devised steps and conditions that, when followed, would produce a creative solution to a problem (Savransky 2000). These steps and conditions are what make up TRIZ today.

Horowitz and Maimon (1997) developed the SIT (Structured Inventive Thinking) Method based on the TRIZ method. The purpose of the SIT method was to make a method that was more accessible to everyone for everyday use (Horowitz and Maimon 1997). What differentiates the SIT method from other problem solving methods is the concept that two conditions that must be met to produce an innovative solution. The first condition, Closed World (CW), specifies that only those objects that are in the immediate problem world can be utilized in the solution. The second condition, Qualitative Change (QC), refers to eliminating the conflict that is causing the problem. More about this method is explained in a later section. There have been a number of studies carried out investigating the impact of implementing the SIT method in various professional organizations, including some Israeli technology companies as well as the Ford Motor Company (Sickafus 1997).

In a recent study, Barak and Mesika (2007) explored how teaching the SIT method to students in a junior high technology education classroom affected student's attitudes and capabilities in problem solving (Barak and Mesika 2007). In this study, Barak and Mesika (2007) took students from two junior high schools in a medium-sized city in Israel and taught a course in inventive problem solving (in this case the SIT method). These researchers utilized pre- and post- tests to measure quantitative differences and interviews to measure qualitative differences between the treatment and control groups of students participating in an inventive problem-solving course. These researchers found a statistically significant difference in the ability of the students in the treatment (SIT) group to produce inventive solutions (four times greater) when compared to students in the control group.

Barak and Mesika (2007) found in this study that students demonstrated an increased ability in finding original solutions to a given problem and preferred this method to other less organized methods that were being taught (Barak and Mesika 2007). The participating students also showed a greater understanding of how problem solving could be applied to subjects beyond school and a willingness to share what they learned with their peers and families (Barak and Mesika 2007).

### **1.3 Problem Statement**

Barak and Mesika found success teaching the SIT method to Israeli junior-high students and saw an increase in original solutions presented and more positive attitudes towards problem-solving. Since the study by Barak and Mesika, the SIT method has been further commercialized into a curriculum that teachers can easily implement into their classrooms. The commercialized version is known as the Advanced Systematic Inventive Thinking or ASIT. To date, there has

been no additional research studies to evaluate the effectiveness of the ASIT method in an educational setting to see if the results similar to what Barak and Mesika found could be found in other settings.

The purpose of this study was to assess the impact of teaching the ASIT method to middle school students in a suburban area in the state of Utah and assess any differences in their abilities and attitudes with regard to problem solving. This study was designed to be comparable to the study conducted in Israel by Barak and Mesika (2006) to see if similar student outcomes could be achieved using a structured problem-solving method in a middle school technology education setting in the United States. The reason why this is important is because in the field of Technology Education, creativity and problem solving are essential. Sadly, “in practice, few technology study programs make a focused and intensive effort to develop creativity” (Barak and Goffer 2002). Creativity and problem solving is sometimes viewed as a mere by-product of technological studies.

#### **1.4 Scope of Study**

The scope of the study was to look at the effect of teaching the ASIT method to students aged 12-13 in a public school in a medium-sized suburban community. The students came from the general school population and included both males and females and students with IEP's (Individual Education Plan). The location where the study took place is in northern Utah.

This study was not a duplication of the study by Barak and Mesika (2007) but was designed to have similarities to their study in that student problem-solving abilities and associated attitudes were investigated in order to see if similar student outcomes can be achieved

using a structured problem-solving method in a junior high technology education setting in the United States. Please see section 3.7 for the limitations section referenced in this study.

## **1.5 Definition of Terms**

**IEP.** – Stands for “Individualized Education Program”. The IEP creates an opportunity for teachers, parents, school administrators, related services personnel, and students (when appropriate) to work together to improve educational results for children with disabilities. The IEP guides the delivery of special education supports and services for the student with a disability. (U.S. Dept. Education)

**Heuristic** – a general “rule of thumb” that provides guidance for an action.

**Creativity** – “The ability to produce ideas, processes or products that are novel (original, unexpected, imaginative) and useful (appropriate or adaptive regarding task constraints)” (Guilford 1967).

## **1.6 Assumptions**

Because studies conducted in an educational setting contain a many variables, a few assumptions need to be defined. The first assumption is that students from the control group and the treatment group begin with the similar background and level of understanding with regards to problem solving. Another assumption is that test-taking abilities of all the students are representative of all test takers within the school.

## **1.7 Research Questions**

### Research Question #1

Will pre-test, post-test mean scores of students who are introduced to the ASIT method (treatment) differ from those who are not introduced to the ASIT method (control) with regards to: (a) fluency in the ability to generate solutions to given problems and (b) ability to produce inventive solutions when engaged in the problem solving process? Furthermore, will the magnitude of any differences between the mean scores between groups be large enough to be statistically significant or practically significant?

### Research Question #2

Will mean gain scores on the Modified Fennema-Sherman attitude survey by students who are introduced to the ASIT method (treatment) differ from those who are not introduced to the ASIT method (control) with regards to: (a) attitudes regarding perceived competence in solving a problem, and (b) attitudes towards using structured problem solving in everyday life? Furthermore, will the magnitude of any differences between the mean responses between groups be large enough to be statistically significant or practically significant?

## **2 REVIEW OF LITERATURE**

### **2.1 Creative Thinking and Innovation**

The topic of creativity has a wide scope of importance, from the individual level of solving problems during daily life to society-level in new scientific findings, inventions, and social programs (Sternberg and Lubart 1996). Barak (2009), referencing Guilford (1967), states creativity as “the ability to produce ideas, processes or products that are novel (original, unexpected, imaginative) and useful (appropriate or adaptive regarding task constraints)”.

Due to the inherent importance and scope of creativity, it is interesting to note that the subject of creativity has been severely neglected in the circles of psychological research and education. Guilford (1950) noted that less than two-tenths of one percent of studies conducted in the psychological area focused on creativity before the 1950s. By the early 90s, that number had risen to approximately one-half of one percent, though this was still lagging far behind other areas of psychological interest (Sternberg and Lubart 1996).

Sternberg and Lubart (1996) argue the importance of creativity and its importance as a topic of research:

Creativity is probably at least as important as intelligence. It is through creativity that we can cope with significant challenges in our environments in novel and appropriate ways. Indeed, given the rate at which the world is changing, the importance of creativity to our lives is likely to increase. And certainly it is important for success in almost any occupation that requires thinking, whether it be as an artist, writer, scientist, business person, salesperson, teacher, or whatever.

Sternberg (1988) suggests there is an “investment theory” that encourages creative ability. As part of this theory, he asserts that in order to foster creativity, educators should consider six resources: Intelligence, thinking styles, knowledge, motivation, environmental context, and personality. This theory was presented to show that creativity may not be fostered because all of these areas need to be addressed and many people are not willing to “invest” in all aspects of creativity (Sternberg and Lubart 2010).

Guilford (1967) introduced the idea of two stages that make up the process of creativity. The first stage, divergent thinking, is categorized as generating many ideas and possible solutions that could answer a given problem. This stage emphasizes the idea of open-thinking and delayed judgment of ideas. The second stage, convergent thinking, is using various logic-techniques to then narrow the ideas down into the one that would be the most suitable answer or solution to the problem.

De Bono (1992) also defined two methods of thinking that are in the same vein as divergent and convergent thinking. He defined two processes of thinking: lateral thinking and vertical thinking. Lateral thinking is similar to divergent thinking, as this method encourages idea generation, different of judgment, and variety over structure. Vertical thinking could be said to be similar to convergent thinking, where a thought process is fairly linear, structured and selective in what ideas to entertain and are viable solutions to a problem (Barak and Goffer 2002).

Often referred to as the “Father of Creativity,” Ellis Paul Torrance spent the majority of his life dedicated to the study of creativity in educational settings (Kim 2006). His contributions have had major impact on the direction of modern research dealing with creativity (Kay, et. al. 2010). Torrance worked under the premise that school curriculum should be based on creative



processes and by so doing, the students would create a link between learned knowledge and real-life application (Kim 2006). Sternberg (2000) asserts that creativity is a choice and that education should teach and strongly encourage students to opt for creativity.

## **2.2 Idea Generating in Problem-Solving**

The term problem generally connotes a situation, issue, or condition that needs to be answered or resolved (Barak 2009). The issue of problem solving is then identifying what the problem is and how that problem might be resolved to achieve a specific outcome (McCormick 2004). Savransky (2000) defined a problem as a “gap” between a starting situation and a desired situation. Polya (1945) described problem solving as a method “to find a way out of difficulty, around an obstacle, or to attain a desired end that is not immediately attainable by appropriate means.”

Metacognition is an aspect of generating ideas that focuses on “thinking about thinking” (Barak 2009). This includes a broad scope of memory, communication and problem solving. Flavell (1979) introduced two concepts, metacognitive knowledge and metacognitive regulation. Metacognitive knowledge can be defined as knowing what variables are associated with the cognitive process. Metacognitive regulation is using specific cognitive strategies to achieve a specific goal (Barak 2009).

Disordered thinking has been a proposed method of generating ideas that can be used to problem solve. Alex F. Osborn in the late 1930s first proposed the idea of brainstorming as a heuristic for solving a problem (Osborn 1953). In essence, brainstorming is the process of generating large number of ideas or solutions without any pre-judgment (Simonton 1988). Osborn (1953) created four general guidelines to follow that would help increase the overall creative output of the group. The four ideas presented are: (1) Focus on quantity, with the

purpose that creating many solutions will increase the chance of creating the best solution (2)  
Withhold criticism, as this inhibits the group from thinking outside the normal constraints (3)  
Welcome unusual ideas, as these can usually be modified into a more practical solution (4)  
Combine and improve the idea, which means that participants are encouraged to combine suggested ideas into new ideas, or take components of various ideas to generate new ideas.

There are numerous other methods to solve a problem, such as trial-and-error, where various trial steps are conducted in an irregular fashion in order to find a solution (Savransky 2000). Another approach to problem solving utilizes decision aids, such as a decision matrix, that helps the solver to be specific about the qualities that are required in the solution and the priority of those qualities. These charts help to encourage analytical thinking as the problem solver considers solutions but they do not provide additional information or direction in making decisions. These charts only provide the problem solver the ability to confidently analyze the situation (Savransky 2000).

As more research has been conducted, many researchers are becoming aware that these forms of “disordered thinking” may not be as productive as previously predicted (Stroebe and Diehl 1994). Methods that involve “ordered thinking” or structured problem solving have gained awareness as ways to not only generate ideas but to produce creative results. As Barak and Mesika (2006) state, “creative individuals do not produce new ideas ‘de novo’, rather these ideas arise from a large set of well-developed, problem-solving skills and a rich body of domain-relevant knowledge.”

### **2.3 TRIZ Method**

Genrich Altshuller, an inventor and science fiction author in the former Soviet Union, spearheaded the development of the study of inventiveness in problem solving. Altshuller and

his associates examined thousands of filed patents and inventions. They then categorized the tools and properties used to create a creative solution (Freshner and assoc 2010) in order to see if any patterns could be found. Altshuller's main findings after examining the patents were that creative solutions were ones that eliminated a conflict in the problem (Horowitz and Maimon 1997). A conflict is where the change in one parameter has a detrimental effect on another parameter in the system. An example of this would be looking at the general design of an incandescent light bulb. One parameter of the light bulb is the filament temperature and another parameter is the longevity of the bulb. The conflict arises as a high-filament temperature is required to accomplish high-energy efficiency, but increasing temperature decreases the lifetime of the light bulb (Maimon and Horowitz 1999). This conflict between parameters is where problems arise.

With these findings, the TRIZ method was created to give engineers a chance to categorically define the parameters involved, then use certain strategies to approach the problem and eliminate the conflict in the system to generate an innovative solution to a given problem (Altshuller 1984). Three major strategy areas are defined in the TRIZ method: principles, standards, and physical effects. Principles are the thinking strategies used to solve the problem and 40 are given in the TRIZ method. 70 Standards are identified which are ideas based on past solutions. Physical effects are the physical effects of various materials and their functions. The TRIZ method contains 400 effects that are used to understand various situations (Horowitz and Maimon 1997).

These strategies are then used to address the problem, through classification and organization. A problem is defined with the conflict of parameters identified. A user then takes various principles of the physical effects to attempt to identify a potential solution. These

physical effects come from deep understanding of engineering and physics principles. Savransky (2000) proposed a definition for the TRIZ method as, “a human-oriented knowledge-based systematic methodology of inventive problem solving”.

