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# Investigating the Effects of Cognitive Diversity on the Small Gasoline Engines Problem Solving Ability of Undergraduate Students Enrolled in a Team-Based Learning Formatted Agricultural Mechanics Course

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**INVESTIGATING THE EFFECTS OF COGNITIVE DIVERSITY ON THE SMALL  
GASOLINE ENGINES PROBLEM SOLVING ABILITY OF UNDERGRADUATE  
STUDENTS ENROLLED IN A TEAM-BASED LEARNING FORMATTED  
AGRICULTURAL MECHANICS COURSE**

A Thesis

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Master of Science

in

Department of Agricultural and Extension Education

by  
Whitney Lynn Figland  
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## ABSTRACT

Perhaps the most challenging factor in teaching is being able to foster a learning environment that meets the needs of all learners, which is often achieved by utilizing a plethora of instructional methods that develop critical thinking and problem solving skills. These 21st century skills have been recurrently identified as a critical component of today's workplace and employers are hiring individuals who can solve complex problems, especially within agriculture. However, students in today's educational classrooms are often not receiving the hands-on instruction that is needed in order to foster the development of critical thinking and problem solving skills. Further, problem solving skills have been identified as one of the most crucial cognitive activities that we encounter every day in our personal and professional lives. In order to combat this problem, educators have moved to more active learning environments to help develop critical thinking and problem solving skills that are needed for employment in the workforce. Previous research supports the idea that active learning classrooms provide students with the necessary hands-on activities that develop their critical thinking and problem solving skills. Previous research also has been conducted to understand how cognitive style, learning style, and critical thinking style affect an individual's problem solving ability. However, little research has been conducted to understand how cognitive diversity amongst a group affects the problem solving process. Therefore, this study sought to understand how cognitive diversity affects the problem solving ability of students in an agricultural mechanics class. This study compared students' problem solving ability by measuring time to solution and hypothesis generation ability when troubleshooting a small gasoline engine. A one-group pretest-posttest design was utilized for this study. In all, 31 participants elected to participate in this study and completed a criterion-referenced test, course motivation survey instrument, and a troubleshooting

exercise. Data were analyzed using nonparametric statistics, specifically, Mann-Whitney U tests, Kruskal-Wallis test, and the Pearson's Chi-Square test. The analysis rendered no statistically significant differences between cognitive style and content or course motivation. However, further analysis revealed a statistically significant difference was found between cognitive diversity groups and time to solution and hypothesis generation.

## **CHAPTER I: INTRODUCTION TO RESEARCH**

### **Background**

Perhaps one of the most challenging aspects of teaching is fostering a learning environment that meets the needs of all students. In order for teachers to foster student learning, a variety of instructional approaches are utilized to provide students with the opportunity to develop problem solving and critical thinking skills (Allen, Donham, & Bernhardt, 2011; Hanson, 2006). In today's workplace, employers want individuals who are able to identify and find solutions to complex problems in an effective and efficient manner (Jonassen, 2001). Therefore, skills associated with problem solving are highly desired (Gokhale, 1995). This need for skilled employees has become critical as the complexity of technology rises, especially within agriculture. However, this problem is compounded by a lack of hands-on instruction in today's educational classroom, which is often not encouraging students to develop critical thinking and problem solving skills that are highly desired in the today's workplace (Gokhale, 1995; Jonassen, 2000; Ulmer & Torres, 2007).

Of all the instructional approaches that could be utilized, active learning strategies provide individuals the opportunity to engage in real-world learning experiences. Active learning can be defined as an activity that required students to engage in critical thinking and problem solving (Bonwell & Eison, 1991). Further, Felder and Brent (2009) added that for students to be learning actively in the classroom, they must be engaged in the activity or experience, rather than just simply watching, listening, or taking notes. Within the active learning realm, collaborative and problem-based learning (PBL) make up the majority of learning activities (Bonwell & Eison, 1991; McCubbins, Paulsen, & Anderson, 2016). Collaborative learning allows the learner to

engage in group work situated around real-life problem solving (Cornell University Center for Teaching Innovation, 2012). Similarly, PBL integrates group work into a student-centered approach that allows individuals to solve open-ended problems (Center for Teaching Innovation, 2012). Further, group instruction has been noted to promote (a) cognitive development, (b) enhance critical thinking skills, and (c) create environments for frequent learner feedback (Cooper & Robinson, 2000; Michaelsen, Knight, & Fink, 2004; Michaelsen, Sweet, & Parmalee, 2011), which has become a critical component of today's workplace (Gokhale, 1995).

Within agricultural education, problem solving and critical thinking skills have been commonly taught through the problem solving approach to teaching and learning (Phipps & Osborne, 1988). For many years, the problem solving approach has been considered the best method of instruction in agriculture (Phipps & Osborne, 1988) because secondary agricultural education programs are an optimal place to assist students in developing and refining problem solving and higher order thinking skills (Pate & Miller, 2011a). However, educators generally do not teach an ample amount of problem solving skills in their curriculum (Pate & Miller, 2011b), which could be compounded by the teacher's lack of knowledge on how to effectively implement a new teaching strategy to foster problem solving skills development (Jonassen, 2000; Ulmer & Torres, 2007).

The skills associated with problem solving and critical thinking have been considered one of the most critical cognitive activities we go through in our everyday personal and professional lives (Jonassen, 2000). In a broad context, cognitive style can be defined as an individual's preferred way to organize and retain information (Keefe, 1979; Kirton, 2003). However, students are often not aware of their preferred way to learn nor have they ever been assessed. Further, Jonassen (2000) concluded that awareness of a student's cognitive style is an important key to



successfully problem solve. However, individuals often vary in their preferred mode to learn, which can influence a person's pattern of thinking and reasoning (Jonassen, 2000).

A strong indicator of problem solving ability lies in the individuals' metacognitive skill development (Zimmerman & Risemberg, 1997). Research in education has emphasized the development of student's metacognitive skills in order for them to be effective problem solvers (Zimmerman & Risemberg, 1997). Specifically, metacognitive skills allow students to encode the problem type by forming mental schemas of the problem, thereby allowing them to select appropriate plans and identify and overcome obstacles (Davidson & Sternberg, 1998). These metacognitive actions are a driving force in an individual's ability to problem solve. However, an individual's beliefs and attitudes play a major role in their ability to solve problems effectively (Lester, 1994). Specifically, previous research in education has suggested content in a domain should be specifically linked with instruction to encourage metacognitive skills development in order to help improve students' problem solving abilities (National Research Council, 2000; Pintrich, 2002; Schraw, 1998).

Another integral factor in a student's ability to problem solve, especially in mechanical systems, is their general and specific domain knowledge (Hegarty, 1991). General knowledge, refers to basic concepts in a given area (e.g., heuristics) and general knowledge is an important factor in the solvers ability to effectively solve a variety of problems (Hegarty, 1991). Specific knowledge, however, refers to the individuals' knowledge in a given domain (i.e. mechanics) and can be broken into two types of knowledge (a) conceptual and (b) procedural knowledge (Hegarty, 1991). Conceptual knowledge is the basic understanding of general principles in a domain. For example, in the area of small gasoline engines technology, having a knowledge of basic engine components and functions (Hegarty, 1991). However, procedural knowledge refers

to the knowledge an individual possessed to be able to carry out processes (i.e., fixing broken piston rings) (Hegarty, 1991). Further, being familiar with the domain is considered one of the strongest predictors of problem solving ability; specifically, within the area and problem type (Hegarty, 1991; Jonassen, 2001). However, it should be noted that there are several types of knowledge that affect how a person solves problems (Jonassen & Hung, 2006) and without foundational knowledge in multiple domains, solving everyday problems can become a complex task (Hegarty, 1991; Jonassen, 2000; Jonassen & Hung, 2006).

A common type of problem solving that is often encountered in our everyday lives revolves around the ability to troubleshoot problems. Troubleshooting, as defined by Herren (2015), is determining what causes a malfunction in machine or process. Further, Custer (1995) and Jonassen (2000) added that troubleshooting also includes a subset of problems, where the problem is situated into a real-world context. These problems are often integrated into our daily lives and are ill-structured in nature, which means they are constrained by a single domain and often their solutions are undefined. They often require the learner to integrate multiple domains to achieve the solution (Jonassen, 2000). These ill-structured problems require the troubleshooter to possess knowledge, skill, and multiple experiences to interact effectively with the complex system they are troubleshooting (Johnson & Fleshner, 1993; Jonassen, 2003). Also, according to Halpern (1984), the most important piece to effective problem solving is the troubleshooter's ability to recognize and select the most appropriate solution. However, it has also been determined that the path to deriving a solution between novice and expert troubleshooters is often quite different (Pate, Wardlow, & Johnson, 2004).

Prior research has been conducted to understand the differences between novice and expert troubleshooters. Dixon and Johnson (2011) found that expert troubleshooters constructed

better mental schemas of the troubleshooting task, which can be linked to better metacognitive skills. Whereas, novices had a more difficult time troubleshooting because of a lack of mental schemas (Dixon & Johnson, 2011; Gitomer, 1988). However, this finding could be linked to less experience and knowledge, which hinders a novice from successfully troubleshooting.

Nevertheless, it has been reported that a main difference in troubleshooting ability among expert and novice troubleshooters were attributed to the plethora of information received and acquired in a specific domain (Johnson, 1989).

Research has focused on the influence of cognitive styles, specifically its influence on decision making (Witkin, Moore, Goodenough, & Cox, 1977). Blackburn, Robinson, and Lamm (2014) sought to assess the effects cognitive style and problem complexity had on the problem solving ability of undergraduate students. The results of this study indicated there were no statistically significant differences in the problem solving ability of the more innovative individuals when solving a simple or complex problem. Further, Blackburn & Robinson (2016) assessed the troubleshooting ability of undergraduate students based on cognitive style, problem complexity, and hypothesis generation ability. Much like Blackburn et al. (2014), cognitive style was determined prior to any treatment or intervention. However, the results of this study indicated regardless of problem complexity, students who generated the correct hypothesis were more efficient problem solvers.

### **Theoretical Framework**

This study was grounded in Kirton's (2003) Adaptation-Innovation Theory (A-I theory). Kirton's (2003) Adaptation-Innovation Theory was being utilized to understand the individual's cognitive style and their preferred way to think and learn to further enhance their learning problem solving ability.

Within Kirton's Adaptation-Innovation Theory, individual cognitive style falls between adaptation and innovation on a continuum from 32-160 (Kirton, 2003). This type of scale does not allow any individual to be purely an adaptor or purely an innovator. Specifically, individuals with scores ranging from 32-95 are considered more adaptive and prefer a more structured environment when solving problems. These individuals prefer well-established problems and favor working within the current problem structure (Kirton, Bailey, & Glendinning, 1991). More adaptive individuals tend to collaborate well with group members and generate ideas that favor consensus (Kirton, 2003). On the contrary, individuals who scores range from 96-160 are considered more innovative in nature and prefer less structure to solve the problem and often challenge boundaries (Kirton, 2003; Lamm, Shoulders, Roberts, Irani, Unruh, & Brendemuhl, 2012). More innovative individuals tend to break the boundaries and generate ideas outside the current group structure (Kirton, 2003). Often, individuals falling more on the innovative side of the continuum tend to be novel and find different ways to solve problems. Whereas, adaptors tend to be safer, more predictable, conforming, and less ambiguous when solving problems (Kirton, 1999, 2003).

### **Conceptual Framework**

The conceptual framework utilized for this study is Bransford's (1984) IDEAL problem solving model. Conceptually, this model allowed the researcher to understand how each troubleshooting group progressed through problem solving when completing the troubleshooting task.

Bransford's (1984) IDEAL problem solving approach encompasses the ideas and theories from a variety of scholars, philosophers, and practitioners (Sternberg, 1981; Kolb, 1984; Newell & Simon, 1972). The IDEAL problem solving model closely mirrors the steps in the scientific

method and John Dewey’s reflective thinking model (Phipps, Osborne, Dyer, & Ball, 2008). Bransford’s (1984) IDEAL problem solving model incorporates Dewey’s problem solving approach in a five step model, which includes (a) Identify problems and opportunities, (b) Define goals, (c) Explore possible strategies, (d) Anticipate outcomes/Act, and (e) Look back and Learn. A key factor to remember in the IDEAL problem solving model is that each step is presented in a fluid linear process (Bransford, 1984); however, each step in the IDEAL problem solving model does not occur completely independently of one another and there are often unclear boundaries when observed (Lamm et al., 2012; Bransford, 1993). Figure 1.1 depicts the five steps of Bransford’s (1984) IDEAL problem solving model.

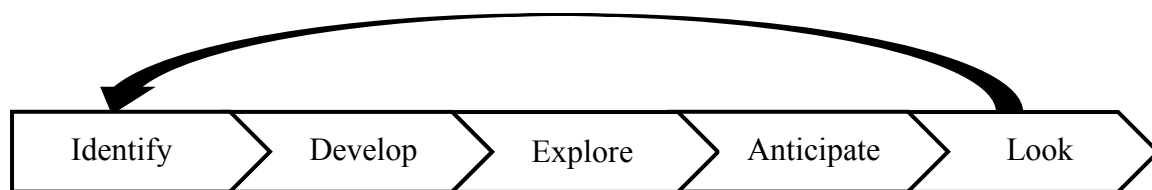


Figure 1.1. Bransford’s (1993) IDEAL problem solving model. Adapted from “The Influence of Cognitive Diversity on Group Problem Solving Strategy” by A.J. Lamm, C. Shoulders, G.T. Roberts, T.A. Irani, L.J. Snyder, & J. Brendemuhl, 2012, *Journal of Agricultural Education*, 53(1), p.19. Copyright 2012 by Journal of Agricultural Education. Reprinted with Permission.

### **Statement of the Problem**

In recent years, it has become increasingly important for educators to adapt to new pedagogies in order to develop higher order thinking skills for their students to meet the demands of the 21st century workplace (Fuhrmann & Grasha, 1983; Jonassen, 2000; Ulmer & Torres, 2007). Due to the highly structured components of the work place, skills associated with problem solving or critical thinking are highly desired (Gokhale, 1995) because employers want individuals who can find, identify, and solve complex problems in an effective and efficient manner (Johnson, 1991).

Generally, educators have a wide variety of instructional methods available to them in order to meet needs of diverse learners. However, the problem solving approach, especially in agricultural education, has been highly regarded as the best method of instruction (Dyer, 1995). The problem solving approach provides students with the skills necessary to develop important metacognitive processes, which promote higher order thinking skills and improved problem solving ability (Dyer, 1995; Zimmerman & Risemberg, 1997). Historically, this has been achieved more easily in the agricultural education curriculum, which is known for its hands-on learning processes designed to provide students with the necessary real-world learning experiences.

Problem solving skills have been identified as one of the most important cognitive activities encountered in our everyday lives (Jonassen, 2000). As part of our routine, we often solve hundreds of problems a day ranging from simple to complex (Jonassen, 2000). However, students today often do not solve meaningful problems as a part of their curricula (Jonassen, 2000). Fortunately, problem solving skills can be taught and refined by enhancing the learning environment and building metacognitive skills (Lester, 1994; Sproull, 2001).

Education literature conveys the importance of cognitive styles of students as an important function of our everyday lives (Myers & Dyer, 2006; Parr & Edwards, 2004; Thomas, 1992; Torres & Cano, 1995a; Witkin et al., 1977). However, educators generally do not teach a significant amount of problem solving or critical thinking skills in their curriculum in order to build effective problem solvers (Jonassen, 2000; Ulmer & Torres, 2007). Blackburn et al. (2014), and Lamm et al. (2011) concluded educators must be aware of different cognitive styles and understand how to tailor lessons to effectively teach critical thinking and problem solving skills.

The previous review raises the question: How does cognitive style influence a student's ability to effectively problem solve in a small group setting?

### **Purpose of the Study**

The primary purpose of this study was to investigate the effects of cognitive diversity on the problem solving ability of undergraduate students enrolled in an agricultural mechanics course.

### **Research Problem**

What effect does cognitive diversity have on students' ability to solve problems when troubleshooting a small gasoline engine?

### **Research Questions**

1. Do differences exist in content knowledge of undergraduate students enrolled in an introduction to agricultural mechanics course by cognitive style?
2. Do differences exist in course motivations of undergraduate student enrolled in an introduction to agricultural mechanics course by cognitive style?
3. Does team cognitive diversity have an effect on time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?
4. Does team cognitive diversity have an effect on the hypothesis generation ability of undergraduate students enrolled in an introduction to agricultural mechanics course when solving small gas engine problems?

5. Does hypothesis generation have an effect on the time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?

### **Operational Definitions**

**Cognitive Style** – An individual's preferred way of going about solving problems (Kirton, 2003).

**Cognitive Diversity** – Learning style differences amongst individuals who are working in a team or group.

**Hypothesis Generation Ability** – Whether or not they correctly hypothesized on the first attempt.

**Metacognition** – An active reflective process that is explicitly and exclusively directed at one's own cognitive activity. It involves the self-monitoring, self-evaluation, and self-regulation of on-going tasks (Berardi-Coletta, Buyer, Dominowski, & Rellinger, 1995).

**More Adaptive** – An individual whose score is 95 or below on Kirton's Adaption-Innovation Inventory (Kirton, 2003).

**More Innovative** – An individual whose score is 96 or higher on Kirton's Adaption-Innovation Inventory (Kirton, 2003).

**Problem-Solving** – Any goal-directed sequence of cognitive operations to achieve a goal (Anderson 1980).

**Problem Solving Ability** – Student's ability to correctly identify the problem.

**Time to Solution** – The time required to successfully identify and correct the problem.

**Troubleshooting** – Determining what causes a malfunction in a machine or process that includes a subset of problems (Custer, 1995; Herren, 2015; Jonassen, 2000; Morris & Rouse, 1985).



**Technical Troubleshooting** – A specialized subset of problem solving where the problem has been integrated into a real-life problem (Custer, 1995; Jonassen, 2000; Macpherson, 1998).

### **Limitations of the Study**

1. The study was limited to students enrolled at Louisiana State University
2. The study was limited to students enrolled in *AEEE 2003-Introduction to Agricultural Mechanics course*
3. Findings from this study cannot be generalized outside of the students enrolled in an Introductory Agricultural Mechanics course at Louisiana State University during spring 2018 and 2019 semesters.

### **Assumptions**

For the purpose of the study, the following assumptions were made:

1. All participants were students of Louisiana State University
2. All participants were enrolled in AEEE 2003-Introduction to Agricultural Mechanics
3. All participants provided true and accurate information on the survey and questionnaire

### **Need for the Study**

Secondary agricultural education programs are the prime place to help students develop problem solving and higher order thinking skills (Pate & Miller, 2011a). In today's workplace, employers want employees who can identify problems and find successful solutions to those problems (Johnson, 1991). Due to those highly structured components of society's work places today, skills associated with problem solving are highly sought after (Gokhale, 1995). To help combat this problem, agricultural education curriculum has been designed for hands-on learning processes that get students the necessary real-world learning experiences.

Previous research conducted within agricultural education implies teachers need to structure their instructional methods around developing and implementing problem solving skills (Parr, Edwards, & Leising, 2006). Hill (1997) stated, “it is imperative that professionals in the field incorporate problem solving concepts and strategies as a significant element in the curriculum design and implementation” (p.32). Similarly, Pashler et al. (2007) recommended educators find the opportunities to ask students questions to promote explanations that are metacognitive in nature and help improve student’s higher order thinking skills. Edwards (2004) also plainly stated “cognitive learning, including student behaviors involving critical thinking, higher-order thinking skills, and problem-solving, ought to be occurring in secondary agricultural education” (p. 234).

Furthermore, it is well known that problem solving skills have been identified as one of the most important cognitive activities we perform in our personal and professional life as part of our everyday routine (Jonassen, 2000). However, students today often do not solve meaningful problems as a part of their education (Jonassen, 2000). This is troubling considering that problem solving has been identified as one of the most essential skills for employment, especially in the agricultural industry (Alston, Cromartie, Wakefield & Warren English, 2009; Graham, 2001; Robinson & Garton, 2008; Robinson, Garton, & Terry Jr., 2007), which has been compounded by an influx in technology that has created an increase from employers who want employees who can identify and solve complex problems (Johnson, 1991).

It has become increasingly important for educators to adapt to new pedagogies to meet the every changing demands of 21st century, especially within education (Fuhrmann & Grasha, 1983; Chumbley, Haynes, Hainline, & Sorensen, 2018; Jonassen, 2000; Ulmer & Torres, 2007). However, this problem has continued to increase because educators generally are not teaching a

significant amount of problem solving skills in their curriculum (Jonassen, 2000; Ulmer & Torres, 2007). In order for educators to implement higher order thinking skills, teachers must be aware of different cognitive styles and know how to tailor those instructional methods to effectively teach problem solving skills (Blackburn et al., 2014; Lamm et al., 2011).

## CHAPTER II: LITERATURE REVIEW

### Statement of the Problem

In recent years, it has become increasingly important for educators to adapt to new pedagogies in order to develop higher order thinking skills for their students to meet the demands of the 21st century workplace (Fuhrmann & Grasha, 1983; Jonassen, 2000; Ulmer & Torres, 2007). Due to the highly structured components of the work place, skills associated with problem solving or critical thinking are highly desired (Gokhale, 1995) because employers want individuals who can find, identify, and solve complex problems in an effective and efficient manner (Johnson, 1991).

Generally, educators have a wide variety of instructional methods available to them in order to meet needs of diverse learners. However, the problem solving approach, especially in agricultural education, has been highly regarded as the best method of instruction (Dyer, 1995). The problem solving approach provides students with the skills necessary to develop important metacognitive processes, which promote higher order thinking skills and improved problem solving ability (Dyer, 1995; Zimmerman & Risemberg, 1997). Historically, this has been achieved more easily in the agricultural education curriculum which is known for its hands-on learning processes designed to provide students with the necessary real-world learning experiences.

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2000). Fortunately, problem solving skills can be taught and refined by enhancing the learning environment and building metacognitive skills (Lester, 1994; Sproull, 2001).