## **2.4 SIT Method in Industry and Education**

Although the TRIZ method is highly effective in generating inventive solutions to problems, the amount of information needed to properly complete the steps is daunting, as seen in the number of principles, standards and physical effects listed above. In an attempt to simplify the TRIZ process and make the method more accessible, Roni Horowitz, Oded Maimon, and their colleagues studied the processes given in the TRIZ method and eventually developed the SIT (Structured Inventive Thinking) method (Horowitz and Maimon 1997).

Horowitz identified four key areas where he believed the TRIZ method could be modified to improve its accessibility and usability (Horowitz 2001). Horowitz listed these four areas as: (1) evolve ‘Ideal Final Result’ to the ‘Closed World’ condition (2) evolve ‘Resolving Contradictions’ to ‘achieving Qualitative Change’ (3) combine and modify the 40 principles to SIT’s five idea-provoking tools and finally (4) eliminating other TRIZ elements not being utilized (Horowitz 2001).

The development of the SIT method was not to replace or supplant the TRIZ method, rather as an evolution of the TRIZ method into a more ‘user friendly’ methodology (Turner 2008). In contrast to the TRIZ method, which is a domain-specific tool, the SIT method is a thinking strategy that is more widely applicable. According to Horowitz, “Using SIT, the problem solver first reformulates his problem by changing the goal from ‘find a solution’ to ‘find a solution that satisfies the conditions’” (Horowitz and Maimon 1999). This method is based off two general guiding principles that encompass the problem solving experience.

The first is the Closed-World (CW) condition, which in essence limits the modifications to those things that are in the “world of the problem” or nearby environment (Horowitz and Maimon 1999). This means that there should not be anything used to solve the problem that is not already included in the immediate or related area of the problem. After studying the TRIZ method and investigating the most elegant solutions that have been developed over many years, Horowitz determined that all of these elegant solutions did not include any new components being introduced into the problem world. This principle focuses the problem solver’s attention on the real problem and the components needed to solve the problem (Turner 2008).

Maimon and Horowitz (1999) gave an example of this principle by looking at a contract given out for a redesign of a military antenna. The antenna was designed to be carried by one soldier, and when set-up, designated to stay in one location for an extended period of time until being moved. The problem came as the antenna was left in a location, ice would build-up, increasing the stress on the mast and ultimately causing a collapse. While many solutions could be presented to solve this problem, from heating the mast to using stronger materials, the goal of the closed-world condition would be not to add anything additional to the system. A solution presented was to alter the existing structure of the mast to encourage the build-up of ice on the mast itself, thus using the build-up of ice as reinforcement for the antenna. Thus, nothing new is added to the system, yet the mast is able to withstand the additional weight of the ice. When it needs to be moved, the soldier only needs to knock off the ice and the device is one-man portable once again.

The second guiding principle is the Qualitative Change (QC) principle, which in essence, is eliminating the conflict in the system. As stated by Maimon and Horowitz (1999), “This means that each functional requirement is dependent on a single design parameter and is not

related to any other.” In simpler terms, the QC principle means that the goal is to make each variable independent of one another by identifying where the conflict is arising and eliminating that conflict or even reversing the effect to be a benefit to the problem (Horowitz 2001).

Using the example of the incandescent light bulb previously mentioned, the ideal goal would be to make the two variables, filament temperature and endurance of the filament, not dependent on each other. By making the two variables independent of each other, the ideal goal would then be “increasing the filament temperature will result in longer life” (Maimon and Horowitz 1999).

Putting it all together, when a solution can satisfy both the Closed World condition and the Qualitative Change condition, that solution is deemed “innovative” by the SIT method. Figure 1 shows how these two criteria come together to give a creative solution.



Fig. 1 - Alternating Cups

The problem is to arrange these cups in alternating order of full and empty. The conditions are that you are only allowed to move one cup. Although many solutions could be suggested such as moving cups around to change the order, one solution fits both the SIT conditions and would be considered innovative. If you take the second full cup and empty its contents into the second empty cup, you now have solved the problem only moving one cup. Examining the response, we see that the Closed World condition is satisfied as no new items were introduced to the environment. The Qualitative Change condition was satisfied because we

separated the liquid parameter from the glass and made the location of the liquid not dependent on the glass.

Through using these two conditions as guiding principles, the SIT method puts an emphasis on inventiveness while looking at all the possible solutions (Sickafus 1997). While the SIT method does not introduce solutions that could not be found in various other methods of structured problem solving, this method helps to streamline and shorten the time that it takes to discover an inventive solution (Sickafus 1997).

To approach a problem using the SIT method, a user must first identify what the components of the problem are in order to ensure compliance with the Closed World (CW) condition. After identifying all the components to the problem, the user is then tasked with categorizing these components into one of two groups. The first is the problem objects and the second is the environmental object. The problem objects are the components of the problem that are directly related to the given problem. These are the objects where a qualitative change is needed in order to resolve the conflict. The environmental objects are those components of the problem that are not directly related to the conflict causing the problem but are still found within the realm of the problem. A visual representation is shown below:

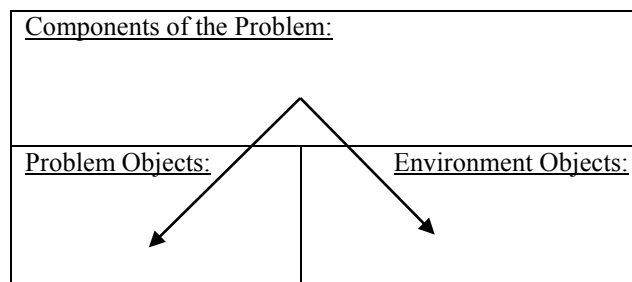


Fig. 2 - Components of Problem

Users of the SIT method are given five idea-provoking tools to approach a problem. These tools are used within the construct of the two conditions mentioned above to give the user a framework to find solutions to a problem. These five thinking tools include: (1) Unification: assigning a new use to an existing component (2) Multiplication: introducing a slightly modified copy of an existing object into the current system (3) Division: dividing an object and reorganizing its parts (4) Breaking Symmetry: turning a symmetrical situation into an asymmetrical one and (5) Object Removal: removing an object from the system and assigning its action to another existing object.

A simple example problem can be used to demonstrate how these five thinking-tools are utilized when problem solving. Currently, helicopter pilots are unable to safely escape the helicopter in case of technical problems. A good solution would be to eject the pilot upward before he parachutes down like in airplanes, but this is impossible because of the danger of being hit by the rotor located on the top of the helicopter.

A SIT user first defines the problem world to satisfy the Closed World (CW) condition. In this case, the helicopter, the pilot, the rotors, and the air qualify as components of our problem world. The problem objects, or the point where conflict or contradiction is taking place, are identified. In the helicopter problem, these objects are the pilot and the rotors. To stay within the Qualitative Change (QC) parameter, the solution must somehow resolve the conflict between these two components. The environmental objects would then be the remaining components; the helicopter and air.



<u>Components of the Problem:</u>	
helicopter, pilot, rotor, air	
<u>Problem Objects:</u>	<u>Environment Objects:</u>
pilot and rotor	helicopter and air

Fig. 3 - Helicopter Problem

Using the object removal thinking tool from the SIT method, a user looks to see if removing a component of the existing problem could solve the problem. A simple solution presents itself, where the rotor is selected to be removed from the problem in order to solve the contradiction. If the pilot makes the decision to eject, the rotors are no longer needed to keep the helicopter aloft, thus by removing the rotors before the pilot ejects, the pilot will safely be removed from the crashing aircraft.

The ASIT (Advanced Systematic Inventive Thinking) method is an evolution of the SIT method, with an emphasis on creating a method that is easier to learn, retain, and more universally applicable (Horowitz 2001). The principles are the same, as are the five thinking tools that are used to solve a problem. The ASIT method is a program developed to give a tighter framework for its users and keeps them focused on the problem at hand and specifically designed to be implemented into classrooms and workplaces.

## 2.5 Differences Between Brainstorming, TRIZ and the ASIT Method

Brainstorming is probably the most popular method of creative problem solving (Horowitz 1999). Although it has seen strong popularity, there are some drawbacks that hinder users of the brainstorming method. It first lacks general or specific criteria for defining a problem, thus non-creative solutions often present themselves. The second major drawback is

since quantity is favored over quality; a large amount of intellectual effort and time is spent on non-realistic solutions (Horowitz 1999). The ASIT method, in contrast, gives value to the solution that fits within a defined framework of what is considered inventive. This defined framework leads to a focused work ethic that generally avoids wasting time on non-creative solutions.

Another drawback to exclusively utilizing brainstorming is the lack of techniques given and the non-systematic methodological approach. Brainstorming does not provide any framework to begin problem solving or organization to possible solutions as the user is generating solutions. This is in contrast to the ASIT method, which contains a few (five) guiding principles to help the user start on the right path. There is a systematic approach to the ASIT method that is repeatable and learnable, leading to faster results the more the user utilizes it.

While the TRIZ method and the ASIT method are similar in many regards, there are a few differences to point out when approaching problem solving. While the TRIZ method requires a strong domain or background knowledge of the problem, the ASIT method focuses more on the inventive solution that then can be technically applied to the problem. Along with this domain knowledge, the TRIZ method contains a large amount of techniques that can be utilized when approaching a problem. The ASIT method reduces that number down to a more manageable amount to make it more approachable and applicable for everyone, no matter the subject or problem.

The following chart gives a visual representation of the differences between brainstorming, the TRIZ method, and the ASIT method.

Table 1 - Problem Solving Methods Comparison

	Brainstorming	TRIZ	ASIT
Main creative mechanism	Suspension of judgment	Principles, Standards, Effects	Solution techniques
Number of Techniques	No established techniques	Large (over 400)	Small (5 principles)
Is domain knowledge included?	No	Yes (Standards and effects)	No
Group or individual	Both	Individual	Both
Criteria for inventiveness	None	Conflict elimination	Meet 2 conditions (CW and QC)
Systematic or Non-systematic	Non	Systematic	Systematic

## 2.6 Importance of Problem Solving in Technology Education

Technology education can trace its roots back to numerous related subject areas taught in schools systems, including industrial education, crafts, and vocational education (Barak 2009). Technology education was also sometimes considered to be a part of science education or in the application of technology in education for teachers and learners, often referred to as *educational technology* (Wicklein 2006).

According to the United States Department of Education, the purpose of technology education is to help “all students acquire challenging academic and technical skills and be prepared for high-skill, high-wage, or high-demand occupations in the 21st century global economy” (U.S. Dept. Education). Robert Wicklein (2006) asserts that the modern era of technology education came about as a result of the publication of the document titled, “Jackson’s Mill Industrial Arts Curriculum Theory”.

This document helped to redefine and refocus the curriculum found in industrial arts programs and focus more on the technological impacts that are found in industry. The first pages of this document proposed a definition of industrial arts as, “comprehensive educational

programs concerned with technology, its evolution, utilization, and significance; with industry, its organization, personnel, systems, techniques, resources, and products; and their societal impact" (Snyder and Hales 1981, pp. 1-2). The document further asserts that industrial arts should emphasize the study of technology and industry in addition to manual training (Wicklein 1990).

As time has passed, technology education has moved from the "shop classes" such as woodshop and metal shop, to a method of providing technological literacy to citizens living in an increasingly technological world (Wicklein 2006). In 2000, the International Technology Education Association (ITEA), the international organization dedicated to enhancing technology education, published the first edition of their Standards for Technology Literacy (STLs). These STLs were established to help define standards and benchmarks that would lead to the development of literacy in technology, including an understanding of the nature of technology, technological impacts on society, design, application of design, and the implementation of technology in society.

Although not curriculum, these standards "have been designed to prescribe the content knowledge and abilities of what students should know and be able to do in order to be technologically literate." Or, in similar terms, the standards were developed to help guide educators in developing their own curriculum with these goals in mind to encourage technological literacy in students.

Barak (2009) explains, "Technology education, more than other school subjects, relates to people's daily lives, needs and desires, and combines the acquisition of both theoretical knowledge and practical skills." In 2010, the ITEA changed to the International Technology and Engineering Education Association (ITEEA) and has continued to developed a list of standards

of technology literacy that “presents a vision of what students should know and be able to do in order to be technologically literate” (ITEA 2007). This organization presents 20 areas of focus, with Standard Number 10 being of particular importance to problem solving. Standard of Technology Literacy 10 states, “Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving,” which increases the importance of integrating a curriculum based on creative problem solving in an educational setting (ITEA 2007).

The nature and scope of Technology Education lends itself to instructing students on developing and designing solutions to real world technological problems. The application of the ASIT method has the potential to cultivate the necessary tools and strategies to meet this need not only in a Technology Education classroom, but also in other subjects across the school curriculum and in students lives (Turner 2008).

### **3 METHODS**

#### **3.1 Purpose**

The purpose of this study was to assess the impact of teaching a structured problem-solving method (ASIT) had on students' innovative output. While not a replication of the Barak and Mesika (2006) study, this study was designed to have similarities to the study conducted by Barak and Mesika in order to see if similar student outcomes can be achieved using a structured problem-solving method in a junior high technology education setting in the United States.

#### **3.2 Design and Demographics**

The population of interest for this study was seventh grade students enrolled in Career and Technology Education (CTE) courses in the state of Utah. The experimentally accessible population was seventh grade students enrolled in CTE courses at Centennial Middle School, Provo, Utah.

Random assignment of students to the treatment and control groups was beyond the scope of control by the researcher. However, because every student in the school is required to enroll in the 9-week CTE class, it was assumed that the technology classes selected were representative of the entire body of 7th graders who attend Centennial Middle School. In addition, the use of a pre-test was used to assess students' equality before the implementation of the treatment.

This study utilized a quasi-experimental design where random assignment of classes was used to assign classes to either the control or the treatment group (Borg and Gall 1996). A total of four seventh-grade classes participated in the study. Two classes were randomly assigned to represent the control group and were taught the standard problem-solving curriculum while the other two classes were randomly assigned to represent the treatment group and received the ASIT method of instruction. The sample size for this study was approximately 120 seventh grade students from Centennial Middle School. The school has a student population of approximately 1000 7<sup>th</sup> and 8<sup>th</sup> grade students. The demographics of the school are 3.78% Asian, 1.55% African American, 68.51% Caucasian, 21.32% Hispanic, 1.45% Native American, 2.71% Pacific Islander, and 0.68% reporting as other.

### **3.3 Research Process**

Two classes were randomly assigned to the treatment group and two were assigned to the control group. The selection of classes was accomplished utilizing a random number generator to eliminate possible researcher bias. The selection took place prior to the names of the students being released as an additional precaution.

The study took place over a period of two weeks. Each class met for the equivalent of five 45-minute class periods over the course of a week. The content for the instruction focused on helping students become more effective problem solvers. This content was chosen because of its importance in the Technology and Engineering curriculum as evidenced by the Utah State Office of Education (USOE) CTE Intro outcomes and the ITEEA Standards for Technological Literacy (ITEEA 2007, USOE). To avoid any bias, all of the days were scripted and planned before the two-week period began.

The students in the control groups were taught a problem-solving process that is typical in CTE classes and one the teacher has used previously. This process is described in greater detail below. An example from this curriculum is challenging the students to design a rollercoaster that gets a marble from one location to another location, with certain design elements required in order to be passed off. The students in the treatment classes were taught a problem-solving process using strategies from the ASIT problem-solving method. Details regarding the treatment and controls group instruction are presented below and a day-by-day outline of the activity is found in Appendix G.

Prior to the research study, students were given a pre-test consisting of three open-ended questions (see Appendix C) in order to measure how many solutions students can create for a given problem (fluency) as well as to determine students' ability to produce inventive solutions to problems. According to the ASIT method detailed in the previous section, an inventive solution is one that satisfies both the Closed World (CW) principle and the Qualitative Change (QC) principle. The treatment and control groups were then presented with a two-week unit of problem solving instruction. As part of the two-week unit of instruction, both treatment and control groups were presented with a common final project in order to put into practice the principles learned. At the end of the instruction period, a post-test, consisting of three additional open-ended questions was given to again measure how many solutions students could create for a given problem (fluency) as well as to determine students' ability to produce inventive solutions to problems.

#### Treatment Group

The students in the treatment group first learned what inventive problem solving is and the differences between an inventive solution and a conventional solution. This was



accomplished by examining some examples of inventive solutions from history and why they were regarded as inventive. This first part of the unit gave the students context as to why problem solving is important and applicable not only in their lives but in society as a whole.

The middle portion of the unit and major focus was on learning inventive principles that help in systematically generating inventive solutions for problems. Although the ASIT method contains five principles that can be utilized to produce an inventive solution, due to the limited time frame, only three principles (Unification, Multiplication, and Division) were covered with the treatment group. This allowed sufficient time to ensure understanding in the three areas, rather than attempting to instruct on all five methods with insufficient time to properly practice and internalize all of the uses of these principles. Although it is ideal for learners of the ASIT method to understand all five principles in order to approach problem solving, knowing even a few of the principles and the core ideas of Closed World and Qualitative Change can be beneficial in solving a problem (Moon et al. 2011, Horowitz 2001).

Each of these techniques was introduced by a definition, followed by an example problem that showed how the technique could be used. The students were then presented with an additional problem and given the chance to work on it individually and as a group in order to further their understanding of the technique. The students were also periodically given ungraded quizzes on the steps of the ASIT method and the various principles in order to ensure internalization of the principles.

A culminating project revolving around a community problem gave the students the opportunity to put what they had learned into practice. This project consisted of finding an innovative solution to the problems associated with a new high-speed rail system being constructed in the neighborhood and the public safety concerns associated with the rail system.

There have been a number of accidents and news reports about rail-related deaths in the area where the study takes place, so this topic is directly relevant to the participating students. The students were divided into groups of 3-4 students, and each group researched potential issues and risks involved with public rail transportation. Each group was then tasked with generating a solution using the ASIT method on how to address the safety concerns of the rail system. The groups were tasked to develop a plan and a scale model to visually represent their solution.

### Control Group

The control groups were instructed concurrent to the treatment groups in order to minimize as many confounding variables as possible such as time of the year or holiday breaks. These classes met the same number of periods for the same amount of time as the treatment group. The control groups were also instructed in problem solving, but used the traditional curriculum that has been utilized with past classes. The students began by participating in an open-ended problem-solving activity (e.g., marble rollercoaster activity) and then received instruction on the concept of brainstorming. As part of this instruction, the proper techniques to utilize while participating in the brainstorming process was covered. These techniques include: (1) deferring judgment; (2) “Quantity breeds quality” (Osborn 1953); (3) hitchhiking welcome; and (4) no criticism. The control groups then learned the steps in the problem solving method and the value of each step. Those steps include: (1) Define the problem; (2) brainstorm ideas; (3) Evaluate ideas; (4) Test ideas. Over the next several class periods, the students participated in personal, small group, and large group brainstorming opportunities in order to refine what they had been taught.

A final, culminating project was presented to the control groups, which was the same as the community issue presented to the treatment group. The students were divided into groups

and asked to research the issue. Then, using the brainstorming technique, each group brainstormed ideas and chose an appropriate solution. Each group then presented a visual representation for what their group devised to address the public safety issue.

### **3.4 Data Collection**

The independent variable in this study is the method in which students were taught to engage in the problem-solving process. The independent variable has two levels: (a) traditional problem solving instruction and (b) the ASIT method of problem-solving method. The dependent variables in this study are (a) fluency with which students can create solutions to a problem, (b) the number of inventive solutions, (c) student attitudes towards their perceived competence in problem solving, and (d) student attitudes toward using problem solving in their learning environment.

The purpose of the data collection was to assess the impact of teaching a structured problem-solving method, specifically the ASIT method, to investigate the effects on innovative creative output. In order to do this, data was collected on the pre-test, post-test and the pre- and post-attitude questionnaires. The type of data collected in each of the assessments was similar to the study by Barak (2006). The effectiveness of using the ASIT method was assessed by collecting data on the number of solutions presented by a student (S) and also the number of inventive solutions (I) presented. According to the ASIT method, an inventive solution is one that satisfies both the Closed World (CW) principle and the Qualitative Change (QC) principle. The first condition, Closed World (CW), specifies that only those objects that are in the immediate problem world can be utilized in the solution. The second condition, Qualitative Change (QC), refers to eliminating the conflict that is causing the problem.

The number of solutions (S) presented was different than the number of inventive solutions (I) as a student was able to present a number of solutions to a given problem, but all of these solutions did not fit within the guidelines of what an inventive solution is. In order to ensure reliability, multiple scorers trained together on the methods of scoring and the criteria for what constitutes an inventive solution. These scorers were responsible for counting the number of solutions presented along with determining which solutions could be labeled as inventive. The rubric used for grading the tests can be found in Appendix I.

In order to reduce any potential bias from the grading of the pre- and post- tests, a third party was responsible for administering the tests, with each period assigned a unique letter to keep track of which periods received which test. The graders were only presented with the tests, not knowing which letter corresponds to which period until after the assessing and grading had been accomplished.

Additionally, an attitude questionnaire based on a Likert-scale was administered in order to gauge student's perceptions on their abilities and attitude toward problem solving with both the pre-test and the post-test. Every student took this survey after completing the appropriate test and turned these items in together. These surveys were also assigned a unique, random number that was not revealed until after the scores had been recorded to eliminate possible bias.

### **3.5 Instrumentation**

There were two instruments utilized in the study. The first instrument was used to determine student fluency and the ability to generate inventive solutions was developed by the researcher and is derived from the ASIT training program available online ([http://www.start2think.com/check\\_pass.php](http://www.start2think.com/check_pass.php)) which is produced by the creator of the ASIT

method, Dr. Roni Horowitz and was utilized for the pre and post-tests. Each test consisted of three carefully developed and worded questions that gave the test-taker an open-ended problem that needed to be solved. Open-ended questions allow for a multitude of answers to be presented, not confining the thought processes of the taker (Bogdon and Bilken 1982, pg. 1). Two versions were created, test A and test B, in order to represent the pre-test and post-test.

The method for administering the pre- and post-tests was to have both control groups and both treatment groups take the *A* version for the pre-test and then every group took the *B* version for the post-test. This is depicted in table 2, with the ‘C’ representing a control class and a ‘T’ representing a treatment group.

Table 2 - Test Administration – Control and Treatment Groups

<i>Test Administration</i>	
<u>Pre-test</u>	<u>Post-Test</u>
C <sub>1</sub> = A	C <sub>1</sub> = B
C <sub>2</sub> = A	C <sub>2</sub> = B
T <sub>1</sub> = A	T <sub>1</sub> = B
T <sub>2</sub> = A	T <sub>2</sub> = B

The advantage of using this method to administer the test was that every group was presented with the same questions, so that when the data was collected and analyzed, a direct comparison between the two groups could be made. This helped eliminate the chance that one version of the test may be easier than the second, as this would show up evenly across all scores at the same time, whether pre- or post-test.

The second instrument utilized to investigate student attitudes was based off of an instrument designed by Elizabeth Fennema and Julia A. Sherman from the University of Wisconsin-Madison (Fennema and Sherman 1976). Their instrument was developed through a National Science Foundation grant to assess student attitudes towards mathematics and various variables that are associated with the students electing to pursue math. This instrument was modified to reflect attitudes towards other subjects by various researchers in subsequent years (Hacket and Betz 1989; Langenfeld and Parajes 1992; Parajes and Miller 1994), and has yielded success in assessing student attitudes.

The Modified Fennema-Sherman Attitude Scale used for this study is a variation of the existing scale. The researcher used previously modified attitude scales (Hacket and Betz 1989; Langenfeld and Parajes 1992; Miller and Parajes 1994) as the basis for his modification. The variation selected is designed to specifically test student attitudes towards problem solving using a 5-item Likert-scale.

This attitude scale was selected first because of the large amount of studies that have used a modified version in their studies. A second reason for the selection of this attitude survey was the methodology of asking both positive and negative questions about the student's view of their own capability when doing problem solving and also about the student's view of how useful problem solving is in their own lives. Some questions from the survey include: *I am sure that I can learn problem solving, problem solving is hard for me, and problem solving is not important in my daily life.* The full list of questions contained in the modified instrument can be found in the appendix E.

### **3.6 Data Analysis**

#### Research Question #1

Will pre-test, post-test mean scores of students who are introduced to the ASIT method (treatment) differ from those who are not introduced to the ASIT method (control) with regards to: (a) fluency in the ability to generate solutions to given problems and (b) ability to produce inventive solutions when engaged in the problem solving process. Furthermore, will the magnitude of any differences between the mean scores between groups be large enough to be statistically significant or practically significant?

Research question #1 has been designed to look at the mean scores between the pre and post-tests with the treatment and control groups. The research looked at the statistical and practical difference between the mean scores of the treatment and control groups. A two-sample t-test of significance was utilized to verify the statistical significance of the mean score difference.

While statistical significance is important in assessing the probability of a difference being left to chance versus a true difference, studies dealing with human subjects sometimes refer to practical significance as a more “true” way of reporting results (Kirk 1996). Practical significance is concerned with how the results of a study are useful in the real world.

A standardized way of reporting findings in educational studies is to report the effect size (Olejnik and Algina 2000). The effect size is a comparison of means between the control group and the treatment group, or the standardized mean difference (SMD). Standardized mean difference allows researchers to approximate how much the two group scores overlap and contrast with one another and give a sense of the practical or real world significance between the difference. Standardized mean difference assumes normal distribution of scores and gives us the

percentage of scores found at or below the mean of the treatment group. To give an example, an effect size of 1.0 shows that the mean of the treatment group is found to be equal to or higher than 84% of scores in the control group. See the graphic below.