Education literature conveys the importance of cognitive styles of students as an important function of our everyday lives (Myers & Dyer, 2006; Parr & Edwards, 2004; Thomas, 1992; Torres & Cano, 1995a; Witkin et al., 1977). However, educators generally do not teach a significant amount of problem solving or critical thinking skills in their curriculum in order to build effective problem solvers (Jonassen, 2000; Ulmer & Torres, 2007). Blackburn et al. (2014), Lamm et al. (2011) concluded educators must be aware of different cognitive styles and understand how to tailor lessons to effectively teach critical thinking and problem solving skills. The previous review raises the question: How does cognitive style influence a student's ability to effectively problem solve in a small group setting?

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5. Does hypothesis generation have an effect on the time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?

### **Overview of School-Based Agricultural Education and Agricultural Mechanics**

The first foundations of teaching agriculture can be seen as far back as 1621 when a Patuxet Indian named Squanto taught the Pilgrims how to plant and grow corn (Talbert, Vaughn, Croom, & Lee, 2007). From this point, American agriculture expanded from being a self-sustaining ritual to what we know today as modern production agriculture. It is also well known that during the early 19th century America was experiencing rapid technological advancements and industrialization. Due to this large shift in society, the demand for skilled labor increased dramatically which led to a sociological change in education (Roberts, 1957).

This sociological shift peaked national interest in preparing skilled laborers, which led to the passage of the Smith-Hughes Act of 1917 (Roberts & Ball, 2009). This law provided federal

aid to states for the purpose of promoting precollegiate vocational education in agricultural trades and home economics (Steffes, 2018). The passing of the Smith-Hughes Act undoubtedly changed the paradigm of vocational education and this event led to a two-dimensional shift in education: (a) education with a purpose of career preparation, and (b) less federal involvement in education (Roberts, 1957; Roberts & Ball, 2009). Further, advancements in technology and society have led to the creation and passing of other legislation that supports the purpose of School-Based Agricultural Education (SBAE). The Smith-Hughes Act, along with many others, laid a foundation for nearly a century of vocational education, which we refer to today as career and technical education (CTE) (Roberts & Ball, 2009).

Modern career and technical education (CTE), began in the late 19th and early 20th century (Gordon, 2014). Vocational education saw its strongest push after the adoption of the Smith-Hughes Act of 1917. At the time, America needed highly skilled labor and vocational education developed individuals who were prepared to take on the workforce. Due to the rapid increase in industrialization, agricultural mechanics became an integral part of vocational agriculture during the 20th century (Gordon, 2014).

Throughout the 20th century, agricultural mechanics and CTE programs continued to grow and developed into their current structure and are a product of an extensive evolutionary process (Gordon, 2014). Since its adoption into vocational education curriculum, agricultural mechanics has retained its popularity and has been considered a pivotal cornerstone in secondary programs (Chumbley, Haynes, Hainline, & Sorensen, 2018). For example, in Texas, 925 schools offer agricultural mechanics in their SBAE program, which included almost 28,000 students (Hubert & Leising, 2000). Similarly, in Oklahoma nearly 5,000 students were enrolled in the Agricultural Power, Structures and Technology Career Pathway from 2010–2012 (Blackburn,

Robinson, & Field, 2015; Oklahoma Department of Career and Technology Education, 2012). Without the passing of the Smith-Hughes Act of 1917 vocational education and agricultural mechanics may have never reached secondary education and SBAE could have evolved vastly different.

### **Problem Solving in SBAE**

In the context of SBAE, however, the problem-solving method has been considered an integral component of its educational philosophy since its early origins (Parr & Edwards, 2004). The problem-solving approach appeared to emerge in SBAE in concert with the Smith-Hughes Act of 1917 (Moore & Moore, 1984) when the U.S. experienced the industrial revolution (Roberts, 1957; Roberts & Ball, 2009; Talbert et al., 2007). Due to the resulting change of society, it is believed that the problem-solving method was subsumed as a pedagogy for agricultural education (Moore & Moore, 1984). From this event, many agricultural educators believed this method supported agricultural education's aim and purposes (Boone, 1990; Cano & Martinez, 1989; Conroy, Trumbull, & Johnson, 1999; Crunkilton & Krebs, 1982; Dyer & Osborne, 1996; Flowers & Osborne, 1988; Hammonds, 1950; Krebs, 1967; Newcomb, McCracken, Warmbrod, & Whittington, 1993; Phipps & Osborne, 1988; Torres & Cano, 1995).

However, over the past three decades, the problem-solving approach has been reintegrated into other pedagogies in order to meet the demands of the 21st century. These demands included a push for education reform and the creation of a standardized national curriculum (U.S. Department of Education, 2001), which led to standards-based testing in math and reading. Because of this shift, active teaching pedagogies like (a) inquiry-based learning (IBL) and (b) experiential learning rose to the forefront in agricultural education. These pedagogies allowed SBAE to integrate 21st century skills and science, technology, engineering,



and math (STEM) into their curriculum to develop students who would have the necessary problem solving and critical thinking skills to enter a changing workforce (Allen, Donham, & Bernhardt, 2011; Baker, Robinson, & Kolb, 2012; Retallick & Miller, 2005; Gokhale, 1995).

### **Flipped Classrooms**

The first flipped classroom model can be seen emerging into secondary and postsecondary education starting in the early 2000's after the inception of No Child Left Behind (NCLB) (Frederickson, Reed, & Clifford, 2005; U.S. Department of Education, 2001; Strayer, 2007). Over the past two decades, the flipped classroom approach has gained increased attention in secondary and postsecondary education for its student-centered teaching approach (Barkley, 2015; McCubbins, Paulsen, & Anderson, 2018). This increase in attention has been attributed the rise in technology and the creation of the internet, but also to an online system called the Kahn Academy, which was founded by Salman Kahn for its use in teaching economics (Roach, 2014). These types of online learning platforms have allowed for instructors to broaden their pedagogies and allow students to take command of their own learning. Lage, Platt, and Treglia (2000) defined flipped classrooms as “inverting the classroom means that have traditionally taken place inside the classroom now take place outside the classroom or vice versa” (p.32). Lage et al. (2013) go on to describe flipped classrooms as “an education[al] technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom” (p.5).

In a traditional flipped classroom, the course materials (i.e. PowerPoints, videos, etc.) have been converted to an online format (Bishop & Verleger, 2013; Roach, 2014) designed to be viewed outside of instructional time. Often, students engage with the course material through an online format or traditional readings and participate in a form of summative assessments

(Michaelsen, Knight, & Fink, 2004). Such a strategy allows the instructor to devote less time in class to delivering content and more to conducting activities that empower students to apply their learning (Michaelsen et al., 2004). However, empirical evidence on the use of flipped classrooms, especially in agricultural education, are rather scant. Recently, Gardner (2012) utilized a flipped classroom approach in an undergraduate agricultural economics course. In this course the content was designed to be viewed outside of classroom time, while application exercises happened in class. The results of this study found that the students' perceptions of the course were overall excellent and they felt the flipped classroom approach allowed them to achieve mastery of concepts (Gardner, 2012). Similarly, Connor, Stripling, Blythe, Roberts, and Stedman (2014) conducted a study to investigate undergraduate student perception of a flipped classroom in an agricultural education teaching methods course. The results from this study indicated that students were highly satisfied with course and that the flipped classroom approach helped foster their learning (Connor et al., 2014). However, the students expressed concern over the online videos, and believed that they were hard to digest, and were not needed (Connor et al., 2014).

This flipped classroom approach allows for teachers to become the facilitator of learning activities and students to become actively engaged in the learning experience (Connor et al., 2014). This transition allows for more student-centered activities to occur in class that enhance students' critical thinking and problem solving skills (Allen et al., 2011; Hanson, 2006). Active learning strategies promote a student-centered learning environment by creating opportunities for students to solve problems in a real-world context (Michaelsen & Sweet, 2008; Sibley & Ostafichuk, 2015). Team-based learning is a modified version of flipped classroom which

provides students the opportunity to work collaboratively to solve complex problems (Michaelson & Sweet, 2008).

### **Team-Based Learning**

There are a variety of instructional approaches that could be implemented to provide students with the opportunity to develop higher order thinking skills and promote the development of critical thinking skills (Allen et al., 2011; Hanson, 2006). Of those strategies, TBL is an active learning strategy that incorporates both collaborative and problem-based learning. The primary learning goal of TBL is to promote and enhance students' opportunities to use course concepts to solve real-world problems (Michaelson & Sweet, 2008). Further, TBL is designed to provide students with opportunities to learn conceptual and procedural knowledge. Of all the instructional strategies teachers can choose from, (TBL) provides a complete framework for cognitive development, critical thinking skills development, and building problem solving skills (Michaelson & Sweet, 2012).

TBL is a student-centered instructional approach that shifts instruction away from a traditional lecture based format to create a student-centered learning environment (Artz, Jacobs, & Boessen, 2016; Nieder, Parmalee, Stolfi, & Hudes, 2005). In a TBL formatted course, students take on the responsibility of learning conceptual knowledge outside of class time and spend more time applying that knowledge in class (Michaelson et al., 2004). Essentially, TBL is formatted to provide students with opportunities to learn both declarative and procedural knowledge to enhance critical thinking and problem solving skills (Michaelson & Sweet, 2008). TBL follows the framework of a flipped classroom where students are required to acquire the conceptual knowledge before class, which creates time in class to apply the knowledge (Wallace, Walker, Braseby, & Sweet, 2014).

In a TBL formatted course, the instructor's primary role shifts away from dispensing information to facilitating the overall instructional process (Michaelsen & Sweet, 2008), while the students shift from being passive learners to taking on the responsibility of learning conceptual knowledge before class so that they will be a valuable team member for in-class work (Michaelsen & Sweet, 2008). For TBL to be implemented properly there are four essential elements to consider:

- (a) *Groups*—formation/management of teams
- (b) *Accountability*—students must be held responsible for the effort given on individual and team work
- (c) *Feedback*—students must receive frequent/timely feedback
- (d) *Assignment design*—team work must promote both learning and team development (Michaelsen & Sweet, 2008).

If TBL is implemented properly, classroom experiences can be much more enjoyable for both student and instructor (Sibley & Ostafichuk, 2015; Michaelsen & Sweet, 2008).

A traditional TBL course is normally formatted into five to seven modules with each requiring two weeks to complete (Michaelsen et al., 2004). Prior to instruction students will engage in introductory material that will prepare them for the class. Then, during class, students are assessed individually over the material using an Individual Readiness Assurance Test (IRAT). This test is designed to individually assess the student's conceptual knowledge over the learning module individually. Once they have completed their IRATs are assessed again in their team with a Team Readiness Assurance Test (TRAT). This test is designed to assess the same content as the IRAT, but allows the students to work out problems together as a group. Once both exams are completed, the students receive immediate feedback over items, which allows the

students to discuss the missed questions with teammates and promotes collaboration. After completing the IRAT and TRAT, the remainder of the class is devoted to skills application and allowing the students to engage in real-world problem solving designed to develop their procedural knowledge (Michaelsen, et al., 2004).

The TBL platform allows students to develop problem solving skills by providing real-world application exercises that are designed to foster their learning. Perhaps one of the most important components in implementing TBL is effectively designing application exercises under the framework known as the 4S's which include: (a) Significant problem; (b) Same problem; (c) Specific choice; and (d) Same reporting (Michealsen et al., 2004). For example, all teams will complete an application exercise that presents a significant problem (i.e. troubleshooting). The application exercises for each team are identically the same. As a team they will evaluate, analyze, and make a specific decision on the problem, based off of their prior conceptual knowledge of the scenario presented. That decision will be completed and simultaneously reported in the same class period (Michealsen & Sweet, 2008).

Before action is taken on the problem, students discuss with their team and come to a final decision. Once the team decision is made, the application for the exercise will begin (i.e. testing their decisions). For example, when troubleshooting a small gasoline engine, the students would all be provided with the same specific scenario. They would then analyze and evaluate the possible engine faults/failures based off previous knowledge of engine systems. They would then report their findings together as a team and decide on the problem presented. After a common agreement has been reached, students would then test their hypothesis in the hands-on learning exercise (i.e. troubleshoot the engine). This process is continuous and teams may have to revert back to step one and re-evaluate the problem.

Although TBL emerged in the 1970's, research supporting its use and effectiveness have been rather few and far between, especially in agricultural education. However, recent research on the use of TBL has been conducted. McCubbins, Anderson, Paulsen (2016) conducted a study to examine student perceptions of TBL in a capstone course. The findings from this study suggest that students had a positive view of TBL and were highly satisfied with the student-centered learning environment (McCubbins et al., 2016). Further, the results also indicated that working in teams had a positive impact on student motivation to work and learn in a collaborative setting (McCubbins et al., 2016). Similarly, McCubbins, Anderson, and Paulsen (2018) conducted a study to assess student engagement in a TBL formatted course and found that TBL in fact did support students critical thinking, motivation to learn, and ability to effectively apply course concepts. Further, Figland, Blackburn, and Roberts (2019) reported that students were highly satisfied with a TBL formatted agricultural mechanics course. These students perceived that TBL supported the development of problem solving skills and promoted positive collaboration between group members and increased student self-efficacy in agricultural mechanics (Figland et al., 2019).

### **Metacognition and Cognitive Styles**

#### **Metacognition**

A student's ability to learn material in a specified domain relates to his/her metacognitive ability. Previous research has emphasized the need for development of students' metacognitive skills in order for them to be effective problem solvers (Zimmerman & Risemberg, 1997). Metacognitive skills allow students to encode the problem type by forming mental schemas of the problem, which allows them to select appropriate plans, and identify and overcome obstacles (Davidson & Sternberg, 1998). According to Flavell (1979), metacognition can be defined as

“the active monitoring and consequent regulation and orchestration of these [cognitive] processes in relation to some concrete goal or objective” (p. 232). Similarly, Berardi-Coletta, Buyer, Dominowski, and Rellinger (1995) defined metacognition as “an active reflective process that is explicitly and exclusively directed at one’s own cognitive activity. It involves the self-monitoring, self-evaluation, and self-regulation of on-going tasks” (p. 206). These metacognitive actions are a driving force in one’s ability to effectively problem solve.

Vermunt (1996) stated there are three main types of learning: cognitive, affective, and regulative (metacognitive). Cognitive activities are those which people use to process content and are directly related to building basic knowledge and skills. These activities can include: (a) relating; (b) analyzing; (c) concretizing; (d) applying; (e) memorizing; and (f) selecting. For example, in troubleshooting, students need knowledge of engine components and terms to be able to look for relationships between parts or subject matter (relating). Then the individual would need to be able to look for relationships between the engine systems to draw conclusions and discern between focus points (selecting). The individual would then think of possible problems associated with those systems by using previous knowledge (concretizing). Finally, the individual could solve the problem and test their solution (applying). Further, affective learning is associated with a person’s ability to cope with difficulties in learning. Affective (affirmative) learning activities can include: (a) attributing; (b) motivating; (c) generating emotions, and (d) exerting effort. However, Vermunt (1996) concluded that a person’s emotional state can have a large influence on their progression of learning. For example, a student who becomes frustrated trying to figure out a problem associated with their small gasoline engine could develop a negative attitude toward the learning activity, which would lead to a loss in progression of learning or learner regression. Perhaps the most important piece is metacognitive activities,

which can include setting goals, identifying problems, and evaluating and revising their own work (Vermunt, 1996). These metacognitive activities help to regulate both cognitive and affective learning activities. Therefore, metacognitive activities are directed to regulate those activities, which help indirectly lead to the learning outcomes (Vermunt, 1996).

### **Cognitive Styles**

Awareness of a student's cognitive style is an important factor in the success of the individuals' ability to solve problems (Jonassen, 2000). Broadly, cognitive style can be defined as an individuals' preferred way of going about organizing and retaining information to solve problems (Keefe, 1979; Kirton, 2003). However, it should be noted that individuals vary in their preferred cognitive style which can influence a person's pattern of thinking and reasoning (Kirton, 2003; Jonassen, 2000). For quite some time, research has focused on the influences of cognitive styles on teaching and learning, specifically its influence on decision making (Witkin et al., 1977). Education literature overwhelmingly conveys the importance of cognitive styles of individuals as an important function of an their everyday life (Witkin et al., 1977; Thomas, 1992; Torres & Cano, 1995; Parr & Edwards, 2004; Myers & Dyer, 2006). Kirton (2003) developed the Adaptation-Innovation Theory (A-I Theory), which is founded on the belief that every individual is creative and can solve problems (Kirton, 2003). The A-I theory was originally developed to be utilized with working adults, however, it has also been an effective measure of cognitive style with teenagers, those of varying cultures, countries, and occupational status (Kirton, 2003).

A sample of hundreds of 13-18 year old school children obtained from schools in the United Kingdom, U.S., and Europe found that there are statistically significant differences between the responses from the teenagers and the adults (Kirton, 2003). Similar results were also



found by studies completed with school aged children by Taylor (1993), Selby, Treffinger, Isaksen, and Powers (1993), and Brinkman (1999). Results from these studies indicated the characteristics identified in the A-I Inventory are representative of all ages, which concludes that cognitive style preference is developed at a young age (Kirton, 2003). Also, these studies concluded that no matter the age, culture, and experience, individuals cognitive level and style are not related (Kirton, 2003).

Within agriculture, multiple studies have been conducted utilizing the Kirton's Adaptation-Innovation Inventory (KAI) to determine its effects on critical thinking, problem solving, problem complexity, and hypothesis generation (Blackburn, Robinson, & Lamm, 2014; Blackburn & Robinson, 2016; Blackburn and Robinson, 2017; Friedel, Irani, Rhoades, Fuhrmann, & Gallo, 2008). Friedel et al. (2008) investigated the relationships between critical thinking and problem solving in undergraduate students abilities to explore Mendelian genetics. However, they found no relationships between a student's critical thinking ability and cognitive style in relation to problem solving (Friedel et al., 2008). Similarly, Blackburn et al. (2014) and Blackburn and Robinson (2016) found that there were no statistically significant differences between an individual's cognitive style, problem complexity, and their hypothesis generation ability on problem solving ability. However, these findings support the research completed by Kirton (2003) describing the differences in problem solving preferences of more adaptive versus more innovative individuals, which allows an individual to understand their preferred learning style.

### **Critical Thinking Style**

Within the realm of cognitive styles, critical thinking style has been identified as critical skill for students in the 21st century and crucial for individuals to be able to deal with decisions

faced every day (Myers & Dyer, 2006; Torres & Cano, 1995b). Critical thinking is an area of higher order thinking that can be challenging to define because of the wide scope of definitions available in the literature. However, Rudd, Baker, and Hoover (2000) defined critical thinking as “a reasoned, purposive, and introspective approach to solving problems or addressing questions with incomplete evidence and information, and for which an incontrovertible solution is unlikely” (p. 5). It has been identified that critical thinking skills are one of the most important cognitive traits that leads to a person’s success on specific tasks (i.e. problem solving) (Rudd et al., 2000; Irani et al., 2007; Lamm et al., 2012), however, it is important to note that an individual’s critical thinking ability is constantly changing as the student matures (Lamm et al., 2011; Irani et al., 2007).

In an attempt to understand the individual factors associated with critical thinking, critical thinking dispositions have been identified to allow for a deeper understanding of the factors that influence an individual’s critical thinking ability. One of the first attempts to describe these dispositions was completed in the 1990’s by Peter Facione (1990) by which he conducted a Delphi study where he gathered 46 educators and top researchers in the critical thinking field to participate in multiple rounds of questions and discussion. At the conclusion of the discussion, these scholars identified seven disposition traits (Facione, 1990). However, in attempt to more accurately describe the dispositions, Irani et al. (2007) constructed a new instrument called the UF-EMI. The UF-EMI was developed with three constructs instead of the seven outlined by Facione (1990). The constructs included in the UF-EMI instrument were (a) engagement, (b) cognitive maturity, and (c) innovativeness (Irani et al., 2007). Irani et al. (2007) utilized these critical thinking dispositions to help identify deeper preferences that affect the way individuals’ critically think rather than utilize ability as the unit of measurement. These critical measurements

can help educators assess students' abilities and then develop a tailored educational curriculum to meet the needs of their students (Lamm et al., 2011). However, because of the relatively low reliability of the UF-EMI instrument within constructs, scholars at the University of Florida attempted to create a new instrument that focused on accurately describing and measuring critical thinking style (Friedel et al., 2008; Lamm et al., 2011), which was called the University of Florida's Critical Thinking Inventory (UF-CTI). The UF-CTI comprised of 20 items scored on a five point Likert-type scale that is used to describe an individual's critical thinking style.

Further, critical thinking and problem solving skills have been recurrently identified as essential skills for employment in the agricultural industry, specifically in technical areas like agricultural mechanics (Alston et al., 2009; Graham, 2001; Robinson & Garton, 2008; Robinson et al., 2007). Gokhale (1995) stated that skills associated with critical thinking and problem solving are highly desired due to the highly structured components of today's society. However, with the development of an individual's critical thinking skills, it is important for them to understand their preferred way to learn in order to be effective and efficient problem solvers (Jonassen, 2000).

### **Learning Styles**

While it is known that several individual factors influence a student's cognitive development, individual learning styles are factors that can play a large role on performance during problem solving and critical thinking (Dunn & Dunn, 1979; Claxton & Murrell, 1987). Gregorc (1979) described learning style as "consisting of distinctive behaviors which serve as indicators of how a person learns from and adapts to his/her environment. It also gives clues as to how a person's mind operates" (p. 234). Previous literature has revealed that learning style could be an extremely important element in improving the teaching and learning process (Claxton &

Murrell, 1987; Dunn & Dunn, 1979; Fisher & Grant, 1983; Miller, 1989; Pickford, 1988; Thomas, 1992) and researchers within agricultural education are rapidly increasing the amount of research and education focused on understanding and utilizing these cognitive functions to improve educational programs and learning outcomes (Boone, 1990; Cano, 1999; Dyer & Osborne, 1996; Gay, Terry, & Lamm, 2015; Parr & Edwards, 2004).

### **Problem Solving**

Problem solving skills have been regarded as one of the most important cognitive activities in everyday life (Jonassen, 2000). We regularly encounter and solve problems everyday as part of a routine in our personal and professional lives. However, students today often do not solve meaningful problems as a part of their curricula (Jonassen, 2000). The ability to solve problems has been recurrently identified as a critical skill for employment in the agricultural industry, specifically within technical areas (Alston et al., 2009; Graham, 2001; Robinson & Garton, 2008; Robinson et al., 2007). Anderson (1980) defined problem solving as “any goal-directed sequence of cognitive operation” (Anderson 1980, p. 257). However, Jonassen (2000) added that for problem solving to occur there must be social, cultural, and intellectual value. With that being said, in order for a problem to be solved there must be an individual that believes that there is worth in finding and solving the unknown (i.e. the problem). Jonassen (2000) stated that “finding the unknown is the process of problem solving” (p. 65).

It is widely known that problems are often never the same in type and kind. Problem solving is not a uniform activity and is often not equivalent in form or context (Jonassen, 2000). Problems are defined as either well-structured or ill-structured in nature and are distinguished from learning outcomes (Jonassen, 2000). Well-structured problems are often associated with schools or universities and have three key elements: (a) they are well-defined problems and all

elements are given, (b) goal oriented, and (c) contain a specific set of logical operators and solutions (Greeno, 1991; Jonassen, 2000; Wood, 1983). These well-structured problems have a finite number of constraints and limitations to solve the problem. However, problems that are encountered in our everyday lives are commonly defined as ill-structured problems. Ill-structured problems are often not constrained by one domain and their solutions are not predictable and undefined. Often ill-structured problems require the learner to integrate multiple domains to achieve the solution (Jonassen, 2000). Ill-structured problems possess four key attributes: (a) elements are unknown, (b) problem possess multiple solutions and solution paths, (c) there are multiple ways for evaluation, and (d) they require the learner to make judgments from personal opinion (Jonassen, 2000; Wood, 1983). Jonassen (2001) stated real-world problems are often situated in a specified context and are ill-structured in nature. For example, troubleshooting a small gasoline engine is a specified context and an ill-structured problem (Blackburn & Robinson, 2017; Jonassen, 2000). In this example, troubleshooting small gasoline engines is ill-structured in nature because it has real-world applicability and is situated in a specific domain, which constrains the problem and allows the learner to build off previous knowledge.

### **Mechanical Problem Solving**

A critical subset of problem solving lies within solving mechanical problems. Mechanical problem solving can be defined as a system that interacts with other components to create movement or energy (Hegarty, 1991). In mechanical problem solving there are two type of knowledge, conceptual and procedural (Hegarty, 1991). Conceptual knowledge refers to an individual's ability to utilize basic knowledge that can influence the beginning of the problem solving process. For example, basic knowledge could refer to an individual's knowledge of engine parts and components. Whereas, procedural knowledge deals with the individuals

knowledge on how to carry out processes or operations to solve the problem (Hegarty, 1991; McCormick, 1997). Psychologists, dealing with cognition, attribute procedural knowledge to ones knowledge on *how* to do something, whereas conceptual knowledge is the individuals' knowledge of *facts* about a domain (Anderson, 1980; McCormick, 1997).

### **Troubleshooting**

Troubleshooting is one of the most commonly experienced types of problem solving we encounter in our everyday lives (Jonassen, 2003). Troubleshooting can be broadly defined as determining what causes a malfunction in a machine or process (Herren, 2015; Morris & Rouse, 1985). Custer (1995) and Jonassen (2000) added that troubleshooting includes a subset of problems where the problem is situated into a real-world situation. As stated in previous literature, troubleshooting is a type of problem that is situated in a specific context, which makes it ill-structured in nature (Blackburn & Robinson, 2017; Jonassen, 2000). In order for a troubleshooter to be successful, he/she must use a multitude of domain knowledge and be able to utilize cognitive skills to find faults in a system (Jonassen & Hung, 2006; Schaafstal, Schraagen, & Van Berl, 2000). Specifically, troubleshooting requires the individual to employ previous knowledge and experiences to effectively interact with the complex system (Johnson & Flesher, 1993).

Therefore, one of the strongest predictors of an individual's problem solving ability lies within their familiarity with the domain and problem type (Jonassen, 2001); however, there are several types of knowledge that has an effect how a person solves problems (Jonassen & Hung, 2000). Specifically, domain knowledge is a key factor in the solvers ability to problem solve. Domain knowledge specifically refers to basic concepts in a given area. For example, when troubleshooting small gas engines, it would be critical for the beginner troubleshooter to have

basic systematic understanding to identify problems. However, a recent study conducted by Blackburn (2013) concluded conceptual knowledge in small gasoline engines had no statistically significant effect on the individuals' ability to effectively or efficiently problem solve.

### **Technical Troubleshooting**

Technical troubleshooting, or more commonly known as technical problem solving, is generally defined as a specialized subset of problem solving where the problem has been integrated into a real-life situation (Custer, 1995; Jonassen, 2000; Macpherson, 1998). Previous research has indicated three skill sets essential in technical troubleshooting, including: (a) the ability to make tests; (b) the ability to replace or repair faulty components; and (c) the ability to employ reasoning when searching for the source (Morris & Rouse, 1985). Further, Morris and Rouse (1985) concluded that of the three components, the ability to identify and employ a strategy were the most difficult skills for the troubleshooter to develop. According to Halpern (1984), the most important piece to effective problem solving is the troubleshooter's ability to recognize and select the most appropriate solution. However, it was also identified that the path to solution between novice and expert troubleshooters is often quite different (Pate, Wardlow, & Johnson, 2004).

### **Expert and Novice Troubleshooters**

Previous literature irradiates the importance of knowledge, skill, and experience that a troubleshooter must possess in order to interact effectively with the complex system they are troubleshooting (Johnson & Flesher, 1993; Jonassen, 2003). It is often thought that troubleshooting is a linear process that directs the troubleshooter through a series of decisions that then directs them to the faults (Jonassen, 2003). However, Jonassen (2003) found this linear approach to troubleshooting may only work for a novice troubleshooter and may not be

conducive for more experienced troubleshooters. Further, Johnson (1989) identified performance differences between expert and novice technicians who troubleshoot faulty equipment. After evaluation, it was concluded that the primary performance difference between the experts and novice troubleshooters was in the quality of the information acquired and the quality of the generated hypotheses (Johnson, 1989), however, these factors were found to be not statistically significant (Johnson, 1989). It has been concluded that expert troubleshooters constructed better mental schemas of the troubleshooting task; whereas, novices had a more difficult time troubleshooting because of a lack of mental schemas (Johnson & Flesher, 1993; Gitomer, 1988). However, this finding should surprise few because it is likely that an expert troubleshooter have a well-developed conceptual and procedural knowledge of the task, while novices many still be learning the conceptual and procedural knowledge that is needed to successfully troubleshoot. Overall, it was concluded that expert troubleshooters possessed a greater amount of knowledge and a greater ability to organize information that was relevant (Johnson, 1989). Often novice troubleshooters began troubleshooting the same symptoms as the experts, but were unable to recognize which of those symptoms were important (Johnson, 1989).

Johnson and Flesher (1993) analyzed 50 novice and expert technicians and found consistent behaviors of patterns called troubleshooting styles. Those styles consist of three primary categories: (a) Gamblers, (b) Testers, and (c) Thinkers. Just as different learning and cognitive styles have an impact on individual learning and how trainings are conducted, different types of troubleshooting styles also have an impact on a troubleshooter's ability to effectively troubleshoot (Johnson & Flesher, 1993).

**Gamblers.** Gamblers can be broadly defined as “troubleshooters who depend on an element of chance to support their work” (Johnson & Flesher, 1993, p. 15). There are four



different types of gamblers, which include (a) Wanderers, (b) Risk Takers, (c) Oddsmakers, and (d) Swappers (Johnson & Flesher, 1993). Wanderers are those troubleshooters who rely completely on random chance to find the problem. These types of troubleshooters often have limited system understanding and lack systematic and component skills (Johnson & Flesher, 1993). Risk takers often like to experiment with the components in the system to find the problem (Johnson, 1993). These types of troubleshooters often have a high level of general and specific knowledge to ensure that they do not create new faults (Johnson & Flesher, 1993). The oddsmaker relies heavily on common knowledge of faults and components to guide them through the troubleshooting process (Johnson & Flesher, 1993). However, oddsmaker can quickly become wanderers if they fail to locate the fault on their second or third guess (Johnson & Flesher, 1993). Finally, the last type of gamblers are swappers. Swappers try to eliminate the fault by substituting a properly functioning part for an assumed malfunctioning part (Johnson & Flesher, 1993). However, all four types of gamblers typically involve trial and error strategies. Further, it should be noted that these strategies are not always limited to novice troubleshooters and any one of these four types of gamblers is often desirable when troubleshooting because of their ability to utilize multiple strategies to problem solve (Johnson & Flesher, 1993).

**Testers.** Testers can be broadly defined as those troubleshooters who rely heavily on information acquired through tests or previous experiences to locate faults (Johnson & Flesher, 1993). There are three identified types of testers, which include (a) Sensors, (b) Tracers, and (c) Splitters (Johnson & Flesher, 1993). Sensors can be described as troubleshooters who isolate problems by looking, listening, touching, and smelling to identify and isolate the fault (Johnson & Flesher, 1993). However, this approach is only useful if the troubleshooter knows what sensory information is relevant. Tracers generally use a schematic diagram as a tool to locate the

possible cause of the fault (Johnson & Flesher, 1993). This type of troubleshooter must have the ability to read schematics and recognize dead ends. Tracers are most commonly utilized with semi-skilled troubleshooters (Johnson & Flesher, 1993). Lastly, splitters are often the troubleshooters who use the divide and conquer technique to troubleshooting (Johnson & Flesher, 1993). Therefore, the splitter will divide a system in half and check for faults. This has been considered the most highly attempted methods of troubleshooting (Johnson & Flesher, 1993). However, these individuals tend to get lost in their approach and often find themselves in confusion (Johnson & Flesher, 1993).

**Thinkers.** Thinkers can be broadly defined as “troubleshooters who use a logical approach to troubleshooting and relies on the troubleshooter’s ability to process correct information” (Johnson & Flesher, 1993, p. 17). There are four different types of observed thinkers that include (a) Readers, (b) Recallers, (c) Designers, and (d) Analyzers (Johnson & Flesher, 1993). Readers are considered the least skilled of thinkers because the troubleshooter often uses someone else’s thought process, which may include manuals and troubleshooting trees (Johnson & Flesher, 1993). Recallers use their ability to see a set of symptoms and almost immediately find the problem or fault from many years of experience (Johnson & Flesher, 1993). Novice troubleshooters often envy these types of troubleshooters because of their ability to find faults so quickly. However, this type of troubleshooter can create problem solvers who lose their troubleshooting skills after long periods of time because they rely heavily on their memory of symptoms and solutions (Johnson & Flesher, 1993). Designers are troubleshooters who use theoretical knowledge to evaluate a fault (Johnson, 1993). This knowledge often comes from knowledge that is learned in technical school and formal trainings. While this type of troubleshooter is great in design activities, they are rarely efficient at fixing problems (Johnson

& Flesher, 1993). Finally, analyzers are troubleshooters who use system knowledge and previous experiences to eliminate possible faults of a system in a logical fashion before attempting to test the equipment (Johnson & Flesher, 1993). These troubleshooters have a “think before you act” mentality that allows them to be highly efficient and successful at troubleshooting (Johnson & Flesher, 1993, p. 18). These types of thinkers are highly skilled troubleshooters and have been identified as a key difference between expert and novice troubleshooters (Johnson & Flesher, 1993).

### **Problem Solving Research in Agricultural Education**

A variety of research examining how critical thinking style, problem solving style, and learning style as individual concepts impact decision making and problem solving have been conducted in agricultural education. Lochhead and Whimbey (1987) developed Think-Aloud Pair Problem Solving (TAPPS) to help students verbalize their thoughts and clarify their thinking while problem solving. The TAPPS method requires two individuals to collaborate and work through problems. For this method to be effective, it is important that one individual in the group is the problem solver and the other is the listener and note taker (Lochhead, 2001; Lochhead & Whimbey, 1987; Pate & Miller, 2011a). The primary goal of TAPPS is to help develop the learner’s ability to monitor their cognitive and metacognitive progress (Gourgey, 1998; Pate & Miller, 2011a). Previous research in agricultural education has suggested TAPPS can aid problem solvers in avoiding skipping important steps and getting consumed with one component of the problem (Heiman & Slomianko, 1987; Pate & Miller, 2011a). TAPPS has shown statistically significant improvements in postsecondary student success when identifying and repairing faults during troubleshooting (Johnson & Chung, 1999; Pate, Wardlow, & Johnson, 2004). However, no statistically significant differences were found between students who

utilized TAPPS and those who chose to work independently (Johnson & Chung, 1999; Pate, Wardlow, & Johnson, 2004). Further, Pate and Miller (2011a) also found students who utilized TAPPS had a lower completion rate than the students who worked independently, however, there was no statistically significant differences. Also, in regard to time to completion, the students who utilized TAPPS required 4 minutes longer than the students working independently (Pate & Miller, 2011a).

Also, cognitive relationships between critical thinking style and learning style have been explored in the agricultural education literature (Friedel et al., 2008; Myers & Dyer, 2006; Lamm et al., 2011; Rudd et al., 2000; Torres & Cano, 1995). Rudd et al. (2000) studied these relationships in undergraduate students and reported that there were no statistically significant differences between an individual's learning style and their critical thinking disposition. It was also concluded that learning style accounts for only nine percent of the total variance in an individual's critical thinking ability (Torres & Cano, 1995). However, Lamm et al. (2011) found a statistically significant relationship did exist between learning style and critical thinking disposition in postsecondary students from the University of Florida, Texas A&M, North Carolina State University, Purdue University, and The Ohio State University. While an individual's cognitive style scores and learning style scores were not strongly related, there were found to be statistically significant connections within the constructs.

Dyer and Osborne (1996) studied the effect of teaching approach on the problem solving ability of students with varying learning styles. The results from this study indicated those students who were taught by the problem solving approach had a significantly higher problem solving ability than those taught by the subject matter approach. Also, no statistically significant differences were present between pretest and posttest problem solving ability scores of students

with the same learning style. However, students of different learning styles benefited from the instruction using the problem solving approach. Similarly, Torres and Cano (1994) found learning style had an effect on the learning success of students in specific kinds of situations and different types of learning environments (i.e. labs).

Recently, researchers have started to focus on how cognitive styles influence team dynamics during the decision making process in order to enhance student performance. Lamm et al. (2011) examined how cognitive style grouping influenced the students' ability to group problem solve with students who had participated in a study abroad trip to Costa Rica. In this study, students were organized into three focus groups based on their KAI cognitive style score and were asked a variety of questions regarding their perceptions of how they problem solved in their group setting. For this course, the students were required to complete an entrepreneurship project, which included creating a natural chocolate product, marketing their product, and evaluating the products success. The interpretation of the findings were conducted through Bransford's (1984) IDEAL problem solving model. The findings suggest the homogeneous innovator and heterogeneous group were able to progress through all five stages, however, they did not solve the problems linearly per the model. Further, the homogeneous adaptive group did not utilize all five stages of the model because they spent a significant portion of time on the anticipate stage. In a recent study, Lamm, Carter, Settle, & Odera (2016) found an individual's problem solving style influenced how opinion leaders worked collaboratively in teams while building agendas around critical agricultural and natural resource issues. In this study, the findings suggested that teams representing diverse problem solving styles enhanced the consensus building process. These results imply that when building teams around critical issues educators should focus on establishing well-structured groups that will allow participants to

“share their conceptual and procedural knowledge in the joint construction of problem solution, so that all students are actively engaged in the problem-solving process and differences of opinion are resolved in a reasonable manner” (Heller & Hollabaugh, 1992, p. 637).

Friedel et al. (2008) investigated the relationships between critical thinking and problem solving in undergraduate students abilities to explore Mendelian genetics. This study utilized Kirton’s Adaptation-Innovation Inventory (KAI). This theory takes into consideration the individuals’ cognitive style and learning preference. However, from their study they found no statistically significant relationships between a student’s critical thinking ability and cognitive style in relation to problem solving (Friedel et al., 2008).

Blackburn et al. (2014) sought to assess the effects of cognitive style and problem complexity on the problem solving ability of undergraduate students enrolled in an agricultural mechanics course. The KAI was administered to determine if the students’ cognitive style was more adaptive or more innovative in nature. The results of this study indicated there were no statistically significant differences between the students based on cognitive style or problem complexity; however, there was a difference in the ability of the more innovative individuals to solve the simple problem versus the complex problem. Therefore, the more innovative individuals should recognize these problems and have success when solving complex problems (Blackburn et al., 2014).

Similarly, Blackburn and Robinson (2016) investigated the effects of cognitive style, complexity, and hypothesis generation on the troubleshooting ability of school-based agricultural education (SBAE) students. Again, the students were divided into groups consisting of more innovative and more adaptive based on the KAI. The results of this study indicated regardless of

problem complexity, students who generated the correct hypothesis were more efficient problem solvers than their counter parts.

Blackburn and Robinson (2017) also investigated the factors that effected hypothesis generation ability of SBAE students. The factors investigated in this study were cognitive style, age, GPA, and content knowledge in small gasoline engines. Much like the previous two studies, the individuals were randomly assigned to a treatment group (simple or complex) and administered the KAI to determine their cognitive style. The findings suggested a majority of students were able to hypothesis correctly regardless of cognitive style. However, further analysis of data revealed that more adaptive students were likely to hypothesize the simple problem; whereas, the more innovative individuals were more likely to hypothesis the complex problem (Blackburn & Robinson, 2017).

### **Theoretical Framework**

The theoretical framework for this study was Kirton's (1976, 2003) Adaptation-Innovation Theory (A-I Theory). This theory is founded on the belief that every individual is creative and can solve problems (Kirton, 2003); however, the A-I theory is only concerned with the *how* an individual solve problems. Therefore, this theory allows an individual to understand their cognitive style and how they go about solving everyday problems (Kirton, 2003).

Kirton's (2003) A-I theory is a measure of cognitive style that primarily examines problem solving on a strictly individual basis. Individual problem solving ability is primarily influenced by the capacity and learned levels of problem solving (Kirton, 2003). This theory is concerned with the influence of individual cognitive style and preferred mode to learn.

According to Kirton (2003) cognitive style is "the preferred way to which people responds to and seek to bring about change" (p. 43), therefore resulting in problem solving and

cognitive style differences between individuals. Foundationally, the A-I theory presumes individual cognitive style is predetermined from the early stages of life and remains stable, regardless of a person's previous experiences or age. It is also important to note, that the term *preferred* relates to the difference between an individual's style and behavior and the term *style* indicates a distinction between individual style and the level of cognitive capacity (Kirton, 2003).

According to this theory, individual cognitive styles fall between adaptation and innovation on a continuum (Kirton, 2003). This continuous range indicates that cognitive style can fall anywhere in the range of 32-160. This type of scales does not allow any individual to be purely an adaptor or purely an innovator. However, individuals whose tendencies were more adaptive (32-95) prefer a more structured environment when solving problems. These individuals prefer well-established problems and favor working within the current paradigm (Kirton, Bailey, & Glendinning, 1991). However, individuals whose tendencies were more innovative (96-160) preferred less structure to solve the problem and challenge boundaries of the prevailing paradigm. (Lamm et al., 2012; Kirton, 2003). Often, individuals falling on the more innovative side of the continuum tend to be novel and find different ways to solve problems. On the contrary, adaptors tend to be safer, more predictable, conforming, and less ambiguous when solving problems (Kirton, 1999, 2003).

The qualities between adaptors and innovators are also quite different, as are there perceptions of each other (Kirton, 2003). Therefore, purposefully grouping individuals based on cognitive style can be important in the success of group work. Kirton (2003) identified that homogeneous groups, of either all individuals who are more adaptive or more innovative, tend to collaborate easily and experience success in simple projects or problems. However, when faced



with more complex problems these types of groups tend to struggle (Kirton, 2003). A homogeneous group of all more innovative individuals will likely work better with little structure but will subsequently be less efficient in solving problems. However, with a group consisting of all more adaptive individuals an increase in structure by all member tends to trap the individuals in a reoccurring paradigm of reform; therefore, decreasing their overall efficiency on simple tasks (Kirton, 2003).

Kirton (2003) identified that a difference of 5-10 points between KAI scores of two groups or individuals is optimal because it narrows the thinking diversity range; therefore, subsequently diversifying the range of problem solving potential. This narrow range allows enough variance in style between individuals to create a more diverse thinking range, but not enough to create difficulties in communication.

Also, Kirton (2003) identified that individuals with a KAI score difference of 20 points or greater difference can lead to communication problems and coping behaviors are needed to close the thinking gap in order to problem solve efficiently when faced with small problems. It was identified that homogeneous groups are more efficient at solving the problem than heterogeneous in situations with narrow based problems. However, when faced with a broad range of problems or situations heterogeneous groups are more efficient than homogeneous groups. Therefore, if heterogeneous groups manage their wide variety of cognitive diversity they are expected to be more successful at broad scope problem solving (Gokhale, 1995; Kirton, 2003).

Further, the KAI is divided into three style subscales. These style subscales make up the individuals overall KAI score. Those subscales include (a) Sufficiency of Originality versus Proliferation of Originality (SO), (b) Efficiency (E), and (c) Rule/Group Conformity (RG)

(Kirton, 2003). The SO scale deals with individuals preferred way to find solutions to problems. With that being said, adaptors produce fewer ideas that are useful in solving the problem, however, innovators prefer to construct a plethora of ideas to solve the problem (Kirton, 2003).

The second subscale is E, which refers to a “preference for adaptive efficiency” (Kirton, 2003, p.59). The more adaptive individuals prefer to solve problems within boundaries, while innovators prefer *think-out-side* of the prevailing paradigm to solve problems (Kirton, 2003). However, organizations prefer a more adaptive problem solver because their ideas are generally more accepted (Kirton, 2003).

Finally, the RG subscale deals with a person’s preference to structure or conformity. Kirton (2003) described conformity was made up from two factors (1) formal/impersonal rule, and (2) personal/less formal rule. These two factors are closely related in groups that have members who monitor the RG, regardless of the originality of the idea (Kirton, 2003). More adaptive members of the group tend to collaborate and generate ideas that are acceptable to the group, while being cautious of the rules. Conversely, more innovative individuals in a group tend to generate ideas that are outside of the box and are willing to disregard rules, and group collaboration (Kirton, 2003).

### **Conceptual Framework**

Conceptually, this study was underpinned by Bransford’s (1986) IDEAL problem solving model. Foundationally, the basic idea behind this model is to draw focus on the importance of how an individual utilizes information to build new tools that will help the individual solve problems (Bransford, 1993). More specifically, this model can be utilized to address individual awareness on the problem solving process. Therefore, allowing the individual to reflect and analyze their problem solving procedure (Bransford, 1993).