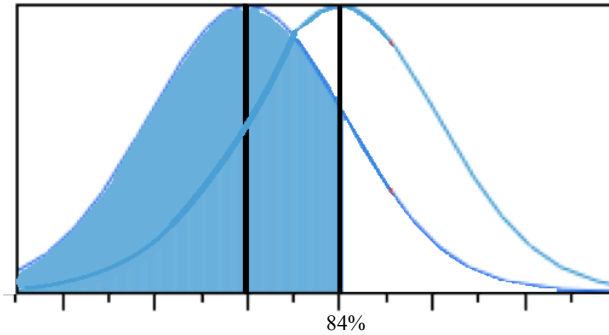


Fig. 4 - Effect Size

In order to figure out the effect size, the following formula is used:

$$\text{effect size} = \frac{\text{mean of experimental group } (\bar{x}_i) - \text{mean of control group } (\bar{x}_c)}{\text{Standard Deviation (SD)}} \quad (3-1)$$

Since the standard deviations from the two groups are not similar, the pooled standard deviation was used as the denominator, which is the following formula:

$$SD_{pooled} = \sqrt{\frac{(N_E - 1)SD_E^2 + (N_C - 1)SD_C^2}{N_E + N_C - 2}} \quad (3-2)$$

When analyzing effect sizes, Cohen (1988) indicated that effect sizes less than .1 is considered trivial. Effect sizes between .1 and .5 are considered to be small to moderate effect sizes. Anything over an effect size of .5 indicates a large effect and considered to have a significant impact.



## Research Question #2

Will mean gain measured responses on the Modified Fennema-Sherman attitude survey by students who are introduced to the ASIT method (treatment) differ from those who are not introduced to the ASIT method (control) with regards to: (a) attitudes regarding perceived competence in solving a problem, and (b) attitudes towards using structured problem solving in everyday life. Furthermore, will the magnitude of any differences between the mean responses between groups be large enough to be statistically significant or practically significant?

When looking at the attitudes of the students with regard to problem solving, the data collected from the Modified Fennema-Sherman survey was utilized. A standard mean difference analysis was used to show whether the effect size between groups is significant or not. Using the standardized mean difference allows researchers to assess the amount of overlap that occurs between the distribution of the treatment and control groups. The research was looking to see if the attitudes of the treatment groups differed enough from the attitudes of the control groups to say that there is a practical significant difference.

In order to score the surveys, students were asked to circle the corresponding number of a Likert Scale, with 1 being in strong disagreement to the statement up to a 5, which is a strong agreement to the statement. The numbers were then compiled, with all of the negative questions having their scores flipped to represent the negative aspect of the question. This means that if a student marked a 1 on a negative question, their score would be changed to a 5 for the data collection, as their 1 represents a disagreement to a negative statement. As further clarification, if a student marks a 1 for a question that states, "*I am not a good problem solver*", that 1 represents the student actually stating they view themselves as a very strong problem solver. Thus, the higher the average score for a student, the more confident they were in that category.

### **3.7 Limitations**

One limitation is the fact that this study did not involve the random selection of schools. The main reason for the selection of the middle school is the fact that the researcher currently teaches there and the close proximity to the university where the research is being conducted. Another limitation is although the school is a public school; the student population may not accurately represent all suburban students. To minimize the impact of this limitation, the researcher only intends on generalizing the results to similar groups of students, which means 7th grade students in suburban Utah. Another limitation is the fact that only 7th graders were included in the research, so although other grade levels may be found at a middle school, because of developmental differences the results are only going to be generalized to 7th grade students from similar populations.

As Hall and Betsy (2009) state, “creativity is a process, and it may take time to manifest in some students.” This means that the time frame used in this study may not be a totally sufficient time for some students to demonstrate a change in creative ability. The last limitation is the fact that the very construct of creativity is difficult to assess. Creativity tests are generated in an attempt to measure creative potential and allow for a variety of responses which the scorer’s attempt to score. Because of individual interpretations, the results may be more difficult to compare with other findings from different studies or scorers.

With any research studies, there is a possibility that the instrument designed for assessing learning may have an impact on the findings. The results may be confounded if one test version is more difficult to understand or contains more difficult questions. The grade level of the questions also has an impact on whether the results show an accurate portrayal of student ability.

An important limitation to note is the fact that this study is not looking at a correlation between fluency (as defined by the number of solutions presented and the number of inventive solutions presented) and student attitudes towards problem solving. No analysis is being conducted at this time to support any sort of correlation; only the separate findings are presented.

In addition, an item analysis is not being conducted, as the researcher is only interested in the mean scores of student attitudes towards perceived competence in problem solving and student perception on the usefulness of problem solving in their everyday lives. A breakdown of each question and student's response is not relevant for the data being collected at this time.

The results of this study cannot be generalized to a larger group of students. While every effort was taken to ensure random selection of students and random assignment of treatments, because the study dealt with human subjects in an educational setting, the results can only be generalized within the same set of conditions that existed in the study (Borg and Gall 1996). This means that conclusions can be made with those students who participated in the study, but nothing conclusive beyond that.

## **4 RESULTS AND FINDINGS**

### **4.1 Purpose**

The purpose of this study was to assess the impact of teaching the ASIT method to middle school students in a suburban area in the state of Utah and assess any differences in their abilities and attitudes with regard to problem solving. This study was designed to be comparable to the study conducted in Israel by Barak and Mesika (2006) to see if similar student outcomes could be achieved using a structured problem-solving method in a middle school technology education setting in the United States. The research was conducted with the following two research questions as guiding factors:

#### Research Question #1

Will pre-test, post-test mean scores of students who are introduced to the ASIT method (treatment) differ from those who are not introduced to the ASIT method (control) with regards to: (a) fluency in the ability to generate solutions to given problems and (b) ability to produce inventive solutions when engaged in the problem solving process. Furthermore, will the magnitude of any differences between the mean scores between groups be large enough to be statistically or practically significant.

#### Research Question #2

Will mean gain scores on the Modified Fennema-Sherman attitude survey by students who are introduced to the ASIT method (treatment) differ from those who are not introduced to the ASIT method (control) with regards to: (a) attitudes regarding perceived competence in

solving a problem and (b) attitudes towards using structured problem solving in everyday life. Furthermore, will the magnitude of any differences between the mean responses between groups be large enough to be statistically or practically significant?

The first step in reporting data is to ensure that the results can be considered valid based on the internal consistency of scoring the tests. Internal consistency is reported based on the Cronbach's Alpha Reliability coefficient that shows the consistency of the grading and reliability of the results that came from the grading (Gliem 2003). George and Mallery (2003) provide a general guideline for reading a Cronbach's Alpha score:

> .9 – Excellent

> .8 – Good

> .7 – Acceptable

> .6 – Questionable

> .5 – Poor

< .5 – Unacceptable

In this study Cronbach's Alpha was calculated for both fluency (S) (i.e., the number of solutions) and for inventive solutions (I) based on the scored responses of the two scorers. The reliability coefficient for fluency (S) was calculated at a .98, which indicates a very high degree of reliability in the scoring of the pre- and post-tests. The alpha score for the scoring of the inventive solutions (I) was also very good, calculated at a .86 on the alpha score scale. These two high levels of internal validity and consistency help ensure that the scores calculated accurately reflected the learning accomplished by the students who participated in the study. See Appendix J for calculations of internal validity.

## 4.2 Research Question #1

The purpose of the first research question was to determine whether teaching the ASIT method to middle school students had any impact on their abilities to generate inventive solutions when involved in the problem solving process. To assess the difference, pre-tests and post-tests were utilized and scores were recorded on these tests based on the number of solutions (S) supplied and the number of inventive (I) solutions supplied. The control group consisted of 57 students and the treatment group contained 59 students. The following table displays the data collected for the study. More detail about results in the control group and treatment group follow the table.

Table 3 - Comparison of Aptitude Scores

			n	M	SD	difference	t-value	p-value	Effect Size
Pre-Test	# of Solutions	Control	57	4.52	1.63				
		Treatment	59	5.77	2.84	1.25	2.90	.004*	.54†
	Inventive solutions	Control	57	1.62	1.13				
		Treatment	59	1.64	1.13	.02	.10	.919	.02
Post-Test	# of Solutions	Control	57	4.24	2.46				
		Treatment	59	3.99	1.46	.25	-.66	.513	-.12
	Inventive solutions	Control	57	1.39	1.29				
		Treatment	59	1.86	1.04	.47	2.16	.033*	.40†

\* significant at  $\alpha = .05$

† moderate to large effect

### 4.2.1 Pre-Test Data

When looking at the number of solutions (S), the scores from the pre-test were analyzed in order to form a baseline for student abilities. Looking at the data provided, the average number of solutions (S) per student for the control group was 4.52 compared to an average of 5.77 solutions per student for the treatment group. This difference of 1.25 solutions per student between the two groups resulted in a t-score of 2.90 and a Standardized Mean Difference (SMD) effect size of 0.54. From the scores on the pre-test it would appear that the students in the treatment groups were more proficient at fluency in describing solutions for problems than students in the control groups and that this mean difference in scores was large enough to be considered practically and statistically significant (p-value = .004 )(t-score = 2.90).

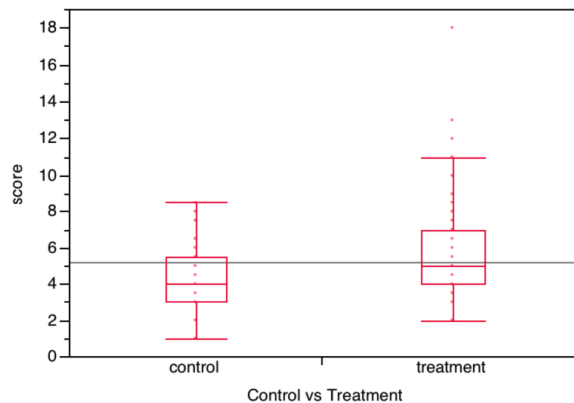


Fig. 5 - Pre-test Control vs. Treatment Solutions

For the number of inventive (I) solutions from the pre-test, the control group averaged 1.62 inventive solutions per student while the treatment group average 1.64 solutions per student with an average mean score difference between the groups at .02 solutions per student. With a p-value of .92 (t-score = .10)(ES = .02), we are 95% confident that there is no statistical or

practically significant difference between the means of the control and treatment groups with regard to the number of inventive solutions presented on the pre-test.

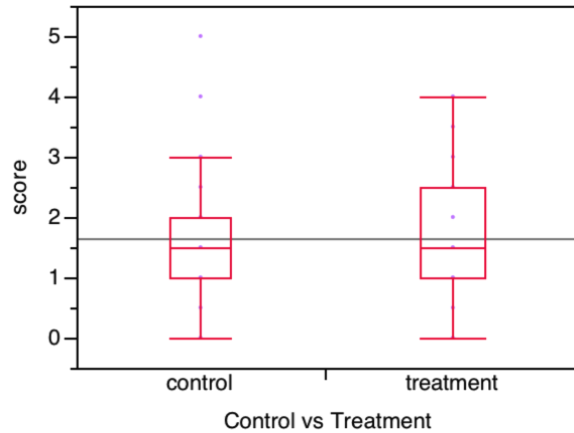


Fig. 6 - Pre-test Control vs. Treatment Inventive Solutions

#### 4.2.2 Post-Test Data

On the post-test, the average solutions (S) per student for the post-test control group was 4.24 solutions while the treatment group averaged 3.99 solutions per student. From Table 5 it can be seen that this resulted in a calculated t-score of  $-.66$  ( $ES = .12$ ). With a p-value of  $.51$  (t-score =  $-.66$ ), we are 95% confident that there is no statistically significant difference in the number of solutions presented by students in the control and treatment groups and that this result also lacks practical significance.