The IDEAL problem solving model was developed by Bransford (1986) to understand how an individual solve problems. The IDEAL problem solving model consists of five steps (a) Identify, (b) Define or Develop goals, (c) Explore, (d) Anticipate or Act, and (f) Look and Learn.

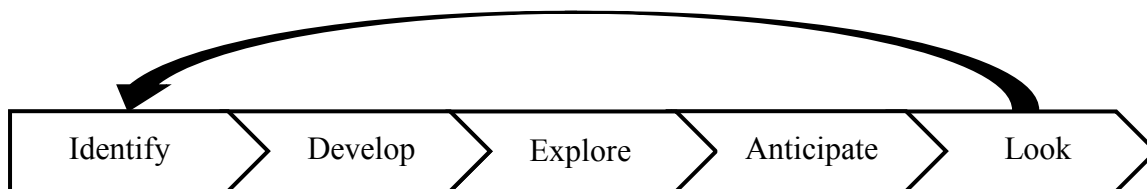


Figure 2.1. Bransford’s (1993) IDEAL problem solving model. Adapted from “The Influence of Cognitive Diversity on Group Problem Solving Strategy” by AJ Lamm, C Shoulders, GT Roberts, TA Irani, LJ Snyder, & J Brendemuhl, 2012, Journal of Agricultural Education, 53(1), p.19. Copyright 2012 by Journal of Agricultural Education. Reprinted with Permission.

The first component of the IDEAL problem solving model is Identify. In this step the individual needs to be able to identify potential problems and opportunities (Bransford, 1993). These problems can often be problems that go unnoticed or considered as inconveniences (Bransford, 1984). However, identifying important problems and treating them as opportunities often leads to individuals who are more creative and successful at solving problems (Bransford, 1984, 1993).

The second aspect of the IDEAL problem solving model is Develop or Define goals. This step is designed to help the individual develop a deeper understanding of the identified problem and find possible solutions to those problems. Even though individuals are identifying possible problems though the first phase, the second phase is used to focus their understanding of the problem and define goals that could help them solve the problem (Bransford, 1984).

The third step in the IDEAL problem solving model is Explore. This step often will involve a reanalysis of defined goals and considerations of alternative strategies (Bransford, 1993). This step is considered *the let-me-out-of-here* approach or possible other strategies to fix the problem if encountered with other problems (Bransford, 1993, p.27). After exploring possible

other strategies, the next phase is to Anticipate and Act on that strategy (Bransford, 1993). However, before Acting on your strategy it is important to Anticipate possible outcomes from the actions that are about to be performed. This is critical because anticipating possible outcomes can save the individual from actions that they may regret later on in the process (Bransford, 1993). After anticipating possible outcomes the individual can now act on the chosen strategy. Acting on the chosen strategy is an important piece because it allows the individual to actively engage their strategy and discover ways to improve (Bransford, 1993). This step allows the individual to evaluate their outcomes from acting on their chosen strategy.

Finally, the last step in the IDEAL problem solving model is Look and Learn. This step could be considered by far the most critical step because it allows the individual to look at the true effects of the strategy chosen and then learn from the experience (Bransford, 1993). This is the time when all the success and failures of the chosen strategy are evaluated and learning occurs. This reflection over the process and experience also allows for further problem solving if necessary, which is shown in Figure 2.1 as the arrow. If after this step further problem solving is necessary, the problem solver would then start back at step one in the process (see Figure 2.1).

### **Summary**

Perhaps one of the most difficult factors in teaching is being able to foster learning among diverse learners. In order to foster student learning, educators must implement a variety of instructional approaches to provide students with the opportunity to develop higher order thinking skills (Allen et al., 2011; Hanson, 2006). Over the past decade, the flipped classroom model has gained an immense amount of attention at both the pre-collegiate and collegiate level (Barkley, 2015; McCubbins et al., 2018). A flipped classroom approach allows the teachers to become facilitators of the learning experience and empowers students to take control over their

own learning. A flipped classroom allows content delivery to occur before instructional time (Michaelsen et al., 2004). Moving the course material to an online structure that the students complete outside of class time allows for more time to be devoted to applying the concepts toward real-life learning experiences (Michaelsen et al., 2004).

A form of a flipped classroom is Team-based learning. TBL is an active learning strategy that incorporates both collaborative and problem-based learning. The primary learning objective of TBL is to promote and enhance students' opportunities to use course concepts to solve real-world problems (Michaelsen & Sweet, 2008). TBL is designed to provide students with opportunities to learn both conceptual (declarative) and procedural knowledge. In a TBL course the instructor's primary role shifts from dispensing content/information to facilitating the overall instructional process. The students move from being passive learners to taking on the responsibility of learning conceptual knowledge before class (Michaelsen & Sweet, 2008). These active learning strategies have starting gaining attention in recent years because they promote critical thinking and problem solving skills, which has become a critical component of today's workplace (Gonkale, 1995).

These critical components encourage employers to find individuals who can efficiently and effectively solve complex problems (Gonkale, 1995). Even though we solve problems every day, problem solving activities are never uniform and are often not equivalent in form or context (Jonassen, 2000). Problems have been operationalized as either well-structured or ill-structured. Well-structured problems are often the ones we encounter in our formal education. However, ill-structured problems are problems that we often encounter in our daily lives that have an infinite number of solutions (Jonassen, 2000; Kitchner, 1983; Wood, 1983). Therefore, in order for the individual to successfully solve the problem, they must possess and utilize a wide range of

knowledge in many domains to solve the problem (Jonassen, 2000; Kitchner, 1983; Wood, 1983).

However, one of the largest factors affecting an individual to effectively problem solve lies within their metacognitive ability. To get an individual to problem solve, the learner must have the ability to learn material in a specified domain. The development of these metacognitive skills allows the individual to encode a problem by formulating mental schemas of the problem and then selecting appropriate plans to overcome the obstacle (Davidson & Sternberg, 1998; Zimmerman & Risemberg, 1997). Along with a learner's metacognitive development, awareness of cognitive style is also an important key in their ability to efficiently solve problems.

Another key factor in an individual's problem solving ability is their familiarity with the domain and problem type (Jonassen, 2001). This a particularly strong predictor because it has to deal with the development of the solvers mental schemas. These highly development mental schemas help the solver utilize different domain knowledge to successfully solve a problem (Jonassen & Hung, 2000). An individual must possess multiple types of domain knowledge in order to successfully solve problems, especially in troubleshooting (Jonassen & Hung, 2006; Schaafstal & Schraagen, 2000).

Troubleshooting is often amongst the most commonly experienced type of problem solving in our everyday lives (Jonassen, 2003). In troubleshooting the most important piece to effectively problem solve is the troubleshooter's ability to recognize and select the most appropriate solution to the problem (Halpern, 1984). However, the troubleshooter's ability to utilize multiple domains, recognize solutions, and select the appropriate action are often different between novice and expert troubleshooters (Pate et al., 2004).

In order to understand an individual's process of decision making during a task, Bransford (1993) designed the IDEAL problem solving model. This model explores an individual's decision making process during a problem solving task. Understanding how an individual's cognitive style affects their decision making process is an integral factor in understanding how individuals are problem solving and where they are missing key pieces in order to be successful. Further, Johnson (1989) developed a technical troubleshooting model that comprised of two distinct phases. This model is used to conceptualize a troubleshooter's process of problem solving and path to solution. By utilizing this model, it is possible to understand the phases and steps troubleshooters are going through to solve problem.

Education literature has been conducted in agricultural education to examine problem solving style, learning style, and cognitive style impact an individual's decision making process (Blackburn & Robinson, 2016; Blackburn et al., 2014; Boone, 1990; Cano, 1993, 1999; Dyer & Osborne, 1996; Garton, Spain, Lamberson, & Spiers, 1999; Parr & Edwards, 2004; Rudd, Baker, & Hoover, 1998; Torres & Cano, 1994). Research has also found relationships between cognitive style, critical thinking and problem solving ability (Friedel et al., 2008; Myers & Dyer, 2006; Lamm et al., 2011; Rudd et al., 2000; Torres & Cano, 1995a). Recently research has been conducted to investigate the effects of cognitive style, complexity, time to solution, and hypothesis generation on the troubleshooting ability of undergraduate students (Blackburn & Robinson, 2016; Blackburn et al., 2014).

## CHAPTER III: METHODOLOGY

### Statement of the Problem

In recent years, it has become increasingly important for educators to adapt to new pedagogies in order to develop higher order thinking skills for their students meet the demands of the 21st century workplace (Fuhrmann & Grasha, 1983; Jonassen, 2000; Ulmer & Torres, 2007). Due to the highly structured components of the work place, skills associated with problem solving or critical thinking are highly desired (Gokhale, 1995) because employers want individuals who can find, identify, and solve complex problems in an effective and efficient manner (Johnson, 1991).

Generally, educators have a wide variety of instructional methods available to them in order to meet needs of diverse learners. However, the problem solving approach, especially in agricultural education, has been highly regarded as the best method of instruction (Dyer, 1995). The problem solving approach provides students with the skills necessary to develop important metacognitive processes, which promote higher order thinking skills and improved problem solving ability (Dyer, 1995; Zimmerman & Risemberg, 1997). Historically, this has been achieved more easily in the agricultural education curriculum which is known for its hands-on learning processes designed to provide students with the necessary real-world learning experiences.

Problem solving skills have been identified as one of the most important cognitive activities encountered in our everyday lives (Jonassen, 2000). As part of our routine, we often solve hundreds of problems a day ranging from simple to complex (Jonassen, 2000). However, students today often do not solve meaningful problems as a part of their curricula (Jonassen,



2000). Fortunately, problem solving skills can be taught and refined by enhancing the learning environment and building metacognitive skills (Lester, 1994; Sproull, 2001).

Education literature conveys the importance of cognitive styles of students as an important function of our everyday lives (Myers & Dyer, 2006; Parr & Edwards, 2004; Thomas, 1992; Torres & Cano, 1995a; Witkin et al., 1977). However, educators generally do not teach a significant amount of problem solving or critical thinking skills in their curriculum in order to build effective problem solvers (Jonassen, 2000; Ulmer & Torres, 2007). Blackburn et al. (2014), Lamm et al. (2011) concluded educators must be aware of different cognitive styles and understand how to tailor lessons to effectively teach critical thinking and problem solving skills. The previous review raises the question: How does cognitive style influence a student's ability to effectively problem solve in a small group setting?

### **Purpose of the Study**

The primary purpose of this study was to investigate the effects of cognitive diversity on the problem solving ability of undergraduate students enrolled in a team-based learning formatted agricultural mechanics course.

### **Research Problem**

What effect does cognitive diversity have on students' ability to solve problems when troubleshooting a small gasoline engine?

### **Research Questions**

1. Do differences exist in content knowledge of undergraduate students enrolled in an introduction to agricultural mechanics course by cognitive style?

2. Do differences exist in course motivations of undergraduate student enrolled in an introduction to agricultural mechanics course by cognitive style?
3. Does team cognitive diversity have an effect on time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?
4. Does team cognitive diversity have an effect on the hypothesis generation ability of undergraduate students enrolled in an introduction to agricultural mechanics course when solving small gas engine problems?
5. Does hypothesis generation have an effect on the time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?

### **Institutional Review Board**

To meet federal regulations and ethics standards, all studies which include human subjects must be reviewed and approved by the institution's compliance board. For the study in question, an electronic application was submitted to the Institutional Review Board (IRB) at Louisiana State University Office of Research and Economic Development. Per the requirements of the application, all documents for the research proposal were included and requirements of safe and humane treatment of human subjects were met. The IRB approval needed to conduct this study was approved (#E10769) on December 5, 2017 (see Appendix A).

## Course Structure

### Team-Based Learning Format

A Team-Based Learning (TBL) approach was utilized during the entire duration of the Introduction to Agricultural Mechanics course during the spring semesters of 2018 and 2019. TBL is a student-centered teaching approach that is designed to allow students to learn the course material outside of class time and apply their new knowledge during hands-on learning exercises during scheduled class time in order to foster problem solving and critical thinking skills development. The course layout was adapted from Michealsen and Sweet (2008). The course readings, videos, worksheets, and Individual Readiness Assurance Tests (IRATs) and Team Readiness Assurance Tests (TRATs) were all developed by the researcher utilizing the *Agricultural Mechanics Fundamentals and Applications 7<sup>th</sup> Edition* Textbook by Herren (2015), *Small Engines 4th Edition* Textbook by Radcliff (2016), and *Small Engine and Equipment Maintenance* Textbook by London (2003).

At the beginning of the 2018 and 2019 semesters the students were divided into seven teams based on their cognitive style as determined by Kirton's Adaptation-Innovation Inventory (KAI). Each team consisted of 4-6 members, which they remained in for duration of the course. The course layout was comprised of four foci, (a) safety, (b) agricultural structures, (c) electricity, and (d) small gasoline engines. This research is associated with data collected during the small gasoline engines portion of the course. Within the small gasoline foci, five individual modules were constructed including (a) small engine tool and part ID, (b) 4-cycle theory and fuel, (c) ignitions and governor system, (d) cooling/lubrication system, and (f) troubleshooting. After every module, students completed an IRAT to determine the content knowledge retained. After completing the IRAT, the students would then join their assigned team and complete the TRAT. During the TRATs, students were allowed to collaborate with other members to come to

agreements on items they may have gotten incorrect. The goal of completing the IRAT before the TRAT is to ensure that all group members of the team contribute equally.

After the assessments were completed, the remainder of the course was dedicated to hands-on learning activities. The students participated in all course activities in their teams and were directed to ask questions to their team members before they asked the instructors. This was completed to promote critical thinking and problem solving skills development among the students.

### **Research Design**

This study employed preexperimental research. Preexperimental designs are considered *pre* because they are preparatory to true experimental designs or quasi-experimental designs (Salkind, 2010, p. 1081). Preexperimental designs utilize either single or multiple groups of participants and are observed after some intervention presumed to cause the change (Salkind, 2010). However, these designs often fail to include either a pretest, control/comparison groups, and no randomization is used to control for extraneous variables (Campbell & Stanley, 1963; Salkind, 2010). Preexperimental designs contain three sub-designs; (a) one-group posttest (b) one-group pretest-posttest, and (c) posttest-only nonequivalent groups design (Salkind, 2010). Each sub-design has specific strengths and weaknesses that are used to help overcome the lack of internal validity (Campbell & Stanley, 1963; Salkind, 2010).

Specifically, the sub-design of this study utilized a one-group pretest-posttest design, which is widely used in educational research (Campbell & Stanley, 1963; Salkind, 2010). In this approach, all individuals are assigned to the experimental group and are observed at two time points (Campbell & Stanley, 1963; Salkind, 2010). The changes from the pretest to the posttest determine the results from the intervention. However, in this design there is no comparison group

which makes it almost impossible to determine if the change would have occurred only from the intervention and not from extraneous variables (Salkind, 2010). Extraneous variables must be considered and dismissed in order to make any types of generalizations between the interventions and change (Salkind, 2010).

### **Population and Sample**

The population of this study were students enrolled in *AEEE 2003-Introduction to Agricultural Mechanics* at Louisiana State University during the spring of 2018 ( $n = 17$ ) and Spring 2019 ( $n = 15$ ) semesters. During the spring semester of 2018, one individual did not complete enough course material and did not participate in the troubleshooting activity; therefore, data associated with that individual was dropped from the study and our recorded sample was ( $n = 16$ ). Since this course is only offered every spring, the accessible population consisted of students enrolled in introduction to agricultural mechanics for the spring of 2018 and 2019. Per IRB protocol, the students were notified of the study prior to the course by reviewing a student consent form (see Appendix B). If a student elected not to participate they were simply not required to take part in those activities where data were being collected and not counted in our population. All students elected to participate, therefore the total sample for this study was ( $n = 31$ ).

There were no sampling procedures conducted for this study because the individuals in this class elected to enroll in the course and were not randomly assigned to treatment groups. Further, their treatment groups were determined by each participants individual cognitive style score as determined by the Kirton's Adaptation-Innovation (A-I) Theory. Since no random sampling procedures were utilized, no generalizations past the population can be made.

Demographically, our students were asked to identify their age, gender, academic classification, college major, if they completed an agricultural education class in high school, the number of agricultural education courses they took in high school (if applicable), how many of those agricultural education courses were focused on agricultural mechanics, if they ever participated in an agricultural mechanics CDE, and if they were an FFA member by responding to the personal and educational characteristics survey (see Appendix C).

As reported in Table 3.1, the sample consisted of 14 (45.2%) males and 17 (54.87%) females. When asked about their age one student (3.2%) was 18 years old, nine (29%) were 19 years old, seven (22.6%) were 20 years old, nine (29%) were 21 years of age, one (3.2%) was 22 years old, two (6.5%) indicated they were 23, and two (6.5%) were 24 years of age. In regards to their academic classification, three (9.7%) indicated they were freshman, 13 (41.9%) were sophomores; nine (29%) indicated they were juniors, and six (19.4%) were seniors. When asked about their major, most of students were in Agricultural and Extension Education ( $f = 13$ , 41.9%), six (19.3%) were Animal Science, two (6.5%) indicated their major was Plant & Soil Science, three (9.7%) were enrolled in Natural Resources Ecology Management (NREM), one (3.2%) was Agricultural Business, one (3.2%) indicated he or she was in Turf and Landscape Management, two (6.5%) indicated Mechanical Engineering, two (6.5%) were Horticulture majors, and one (3.2%) indicated he or she was a Sports Administration major. In regards to participation in agricultural education courses in high school, 14 (45.2%) had been in an agricultural education course and 17 (54.8%) indicated that they did not participate in agricultural education courses in high school. In regards to the number of agricultural education courses taken, two (6.5%) had taken one course, eight (25.8%) indicated that they had taken four courses, two (6.5%) had taken five courses, one (3.2%) had taken six courses, and one (3.2%)

indicated that they had taken eight courses in high school. Of this population students also indicated that 13 (41.9%) were FFA members, and 18 (58.1%) were not FFA members. Also, only one (3.2%) of the students participated in a state agricultural mechanics CDE events (i.e. welding, small engines, electricity) (see Table 3.1).

Table 3.1. Personal and Educational Characteristics of Undergraduate Students Enrolled in Introduction to Agricultural Mechanics at Louisiana State University During the Spring 2018 and 2019 Semesters (n = 31)

Variable	<i>f</i>	%
Age		
18	1	3.2
19	9	29
20	7	22.6
21	9	29
22	1	3.2
23	2	6.5
24	2	6.5
Gender		
Male	14	45.2
Female	17	54.8
Academic Classification		
Freshman	3	9.7
Sophomore	13	41.9

(table cont'd)

Variable	<i>f</i>	%
<b>Academic Classification</b>		
Junior	9	29
Senior	6	19.4
<b>Major</b>		
Agricultural & Extension Education	13	41.9
Animal Sciences	6	19.3
Plant & Soil Science	2	6.5
NREM	3	9.7
Agricultural Business	1	3.2
Mechanical Engineering	2	6.5
Turf & Landscape Management	1	3.2
Horticulture	2	6.5
Sports Administration	1	3.2
<b>Agricultural Education Courses in High School</b>		
Yes	14	45.2
No	17	54.8
<b>FFA Member</b>		
Yes	13	41.9
No	18	58.1
<b>Participation in Agricultural Mechanics Career Development Event</b>		
Yes	1	3.2
No	30	96.8



After the students had indicated how many agricultural education courses they completed in high school, they were asked to identify how many of those courses were related to agricultural mechanics. In all, 18 (58.1%) indicated that none of their courses were related to agricultural mechanics, nine (29%) marked that one course was related to agricultural mechanics, two (6.5%) indicated that three courses were related to agricultural mechanics, and two (6.5%) indicated that four of their courses in agricultural education were agricultural mechanics related (see Table 3.2).

Table 3.2. Number of Agricultural Mechanics Courses Taken in High School by Students Enrolled in Introduction to Agricultural Mechanics (n=31)

Number of Courses	<i>f</i>	%
0 Courses	18	58.1
1 Course	9	29
2 Courses	0	0
3 Courses	2	6.5
4 Courses	2	6.5

*Note. Percentages may not equal 100% due to missing data*

The students in this course were also assessed for their cognitive style based on their KAI score, which was administered at the beginning of the semester. In regards to cognitive style, 23 (74.2%) were considered more adaptive (scores ranging from 32-95) and 8 (25.8%) were more innovative (scores ranging from 96-160) (see Table 3.3).

Table 3.3. Cognitive Style of Louisiana Undergraduate Students enrolled in Introduction to Agricultural Mechanics Course (n=31)

Item	<i>f</i>	%
More Adaptive	23	74.2
More Innovative	8	25.8

*Note. KAI scores range from 32-160. Scores from 32-95 = more adaptive; 96-160 = more innovative*

Also, between the two semesters, independent sample t-tests were conducted on individual cognitive score, age, and the students' precourse interest survey to determine if the groups were homologous. The t-test analysis found that there were no statistically significant differences between semester 2018 and 2019 and cognitive style ( $p = .109$ ), age ( $p = .596$ ), and pre-CIS ( $p = .062$ ), respectively (see Table 3.4). To test for homogeneity, a Levene's test for equality of error variances was not statistically significant; therefore, it is assumed that the variances are almost equal and the groups are almost the same (Field, 2011).

Table 3.4. Independent Sample T-test of KAI, Age, & Pre-CIS for Spring 2018 & 2019

Variable	Mean	<i>t</i>	<i>df</i>	<i>p</i>
KAI Score				
2018	86.56	.006	29	.109
2019	86.53			
Age				
2018	21.00	2.197	29	.596
2019	19.87			
Pre-CIS Total				
2018	150.31	-.075	29	.062
2019	150.60			

A Chi-Square test was conducted to determine if gender was a statistically significant factor from 2018 and 2019. However, a statistically significant difference did not exist ( $p = .576$ ) between semester years and gender (see Table 3.5).

Table 3.5. Pearson Chi-Square Test of Gender for Spring 2018 & 2019

Value	<i>df</i>	<i>p</i>
.313	1	.576

From the analysis, it is concluded that our population from both semesters were homologous and subsequently the data were merged for further data analysis.