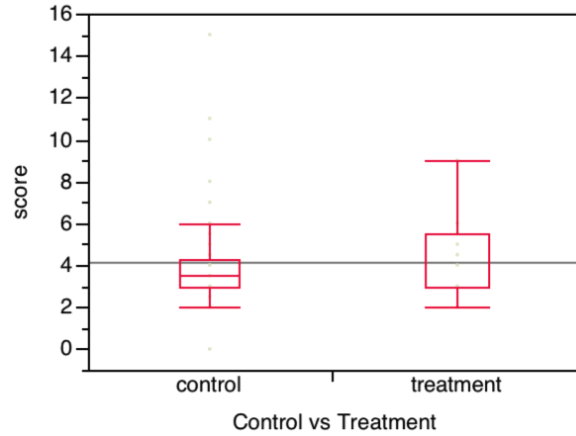


Fig. 7 - Post-test Control vs. Treatment Solutions

The average inventive solutions (I) per student for the post-test control group scored a 1.39. The treatment group averaged 1.86 inventive solutions per student resulting in a difference of average means between groups of .47 solutions ( $t$ -score = 2.16,  $ES = 0.40$ ). With a  $p$ -value of .033 ( $t$ -score = 2.16), we are 95% confident that there is a statistically significant difference in the number of inventive solutions presented by students in the control and treatment groups. In addition, an effect size of .40 would be considered a moderate effect and something that would warrant more attention as there appears to be a practical significance between the control and treatment groups.

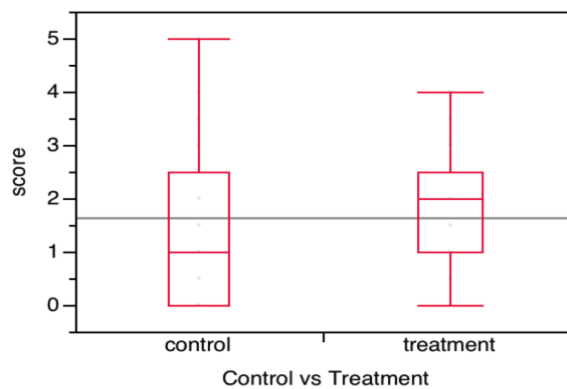


Fig. 8 - Post-test Control vs. Treatment Inventive Solutions

An important point to make is the fact that both the control and treatment groups' average solutions (S) per student actually dropped from the pre-test to the post-test. The control group went from 4.52 solutions per student to 4.24 solutions per student with a difference of -0.28. The treatment group saw a more significant drop in average, from 5.77 solutions per student to 3.99 solutions with a difference of -1.78. This negative difference in means between the pre-test and the post-test can likely be attributed to a difference in the difficulty of questions between the two tests. It is apparent that the post-test questions were more difficult as a whole for the students to generate solutions to address the given problem.

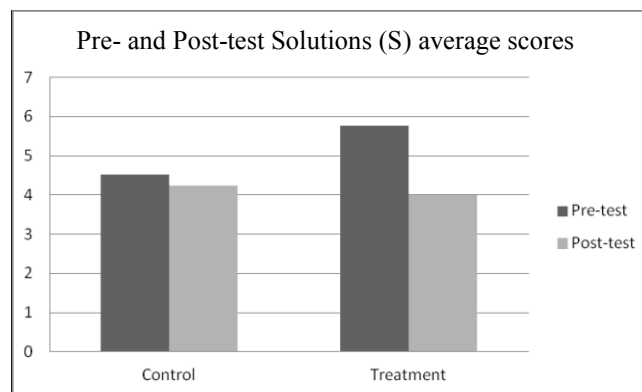


Fig. 9 - Pre- and Post-test Solutions (S) Average Scores

Looking at the number of inventive (I) solutions generated on the pre- and post-test, the control group experienced a drop in the number of solutions (S) presented. The control group went from 1.62 inventive solutions per student to 1.39 inventive solutions per student for a difference of -0.23. Conversely, the treatment group saw a leap in average, from 1.64 solutions per student to 1.86 solutions for a difference of +0.22. This indicates that those students in the treatment group produced an increased number of inventive solutions on their post-test while the control group did not see any increase.

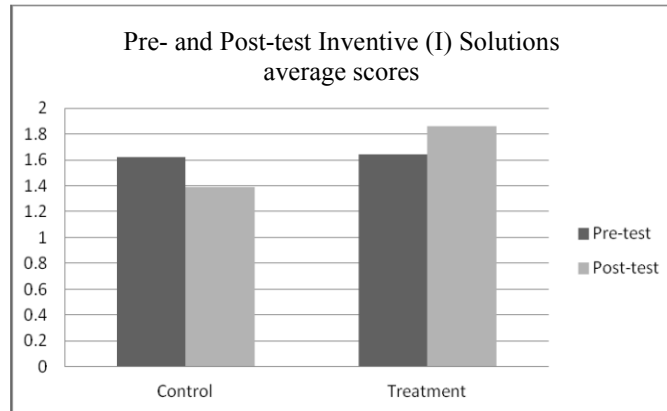


Fig. 10 - Pre- and Post-test Inventive (I) Solutions Average Scores

### 4.3 Research Question #2

The second research question in this study assessed if teaching the ASIT method to middle school students affected student's attitudes towards problem solving. Part one of this research question revolved around changes to student's confidence in their ability to problem solve. The second part to the research question dealt with student's views of the usefulness of problem solving and if there was a change in attitudes between the beginning and at the conclusion of the two-week unit. This survey, based on the modified Fennema-Sherman Attitude survey, consisted of 22 Likert-scale questions about the student's perceptions of their abilities to problem solve and as well as questions about the student's perceptions of the usefulness of problem solving in their life. These surveys were completed and turned in at the same time as the pre- and post-tests.

The surveys were then entered into a spreadsheet divided by class, with the negative scores being reversed to reflect the attitudes of the students in order to standardize the scoring, with a higher score indicating a more positive response. These numbers were then averaged to give an average score per student for the control and treatment groups for student confidence (C)

and perceived usefulness (U). The same thing was done with the post-surveys to give an average score per student for each group in each category.

Table 4 and 5 below shows the data collected from the student attitude surveys. More details about individual sections are found below the tables.

Table 4 - Comparison of Survey Averages – Group Difference

			n	M	SD	difference	t-value	p-value	Effect Size
<u>Perceived</u>	Pre-test	Control	58	3.78	.32	.03	.43	.667	.10
		Treatment	59	3.81	.33				
<u>Competence</u>	Post-test	Control	57	3.89	.33	.04	.43	.666	.12
		Treatment	60	3.93	.35				
			n	M	SD	difference	t-value	p-value	Effect Size
<u>Perceived Usefulness</u>	Pre-test	Control	58	3.77	.68	.09	1.04	.30	.13
		Treatment	59	3.86	.63				
<u>Perceived Usefulness</u>	Post-test	Control	57	3.80	.59	.07	.55	.59	.11
		Treatment	60	3.87	.69				

**Note:** The higher the mean score, the more positive the student response  
 † moderate effect

Table 5. Comparison of Survey Averages – Gain Scores

			n	M	SD	difference	t-value	p-value	Effect Size
<u>Perceived Competence</u>	Control	Pre-test	58	3.78	.32	.11	.79	.430	.34 <sup>†</sup>
		Post-test	57	3.89	.33				
	Treatment	Pre-test	59	3.81	.33	.12	.87	.382	.31 <sup>†</sup>
		Post-test	60	3.93	.35				
			n	M	SD	difference	t-value	p-value	Effect Size
<u>Perceived Usefulness</u>	Control	Pre-test	58	3.77	.68	.03	.44	.661	.05
		Post-test	57	3.80	.59				
	Treatment	Pre-test	59	3.86	.63	.01	.05	.996	.02
		Post-test	60	3.87	.69				

Note: The higher the mean score, the more positive the student response  
<sup>†</sup> moderate effect

Perceived Competence

Student’s perceived competence refers to how competent the student views themselves as a problem solver. Figure 15 graphically represents the scores of student’s perceptions of their own competence in problem solving, with a higher score representing a more positive attitude.

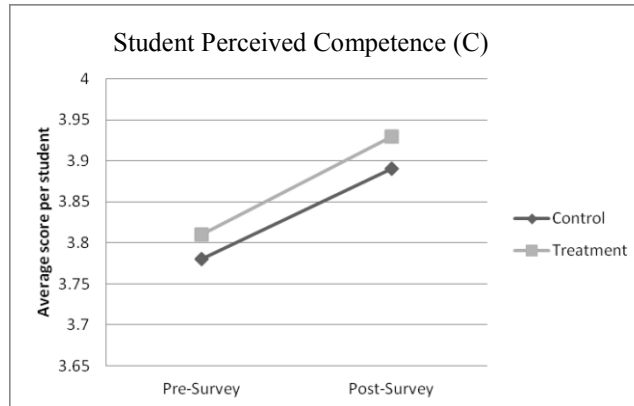


Fig. 11 - Student Perceived Competence (C)

Looking at student's perceived competence (C) in problem solving; the pre-surveys gave an average score per student of 3.78 for the control group and a 3.81 for the treatment group with a higher score indicating a more positive attitude. The post-surveys given to both groups revealed an increase in positive attitude towards their perceived competence. The control group averaged 3.89 and the treatment group averaged a 3.93 on the post-survey.

The difference between the control and treatment groups for the pre-test and post-test was nominal, with .03 difference for the pre-test and a .04 average difference for the post-test. The difference between the means for the pre-test resulted in a statistically and practically insignificant difference ( $t\text{-score}=.44$ ,  $ES=.10$ ) as well as the post-test ( $t\text{-score}=.43$ ,  $ES=.12$ ).

### Perceived Usefulness

Student's perceived usefulness refers to how the student views the usefulness of problem solving in the world around them, whether in the classroom or outside the classroom. Figure 16 graphically represents the scores of student's perceptions of the usefulness of problem solving, with a higher score representing a more positive attitude.

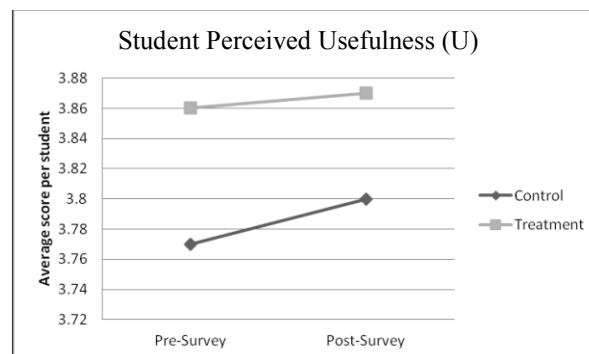


Fig. 12 - Student Perceived Usefulness (U)

Looking at student's perceived usefulness (U) of problem solving in their everyday life; the pre-surveys gave an average score per student of 3.77 for the control group and a 3.86 for the treatment group out of a possible 5. The post-surveys given to both groups revealed an increase in positive attitude towards the usefulness of problem solving in their lives. The control group averaged 3.80 and the treatment group averaged a 3.87 on the post-survey.

The difference between the control and treatment groups for the pre-test and post-test was nominal, with .09 difference for the pre-test and a .07 average difference for the post-test. The difference between the means for the pre-test resulted in a statistically and practically insignificant difference (t-score=1.04, ES= .13) as well as the post-test (t-score=.55, ES=.11).

## **5 CONCLUSIONS AND RECOMMENDATIONS**

With increased focus on problem solving in technology education, it is important for educators to consider effective ways and methods of instructing students on problem solving. There are many ways of teaching problem solving, with the various studies indicating that the ASIT method being an effective method of problem solving. This research study assessed how beneficial instruction in the ASIT method would be for middle school technology students and whether it might be worthwhile to consider in future endeavors.

The focus of the study was to determine the impact of teaching the ASIT method to middle school students in a technology class on their ability to generate solutions and generate inventive solutions in the problem solving process. The students responded well to the treatment and control instruction, with a number of conclusions that can be made from the results that will be discussed in the following sections.

In this chapter, the conclusions are organized according to each of the research questions. Validity and recommendations are addressed at the conclusion of this chapter.

### **5.1 Summary Relevant to Research Question #1**

The first research question addressed in this study was to determine if scored responses on a pre-test and post-test differed between a control group and a treatment group with regard to: (a) number of solutions generated and (b) number of inventive solutions generated. Furthermore, the magnitude of difference between the two groups was analyzed in order to determine whether



the difference was large enough to be considered practically significant as well as statistically significant.

### Number of Solutions

The data pertaining to the number of solutions showed a negative trend in the scores from the pre-test to the post-test. As seen in Figures 17 and 18 below, both the control group and the treatment group averaged lower scores on the post-test compared to the pre-test scores, with the treatment post-test inventive solutions category being the lone exception.