### **Treatment**

#### **Team Cognitive Diversity Scores**

At the beginning of the semester, the students were placed into teams based off their cognitive style obtained from the KAI. These teams consisted of students that were purposefully grouped by cognitive diversity (see table 3.6). The team formation included: (a) four homogeneous adaptive teams, (b) one homogeneous innovative team, and (c) two teams that were heterogeneous. Team one was a group of four students that were homogeneous innovative based off Kirton’s Adaptation-Innovation Inventory. Team two was a group of students that were homogeneous adaptive based off their cognitive style scores. Team three consisted of two students who were more adaptive and two student who were more innovative. This team made a heterogeneous innovative and adaptive group. Team 4 was a group of students who were homogeneous adaptive. Team five consisted of six members, three of which were more innovative and three who were more adaptive and were heterogeneous. Team six consisted of individuals who were homogeneous adaptive. Finally, team seven consisted of five individuals who were homogeneous adaptive. Because of the nature of this study, the group sizes varied based on enrollment in the course. Therefore, not all groups had an equal number of members. Also, it is important to note that teams one through four were from the spring 2018 semester and

teams five through seven were from the spring 2019 semester. The students completed all activities in this course in these teams for the remainder of the semester.

Table 3.6. Team Cognitive Diversity Scores for Students Enrolled in Introduction to Agricultural Mechanics

Team Cognitive Diversity	<i>Individual KAI Scores</i>					
	<i>Member 1</i>	<i>Member 2</i>	<i>Member 3</i>	<i>Member 4</i>	<i>Member 5</i>	<i>Member 6</i>
Team 1-Homogeneous Innovative	101	101	109	117	–	–
Team 2-Homogeneous Adaptive	58	66	69	76	–	–
Team 3-Heterogenous	70	76	95	99	–	–
Team 4-Homogeneous Adaptive	83	84	90	91	–	–
Team 5-Heterogenous	98	97	97	56	73	80
Team 6-Homogeneous Adaptive	95	84	90	78	–	–
Team 7-Homogeneous Adaptive	79	93	92	92	94	–

*Note: Teams 1-4 are from spring 2018 & Teams 5-7 are from spring 2019. A dash indicates those members were not included in that team.*

Students' scores, in team one, ranged from 101-117 with a 16-point score gap. Team two consisted of students' who were homogeneous adaptive and scores that ranged from 58-76 with an 18-point score gap. Team three's scores ranged from 70-99 with a 29-point score gap. Students in team four had scores ranging from 83-91 with an 8-point score gap. Team five, who were heterogeneous, had scores ranging from 98-56 with a 42-point score gap. Students' scores, in team six, ranged from 95-78 with a 17-point score gap. Finally, team seven KAI scores ranged from 94-79, with a 16-point cognitive style gap. For all homogeneous teams point gaps between the highest and lowest students were kept below 20 to help eliminate communication and collaboration problems that can occur with point gaps above 20, as outlined in Kirton (2003).

The heterogeneous teams were created with a 20+ point spread to initiate cognitive style differences between an individual who was more adaptive and an individual who was more innovative (see Table 3.6 above).

### **Small Gasoline Engine Team Grouping Treatment**

During the small gasoline engines unit of AEEE 2003, students in each of the seven teams were further divided down into dyads or triads to eliminate the frustration of four or more people working on one engine (see table 3.7). Team one was divided into two groups, which included: (a) Group 1A consisted of individuals who were more innovative and (b) Group 1B consisting of individuals who were also more innovative. Team two was also divided into two sub-groups. Those groups included: (a) Group 2A-consisted of individuals who were more adaptive and (b) Group 2B-consisted of individuals who were more adaptive. Team three consisted of heterogeneous KAI scores and was grouped into two smaller groups that included an individual who was more adaptive and an individual who was more innovative. Those groups included: (a) Group 3A and (b) Group 3B. Team four consisted of all more adaptive individuals. Those individuals were divided into two sub-groups including: (a) Group 4A and (b) Group 4B. Team five consisted of six individuals with varying cognitive style, those including: (a) Group 5A; (b) Group 5B; and (c) Group 5C. Team six consisted of two subgroups (a) Group 6A and (b) Group 6B. Finally, team seven consisted of five individuals who were all more adaptive. Group 7A and Group 7B.

Table 3.7. Cognitive Diversity Scores for Small Gasoline Engine Sub-Groupings

Teams	<i>Small Gasoline Sub-Grouping</i>						
	<i>Group A</i>		<i>Group B</i>			<i>Group C</i>	
	<i>Individual Group Member KAI Scores</i>						
Team 1	101	117	101	109	–	–	–
Team 2	58	69	66	76	–	–	–
Team 3	70	95	76	99	–	–	–
Team 4	83	90	84	91	–	–	–
Team 5	98	56	97	73	–	97	80
Team 6	95	90	84	78	–	–	–
Team 7	79	92	93	92	94	–	–

*Note: Teams 1-4 are from spring 2018 & Teams 5-7 are from spring 2019. A dash indicates those members were not included in that team.*

In terms of group member scores, Group 1A had scores of 101 and 117 with a 16 point gap and Group 1B had scores of 101 and 109 with an eight point gap. Group 2A had scores of 58 and 69 with an 11 point gap and Group 2B had scores of 66 and 76 with a 10 point gap between members. Group 3A had scores of 70 and 95 with a 25 point gap and Group 3B consisted of scores ranging from 76 and 99 with a 23 point gap. Group 4A consisted of individuals whose scores were 83 and 90 with a 13 point gap and Group 4B consisted of individuals whose scores were 84 and 91 with a point gap of seven. Group 5A consisted of individuals whose KAI scores were 98 and 56 with a 42 point gap, Group 5B scores ranged from 97 to 73 with a 24 point gap, and Group 5C consisted of individuals with scores of 97 and 80 with a 17 point gap. Group 6A consisted of cognitive style scores from 95 and 90 with a five-point gap and Group 6B scores were 84 and 78 with a six-point gap. Finally, Group 7A consisted of two individuals whose cognitive style scores were 79 and 92 with a 13 point gap and Group 7B which consisted of three individuals with scores of 93, 92, and 94 with a two point gap (see Table 3.7 above).

## **Small Gasoline Engine Fault**

The final treatment in this study consisted of small gasoline engines with one known fault. Each subgroup was given an engine with the same known fault and was asked to troubleshoot and fix the problem. Each engine was filled with fresh oil and fuel, and students were allowed to attempt to start the engine to diagnose the symptoms. The engine fault was within the compression system. Specifically, the exhaust valve adjustment screw was completely tightened down, which put the valves at incorrect clearance for proper operation.

### **Instrumentation**

#### **Cognitive Style Instrument**

Kirton's Adaptation-Innovation Inventory (KAI) was used to determine the students' cognitive style (Kirton, 2003). This instrument consists of 32 items that ask questions directed toward the individuals preferred way to learn (see Appendix D). The KAI scores range from 32 to 160 on a continuum from more adaptive to more innovative, with a theoretical mean of 96 (Kirton, 2003). However, the practical mean of the KAI has been found to be 95 (Kirton, 2003). Per the theory individuals who score 95 or below are considered more adaptive, while individuals who score is 96 or above are considered more innovative. This instrument has been successfully utilized to determine a wide variety of individuals streaming from varying backgrounds (Kirton, 2003).

#### **Criterion-referenced Pretest/Posttest**

Due to the nature of this preexperimental study, it was important to determine the students' knowledge in small gasoline engine content prior to and after the intervention. A 30-item criterion-referenced test was developed by the researcher to test the individual's knowledge. It should be noted that half of the questions on this test were developed by Blackburn (2013) and

further modified to meet the needs of this study. The other 15 of the questions on this test were developed by the researcher based off the *Briggs & Stratton Small Engine and Equipment Maintenance*® textbook written by London (2003), a *Small Engines*® textbook written by Radcliff (2016), and the Briggs & Stratton PowerPortal website. The criterion-referenced test was formatted using a four option multiple choice template including one correct answer and three distractors (see Appendix E).

### **Student Course Motivation Instrument**

Student motivation was assessed by utilizing the Course Interest Survey (CIS) developed by Keller (2006) (see Appendix F). The goal of this instrument was to determine how motivated students were before and after a particular lesson or course. This instrument comprised of 34 items, which made up the four subscales of the ARCS model (Attention, Relevance, Confidence, and Satisfaction). Participants responded on a five-point Likert-type scale from *1 = not true*, *2 = slightly true*, *3 = moderately true*, *4 = mostly true*, and *5 = very true*. All students in this course completed the CIS instrument via paper format at the beginning and end of the small gasoline unit. The CIS instrument was attached to the back of the pretest packet and posttest packet, which were handed out on the first day of the small engines module and on the last day of the small engines module.

The scoring guide used to attain the measures of the ARCS utilizing the CIS are displayed below in Table 3.8 (Keller, 2006, p.4). Those items on the instrument that were labeled as *reverse* were reverse coded in SPSS software when the data from the instrument were entered (see Table 3.8).



Table 3.8. Scoring Guide for the CIS (Keller, 2006)

Attention	Relevance	Confidence	Satisfaction
1	2	3	7(reverse)
4 (reverse)	5	6 (reverse)	12
10	8 (reverse)	9	14
15	13	11 (reverse)	16
21	20	17 (reverse)	18
24	22	27	19
26 (reverse)	23	30	31 (reverse)
29	25 (reverse)	34	32
	28		33

### Troubleshooting Instrument

Johnson's (1989) technical troubleshooting model was utilized as a guide to create the small gasoline engines troubleshooting packet (see Appendix G). The troubleshooting packet consisted of three sections that included (a) hypothesis, (b) engine symptoms, and (c) troubleshooting process. Inside each packet were three sets of hypothesis sheets to ensure that if the group hypothesized incorrectly the first time they could use a different sheet to start over. This protocol was developed to follow the technical troubleshooting's model process of hypothesis generation (see Figure 3.1).

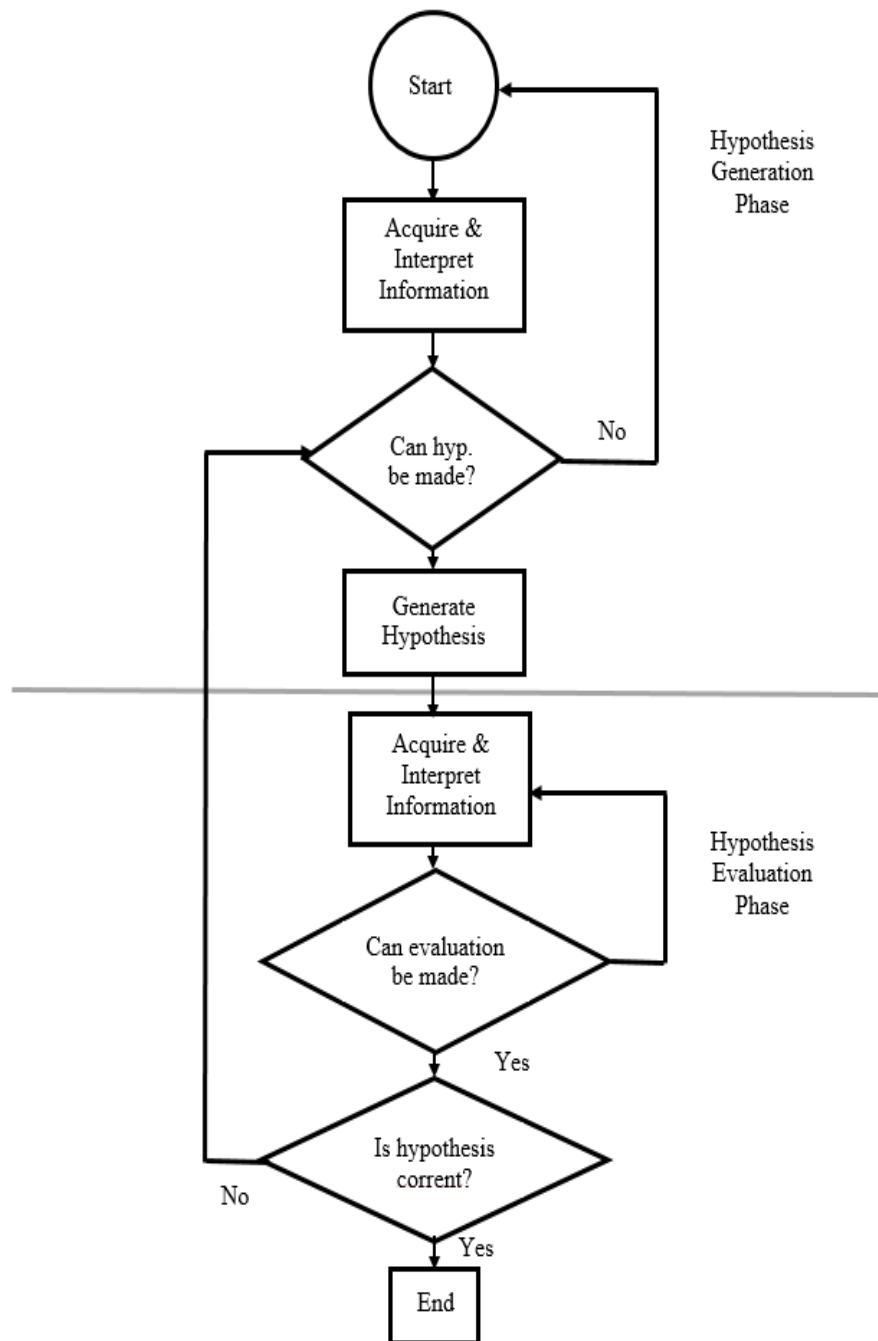


Figure 3.1. Technical Troubleshooting Model. Adapted from “A description of expert and novice performance differences on technical troubleshooting tasks” by S.D. Johnson, 1989, *Journal of Industrial Teacher Education*, 26(3), p. 20. Copyright 1989 by Journal of Industrial Teacher Education. Reprinted with Permission.

## Validity and Reliability

### Threats to Internal Validity

One of the greatest concerns of preexperimental research is the relatively low internal validity (Campbell & Stanley, 1963). When examining internal validity there are eight different classes of extraneous variables that need to be controlled. Those include: (a) history, (b) maturation, (c) testing, (d) instrumentation, (e) statistical regression, (f) selection, (g) mortality, and (h) selection-maturation interaction (Campbell & Stanley, 1963, p. 6). In regards to this specific study, only five of the eight threats to internal validity affected this study and was attempted to be controlled by using a variety of techniques. Three of the eight extraneous variables either did not pertain to this study or were not applicable, which included: (a) statistical regression; (b) selection; and (c) selection-maturation interaction (Campbell & Stanley, 1963).

The first extraneous variable that needs to be controlled is history. History often includes major events that have occurred between the beginning of the research and the end and could potentially influence the outcomes (Creswell & Creswell, 2017). However, history, as a threat to internal validity, becomes a more plausible explanation of change with longer duration of time between the pretest-posttest. To help control for history, the duration of time between the pretest-posttest was held to five weeks and the students completed the test in their normal classroom to help control other distracting events.

Maturation is another extraneous variable that affects this research design and this study. Maturation is the changes individuals may experience during the research study (Creswell & Creswell, 2017). This research study took place during a normal 16-week semester; therefore maturation among participants is possible between the pretest-posttest and could influence the outcomes.

The third threat to internal validity is testing. Testing refers to the individual effect of the pretest on the posttest score (Campbell & Stanley, 1963). For example, an individual who has taken a pretest should score better on the posttest, than an individual who is taking it for the first time. Therefore, differences in posttest scores could be attributed to the individual having already seen and taken the exam and less likely be the cause of the treatment. Instrumentation of the pretest/posttest is another confounding variable. Campbell and Stanley (1963) terms this confounding variable as instrument decay or the changes in the measuring instrument from the pretest to the posttest. Using human observers can cause instrument decay or by changing grading standards from  $O^1 - O^2$ . To control for this variable the researcher created an answer key prior to grading that was reviewed by the panel of experts for accuracy and used the same answer key to grade both tests to prevent answer changes.

The final threat to internal validity for this study was mortality. Mortality refers to losing participants during the experiment (Campbell & Stanley, 1963). The entire sample of this study was 32 students enrolled in introduction to agricultural mechanics; however, only 31 participants completed all parts necessary for this study.

### **Criterion-referenced Test Validity**

A panel of experts comprised of one department faculty member at Louisiana State University who regularly teaches *AEEE 2003-Introduction to Agricultural Mechanics*; and one high school agriculture teacher who previously taught agriculture in Louisiana for 14–15 years and is now the Executive director of the Louisiana FFA association established face and content validity for the criterion-referenced test. These experts reviewed the instrument for content, ease of reading, and question construction. All proposed changes by the panel were considered and changes were made prior to administering the test to the students.

## Criterion-referenced Test Reliability

Wiersma and Jurs (1990) identified eight factors that ensure reliability of criterion-referenced tests. Table 3.9, below, lists the eight factors and how each factor was addressed in this study.

Table 3.9. Examples of Wiersma and Jurs (1990) Eight Factors for Establishing Reliability of Criterion-referenced Tests

Factor	How Factors were Addressed
1. Homogeneous Items	Consistency of the items on the instrument were all constructed using the same font, size, and style
2. Discriminating Items	Items of varying difficulty were included
3. Quantity of Items	The test consisted of 30 multiple-choice items
4. High Quality Test	The test was verified by a panel of experts for formatting
5. Clear Directions	Directions were printed at the top of the test and read aloud
6. Controlled Environment	The test was given in the student's normal classroom
7. Participant Motivation	Students were aware if the test was being used for course grade
8. Scorer Directions	Answer key was developed for accurate assessment

## KAI Instrument Validity and Reliability

Kirton's Adaptation-Innovation Inventory has been widely used to assess cognitive style describe individuals of varying backgrounds. Several studies that utilized the KAI to determine comparative evaluations of each other yielded correlations ranging from .4 –.8 (Kirton, 2003). While this is not the only form of establishing validity for this instrument, this measure is the closest related to align with the current study.

Internal reliability of this instrument has been measured through multiple studies. Kirton (2003) reported that after analyzing data from six different population samples with over 2500

respondents that internal reliability coefficients ranged from .84 – .89. Also, twenty-five other studies that utilized the KAI showed reliabilities between .83 and .91 (Kirton, 2003). Therefore, it has been deemed that this instrument is reliable.

### **CIS Instrument Validity and Reliability**

Situational validity was tested by correlating the students CIS scores with their course grades and overall GPA (Keller, 2010). It was determined that all of the correlations between the CIS and course grades were above the .05 alpha level, and there were no correlations between the CIS and GPA at the .05 alpha level. This supports the validity of the CIS as a situational measure of motivation and not a construct measure of student learning (Keller, 2010).

Internal reliability estimates were determined by utilizing Cronbach’s alpha. The reliability estimates were determined by pretesting, revising, and retesting of 45 undergraduate students at the University of Georgia (Keller, 2010) and are displayed in Table 3.10. Internal consistency estimates were overall high for each subscale, therefore the instrument was deemed reliable.

Table 3.10. CIS Internal Consistency Estimates by Keller (2010)

Scale	Reliability Estimate Cronbach’s $\alpha$
Attention	.84
Relevance	.84
Confidence	.81
Satisfaction	.88
Total Scale (CIS)	.95

## Data Analysis

Data were analyzed and coded utilizing SPSS statistics software version 26.

Nonparametric statistics were utilized to analyze data associated with the research questions because of the small sample size (i.e. <100) (Field, 2009; Hill & Lewicki, 2007). Non-parametric statistics refers to “methods of measurement that do not rely on assumptions that the data are drawn from a specific distribution” (Salkind, 2010, p.915). Unlike parametric statistics, nonparametric statistics make fewer assumptions and are often less powerful than the alternative; however, they are often helpful in preexperimental studies (Salkind, 2010).

Research Question One and Two asked what differences existed in content knowledge and course motivations, respectively, based on cognitive style score. Descriptive statistics, including frequency, mean, standard deviation, and percentages were utilized to give context to the statistical analysis. A Mann-Whitney U test for nonparametric statistics was utilized to analyze individual content knowledge and course motivation based on cognitive style. The Mann-Whitney U test is the nonparametric alternative to an independent t-test, which helps to compare two independent conditions.

Research Question Three asked, “What effect does cognitive diversity among undergraduate students enrolled in an introduction to agricultural mechanics course have on the time required to solve the problem correctly when troubleshooting a small gasoline engine?” Descriptive statistics, specifically, mean, frequency, and standard deviation were used to describe the individual small gasoline engine teams and their time to completion. A Kruskal-Wallis test was also utilized to compare the effect between cognitive diversity and time. The Kruskal-Wallis test is a nonparametric test equivalent to a parametric one-way ANOVA. To determine if a difference existed between the groups, Mann-Whitney U tests were analyzed *post*

*hoc*. An *a priori* significance level of .05 was utilized to interpret the statistical significance of the analyzing because this study is comparing two independent groups with no control; therefore, no adjustments to the critical value needed to be made (Lewis-Beck, Bryman, Liao, 2004).

Pearson's correlation coefficient  $r$  was analyzed after the Mann-Whitney U tests to calculate the effect size and standardize the measure of the size of effect that was observed (Field, 2011). An  $r$  value of .10 represents a small effect, which explains only 1% of the total variance. An  $r$  value of .30 represents a medium effect and explains 9% of total variance. Finally, an  $r$  value of .50 represents a large effect and accounts for 25% of the variance (Field, 2011).

Research Question Four asked what effect does cognitive diversity have on the student's hypothesis generation ability when troubleshooting a small gas engine. Descriptive statistics, specifically, those of frequency and percentage was utilized to describe cognitive diversity and their ability to hypothesize. Hypothesis generation ability was operationalized as whether or not they correctly hypothesized on the first attempt. Because these two variables are categorical, three independent Pearson's Chi-square tests were utilized to determine the relationship between hypothesis generation ability and problem solving ability have on cognitive diversity.

Research Question Five aimed to determine the effect hypothesis generation and time to solution have on problem solving ability. Descriptive statistics of each teams time to solution and hypothesis generation ability were given to given bring context to the research question and statistical analysis. A Mann-Whitney U test was employed to determine the effect hypothesis generation and time to solution have on team problem solving ability. Also, three independent *post hoc* Mann Whitney U tests were conducted to analyze the interaction effect between cognitive diversity groups. An *a priori* significance level of .05 was utilized to interpret the statistical significance of the analysis. Pearson's correlation coefficient  $r$  was analyzed after the



Mann-Whitney U tests to calculate the effect size and standardize the measure of the size of effect that was observed. An  $r$  value of .10 represents a small effect, which explains only 1% of the total variance. An  $r$  value of .30 represents a medium effect and explains 9% of total variance. Finally, an  $r$  value of .50 represents a large effect and accounts for 25% of the variance (Field, 2011).

## **CHAPTER IV: FINDINGS**

### **Statement of the Problem**

In recent years, it has become increasingly important for educators to adapt to new pedagogies in order to develop higher order thinking skills for their students to meet the demands of the 21st century workplace (Fuhrmann & Grasha, 1983; Jonassen, 2000; Ulmer & Torres, 2007). Due to the highly structured components of the work place, skills associated with problem solving or critical thinking are highly desired (Gokhale, 1995) because employers want individuals who can find, identify, and solve complex problems in an effective and efficient manner (Johnson, 1991).

Generally, educators have a wide variety of instructional methods available to them in order to meet needs of diverse learners. However, the problem solving approach, especially in agricultural education, has been highly regarded as the best method of instruction (Dyer, 1995). The problem solving approach provides students with the skills necessary to develop important metacognitive processes, which promote higher order thinking skills and improved problem solving ability (Dyer, 1995; Zimmerman & Risemberg, 1997). Historically, this has been achieved more easily in the agricultural education curriculum which is known for its hands-on learning processes designed to provide students with the necessary real-world learning experiences.

Problem solving skills have been identified as one of the most important cognitive activities encountered in our everyday lives (Jonassen, 2000). As part of our routine, we often solve hundreds of problems a day ranging from simple to complex (Jonassen, 2000). However, students today often do not solve meaningful problems as a part of their curricula (Jonassen,

2000). Fortunately, problem solving skills can be taught and refined by enhancing the learning environment and building metacognitive skills (Lester, 1994; Sproull, 2001).

Education literature conveys the importance of cognitive styles of students as an important function of our everyday lives (Myers & Dyer, 2006; Parr & Edwards, 2004; Thomas, 1992; Torres & Cano, 1995a; Witkin et al., 1977). However, educators generally do not teach a significant amount of problem solving or critical thinking skills in their curriculum in order to build effective problem solvers (Jonassen, 2000; Ulmer & Torres, 2007). Blackburn et al. (2014), Lamm et al. (2011) concluded educators must be aware of different cognitive styles and understand how to tailor lessons to effectively teach critical thinking and problem solving skills. The previous review raises the question: How does cognitive style influence a student's ability to effectively problem solve in a small group setting?

### **Purpose of the Study**

The primary purpose of this study was to investigate the effects of cognitive diversity on the problem solving ability of undergraduate students enrolled in a team-based learning formatted agricultural mechanics course.

### **Research Problem**

What effect does cognitive diversity have on students' ability to solve problems when troubleshooting a small gasoline engine?

### **Research Questions**

1. Do differences exist in content knowledge of undergraduate students enrolled in an introduction to agricultural mechanics course by cognitive style?

2. Do differences exist in course motivations of undergraduate student enrolled in an introduction to agricultural mechanics course by cognitive style?
3. Does team cognitive diversity have an effect on time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?
4. Does team cognitive diversity have an effect on the hypothesis generation ability of undergraduate students enrolled in an introduction to agricultural mechanics course when solving small gas engine problems?
5. Does hypothesis generation have an effect on the time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?

### **Research Question One**

At the beginning of the small gasoline engines module, students were administered a 30-item-criterion-referenced test to assess their overall knowledge of small gas engines and then were reassessed at the end of the module with the same 30-item-criterion-referenced test. Research question one asked what differences exist between content knowledge based on individual cognitive style. Table 4.1 below describes the content knowledge across both cognitive styles on the pre and posttest, respectively. Overall, individuals scored an average of 15.58 (51.9%) out of 30 on the small gasoline engines pretest. After reassessment, at the end of the small gasoline engines unit, students' average score was 23.39 (77.9%) out of 30. When examining cognitive style groups, 23 more adaptive individuals had an average score of 15.48 (51.6%) out of 30 on the pre-test. The eight more innovative individuals had an average score of

15.88 (52.9%) out of 30 on the pre-test. On the posttest the more adaptive individuals had an average score of 22.96 (76.5%) out of 30 items. The more innovative individuals had an average posttest score of 24.63 (82.1%) out of 30 items.

Table 4.1. Content Knowledge of LSU Undergraduates Enrolled in Introduction to Agricultural Mechanics based on Cognitive Style (n = 31)

Item	<i>f</i>	<i>M</i>	<i>SD</i>	%	Minimum	Maximum
Overall Pretest Score	31	15.58	5.277	51.9	7	27
Overall Posttest Score	31	23.39	4.660	77.9	12	30
Pre-test						
More Adaptive	23	15.48	5.583	51.6	7	27
More Innovative	8	15.88	4.612	52.9	9	22
Posttest						
More Adaptive	23	22.96	4.343	76.5	12	29
More Innovative	8	24.63	5.605	82.1	15	30

*Note: 30 total points were possible on the pre and posttest*

A Mann-Whitney U test was employed to determine if a statistically significant difference in content knowledge existed based on cognitive style. This test determined that there was no statistically significant difference in content knowledge by cognitive style ( $p = .292$ ) at the .05 level (see Table 4.2 below).

Table 4.2. Mann-Whitney U Test for Differences in Content Knowledge based on Cognitive Styles for Students Enrolled in Introduction to Agricultural Mechanics

<i>U</i>	<i>Z</i>	<i>p</i>
39	-1.053	.292

## Research Question Two

Along with the criterion-referenced pre/posttest, the students were administered the Course Interest Survey (CIS) (Keller, 2010). The students completed the CIS at the beginning of the small gasoline engines unit and then were reassessed at the end of the unit. Research question two asked do differences exist in course motivation by cognitive style. Table 4.3 describes the course motivation based on the cognitive styles of the students enrolled in *Introduction to Agricultural Mechanics*. Overall, average individual pre-course motivation was 150.45, with scores ranging from 129-167. When looking at individual cognitive style categories, individuals who were more adaptive had a mean score of 149.57, with a range of 129-167 on the pre-course motivation survey, while more innovative individuals had a mean score of 153 and a range of 135-165. In terms of the four CIS construct areas; the more adaptive individuals had a mean score of 4.01 in the pre-attention construct, which is interpreted as *mostly true*. The more innovative students also had a mean pre-attention score of 4.19, which is *mostly true*. On the relevancy area, the more adaptive individuals had a mean score of 4.61 and the more innovative individuals had a pre-relevancy score of 4.68, which are both interpreted as *very true*. Within the satisfaction area, the more adaptive individuals had a mean score of 4.49, which is interpreted as *mostly true*. The more innovative students had a mean score of 4.60 pre-satisfaction construct, which is interpreted as *very true*. Finally, in the area of confidence, the more adaptive students had a mean score of 4.45, which is *mostly true*. While, the more innovative individuals had a pre-confidence mean score of 4.50, which are both interpreted as *very true* (see Table 4.3).

Table 4.3. Pre-Course Interest Survey Scores for Students Enrolled in Introduction to Agricultural Mechanics by Cognitive Style (n = 31)

Item	<i>f</i>	<i>M</i>	<i>SD</i>	Minimum	Maximum
Overall Pre-course Motivation	31	150.45	10.430	129	167
Overall Pre-course Motivation by Cognitive Style					
More Adaptive	23	149.57	10.166	129	167
More Innovative	8	153	11.464	135	165
Individual Construct Pre-course Motivation by Cognitive Style					
Attention					
More Adaptive	23	4.01	.521	2.250	4.750
More Innovative	8	4.19	.496	3.125	4.625
Relevance					
More Adaptive	23	4.61	.293	3.890	5.00
More Innovative	8	4.68	.509	3.625	5.00
Satisfaction					
More Adaptive	23	4.49	.452	3.56	5.00
More Innovative	8	4.60	.385	4.00	5.00
Confidence					
More Adaptive	23	4.45	.384	3.75	5.00
More Innovative	8	4.50	.509	3.625	5.00

*Real Limits: 1–1.50 = not true, 1.51–2.50 = slightly true, 2.51–3.49 = moderately true, 3.50–4.49 = mostly true, 4.50–5.00 = very true*

On the post-course motivation survey the average course motivation scores were 151.10, with scores ranging from 109-167. Also, the 23 more adaptive individuals had an average score

of 152.09, with a range of 109-167 on the post-course motivation survey. Whereas the eight more innovative students had an average score of 156 and ranged from 141-167 on the post-course motivation survey. In terms of the four CIS construct areas; in the attention area the more adaptive individuals had a mean score of 4.09, which is interpreted as *mostly true*. The more innovative students also had a mean post-attention score of 4.33, which is *mostly true*. In the relevancy area, the more adaptive and more innovative individuals both had a mean score of 4.64, which is interpreted as *very true*. Within the satisfaction area, the more adaptive individuals had a mean score of 4.56 and the more innovative students had a mean score of 4.67, which again is recorded as *very true*. Finally, in the area of confidence, the more adaptive students had a mean score of 4.58 and the more innovative individuals had a post-confidence mean score of 4.70, which are both interpreted as *very true* (see table 4.4).

Table 4.4. Post-Course Interest Survey Score for Students Enrolled in Introduction to Agricultural Mechanics by Cognitive Style (n = 31)

Item	<i>f</i>	<i>M</i>	<i>SD</i>	Minimum	Maximum
Overall Post-course Motivation	31	153.10	11.80	109	167
Overall Post-course Motivation by Cognitive Style					
More Adaptive	23	152.09	12.79	109	167
More Innovative	8	156	8.37	141	167
Individual Construct Pre-course Motivation by Cognitive Style					
Attention					
More Adaptive	23	4.09	.565	2.875	5.00
More Innovative	8	4.33	.347	3.875	4.875

(table cont'd)



Item	<i>f</i>	<i>M</i>	<i>SD</i>	Minimum	Maximum
Relevance					
More Adaptive	23	4.64	.418	3.110	5.00
More Innovative	8	4.64	.341	4.110	5.00
Satisfaction					
More Adaptive	23	4.56	.455	3.110	5.00
More Innovative	8	4.67	.316	4.110	5.00
Confidence					
More Adaptive	23	4.58	.341	3.75	5.00
More Innovative	8	4.70	.258	4.25	5.00

*Real Limits: 1–1.50 = not true, 1.51–2.50 = slightly true, 2.51–3.49 = moderately true, 3.50–4.49 = mostly true, 4.50–5.00 = very true*

A Mann-Whitney U test was used to determine the statistical significance of the difference between course motivations by cognitive style. The Mann-Whitney U test determined that there was no statistically significant difference in course motivation by cognitive style ( $p = .619$ ) (see table 4.5).

Table 4.5. Mann-Whitney U Test for Differences in Course Motivation by Cognitive Style for Students Enrolled in Introduction to Agricultural Mechanics

<i>U</i>	<i>Z</i>	<i>p</i>
81	-.498	.619

### Research Question Three

Research Question three sought to determine the relationship between cognitive diversity and time to solution. Each of the small gasoline engines groups were given 1 hour and 50 minutes to complete the troubleshooting activity. Table 4.6, describes the teams/small gasoline

sub-groups and their respective times to solution. Overall, the mean time to solution, across all groups, was 39 minutes. Team 1A successfully completed the troubleshooting task in 90 minutes. Their counterpart, 1B, completed their engine in 60 minutes. Team 2A and 2B took 58 and 42 minutes to complete the task, respectively. Team 3A successfully completed the task in 17 minutes; whereas, team 3B completed in 13 minutes. Teams 4A and 4B successfully completed their task in 52 and 60 minutes, respectively. Team 5A, 5B, and 5C successfully completed their troubleshooting task in 14 minutes, 21 minutes, and 1 hour and 12 minutes, respectively. Team 6A completed their task in 56 minutes, whereas team 6B completed their troubleshooting task in 33 minutes. Finally, team 7A and 7B completed their troubleshooting fault in nine minutes and 12 minutes, respectively.

Table 4.6. Introduction to Agricultural Mechanics Small Engine Sub-Grouping Time to Successful Completion of the Troubleshooting Problem

Teams	<i>Time to completion</i>		
	<i>Group A</i>	<i>Group B</i>	<i>Group C</i>
Team 1-Homogeneous Innovative	1 hour 30 minutes	1 hour	-
Team 2-Homogeneous Adaptive	58 minutes	42 minutes	-
Team 3-Heterogenous	17 minutes	13 minutes	-
Team 4-Homogeneous Adaptive	52 minutes	1 hour	-
Team 5-Heterogenous	14 minutes	21 minutes	1 hour 12 minutes
Team 6-Homogeneous Adaptive	56 minutes	33 minutes	-
Team 7-Homogeneous Adaptive	9 minutes	12 minutes	-
Mean Time Solution	39 minutes		

To understand the interaction effect between the cognitive diversity groups the seven teams were collapsed into three main groups, including (a) heterogeneous, (b) homogeneous adaptive, and (c) homogeneous innovative. The heterogeneous cognitive diversity group consisted of team three and team five. The homogeneous adaptive cognitive diversity group consisted of team two, team four, team six, and team seven. Finally, the homogeneous innovative cognitive diversity group consisted of team one. Overall, the heterogeneous cognitive diversity group average time to solution was 27 minutes and 35 seconds. Whereas, the homogeneous adaptive cognitive diversity group mean time to solution was 40 minutes and 15 seconds and the homogeneous innovative group average time to solution was one hour and 15 minutes to successful completion (see Table 4.7).

Table 4.7. Overall Mean Time to Solution by Cognitive Diversity Groups for Students Enrolled in Introduction to Agricultural Mechanics

Groups	Mean Time to Solution
Heterogeneous	27 minutes 35 seconds
Homogeneous Adaptive	40 minutes 15 seconds
Homogeneous Innovative	1 hour and 15 minutes

A non-parametric one-way ANOVA was utilized to determine the statistical significance of the effect cognitive diversity has on time to solution (see Table 4.8). The Kruskal-Wallis test determined that there was a statistically significant difference in time to solution by cognitive diversity and time to solution,  $H(8.206) = 2, p = .017$ . Effect size was also reported to standardize the measure of the effect observed. The analysis of the effect size revealed an  $r$  value of .70, which is interpreted as a large effect ( $r > .50$ ).

Table 4.8. Overall Kruskal-Wallis Test for Differences in Time to Solution by Cognitive Style Group for Students Enrolled in Introduction to Agricultural Mechanics

<i>H</i>	<i>df</i>	<i>p</i>
8.206	2	.017

In order to compare groups, Mann-Whitney U tests were employed *post hoc* to determine if a difference existed between two independent groups. In this study, the groups in question were homogeneous innovative, homogeneous adaptive, and heterogeneous. Therefore, three independent Mann-Whitney U tests were conducted between homogeneous adaptive and homogeneous innovative, homogeneous adaptive and heterogeneous, and homogeneous innovative and heterogeneous. The Mann-Whitney U test between homogeneous adaptive and heterogeneous groups determined there was no statistically significant difference between the two groups time to solution and cognitive diversity ( $p = .580$ ), however, a statistically significant difference was found between the homogeneous adaptive and homogeneous innovative group ( $p = .023$ ) and homogeneous innovative and heterogeneous group ( $p = .004$ ) (see Table 4.9 below). Effect size was also reported to standardize the measure of the effects observed between all statistically significant cognitive diversity groups. An  $r$  value of .61 was revealed between the homogeneous adaptive and homogeneous innovative, which is a large effect ( $p > .50$ ). Also, between the homogeneous innovative and heterogeneous group revealed an  $r$  value of .63, which is also interpreted as a large effect ( $p > .50$ ).

Table 4.9. Mann-Whitney U Tests of Differences in Time to Solution by Cognitive Diversity Groups for Students Enrolled in Introduction to Agricultural Mechanics

Groups	U	Z	<i>p</i>
Homogeneous Adaptive vs. Heterogeneous	74	-.554	.580
Homogeneous Adaptive vs. Homogeneous Innovative	2	-2.886	.004
Homogeneous Innovative vs. Heterogeneous	4	-2.280	.023

#### Research Question Four

Along with time to solution, the teams were asked to hypothesize the possible problem and solution (see Table 4.10). Hypothesis generation ability was operationalized as correct or not correct on their hypothesis number one. The homogeneous innovative cognitive diversity group consisted of all teams who were more innovative, which included team one. Based on hypothesis generation one, all four individuals hypothesized incorrectly. The homogeneous adaptive cognitive diversity group consisted of teams who more adaptive, which include team two, team four, team six, and team seven. Within this cognitive diversity group, seven (41.18%) of the 17 individuals correctly hypothesized and 10 (58.82%) hypothesized incorrectly on hypothesis one. Finally, the heterogeneous cognitive diversity group consisted of teams who were made up of a more innovative and more adaptive individual, which included team three and team five. Of the members in this cognitive diversity group, six (60%) hypothesized correctly the first time, while four (40%) hypothesized incorrectly.

4.10. Hypothesis Generation Ability based on Cognitive Diversity Groups for Students in Introduction to Agricultural Mechanics

Cognitive Diversity	<i>Hypothesis Generation 1</i>			
	<i>Correct</i>		<i>Not Correct</i>	
	<i>f</i>	<i>%</i>	<i>f</i>	<i>%</i>
Homogeneous Innovative	0	0	4	100
Homogeneous Adaptive	7	41.18	10	58.82
Heterogeneous	6	60	4	40
Overall Total	13	41.94	18	58.06

In order to test for relationships between the cognitive diversity groups, three independent Pearson Chi-Square tests were employed to determine the effect that cognitive diversity has on hypothesis generation ability in order to successfully problem solve. The analysis from these tests revealed no statistically significant difference between the homogeneous adaptive cognitive diversity group and the heterogeneous  $\chi^2 (.894) = 1, p = .345$ . Also, no statistically significant difference was found between the homogeneous adaptive group and the homogeneous innovative group  $\chi^2 (2.471) = 1, p = .116$ . However, a statistically significant difference was found between the homogeneous innovative group and the heterogeneous group  $\chi^2 (4.200) = 1, p = .040$  based on hypothesis generation ability (see Table 4.11).

Table 4.11. Pearson Chi-Square Test between Cognitive Diversity Groups for Students Enrolled in Introduction to Agricultural Mechanics

Groups	Value	<i>df</i>	<i>p</i>
Homogeneous Adaptive vs. Heterogeneous	.894	1	.345
Homogeneous Adaptive vs. Homogeneous Innovative	2.471	1	.116
Homogeneous Innovative vs. Heterogeneous	4.200	1	.040

### Research Question Five

Research question five aimed to describe the effect hypothesis generation had on the time required to solve the problem correctly (see Table 4.12). The students in each team were divided into smaller subgroups (i.e. 1A, 1B, or 1C) and asked to hypothesize the problem first before troubleshooting. Table 4.9 describes each subgroup team and the number of times they were required to hypothesize before they correctly solved the problem. In all, only six of the 15 sub-teams hypothesized correctly the first time. The remaining nine teams required a second hypothesis to correctly troubleshoot the small engine.

Table 4.12. Small Engine Sub-Grouping Hypothesis Generation Ability for Students in Introduction to Agricultural Mechanics

Teams	<i>Group A</i>		<i>Group B</i>		<i>Group C</i>	
	<i>Hyp. 1</i>	<i>Hyp. 2</i>	<i>Hyp. 1</i>	<i>Hyp. 2</i>	<i>Hyp. 1</i>	<i>Hyp. 2</i>
Team 1	No	Yes	No	Yes	-	-
Team 2	Yes	-	No	Yes	-	-
Team 3	Yes	-	Yes	-	-	-
Team 4	No	Yes	No	Yes	-	-
Team 5	Yes	-	No	Yes	No	Yes
Team 6	No	Yes	No	Yes	-	-
Team 7	Yes	-	Yes	-	-	-

*Note: A dash represents hypothesis 2 was not required.*

Table 4.13, below, describes the hypothesis generation ability of the cognitive diversity groups. Within the groups, none of the homogeneous innovative teams hypothesized correctly the first time, but all (4, 100%) hypothesized correctly the second time. Seven of the individuals

in the homogeneous adaptive group hypothesized correctly the first time, while 10 required a second hypothesis. Finally, in the heterogeneous group, six (60%) only required one hypothesis, while four (40%) required a second hypothesis to successfully solve the problem.

Table 4.13. Hypothesis Generation Ability based on Cognitive Diversity Groups for Students in Introduction to Agricultural Mechanics

Cognitive Diversity	<i>Hypothesis Generation Ability</i>			
	<i>Hyp. 1</i>		<i>Hyp. 2</i>	
	<i>f</i>	<i>%</i>	<i>f</i>	<i>%</i>
Homogeneous Innovative	0	0	4	100
Homogeneous Adaptive	7	41.18	10	58.82
Heterogeneous	6	60	4	40

Along with hypothesis generation, the teams were timed on how quickly they could successfully diagnose and fix the problem. Overall, the average time to completion was 39 minutes. Team 7A and 7B completed the task quickest with times of nine and 12 minutes, respectively. Teams 3A and 3B completed the exercise in 17 and 13 minutes, respectively. Teams 6A and 6B completed the troubleshooting exercise in the 56 minutes and 33 minutes, respectively. Team four group A and B completed with times of 52 and 1 hour. Finally, team five groups A, B, and C completed the troubleshooting task in 14 minutes, 21 minutes, and one hour and 12 minutes, respectively. Table 4.14, below, describes the teams and subgroups with their time to completion.



Table 4.14. Introduction to Agricultural Mechanics Small Engine Sub-Grouping Time to Successful Completion of the Troubleshooting Problem

Teams	<i>Time to completion</i>		
	<i>Group A</i>	<i>Group B</i>	<i>Group C</i>
Team 1-Homogeneous Innovative	1 hour 30 minutes	1 hour	-
Team 2-Homogeneous Adaptive	58 minutes	42 minutes	-
Team 3-Heterogenous	17 minutes	13 minutes	-
Team 4-Homogeneous Adaptive	52 minutes	1 hour	-
Team 5-Heterogenous	14 minutes	21 minutes	1 hour 12 minutes
Team 6-Homogeneous Adaptive	56 minutes	33 minutes	-
Team 7-Homogeneous Adaptive	9 minutes	12 minutes	-
Mean Time Solution	39 minutes		

A Mann-Whitney U test was used to determine the statistical significance of the effect hypothesis generation had on the time required to solve the problem correctly (see Table 4.15). The Mann-Whitney U test determined that there was a statistical significance between hypothesis generation ability and time to solution ( $p = <.001$ ) at the .05 level. Effect size was also reported to standardize the measure of the effect observed. The analysis of the effect size revealed an  $r$  value of .70, which is a large effect ( $r > .50$ ).