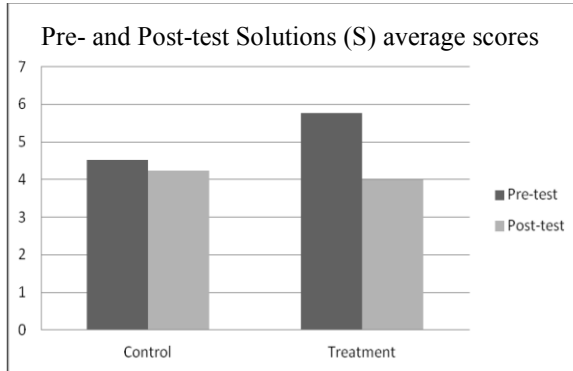


Fig. 13 - Pre- and Post-test Solutions (S) Average Scores

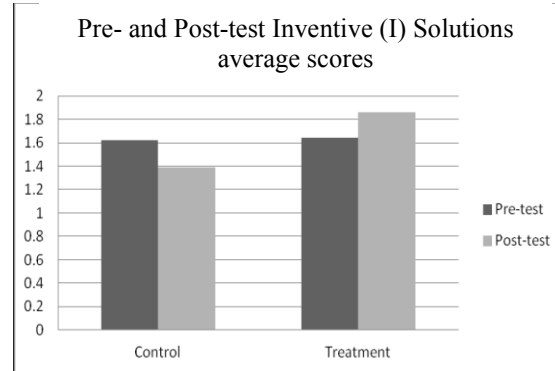


Fig. 14 - Pre- and Post-test Inventive (I) Solutions Average Scores

This negative difference in means between the pre-test and the post-test can likely be attributed to a difference in the difficulty of questions between the two tests. It is apparent that the post-test questions were more difficult as a whole for the students to generate solutions to address the given problem. The research study was arranged in a manner to negate this difference in test difficulty. All groups took test A first as a pre-test and then took test B for the post-test. Thus, a direct comparison can be made involving the performance between groups.

## Inventive Solutions

The scores gathered from the pre-tests showed that while there was a statistically significant difference in the number of solutions generated; the difference between the number of inventive solutions was not statistically significant between the groups. This means that the two groups began the 2-week study period at the same level of understanding and capability with regards to generating a solution that would be considered inventive.

This information is important as the post-test revealed that the students in the treatment group averaged a statistically significantly greater number of inventive solutions (I) compared to the students in the control group. This result was also practically significant. The two groups averaged about the same number of solutions on the post-test; however, an interesting pattern emerged when the data was collected and analyzed involving the number of solutions and inventive solutions presented by the students.

On the pre-test, the treatment group averaged 1.25 more solutions per student when compared with the control group, but on the post-test, although the control group's average solutions per student dropped, the control actually averaged .25 solutions per student more than the treatment group.

Conversely, the treatment group outscored the control group with regard to the number of inventive solutions presented, scoring on average .47 inventive solutions higher than the control group. The figures 19 and 20 visually represent the difference between the groups and the pattern that emerged.

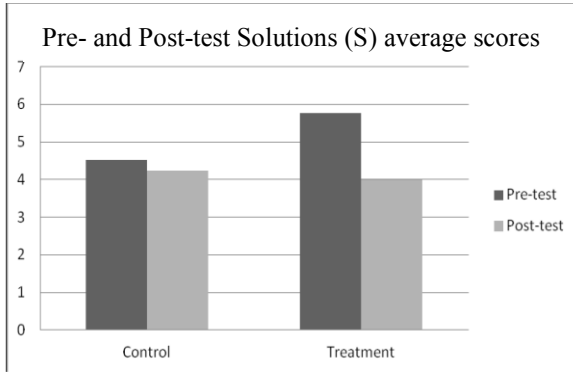


Fig. 15 - Pre- and Post-test Solutions (S) Average Scores

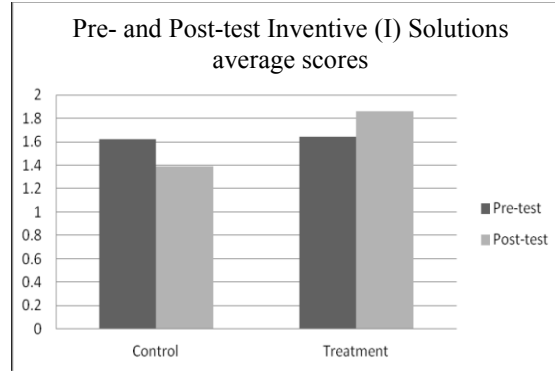


Fig. 16 - Pre- and Post-test Inventive (I) Solutions Average Scores

The pattern seen between groups was a drop in number of solutions in the treatment group, but a higher number of solutions presented were inventive. This seems to indicate that students taught in the ASIT method were more focused in their approach to the problem and generated solutions that were more inventive because of this focus. These students spent less time and focus on ideas that were outside of the problem world and concentrated on presenting more ideas from within the problem world itself.

### Inventive Conditions

Another observation during the two-week course was that students in the treatment group who were being taught the ASIT method were getting a good grasp of the idea of the Closed World (CW) condition but had a more difficult time with the Qualitative Change (QC) condition. Students were able to identify which components made up the given problem and classify these components as a problem object or an environmental object.

These observations were confirmed as the tests were being scored. Many students were able to take the problem and write down the different components of the problem on their tests.

The difficulty came after this first step, where these students would supply solutions that did not address the conflict in the system (QC).

The issue arises when the students are asked to analyze the conflict in the problem and supply a solution that creates a qualitative change in the system. Most of the students seemed to lack the background knowledge necessary to understand the fundamentals behind why the conflict exists and how to resolve it. For example, a practice problem was used during the two-week study dealing with the length of lines in the cafeteria that the students face during their lunchtime. The students were able to identify various components of the problem, such as the number of lines, number of workers and time. However, they did not have the background knowledge to understand how the workers or time affected the problem, such as finances or school schedules that are impacted with changes.

An example from one of the student's tests illustrates this point, as seen in figure 21 below:

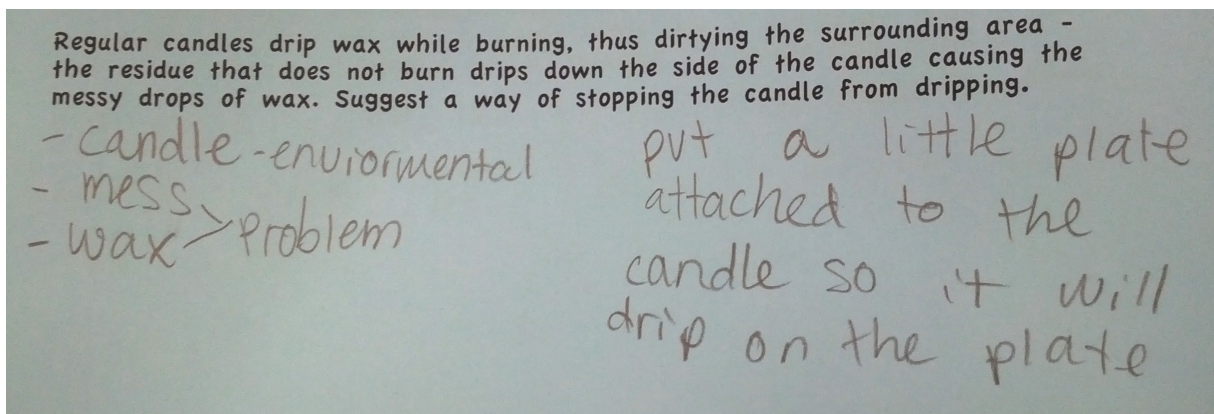


Fig. 17 - Student Problem Solving

This student identified the components of the problem and then assigned each component to be either an environmental object or a problem object. After identifying the components, the

student then supplies an answer that does not resolve the conflict by bringing in an outside object to solve it.

It seems that the cognitive development of 7th graders allows them to understand the fundamentals behind a problem and are able to generally identify the different aspects of a problem. Cognitively, they are able to visualize the problem and visualize what the problem looks like with all of its parts. Unfortunately, many of them are unable to use the Qualitative Change condition and thus be able identify solutions that would be considered inventive.

## **5.2 Summary Relevant to Research Question #2**

### Perceived Competence

When looking at the results of the survey of student's perceived competence in problem solving, there is not a statistically significant difference between the gain mean scores of the control and treatment groups. Each group score increased, but these gain scores are so similar that they are not statistically significant. While there was no statistically significant difference between groups, there was a practical significant difference between the pre-survey and post-survey within each group for students' perception of competence.

For both the treatment and control groups, an effect size of .31 and .34 respectively represents a moderate effect. The important take-away from the data is the fact that both groups' average score increased on both metrics of measure. According to Cohen (1999), with an effect size above .3, the standard mean difference should be considered a moderate effect. A moderate effect signifies that there is enough of a difference in means that the difference has a practical application. An effect size of .31 represents the mean score from the post-test as equal to or

greater than 62% of the pre-test while an effect size of .34 represents a mean score equal to or greater than 63% of the pre-test.

Both groups seemed to benefit from dedicated instruction about problem solving and this instruction seemed to give the students more confidence that they could solve difficult problems and also see how relevant problem solving is outside of the technology classroom. These students scored themselves higher as they were given more tools and confidence to handle problem solving.

### Perceived Usefulness

The results from the pre- and post-survey questions about student's perceived usefulness of problem solving in everyday life did not reveal much detail or information. With a difference of .03 and .01 for the control and treatment groups respectively, there was no statistical or practical difference between how the students viewed the usefulness of problem solving in their everyday lives.

A finding of no difference indicates that through the two-week study, the students did not have a significant change in the attitudes towards how useful problem solving is. This could be due to a number of factors, such as the student's preconceived notion of what is problem solving or the length of time studying problem solving. Many students may view formal problem solving as a purely academic endeavor, which is done only while within the confines of a school or other academic space. While these students routinely participate in problem solving in their lives outside of the classroom, they may not recognize the connections between what they have learned in the classroom and the problem solving they are confronted with.

While the scores did not increase between the pre-survey and post-survey, the results also show that there was no statistically significant drop in student's perceived usefulness of problem

solving. This results in students who were willing to attempt problem solving in a structured manner and this structure did not negatively impact students' attitudes. The danger in teaching an experimental method is student backlash toward a new method that causes them to pushback against new teaching methods and resist changes through a negative attitude (Yeşilyurt 2002). The results seem to indicate no pushback by the students or if there was that it had a negligible effect.

### **5.3 Internal Validity**

Research in the field of education is very difficult as there are many variables that may affect the results of the study. Borg and Gall (1996) attribute that difficulty to the fact that establishing a proper control group that will cause the findings to properly reflect the treatment being imposed by a researcher. Unaccounted for variables may cause the findings to reflect a change occurring in a study that may not be caused by the treatment being imposed. When dealing with human subjects in a research study, it is impossible to control every aspect of the study, though proper research attempts to address as many of these confounding variables as possible (Zelkowitz and Wallace 1998).

A number of steps were taken to address these potential confounding variables. The first concern came from the selection of the students for the study. While it is impossible to get a sample group that perfectly reflects all of the types of students in the school, the classes that were selected came from a course that every 7<sup>th</sup> grader in the school is required to take. This means that every 7<sup>th</sup> grader is randomly placed, to a certain extent, in the course in order to fill the state requirement. While the four classes who participated in the study may not be a perfect reflection of all student types in the school, the cross section represented by the students was deemed accurate enough to be used in the study.

Another concern was the effect the researcher may have had on student performance, as the researcher was also the teacher of the students who participated in the study. There are many concerns that arise from having the instructor conduct the study, as they have a vested interest in the course of the study. To minimize the impact the instructor may have had on the student scores, a third-party administered the pre- and post-tests and surveys to eliminate any bias or influence that the instructor may have had on the students.

To eliminate any bias while scoring the pre- and post-tests, the scorers were unaware of which tests corresponded with the treatment and control groups. After scoring the tests, the scores were compared between the scorers to find the inter-rater reliability. The scoring of the number of solutions was calculated as a .98, which indicates a very high agreement between scorers. A .86 was calculated for the scoring of the number of inventive solutions, indicating a high agreement between the scores of the graders.

There are multiple other validity issues that need to be addressed in order to put the results of the study in the proper light. Because the study took place over the course of multiple class periods, the possibility of students being absent for any of those class periods has to be considered. A student may have been absent for certain critical instruction periods or practice periods and missed out on getting the same amount of exposure to the treatment as other students. A student may have missed out on taking the pre-test or post-test because of being absent from the class as well. Illness also plays a big part in student motivation and attentiveness, as a student who is not feeling well will most likely not perform to the same ability and standards that they usually would. Although many students missed time for a variety of absences and school related activities, the attendance rate was above 90% throughout the two weeks that the study took place.



A major concern with educational studies is the John Henry effect, where subjects try harder when they know they are part of the experimental group in order to show that the treatment works (Adair 1984). This could also be applied with the control group, where subjects alter their effort because they know that they are not part of the treatment group. In order to address this, the form letters sent home to parents and distributed to the students all appeared to be the same, with only one line different between the control and treatment descriptions. All of the students who participated in the study knew they were part of a study, but were never informed whether they were part of the control or treatment groups.

As mentioned in the limitations section, with any research studies, there is a possibility that the instrument designed for assessing learning may have an impact on the findings. The results may be confounded if one test version is more difficult to understand or contains more difficult questions. An item analysis of the questions over a larger study population would help to investigate any potential problems with the questions. The treatment and control groups took the same test for the pre-test in order to form a baseline of performance. These groups then took a different version of the test for the post-test in order to compare similar performances. This is depicted below.

Table 6 - Test Administration – Control and Treatment Groups

<i>Test Administration</i>	
<u>Pre-test</u>	<u>Post-Test</u>
C <sub>1</sub> = A	C <sub>1</sub> = B
C <sub>2</sub> = A	C <sub>2</sub> = B
T <sub>1</sub> = A	T <sub>1</sub> = B
T <sub>2</sub> = A	T <sub>2</sub> = B

The researcher considered crossing the tests in order to potentially negate the difference in difficulty in the two tests. This would involve administering test A to one control group and one treatment group. Test B would be given to the second control group and the second treatment group. The test letter would then be switched for the post-test. This is depicted in the table below. This method was rejected by the researcher as a direct comparison between groups was desired above removing any confounding variables associated with test difficulty.

Table 7 - Alternate Test Administration – Control and Treatment

<i>Test Administration</i>	
<u>Pre-test</u>	<u>Post-Test</u>
C <sub>1</sub> = A	C <sub>1</sub> = B
C <sub>2</sub> = B	C <sub>2</sub> = A
T <sub>1</sub> = A	T <sub>1</sub> = B
T <sub>2</sub> = B	T <sub>2</sub> = A

The grade level of the questions also has an impact on whether the results show an accurate portrayal of student ability. Although evident that test B was more difficult for the students, an analysis of the response rate of each question showed that for each question, more than 93% of students responded for each question. The response rates were very similar between the treatment groups and the control groups, nullifying concerns about students not responding to the questions because of the question difficulty.

As Hall and Betsy (2009) state, “creativity is a process, and it may take time to manifest in some students.” This means that the time frame used in this study may not be a totally

sufficient time for some students to demonstrate a change in creative ability. The very construct of creativity is difficult to assess. Creativity tests are generated in an attempt to measure creative potential and allow for a variety of responses which the scorer's attempt to score. Because of individual interpretations, the results may be more difficult to compare with other findings from different studies or scorers.

An important limitation to note is the fact that this study was not looking at a correlation between fluency (as defined by the number of solutions presented and the number of inventive solutions presented) and student attitudes towards problem solving. No analysis was conducted to support any sort of correlation; only the separate findings are presented.

In addition, an item analysis was not conducted, as the researcher was only interested in the mean scores of student attitudes towards perceived competence in problem solving and student perception on the usefulness of problem solving in their everyday lives. A breakdown of each question and student's response is not relevant for the data being collected at this time.

As a final validity concern, the results of this study cannot be generalized to a larger group of students. While every effort was taken to ensure random selection of students and random assignment of treatments, because the study dealt with human subjects in an educational setting, the results can only be generalized within the same set of conditions that existed in the study (Borg and Gall 1996). This means that conclusions can be made with those students who participated in the study, but nothing conclusive beyond that.

## **5.4 Major Conclusions**

The major conclusions of this research study were:

1. On the post-test, students taught in the ASIT method provided a statistically and practically significant increase of inventive solutions when compared to a control group.
2. On the post- test, students taught the ASIT method presented fewer total solutions but a greater percentage of their solutions were inventive.
3. Student attitudes towards their perceived competence in problem solving increased in both the treatment and control groups with dedicated instruction in problem solving. This increase has practical significance but was not large enough to be considered statistically significant.
4. Student perception of the perceived usefulness of problem solving in their everyday lives did not significantly change between the pre-survey and post-survey.

## **5.5 Recommendations**

### **5.5.1 Research Question #1**

#### Ability to Generate Solutions

A general pattern was observed where the students who were taught the ASIT method generated fewer solutions compared to the students who were taught the regular school curriculum. Insight could be found in future research when looking at any correlation between the number of solutions generated and student's abilities to be capable problem solvers. This research would look in depth on the differences in school subjects to see if the number of solutions has any correlation to the subject being studied and solving problems in those specific subjects. For example, the subject of mathematics may be more conducive to a smaller number of solutions where engineering or English may be more favorable to a larger number of solutions.

### Ability to Generate Innovative Solutions

A recommendation that stems from the findings in this study would be to research how a modified ASIT method would impact student outcomes with regards to problem solving. This modification would emphasize the closed world (CW) condition in an attempt to help focus 7<sup>th</sup> grade age students on what the actual problem is. As mentioned previously, the students who took part in the study seemed to quickly grasp the concept of the problem world and what components fit into that category. Further study could be conducted on how knowing and understanding the components of a problem help students understand a problem and more efficiently generate solutions to a given problem.

Additional study might also utilize a longer time frame for the study to see whether students would grasp more difficult concepts with a longer time to learn and be instructed. As mentioned earlier, the two-week time period was utilized out of convenience in the schedule of the students to avoid as much confounding variables that arise towards the end of a school year. Some of these confounding variables include family vacations; state mandated testing, and student focus and engagement waning towards the end of a long school year. Barak and Mesika (2006) utilized 9 weeks of instruction, so more research could be devoted to studying how the amount of time could influence student ability in problem solving.

This study utilized three of the five ASIT thinking tools during the two-week study. Follow up study could be devoted to assessing the impact and magnitude of difference between learning some of the thinking tools and all five. As mentioned earlier, knowing even a few of the principles and the core ideas of Closed World and Qualitative Change can be beneficial in solving a problem (Moon et al. 2011, Horowitz 2001) but there may be additional benefits from learning all of the thinking tools to have the complete package.

## **5.5.2 Research Question #2**

### Perceived Competence

The data collected on the perceived competence of students indicated that students who are taught problem solving in a formal setting overall gain a more positive attitude in their own abilities to problem solve. These students feel more confident in being able to approach a given problem and feel like they would be successful in solving that problem. With the data showing positive gain in student attitude, more research could be done in comparing groups of students who receive specific instruction in problem solving and control groups that receive no formal instruction in problem solving to see the differences that might arise in abilities and aptitudes in each of these groups.

More research could also be devoted to determining the link between student attitudes and aptitudes with regards to problem solving. As mentioned earlier, the researcher did not attempt to correlate the two research questions and was only looking for patterns that were evident in mean scores of the control and treatment group. Further research could look at individual achievement and attitudes using specific student data across both aptitude tests and attitude surveys.

### Perceived Usefulness

The data collected on the perceived usefulness of problem solving in everyday life raises some interesting questions. There was no significant or practical difference between the gain mean scores for either the control group and the treatment group. More research is recommended on studying this phenomenon to understand why there was no gain in measured responses. Understanding how students view problem solving in their everyday lives would lead to better instructional practices. This understanding would help to provide proper techniques on

helping the students realize the practical application of problem solving in the world around them.

A recommendation for a follow-up study to address this phenomenon could be having the students generate a list of problems that are directly and personally relevant to them. These questions could then be randomly selected to be part of the pre-test and the post-test. The results could then show whether using these more personally relevant questions has any effect on student attitudes towards their perceived usefulness of problem solving.

This study was not organized to compare individual scores on the pre-survey and post-survey, only the overall average mean score of the control and treatment groups. More time and study could be devoted to comparing individual scores on the attitude surveys to see whether certain types of students may have increases or decreases in their attitudes towards the usefulness of problem solving. These groups could include gender, socio-economic status, and student achievement in addition to others.

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## **APPENDICES**

## **Appendix A. Parental Permission for a Minor**

### **Parental Permission for a Minor**

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#### **Introduction**

My name is Jared Merrill, I am a graduate student from Brigham Young University and currently your son or daughter's Career and Technical Education (CTE) Technology teacher. I am conducting a research study under the guidance of Steven Shumway, Professor of Technology and Engineering Department at Brigham Young University revolving around teaching structured problem solving to middle school students. I am inviting your child to take part in the research because (he/she) is currently enrolled in my CTE-Intro class.

#### **Procedures**

*If you agree to let your child participate in this research study, the following will occur:*

- Instruction will take place in your student's regular classroom and during the normal hours of school.
- Two weeks of class time will be used to cover methods for problem solving. Your student will take part in learning various methods to approaching problem solving through using thinking techniques. These techniques lead to creating innovative solutions to problems.
- Your student will be asked to take a pre-test and a post-test consisting of 3 open-ended problems and asked to write down possible solutions to the problem.
- Your child will also be asked to take an attitude questionnaire, which will ask questions such as *I know I can do well in problem solving* and *I'll need problem solving for my future work.*

#### **Participation**

Participation in this research study is voluntary. You are free to decline to have your child participate in this research study. You may withdraw you child's participation at any point without any penalty of loss of grade or participation. Your student will be given other coursework to work from the state prescribed curriculum and will work in the classroom. This work will not have any data collection associated with it and will not be counted towards your student's grade in my class.

#### **Risks**

There are minimal risk to your student. Scores will be taken on the pre-tests, post-tests, and attitude surveys, but your student's school grades will not be affected.

#### **Confidentiality**

The tests and questionnaires will be collected promptly and anonymously. Your student's name

will never be recorded or documented. The tests and questionnaires collected will be kept in a secured filing cabinet that only the researcher has access to. The raw data will be kept in order to help with any additional studies that make take place, but there will not be any identifiable information beyond the class period for the data.

**Benefits**

Although there is no direct benefit to your student, the data collected during the study could provide information on how to teach problem solving in the future.

**Compensation**

There is no compensation for your student to participate.

**Questions about the Research**

Please direct any further questions about the study to Jared Merrill at 801-370-4621 ext. 1307 or by e-mail at [jaredm@provo.edu](mailto:jaredm@provo.edu). You may also contact Steve Shumway at 801-422-6496 or by e-mail at [steve\\_shumway@byu.edu](mailto:steve_shumway@byu.edu)

Questions about your child's rights as a study participant or to submit comment or complaints about the study should be directed to the IRB Administrator, Brigham Young University, A-285 ASB, Provo, UT 84602. Call (801) 422-1461 or send emails to [irb@byu.edu](mailto:irb@byu.edu).

You have been given a copy of this consent form to keep.

Child's Name: \_\_\_\_\_ Period: \_\_\_\_\_

Parent Name: \_\_\_\_\_ Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## **Appendix B. Student Participation in a Study**

### **Student Participation in a Study (7-14 years old)**

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#### **What is this research about?**

My name is Jared Merrill, a Graduate student at BYU and your current CTE-Technology teacher. I want to tell you about a research study I am doing. A research study is a special way to find the answers to questions. We are trying to learn more about problem solving. You are being asked to join the study because you are in one of my CTE-Intro classes for 7<sup>th</sup> grade.

What I want to do is take two weeks and teach you about how to solve problems through using specific steps. These steps help you to figure out what the problem is asking and how you can use different parts of the problem to find a solution. At the end of the two weeks, you will have the chance to do a project where you will create a model of a solution to a problem.

*If you decide you want to be in this study, this is what will happen.*

- You will be asked to take 2 short quizzes, with 3 problems each that will ask you to write possible solutions to a problem.

These problems could be questions like

*how to make a light-bulb work on the moon or how to keep bugs out of a house.*

- You will also be asked to fill out a simple, 22-question survey about problem solving.

#### **Can anything bad happen to me?**

Your participation in this research will not affect your grade in my class.

#### **Can anything good happen to me?**

We are hoping that by taking part in this study, you will get better at problem solving and enjoy solving problems in school and out of school.

#### **Do I have other choices?**

You do not have to be part of this research study if you do not want to. If you or your parents do not want you to participate in this study, please let me know and we will make sure you have other class related projects to do.

#### **Will anyone know I am in the study?**

We won't tell anyone besides your parents or guardians that you took part in this study, the only people who will know will be those students who are in your class with you, also taking part in the study. When we are done with the study, we will write a report about what we learned. We won't use your name in the report.

Before you say yes to be in this study; be sure to ask me, Jared Merrill, to tell you more about anything that you don't understand.

If you want to be in this study, please sign and print your name.

Name (Printed): \_\_\_\_\_ Signature \_\_\_\_\_

Date: \_\_\_\_\_



## Appendix C. Pre-test Quiz A

### Problem-solving

You live in a swamp with bugs that constantly get into your house whenever you go out the front door. What could you do to keep bugs out of your house when you go outside?

Each summer, the Provo river floods and damages the local park. What could you do to prevent this flooding?

A worker lives far away from his job. He wants to save gas and be more environmentally friendly. What could he do?