Table 4.15. Mann-Whitney U Test for Differences in Hypothesis Generation and Time to Solution for Students Enrolled in Introduction to Agricultural Mechanics

U	Z	p
20.00	-3.893	<.001

To understand the interaction effect between hypothesis generation and time to solution based on cognitive diversity group, three independent *post hoc* Mann-Whitney U tests were

conducted (see Table 4.16). The output from this analysis revealed that there was a statistical significance between the homogeneous adaptive group and heterogeneous group ( $p = .001$ ) at the .05 level. Also, a statistically significant difference was found between the homogeneous adaptive and homogeneous innovative group ( $p = .013$ ) and the homogeneous innovative and heterogeneous group ( $p = .002$ ) at the .05 level. To measure the effect observed, effect size was also reported for each Mann-Whitney U test. Between the homogeneous adaptive and heterogeneous group, revealed an  $r$  value of .66, which is a large effect ( $r > .50$ ). An  $r$  value of .54 was revealed between the homogeneous adaptive and homogeneous innovative group, which is also reported as a large effect ( $r > .50$ ). Finally, the homogeneous innovative and heterogeneous group revealed an  $r$  value of .83, which is a large effect ( $r > .50$ ).

4.16. Mann-Whitney U Tests of Differences in Hypothesis Generation and Time to Solution by Cognitive Diversity Groups for Students Enrolled in Introduction to Agricultural Mechanics

Groups	U	Z	p
Homogeneous Adaptive vs. Heterogeneous	20	-3.454	.001
Homogeneous Adaptive vs. Homogeneous Innovative	16	-2.479	.013
Homogeneous Innovative vs. Heterogeneous	0	-3.122	.002

## CHAPTER V: CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

### Statement of the Problem

In recent years, it has become increasingly important for educators to adapt to new pedagogies in order to develop higher order thinking skills for their students to meet the demands of the 21st century workplace (Fuhrmann & Grasha, 1983; Jonassen, 2000; Ulmer & Torres, 2007). Due to the highly structured components of the work place, skills associated with problem solving or critical thinking are highly desired (Gokhale, 1995) because employers want individuals who can find, identify, and solve complex problems in an effective and efficient manner (Johnson, 1991).

Generally, educators have a variety of instructional methods available to them in order to meet needs of diverse learners. However, the problem solving approach, especially in agricultural education, has been highly regarded as the best method of instruction (Dyer, 1995). The problem solving approach provides students with the skills necessary to develop important metacognitive processes, which promote higher order thinking skills and improved problem solving ability (Dyer, 1995; Zimmerman & Risemberg, 1997). Historically, this has been achieved more easily in the agricultural education curriculum which is known for its hands-on learning processes designed to provide students with the necessary real-world learning experiences.

Problem solving skills have been identified as one of the most important cognitive activities encountered in our everyday lives (Jonassen, 2000). As part of our routine, we often solve hundreds of problems a day ranging from simple to complex (Jonassen, 2000). However, students today often do not solve meaningful problems as a part of their curricula (Jonassen,

2000). Fortunately, problem solving skills can be taught and refined by enhancing the learning environment and building metacognitive skills (Lester, 1994; Sproull, 2001).

Education literature conveys the importance of cognitive styles of students as an important function of our everyday lives (Myers & Dyer, 2006; Parr & Edwards, 2004; Thomas, 1992; Torres & Cano, 1995a; Witkin et al., 1977). However, educators generally do not teach a significant amount of problem solving or critical thinking skills in their curriculum in order to build effective problem solvers (Jonassen, 2000; Ulmer & Torres, 2007). Blackburn et al. (2014), Lamm et al. (2011) concluded educators must be aware of different cognitive styles and understand how to tailor lessons to effectively teach critical thinking and problem solving skills. The previous review raises the question: How does cognitive style influence a student's ability to effectively problem solve in a small group setting?

### **Purpose of the Study**

The primary purpose of this study was to investigate the effects of cognitive diversity on the problem solving ability of undergraduate students enrolled in a team-based learning formatted agricultural mechanics course.

### **Research Problem**

What effect does cognitive diversity have on students' ability to solve problems when troubleshooting a small gasoline engine?

### **Research Questions**

1. Do differences exist in content knowledge of undergraduate students enrolled in an introduction to agricultural mechanics course by cognitive style?
2. Do differences exist in course motivations of undergraduate student enrolled in an introduction to agricultural mechanics course by cognitive style?

3. Does team cognitive diversity have an effect on time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?
4. Does team cognitive diversity have an effect on the hypothesis generation ability of undergraduate students enrolled in an introduction to agricultural mechanics course when solving small gas engine problems?
5. Does hypothesis generation have an effect on the time required for undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?

### **Summary of Findings**

#### **Research Question One: Effect of Cognitive Style on Student Content Knowledge**

In all, 23 (74.2%) of the 31 individuals scored a 95 or lower on the KAI and were considered more adaptive, however, 8 (25.8%) individuals scored a 96 or higher on the KAI and were considered more innovative. Based on the 30-item criterion reference test, the overall mean score on the pretest was 15.58 out of 30 and after reassessment the mean posttest score was 23.39 out of 30 possible points. When looking at cognitive style, the more adaptive individuals scored an average of 15.48 out of 30 on the pretest; whereas, the more innovative individuals had an average score of 15.88 on the pretest. On the posttest, the more adaptive individuals had a mean score of 22.96 out of 30 and the more innovative individuals had mean score of 24.63.

A Mann-Whitney U test was utilized to determine if there was a statistically significant difference in cognitive style by content knowledge. The Mann-Whitney U test revealed no statistically significant difference in an individual's content knowledge by cognitive style ( $p =$

.292). To standardize the size of the effect observed, the effect size was reported and revealed an  $r$  value of .189, which is reported as a small effect ( $r < .30$ ). Therefore, cognitive style is interpreted to have very little influence on student's content knowledge from the pre to posttest observation.

### **Research Question Two: Effect of Cognitive Style on Student Course Motivation**

Of our 31 participants, 74.2% of them were considered more adaptive (95 or lower), while only 25.8% were considered more innovative (96 or higher) based on their individual KAI scores. When looking at course motivation, amongst the entire group, the average pre-course score was 150.45 out of 180, whereas post-course motivation mean scores were 151.10. In terms of individual cognitive style categories, more adaptive individuals had a mean pre-course motivation score of 149.57 and a post-course score of 152.09. However, the more innovative individuals had a pre-course motivation mean score of 153 and a post-course motivation score of 156.

To determine the effect cognitive style has on course motivation, a Mann-Whitney U test was utilized to analyze the interaction. It was determined that there was no statistically significant difference in an individual's course motivation by cognitive style ( $p = .619$ ). Also, the effect size analysis revealed an  $r$  value of .089, which is considered a small effect ( $r < .30$ ). Therefore, it is determined that individual cognitive style has little to no effect on students' course motivation from the pretest observation to the posttest observation.

### **Research Question Three: Effect of Cognitive Diversity on Time Required**

Overall, amongst all seven teams, the mean time to solution was 39 minutes. When looking at cognitive diversity groups, the homogeneous innovative group (Team 1) had an average time to solution of one hour and 15 minutes. The homogeneous adaptive cognitive

diversity group (Teams 2, 4, 6, & 7) had an average time to solution of 40 minutes and 15 seconds. Finally, the heterogeneous cognitive diversity group (Teams 3 & 5) had an average time to solution of 27 minutes and 35 seconds.

To understand the interaction between cognitive diversity and time required to effectively solve the problem, a Kruskal-Wallis test was employed and revealed that there was a statistically significant difference between overall team cognitive diversity and time to solution,  $H(8.206) = 2, p = .017$ . However, in order to understand the effect between the three cognitive diversity groups, a series of three *post hoc* Mann-Whitney U tests were conducted. The Mann-Whitney U test between the homogeneous adaptive and heterogeneous cognitive diversity group revealed no statistical significance ( $p = .580$ ) between cognitive diversity and time to solution. However, the Mann-Whitney U tests between the homogeneous adaptive and homogeneous innovative and the homogeneous innovative and heterogeneous both revealed a statistically significant difference between cognitive diversity and time to solution,  $p = .023$  and  $p = .004$ , respectively. Effect sizes were reported for any statistically significant relationships found between cognitive diversity group and time to solution; therefore, an  $r$  value of .61 was revealed between the homogeneous adaptive and homogeneous innovative group and an  $r$  value of .63 was revealed between the homogeneous innovative and heterogeneous groups, which indicate that both values have a large effect ( $p > .50$ ).

#### **Research Question Four: Effect of Cognitive Diversity on Hypothesis Generation**

In terms of hypothesis generation ability, 18 (58.06%) of the 31 students hypothesized incorrectly on their first hypothesis and 13 (41.94%) of the 31 students hypothesized correctly. In terms of cognitive diversity, the homogeneous innovative group was the least successful at hypothesis generation, on hypothesis one, with none being correct. However, of the 17

homogeneous adaptive individuals seven (41.18%) hypothesized correctly the first time, while 10 (58.82%) were incorrect. Finally, within the heterogeneous cognitive diversity group, six (60%) hypothesized correctly and 4 (40%) hypothesized incorrectly on hypothesis one.

To test for relationships between the three cognitive diversity groups, three independent Pearson Chi-Square tests were utilized. The analysis revealed that there was no statistically significant differences between the homogeneous adaptive and homogeneous innovative  $\chi^2 (.894) = 1, p = .345$  and the homogeneous adaptive and heterogeneous group  $\chi^2 (2.471) = 1, p = .116$ . However, a statistically significant difference was found between the homogeneous innovative group and the heterogeneous cognitive diversity group  $\chi^2 (4.200) = 1, p = .040$ .

#### **Research Question Five: Effect of Hypothesis Generation on Time Required**

Overall, of the 15 small gasoline sub-grouping, only six hypothesized correctly on the first try, while the remaining nine small gasoline sub-groups required a second hypothesis to correctly solve the problem. When breaking it down further into the cognitive diversity groups, the homogeneous innovative group did not hypothesis correctly the first time and required a second hypothesis. Within the homogeneous adaptive cognitive diversity group, six hypothesized correctly the first time and 10 required a second hypothesis. Finally, six hypothesized correctly on hypothesis one in the heterogeneous cognitive diversity group, while four required a second hypothesis. Further, in all, the average time to solution between all groups was 39 minutes.

To determine the relationship existed between hypothesis generation and time to solution a Mann-Whitney U test was employed. In regards to the Mann-Whitney U test, there was found to be a statistically significant difference between hypothesis generation and time to solution ( $p = .000$ ). The reported effect size revealed an  $r$  value of .70, which is a large effect ( $r < .50$ ).



Therefore, it is interpreted that if a student hypothesizes correctly the first time they will have a quicker time to solution than someone having to hypothesize twice.

To measure the interaction effect between the cognitive diversity groups, in regards to hypothesis generation and time to solution, three independent *post hoc* Mann-Whitney U tests were employed. These tests revealed a statistically significant difference existed between homogeneous innovators and homogeneous adaptors ( $p = .013$ ), which yielded an  $r$  value of .54. Also, a statistically significant difference was found between the homogeneous innovative and heterogeneous ( $p = .002$ ) and the homogeneous adaptive and heterogeneous group ( $p = .001$ ), which yielded  $r$  values of .66 and .83, respectively.

## **Conclusions/Discussion**

### **Content Knowledge**

At the beginning of the small gasoline engine unit, the students were given a 30-item criterion-reference pretest to assess their content knowledge. The analysis revealed that no differences existed between an individual's content knowledge by cognitive style. This conclusion is consistent with previous research by Dyer and Osborne (1996), which also found no differences between student learning styles and pre and posttest problem solving ability as reported by the GEFT. Conversely, Torres and Cano (1994) found that learning style did however have a positive effect on student achievement in specific situations.

Further, this conclusion is not consistent with much of the troubleshooting literature that reiterates the importance of knowledge a troubleshooter must possess in order to effectively interact with the system (Hegarty, 1991; Johnson & Flesher, 1993; Jonassen, 2003). Hegarty (1991) stated that an effective problem solver must possess an ample amount of conceptual and procedural knowledge. Nevertheless, this conclusion is consistent with the Kirton's Adaptation-

Innovation Theory, which indicated that cognitive style is not an indicator of intelligence, but rather an indicator of *how* individuals go about solving problems (Kirton, 2003).

### **Course Motivation**

After completing the pretest and posttest, students were asked to complete a course interest survey to determine the effects of cognitive style on course motivation. However, much like content knowledge, there were found to be no differences between an individual's course motivations by cognitive style. Also, the more innovative students had higher course motivations on the pre and posttest than the more adaptive students. When examining each individual ARCS construct in the CIS, all students had the highest motivation in the area of relevance and satisfaction. Therefore, the students in this course felt that the course content was relevant to their overall learning and indicated that they were highly satisfied with the course.

This conclusion, however, is not consistent with previous research done by McCubbins et al. (2016) and McCubbins et al. (2018), which indicated that working in teams increased student motivation to learn and work collaboratively. However, it is more consistent with research completed by Figland, Blackburn, and Roberts (2019), which indicate students have an overwhelming positive perception of a team-based learning formatted agricultural mechanics course and are highly satisfied with the course.

### **Time to Solution**

In all, 31 student completed and solved the troubleshooting problem successfully regardless of cognitive style. In terms of group cognitive diversity, the heterogeneous group solved the problem on average 13 minutes faster than the homogeneous adaptive group and 48 minutes faster than the homogeneous innovative group. The homogeneous adaptive group, however, solved the problem on average 34 minutes and 45 seconds faster than the homogeneous

innovative group. Therefore, the heterogeneous cognitive diversity group was more efficient type problem solver. However, Pate and Miller (2011) found that students who utilized groups to problem solve, took an average of four minutes longer to solve the problem. Also, a difference amongst cognitive diversity groups and time to solution was identified between the homogeneous adaptive and homogeneous innovative and the homogeneous innovative and heterogeneous. However, the homogeneous adaptive and heterogeneous cognitive diversity group revealed no difference between cognitive diversity and time to solution. This conclusion also supports the adaptation-innovation theory that indicates each cognitive style has its own distinct characteristics when problem solving, which can affect how efficiently they are able to solve problems (Kirton, 2003).

### **Hypothesis Generation Ability**

During the troubleshooting exercise, students were asked to create a written hypothesis based on the information they collected when trying to start their respective engines. However, regardless of cognitive diversity the teams who generated the correct hypothesis on the first attempt were more likely to solve the problem quicker; whereas, the more times the team hypothesized the more time it took to complete the troubleshooting task. This is consistent with previous research by Blackburn and Robinson (2016), which indicated that regardless of cognitive style and problem complexity, students who generated a correct hypothesis were more efficient problem solvers. Similarly, Blackburn and Robinson (2017) also indicated the majority of students were able to identify and hypothesize regardless of cognitive style, however, more adaptive students were more likely to hypothesize correctly on the simple problem; whereas, the more innovate students were more likely to solve a complex problem. Further, previous research

by Johnson (1989) also concluded that students who generate a correct hypothesis are more likely to be able to solve the problem.

Also, the most efficient group of problems solvers where the heterogeneous teams who solved the problem the quickest, but also were able to more accurately hypothesis. The homogeneous adaptive group was the second most efficient at solving the problem, but were least likely to hypothesize the problem correctly. However, the homogeneous innovative teams were the least efficient at problem solving and did not hypothesis correctly on hypothesis one. This is consistent with previous research conducted in troubleshooting, which ascertain that those who generate a correct hypothesis the first time are more likely to solve the problem faster than those who require more than one hypothesis (Blackburn & Robinson, 2016, 2017; Johnson, 1989). Further, this supports the adaptation-innovation theory that no matter the individual's cognitive style, anyone can solve problems (Kirton, 2003).

Further, the heterogeneous cognitive diversity group were the most efficient at identifying and hypothesizing the problem correctly on hypothesis one. Conversely, the homogeneous innovative cognitive diversity group were the least successful at hypothesizing correctly the first time and were the slowest to completion. These conclusions are consistent with previous research completed by Lamm et al. (2011), which suggests that the heterogeneous groups were able to utilize all five stages of Bransford's (1989) IDEAL problem solving model and were more effective problem solvers. Similarly, Lamm, Carter, Settle, and Odera (2016) found that teams, who represented diverse cognitive styles, enhance the consensus process and problem solving ability. This is also consistent with Kirton (2003) A-I theory, that indicated groups with KAI score gaps of 20+ points, are more efficient at problem solving broad problems as long as they manage their wide variety of cognitive diversity.

## **Problem Solving Ability**

In regards to overall problem solving ability, the students who were able to correctly hypothesize on the first attempt were more efficient at identifying and solving the problem. However, when examining cognitive diversity, the homogeneous adaptive teams were on average half as likely to hypothesize correctly, on the first try, than the heterogeneous teams. However, both the homogeneous adaptive and heterogeneous teams were more effective at hypothesizing correctly on hypothesis one, than the homogeneous innovative teams. Also, the heterogeneous teams solved the problem quicker than the homogeneous adaptive and innovative, but the homogeneous innovative teams were the slowest.

Further, this conclusion is consistent with the Kirton's A-I theory on homogeneous and heterogeneous teams. Kirton (2003) ascertained that groups of either all innovators or all adapters, tend to collaborate easily on simple problems, however, they can struggle when faced with more difficult problems. This theory also states that homogeneous innovative group's likely work better together, but are less efficient at solving problems than any other problem solving style (Kirton, 2003). Per the theory, the most effective and efficient types of problem solvers are those who are put into heterogeneous groups because of the wide variety of cognitive diversity; however, they may have to manage the communication difficulties in order to be effective problem solvers (Kirton, 2003).

Also, this conclusion is supported by Johnson and Flesher (1993) which indicated that differences in cognitive style have an impact on learning and an individual's troubleshooting style. Johnson and Flesher (1993) also ascertain that there are three primary types of troubleshooters, (a) Gamblers, (b) Testers, and (c) Thinkers and all of these troubleshooting

styles are determined by cognitive style and affect how efficient and effective an individual is at problem solving.

### **Implications**

The purpose of this research was to understand the effect cognitive style had on problem solving ability of students who were enrolled in *AEEE 2003-Introduction to Agricultural Mechanics*. To achieve the purpose and research questions, problem solving ability was operationalized as whether or not the students could solve the troubleshooting problem. While troubleshooting, the students were measured on time to solution and on their ability to hypothesize. Overall, 100% of our participants were able to identify and solve the problem, which directly aligns with Kirton's (2003) Adaptation-Innovation theory, which indicates all individuals, regardless of cognitive style, can solve problems.

In regard to cognitive diversity and time to solution, there were statistically significant differences found between the more adaptive and more innovative groups, and the more innovative and heterogeneous groups. Overall, the more heterogeneous cognitive diversity group was able to solve the problem on average 24 minutes quicker than any of the other groups. However, the homogeneous adaptive group was able to solve the problem almost 35 minutes faster than the homogeneous innovator group. These substantial time differences between cognitive diversity groups arose the question "Why do these time differences between cognitive diversity groups exist? Perhaps, it is the differences in how each of the cognitive style groups go about solving problems. Kirton (2003) stated that groups of homogeneous adaptors tend to excel in problem solving when the problem is structured and has boundaries. Whereas, the more innovative individuals tend problem solve more efficiently with less structure and challenge those set boundaries (Kirton, 2003). However, Kirton (2003) also stated the most successfully

types of problem solvers are heterogeneous groups who are able to manage their wide variety of cognitive diversity because they are able to utilize both cognitive styles (Kirton, 2003). Therefore, per the theory, it could be beneficial to purposefully group students based on cognitive style into heterogeneous groups.

Along with time, the teams were asked to identify system symptoms and create a hypothesis of the fault. Again, statistically significant differences were found between the heterogeneous cognitive diversity group and the homogeneous innovative, but no statistical significance was found between the homogeneous adaptive and homogeneous innovative and the homogeneous adaptive and heterogeneous groups. Overall, the most successful cognitive diversity group at hypothesizing correctly on hypothesis one, was the heterogeneous group. The least successful group on a correct hypothesis one, was the homogeneous innovative group. Much like the time to solution question, the same question arose, “Why do differences in hypothesis generation exist between cognitive diversity groups?” Again, per the A-I theory, the more adaptive individuals tend to solve problems more effectively that are structured and have boundaries, while the more innovative excel at problems with no boundaries and little structure (Kirton, 2003). Perhaps, the heterogeneous groups were more successful at hypothesis generation because they were able to utilize and manage the wide cognitive diversity range; therefore, broadening their problem solving ability scope (Kirton, 2003).

In Johnson’s (1989) technical troubleshooting model, the students are required to hypothesize once and if they indicate their initial hypothesis to be incorrect, they are to go back to phase one and hypothesize again. This process is continual until the troubleshooter correctly hypothesizes the fault. Perhaps, the homogeneous innovative cognitive diversity group, were least successful at hypothesizing correctly the first time because they proliferated too many ideas

and were unable to identify and recognize the problems; therefore they struggled to make a hypothesis (Bransford, 1993; Johnson, 1989; Kirton, 2003). Also perhaps, they generated multiple hypotheses from symptom problems and were then unable to make a decision on the correct one.

Nevertheless, the teams who hypothesized correctly on hypothesis one were more likely to have a quicker time to solution. Perhaps, the heterogeneous groups were better at problem solving because they solved problems more linearly and were able to utilize all the steps in Bransford's (1993) IDEAL problem solving model, which allowed them to be effective and efficient problem solvers. Perhaps one of the reasons the homogeneous adaptive and innovative groups were less successful at solving the problem on hypothesis one and had slower times to solution was because they got lost in the details and had a harder time moving through all the steps in the IDEAL model, which created gaps in their problem solving process and led to errors (Bransford, 1993). Perhaps it was a difference in conceptual and procedural knowledge or metacognitive ability?