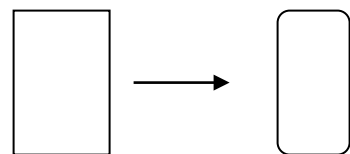
## Appendix D. Post-test Quiz B

### Problem-solving

The Lighthouse of Alexandria was built in 3rd century BC and is considered to be one of the Seven Wonders of the World. Sostratus, the Lighthouse's architect, wanted his name to be perpetrated in the Lighthouse design. This was not allowed by Ptolemy II, the King of Egypt, who forbade his name to be carved on the huge structure. How could the architect solve this problem?

Regular candles drip wax while burning, thus dirtying the surrounding area - the residue that does not burn drips down the side of the candle causing the messy drops of wax. Suggest a way of stopping the candle from dripping.

We must round the corners of a glass board and shape it into a quarter-circle. The problem is that thin glass is easily breakable and is not simple to process. How could we cut the glass without breaking it?



## Appendix E. Modified Fennema-Sherman Attitude Survey

### What I think about Problem-Solving

(1 means strongly disagree)

(5 means strongly agree)

1. I am sure that I can learn how to problem solve.  
1  2  3  4  5
2. Knowing problem solving will help me earn a living.  
1  2  3  4  5
3. I don't think I could do advanced problem solving.  
1  2  3  4  5

---

4. Problem solving will not be important to me in my life's work.  
1  2  3  4  5
5. Problem solving is hard for me.  
1  2  3  4  5
6. I'll need problem solving for my future work.  
1  2  3  4  5

---

7. I am sure of myself when I do problem solving.  
1  2  3  4  5
8. I don't expect to use much problem solving when I get out of school.  
1  2  3  4  5
9. Problem solving is a worthwhile, necessary task.  
1  2  3  4  5

10. I'm not the type to do well in problem solving.  
1                      2                      3                      4                      5  
                                                                                       

---

11. Studying problem solving is a waste of time.  
1                      2                      3                      4                      5  
                                                                                       

12. I think I could handle more difficult problem solving.  
1                      2                      3                      4                      5  
                                                                                       

13. I will use problem solving in many ways as an adult.  
1                      2                      3                      4                      5  
                                                                                       

14. I see problem solving as something I won't use very often when I get out of high school.  
1                      2                      3                      4                      5  
                                                                                       

---

15. I can get good grades using problem solving.  
1                      2                      3                      4                      5  
                                                                                       

16. I'll need a good understanding of problem solving for my future work.  
1                      2                      3                      4                      5  
                                                                                       

17. I know I can do well in problem solving.  
1                      2                      3                      4                      5  
                                                                                       

---

18. Doing well in problem solving is not important for my future.  
1                      2                      3                      4                      5  
                                                                                       

19. I am sure I could do advanced work in problem solving.  
1                      2                      3                      4                      5  
                                                                                       

20. Problem solving is not important for my life.  
1                      2                      3                      4                      5

---

21. I'm no good at problem solving.

1

2

3

4

5

22. I study problem solving because I know how useful it is.

1

2

3

4

5

## Appendix F. Student Worksheets

<b>Multiplication</b>		Name: _____	
<u>Restate problem in one sentence:</u>			
<u>Problem objects:</u>		<u>Environment Objects:</u>	
<u>Undesired effect:</u>			
<u>Action to eliminate undesired effect:</u>			
To prevent _____ from _____			
Select an object to modify to perform the above action:			
Object 1	Object 2	Object 3	
<u>Rules:</u>			
-The new object may not be the same as the existing one			
-There may be an interaction between the new object and the original			
<u>Core Idea</u>	<u>Core Idea</u>	<u>Core Idea</u>	
<u>Elaborate the Idea:</u>			
Multiplication – introducing a slightly modified copy of an existing object into the system			

<b>Unification</b>		Name: _____
<u>Restate problem in one sentence:</u>		
<u>Problem objects:</u>	<u>Environment Objects:</u>	
<u>Undesired effect:</u>		
<u>Action to eliminate undesired effect:</u>		
To prevent _____ from _____		
Select an object to perform the above action:		
Object 1	Object 2	Object 3
<u>Rules:</u>		
-The selected object can be modified		
-Other objects can be modified		
<u>Core Idea</u>	<u>Core Idea</u>	<u>Core Idea</u>
<u>Elaborate the Idea:</u>		
Unification – Solve a problem by assigning a new use to an existing component		

<b>Division</b>	Name: _____	
<u>Restate problem in one sentence:</u>		
<u>Problem objects:</u>	<u>Environment Objects:</u>	
Select an object to divide:		
Object 1	Object 2	Object 3
<u>List of parts of this object</u>	<u>List of parts of this object</u>	<u>List of parts of this object</u>
<u>Rules:</u> Imagine that part being separated from the rest. What if... -That part was moved to another place? -That part was to be treated differently from the others? -That part was to show up or disappear at different times?		
<u>Core Idea</u>	<u>Core Idea</u>	<u>Core Idea</u>
<u>Elaborate the Idea:</u>		
Division – dividing an object and reorganizing it's parts		



## **Appendix G – Day-by-Day Breakdown**

### Methodology - Treatment group

Day 1 - Intro to creativity, divergent thinking, group brainstorming with an example problem.

Problem: Rollercoasters

Day 2 - Breaking a problem down into components, Identifying the “Problem-world”

Problem: Helicopter Pilot ejecting

Day 3 - Review components, ASIT principles and how to apply to components to discover new ideas. (indirect instruction, have students identify what it is before “official definition”)

**Focus - Multiplication Technique**  
activity - Lunchroom

Day 4 (Block)- Review components, ASIT principles and how to apply to components to discover new ideas. Cover  
Cover Qualitative Change Principle

**Focus - Unification Technique**  
activity - Bridges

-use tape, paper,  
10” gap to cross

after 10-15 minutes, pass out unification sheet to discuss its application

Future Tech video

Day 5 -Review components, ASIT principles and how to apply to components to discover new ideas.

### **Focus - Division Technique**

activity - Design a school building for a specific subject area (ie. art school, music school, tech ed school)

Focus on dividing existing components of school (such as cafeteria, gyms) and incorporating those aspects into new design

Day 6 - Mini-quiz on identifying proper techniques

Finish School projects, review division technique

Days 7-10 Large project - New TRAX line next to the school - Work on projects

### **Methodology - control group**

Day 1 - Intro to creativity, divergent thinking, group brainstorming with an example problem.

Problem: Rollercoaster

Day 2 - Steps in the Problem solving method (DBSTE) Helicopter pilot ejecting problem

Day 3 – Cafeteria problem

Review of problem solving method steps

Introduce problem

-split into groups of 3

Start with the first step (define)

-go to cafeteria to gather information

-sketch of layouts, walk the area, mimic buying

come back to room to brainstorm ideas

Evaluate

Select 3 possible solutions from brainstorming

Define 5 criteria for judging

Grade out of 5

Select one to present to the principal

Day 4 (block)– Group brainstorming – egg drop

Do quiz on steps in problem solving

split into groups of 4

write in packets: Define the problem. List materials

-Big Straws - \$10

-Small Straws \$6

-1' Tape \$5

-Toothpicks 10 / \$2

-Rubber Band \$6

-Cotton Balls \$1

Instruct them that I will be dropping their eggs standing on the desk counter. They will have 20 minutes to design and build their device  
Each group keep track of cost

-extra time - watch future Tech Video

Day 5 - individual problem solving - rockets

Challenge - get straw into box

-items launcher

-clay

-tape

-folder paper

rules - cannot throw it

- cannot cross lines to carry it

Day 6 – individual problem solving

finish rockets

Days 7-10 Large project - New TRAX line next to the school - Work on projects

## Appendix H. Rubric for Scoring Pre-and Post-tests

### Problem-solving

Period: \_\_\_\_\_

You live in a swamp with bugs that constantly get into your house whenever you go out the front door. What could you do to keep bugs out of your house when you go outside?

Components- Bugs, house, door

Qualitative Change – Opening door  
doesn't let bugs in

Each summer, the Provo river floods and damages the local park. What could you do to prevent this flooding?

Components – river, park, river bank

Qualitative Change – Flooded river  
doesn't damage park

A worker lives far away from his job. He wants to save gas and be more environmentally friendly. What could he do?

Components – Gas, location, person, job

Qualitative Change – Location does not affect gas consumption

**Problem-solving**

Period: \_\_\_\_\_

The Lighthouse of Alexandria was built in 3rd century BC and is considered to be one of the Seven Wonders of the World. Sostratus, the Lighthouse's architect, wanted his name to be perpetrated in the Lighthouse design. This was not allowed by Ptolemy II, the King of Egypt, who forbade his name to be carved on the huge structure. How could the architect solve this problem?

**Components: Lighthouse, Name of architect, \_\_\_\_\_ King**

**Qualitative Change – Name on lighthouse not  
\_\_\_\_\_ anger the king.**

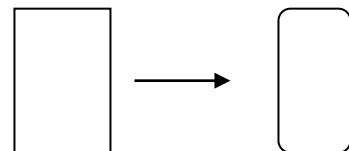
Regular candles drip wax while burning, thus dirtying the surrounding area - the residue that does not burn drips down the side of the candle causing the messy drops of wax. Suggest a way of stopping the candle from dripping.

**Components: Wax, wick, flame, surrounding \_\_\_\_\_ area**

**Qualitative Change - Melted wax doesn't  
\_\_\_\_\_ affect surrounding area**

We must round the corners of a glass board and shape it into a quarter-circle. The problem is that thin glass is easily breakable and is not simple to process. How could we cut the glass without breaking it?

**Components: Glass,  
\_\_\_\_\_ cutting device**



**Qualitative Change - cutting the glass does not break it**

## Appendix I. Rubric for Scoring Pre-and Post-surveys

Modified Fennema -Sherman attitude scale

- |  |   |     |
|--|---|-----|
| 1. I am sure that I can learn how to problem solve.  | C | +   |
| 2. Knowing problem solving will help me earn a living.                                       | U | +   |
| 3. I don't think I could do advanced problem solving.  | C | -   |
| 4. Problem solving will not be important to me in my life's work.                            | U | -   |
| 5. Problem solving is hard for me.   | C | -   |
| 6. I'll need problem solving for my future work.   | u | +   |
| 7. I am sure of myself when I do problem solving.  | c | +   |
| 8. I don't expect to use much problem solving when I get out of school.                      | u | -   |
| 9. Problem solving is a worthwhile, necessary subject task.                                  | u | +   |
| 10. I'm not the type to do well in problem solving.  | c | -   |
| 11. Studying problem solving is a waste of time.   | u | -   |
| 12. I think I could handle more difficult problem solving.                                   |   | c + |
| 13. I will use problem solving in many ways as an adult.                                     | u | +   |
| 14. I see problem solving as something I won't use very often when I get out of high school. |   | U - |

15. I can get good grades using problem solving. c + (u +)
16. I'll need a good understanding of problem solving for my future work. u +
17. I know I can do well in problem solving. c +
18. Doing well in problem solving is not important for my future. u +
19. I am sure I could do advanced work in problem solving. c +
20. Problem solving is not important for my life. u -
21. I'm no good at problem solving. c -
22. I study problem solving because I know how useful it is. u +

## Scoring:

### Key:

C = Personal confidence about the subject matter

U = Usefulness of the subject's content

+ = Question reflects positive attitude

- = Question reflects negative attitude

Each positive item receives the score based on points

A=5 B=4 C=3 D=2 E=1

The scoring for each negative item should be reversed

A=1 B=2 C=3 D=4 E=5

Add the scores for each group, T, C, U, M, to get a total for that attitude.

The highest possible score for each group of statements is 60 points.



## Appendix J. Internal Validity Scoring

The SAS System

14:17 Monday, July 1, 2013

### Variance Components Estimation Procedure

#### Class Level Information

Class	Levels	Values
tests	232	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232
		Number of Observations Read 464
		Number of Observations Used 464

#### MIVQUE(0) SSQ Matrix

Source	tests	Error	solutions
tests	924.00000	462.00000	4755.4
Error	462.00000	463.00000	2405.7

#### MIVQUE(0) Estimates

Variance Component	solutions
Var(tests)	5.08623
Var(Error)	0.12069

For solutions

Reliability is  $1 - (\text{var}(\text{tests}) / \text{var}(\text{error}))$

**0.976271**

Variance Components Estimation Procedure

Class Level Information

Class	Levels	Values
tests	232	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232
judge	2	1 2

Number of Observations Read 464  
 Number of Observations Used 464

MIVQUE(0) SSQ Matrix

Source	tests	Error	inventive
tests	924.00000	462.00000	1234.5
Error	462.00000	463.00000	658.24138

MIVQUE(0) Estimates

Variance Component	inventive
Var(tests)	1.24766
Var(Error)	0.17672

Inventive  
 Reliability is  $1 - (\text{var}(\text{tests}) / \text{var}(\text{error}))$  0.858359