In terms of content knowledge, there was found to be no statistically significant differences by cognitive style. However, the majority of the troubleshooting literature reiterates the importance of declarative knowledge in a domain in order to successfully troubleshoot (Hegarty, 1991; Johnson, 1989; Johnson & Flesher, 1993; Jonassen, 2003). The overall average pretest score was a 15.58 out of 30, which would be considered a failing grade and the posttest score was a 23.39 out of 30, which would be considered an average passing grade. However, even with an increase in conceptual knowledge, some of the cognitive diversity groups were less successful at hypothesizing and had a slower time to completion. Could it be said that perhaps conceptual knowledge is only a prerequisite to troubleshooting and procedural knowledge is



more important? Anderson (1980) and McCormick (1997) stated that conceptual knowledge only deals with the knowledge of *facts*, whereas procedural knowledge is one's knowledge on *how* to do something. Perhaps, the ability to know *how* to troubleshoot and solve problems stems from a lack of metacognitive ability. Perhaps, the heterogeneous groups are more successful troubleshooters because of a wide range of metacognitive ability, which allows them to create more schemas of the problem. Maybe, the homogeneous innovator groups are least successful at troubleshooting because they lack the metacognitive ability to create those schemas. According to Zimmerman and Risemberg (1997) and Davidson and Sternberg (1998) metacognitive skills are essential prerequisite skills to effective problem solving. Davidson and Sternberg (1998) go on to explain that metacognitive activities allow students to encode the problem type by forming mental schemas of the problem, which in turn allow them to select the most appropriate plan. Could it be that the ability to regulate these metacognitive abilities has an effect on how students perform on problem solving when grouped by cognitive style? Perhaps, the ability to regulate the metacognitive process is interfered by motivation. Vermunt (1996) stated that an individual's emotional state can have a large influence on the ability of the person's metacognitive activities. Therefore, maybe the homogeneous innovative group became increasingly frustrated with the problem when they hypothesized incorrectly the first time, which led to more mistakes and the longest time to completion.

Based on the course interest survey, there were found to be no statistically significant differences in course motivation by cognitive style. However, it was found that course motivations, between the two cognitive styles, increased from pre to post. When digging deeper into this category, it was noted that the more innovative individuals had higher course motivation on the pre and the posttest than the more adaptive students, but the more innovative individuals

are the least successful troubleshooters. Perhaps, they have higher motivations because of the course structure, which allows for less structure and more idea generation ability with the more innovative student prefer (Kirton, 2003; Michealsen & Sweet, 2004; Sibley & Ostafichuk, 2015). Maybe, the slight increase in motivation is because of the adoption of a TBL formatted course, which allowed for a student-centered learning environment (Michealsen & Sweet, 2004; Sibley & Ostafichuk, 2015).

## **Recommendations**

### **Recommendations for Practice**

From the results of this study, it is recommended that educators assess students' cognitive styles and then purposefully group students into heterogeneous cognitive diversity groups in undergraduate agricultural courses that are heavily laboratory based. Kirton (2003) concluded that heterogeneous groups can be more effective and efficient problem solvers if they are able to manage their wide range of cognitive diversity.

It is also recommended that educators consider adopting active learning environments, like TBL, to help promote the development of problem solving skills. It has become increasingly important for educators to adapt to new pedagogies in order to meet the demands of the 21st century (Blackburn et al., 2014) because the agricultural industry today desires employees who are able to effectively and efficiently problem solve (Robinson & Garton, 2008). Based off the results of this study, the ability for students to hypothesize correctly has increased their problem solving effectiveness and efficiency.

It is also recommended that educators create more questions or application activities that are specifically designed to help develop an individual's procedural knowledge. Much of the literature on troubleshooting reiterates the importance of developing an individual's conceptual

and procedural knowledge (Anderson, 1980; Johnson & Flesher, 1993; Johnson, 1989; Jonassen, 2003; Hegarty, 1991, McCormick, 1997). Therefore, it is important for educators to be developing the students *how* knowledge when dealing with problem solving tasks.

### **Recommendations for Research**

Additional research is warranted to further investigate the effects of cognitive diversity on hypothesis generation and time to solution on the problem solving ability of undergraduate students. Specifically, it is recommended that this study be replicated to increase the sample size and make the findings more generalizable.

Further replication of this study is also warranted to study the effects of cognitive diversity on hypothesis generation ability and time to solution in SBAE programs. Also, to fully be able to account for extraneous variables, full randomization of treatment and control groups are needed in order to make the findings generalizable to a larger demographic.

Also, research investigating the role conceptual and procedural knowledge have on the troubleshooting process in agricultural mechanics is warranted. The results from this study indicate that there is no statistically significant differences in content knowledge based on cognitive style, however, statistically significant differences were found when specifically looking at cognitive diversity, time to solution, and hypothesis generation ability.

Additional research is also recommended to further investigate the role cognitive diversity has on student motivation. The results from this study indicate no statistically significant relationship existed between cognitive diversity and course motivation. However, the more innovative students reported being more motivated on the pre and posttest than any other group. Investigating factors associated with student motivation may bring insight into the role motivation has on problem solving ability.

Also, further research is warranted to investigate the effects metacognitive activities have on the troubleshooting ability of undergraduate students. Specifically, the effects metacognitive activities have on the individuals' ability to generate hypothesis. Zimmerman and Risemberg (1997) and Davidson and Sternberg (1998) state that metacognitive skills are an essential prerequisite to effectively problem solve. Similarly, Davidson and Sternberg (1998) explain that metacognitive activities are a driving force that allows students to encode the problem type by forming mental schemas of the problem, which in turn allow them to select the most appropriate plan.

Finally, research is also recommended to investigate the short and long-term effects of TBL; specifically, on critical thinking, problem solving ability, and self-efficacy. Previous literature states that active learning classrooms provide students with the opportunity to engage in real-world problems, which increase critical thinking and problem solving skills (Michealsen & Sweet, 2008; Sibley & Ostafichuk, 2015). Also, research indicates that TBL provides students with opportunities to learn conceptual and procedural knowledge and provides a complete framework for cognitive development, critical thinking skills development, and building problem solving skills (Michaelson & Sweet, 2012).

### **Limitations**

Findings from this research study should not be generalized to any other population outside of the sample because the study was limited to the students who were enrolled in *AEEE 2003-Introduction to Agricultural Mechanics* at Louisiana State University. Also, the students elected to take *AEEE 2003-Introduction to Agricultural Mechanics* and were not randomly assigned to treatment groups. Therefore, random assignment to control extraneous variables was not utilized.

Experimental mortality affected the results of this study because one student in the course did not complete the necessary materials required of the course. Experimental mortality refers to losing study participants before the completion of the project or data collection. Data were collected from 32 participants enrolled in the introduction to agricultural mechanics course, however, only 31 students completed all parts of the research project fully. Therefore, incomplete data existed.

Finally, a low sample size affected the generalizability of the results of this study. Because of the limited sample size, this preexperimental study, utilized nonparametric statistics. Nonparametric statistics allowed the researcher to make fewer assumptions of the data, but still allow the research to examine the phenomenon. However, because of this limitation, the results of this study should be confined to this population.

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APPENDIX A. IRB APPROVAL FORM



ACTION ON EXEMPTION APPROVAL REQUEST

TO: Joey Blackburn  
Agricultural and Extension Education & Evaluation

Institutional Review Board  
Dr. Dennis Landin, Chair  
130 David Boyd Hall  
Baton Rouge, LA 70803  
P: 225.578.8802  
F: 225.578.5983  
[irb@lsu.edu](mailto:irb@lsu.edu)  
[lsu.edu/research](http://lsu.edu/research)

FROM: Dennis Landin  
Chair, Institutional Review Board

DATE: December 5, 2017

RE: IRB# E10769

TITLE: Investigating the effects of cognitive style on the small gasoline engines problem solving ability of undergraduate students enrolled in an agricultural mechanics course taught through the team-based learning method

New Protocol/Modification/Continuation: New Protocol

Review Date: 12/5/2017

Approved  X  Disapproved \_\_\_\_\_

Approval Date: 12/5/2017 Approval Expiration Date: 12/4/2020

Exemption Category/Paragraph: 2b

Signed Consent Waived?: No

Re-review frequency: (three years unless otherwise stated)

LSU Proposal Number (if applicable):

Protocol Matches Scope of Work in Grant proposal: (if applicable)

By: Dennis Landin, Chairman 

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –  
Continuing approval is **CONDITIONAL** on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects\*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE: When emailing more than one recipient, make sure you use bcc. Approvals will automatically be closed by the IRB on the expiration date unless the PI requests a continuation.**

\* All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at <http://www.lsu.edu/irb>

## APPENDIX B. STUDENT CONSENT FORM

### Participant Consent and Information Sheet

Protocol Title: Investigating the effects of cognitive style on the small gas engines problem solving ability of undergraduate students in an agricultural mechanics course taught through the team-based learning method

Investigators: Whitney Figland – Graduate Assistant; Joey Blackburn – Assistant Professor

The purpose of this research study is to determine the effects of cognitive style on your ability to troubleshoot problems in small gasoline engines.

Your participation in this study is strictly voluntary and greatly appreciated. Your participation in this study will provide insight into cognitive processes that may affect individual's ability to solve problems. However, this study is being conducted as a part this course, AEEE 2003, in which you are enrolled. As a part of the course you will be required to participate in the learning modules as a part of your course grade. Should you elect not to participate in this research study your data will not be included as a part of the aggregate research data.

Again, you are not required to participate in this study. It is strictly voluntary. Should you decide to participate in this study, not further action is required. Should you elect not to participate, please see Dr. Blackburn after class so your name may be documented. There are no more than minimal risks associated with this research study. There is no penalty for not participating, and there will be no compensation for your participation.

For any general questions concerning this research study, please contact Joey Blackburn via email at: [jjblackburn@lsu.edu](mailto:jjblackburn@lsu.edu). If you have questions about subjects' rights or other concerns, you may contact Dr. Dennis Landin, LSU Institutional Review Board, at (225) 578-8692, [irb@lsu.edu](mailto:irb@lsu.edu), or [www.lsu.edu/irb](http://www.lsu.edu/irb).

Thank you, again. Your time is very much appreciated!

**APPENDIX C. STUDENT CHARACTERISTICS SURVEY**

**AEEE 2003 Small Engines Unit  
Student Demographic Information**

**Directions: Please answer the following questions by either filling in the blank or marking the option that best describes you.**

- What is your age? \_\_\_\_\_
  
- What is your gender?
  - Male
  - Female
  
- What is your academic classification (by credit hours)
  - Freshman
  - Sophomore
  - Junior
  - Senior
  
- What is your major? \_\_\_\_\_
  
- Did you complete agricultural education courses in high school?
  - Yes
  - No
  
- If yes, how many courses did you complete? \_\_\_\_\_
  
- How many courses contained units related to agricultural mechanics content (i.e., carpentry, small engines, welding)? \_\_\_\_\_
  
- Were you an FFA member in High School?
  - Yes
  - No
  
- If yes, were you a member of a Career Development Event team related to agricultural mechanics (i.e., Comprehensive Agricultural Mechanics, Electricity, Small Engines, Welding)?
  - Yes
  - No
  
- If yes, please list which team(s) you were a member of in the space below.

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## APPENDIX D. KAI FORM

**Respondent Details**

Date \_\_\_\_\_

Name \_\_\_\_\_

Age \_\_\_\_\_ Sex \_\_\_\_\_

Occupation/Title \_\_\_\_\_

Department \_\_\_\_\_

Educational Status \_\_\_\_\_

Other \_\_\_\_\_

# KAI RESPONSE SHEET

**IMPORTANT**

- Complete 'Respondent Details'
- Answer all questions
- Use ball point pen and press hard

**Guidance Notes**

We'd like it necessary to present a particular image of ourselves consistently over a long period. In some cases this process may be easier than this sometimes it is very difficult as we are not like this all the time.

For instance, some of us are early risers. It is easy for such people to present the image of good timekeepers at work. So if you are an early riser and were asked how easy or hard it is for you to present an image at work of a good timekeeper, you would put a clear cross on the scale below, on or near 'Very Easy'.

Very Hard	Hard	Easy	Very Easy
.....	.....	.....	.....
			X

If you are the extreme other sort you would find being on time every morning for a long period difficult, and you may put a cross on the scale at the 'Very Hard' end.

Please indicate the degree of difficulty (or ease) that would be required for you to maintain the image, consistently for a long time, that is asked of you by each item below.

**You will find some images easy to present, and some hard, but there are no right or wrong responses.**

**How easy or difficult do you find it to present yourself consistently, over a long period as:**

Very Hard	Hard	Easy	Very Easy
.....	.....	.....	.....

1. A PERSON WHO IS PATIENT.	.....	.....	.....	.....	.....	.....	.....
2. A PERSON WHO CONFORMS.	.....	.....	.....	.....	.....	.....	.....
3. A PERSON WHO WHEN STUCK WILL ALWAYS THINK OF SOMETHING.	.....	.....	.....	.....	.....	.....	.....
4. A PERSON WHO ENJOYS THE DETAILED WORK.	.....	.....	.....	.....	.....	.....	.....
5. A PERSON WHO WOULD SOONER CREATE SOMETHING THAN APPROVE IT.	.....	.....	.....	.....	.....	.....	.....
6. A PERSON WHO IS CAUTIOUS WHEN DEALING WITH AUTHORITY OR SENIOR OFFICIALS.	.....	.....	.....	.....	.....	.....	.....
7. A PERSON WHO NEVER ACTS WITHOUT HIGHER AUTHORITY.	.....	.....	.....	.....	.....	.....	.....
8. A PERSON WHO NEVER SEEKS TO SEND (MUCH LESS BREAK) THE RULES.	.....	.....	.....	.....	.....	.....	.....
9. A PERSON WHO LIKES ROSSIES AND WORK PATTERNS WHICH ARE CONSISTENT.	.....	.....	.....	.....	.....	.....	.....
10. A PERSON WHO HULLS BACK IDEAS UNLESS THEY ARE OBVIOUSLY NEEDED.	.....	.....	.....	.....	.....	.....	.....
11. A PERSON WHO TAKES OPPOSITE PERSPECTIVES ON OLD PROBLEMS.	.....	.....	.....	.....	.....	.....	.....
12. A PERSON WHO LIKES TO VARY SET ROUTINES AT A MOMENT'S NOTICE.	.....	.....	.....	.....	.....	.....	.....
13. A PERSON WHO PERSISTS CHANGES TO OCCUR GRADUALLY.	.....	.....	.....	.....	.....	.....	.....
14. A PERSON WHO IS THOROUGH.	.....	.....	.....	.....	.....	.....	.....
15. A PERSON WHO IS A STEADY PLODDER.	.....	.....	.....	.....	.....	.....	.....
16. A PERSON WHO COPIES WITH SEVERAL NEW IDEAS AND PROBLEMS AT THE SAME TIME.	.....	.....	.....	.....	.....	.....	.....
17. A PERSON WHO IS CONSISTENT.	.....	.....	.....	.....	.....	.....	.....
18. A PERSON WHO IS ABLE TO STAND OUT IN DISAGREEMENT ALONE AGAINST A GROUP OF EQUALS AND SENIORS.	.....	.....	.....	.....	.....	.....	.....
19. A PERSON WHO IS STIMULATING.	.....	.....	.....	.....	.....	.....	.....
20. A PERSON WHO READILY AGREES WITH THE TEAM AT WORK.	.....	.....	.....	.....	.....	.....	.....
21. A PERSON WHO HAS ORIGINAL IDEAS.	.....	.....	.....	.....	.....	.....	.....
22. A PERSON WHO MASTERS ALL DETAILS FASTIDIOUSLY.	.....	.....	.....	.....	.....	.....	.....
23. A PERSON WHO PROLIFERATES IDEAS.	.....	.....	.....	.....	.....	.....	.....
24. A PERSON WHO PREFERS TO WORK ON ONE PROGRAM AT A TIME.	.....	.....	.....	.....	.....	.....	.....
25. A PERSON WHO IS METHICAL AND SYSTEMATIC.	.....	.....	.....	.....	.....	.....	.....
26. A PERSON WHO OFTEN RISKS DOING THINGS DIFFERENTLY.	.....	.....	.....	.....	.....	.....	.....
27. A PERSON WHO WORKS WITHOUT DEFLECTION IN A PRECISE WAY.	.....	.....	.....	.....	.....	.....	.....
28. A PERSON WHO LIKES TO IMPOSE STRICT ORDER ON MATTERS WITHIN OWN CONTROL.	.....	.....	.....	.....	.....	.....	.....
29. A PERSON WHO LIKES THE PROTECTION OF PRECISE INSTRUCTIONS.	.....	.....	.....	.....	.....	.....	.....
30. A PERSON WHO FITS READILY INTO 'THE SYSTEM'.	.....	.....	.....	.....	.....	.....	.....
31. A PERSON WHO NEEDS THE STIMULATION OF FREQUENT CHANGE.	.....	.....	.....	.....	.....	.....	.....
32. A PERSON WHO PREFERS COLLEAGUES WHO NEVER 'ROCK THE BOAT'.	.....	.....	.....	.....	.....	.....	.....
33. A PERSON WHO IS PREDICTABLE.	.....	.....	.....	.....	.....	.....	.....

**PLEASE CHECK THAT YOU HAVE ANSWERED ALL 33 QUESTIONS.**

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 Oxford: All Research Centre, Cambridge: Cambridge Street, Harlow: Station, Essex: S10 8BZ. Oxford: England

## APPENDIX E. SMALL GASOLINE ENGINES PRE/POSTTEST

Name \_\_\_\_\_

### Small Engines Test

**Directions: Read each question carefully, then circle the option that answers the question best.**

1. What is the main purpose of a carburetor?
  - A. store fuel
  - B. clean the fuel
  - C. maintain constant velocity
  - D. **deliver fuel and air mixture to combustion chamber**
2. What attaches the piston to the crankshaft?
  - A. camshaft
  - B. **crankpin**
  - C. rod cap
  - D. piston rings
3. What three governor types are used in small gasoline engines?
  - A. manual, mechanical, automatic
  - B. **electronic, mechanical, pneumatic**
  - C. electronic, hydraulic, manual
  - D. automatic, mechanical, pneumatic
4. Which engine component is connected to the end of the crankshaft to maintain power through the non-power producing strokes of a four cycle engine?
  - A. armature
  - B. **flywheel**
  - C. clutch
  - D. crankpin
5. In which stroke of the piston are spent gasses from the combustion of the air-fuel mixture forced out of the combustion chamber?
  - A. power stroke
  - B. intake stroke
  - C. **exhaust stroke**
  - D. compression stroke
6. During which stroke of the piston is the air-fuel mixture ignited by the spark plug, forcing the piston down the cylinder?
  - A. **power stroke**

- B. intake stroke
  - C. exhaust stroke
  - D. compression stroke
7. As the piston moves down during the intake stroke, what is created in the combustion chamber that allows the air-fuel mix to enter?
- A. compression
  - B. pressure
  - C. density
  - D. **vacuum**
8. Four cycle engines require four strokes of the piston, how many revolutions of the crankshaft does this represent?
- A. 1
  - B. **2**
  - C. 3
  - D. 4
9. Electricity is the movement of which atomic particle?
- A. proton
  - B. neutrons
  - C. quarks
  - D. **electrons**
10. What is the basic idea of Bernoulli's principle of fluid flow?
- A. **As fluid velocity increases, fluid pressure decreases.**
  - B. As fluid velocity decreases, fluid pressure decreases.
  - C. As fluid velocity increases, fluid pressure increases.
  - D. As fluid pressure increases, fluid velocity increases.
11. Which component of the carburetor increases the velocity of air moving through the carburetor?
- A. float
  - B. **venturi**
  - C. main jet
  - D. needle valve
12. Which carburetor component allows for the manipulation of engine speed by regulating the airflow through the carburetor?
- A. choke plate
  - B. needle valve
  - C. float
  - D. **throttle plate**



13. What is the general purpose of the choke plate in the carburetor?
- A. **allow for easier cold starting**
  - B. allow for easier hot starting
  - C. increase the amount of air moving through the carburetor
  - D. increase air pressure behind the carburetor
14. Which of the following is a purpose of the governor system?
- A. Help the engine operate at a constant RPM
  - B. Protect the engine from overheating
  - C. Ensure blade speed safety in lawnmower applications
  - D. **All of the above**
15. What two engine components are most commonly associated with engines hunting and surging?
- A. carburetor/air filter
  - B. governor/compression chamber
  - C. spark plug/governor
  - D. **carburetor/governor**
16. In engines with a pneumatic governor system, what component is often at fault when an engine is overspeeding?
- A. **air vane**
  - B. idle adjustment screw
  - C. governor spring
  - D. flywheel
17. What are benefits of compressing the air-fuel mix during combustion?
- A. increased fuel economy and combustion
  - B. more fuel is consumed and power is increased
  - C. **more efficient combustion and power is increased**
  - D. decreased fuel consumption and more efficient combustion
18. Which of the following can cause an engine to lose compression?
- A. blown head gasket
  - B. worn valve guides
  - C. carbon deposits in valve seats
  - D. **all of the above**
19. During the power stroke, which piston ring is forced against the cylinder wall to prevent expanding gasses from getting by the piston?
- A. **top/compression ring**
  - B. middle/wiper ring

- C. bottom/double-ring
  - D. O-ring
20. Atmospheric pressure forces fuel out of the carburetor bowl and through the main jet. How many psi is atmospheric pressure at sea level?
- A. .147 psi
  - B. 4.7 psi
  - C. **14.7 psi**
  - D. 147 psi
21. What engine component physically compresses the air-fuel mix in the combustion chamber?
- A. crankshaft
  - B. crankpin
  - C. intake valve
  - D. **piston**
22. In what position is the piston when the spark plug ignites the air-fuel mixture?
- A. bottom dead center
  - B. top no load
  - C. **top dead center**
  - D. none of the above
23. Which carburetor component ensures a constant supply of gasoline in the carburetor bowl?
- A. venturi
  - B. main jet
  - C. **float**
  - D. throttle plate
24. What type of magneto ignition system do most modern small gasoline engines employ?
- A. points and condenser
  - B. solid state
  - C. battery
  - D. **spinning magnets**
25. What is the main structure of an engine designed to support and align internal and external components?
- A. cylinder head
  - B. cylinder bore
  - C. crankshaft
  - D. **crankcase**

26. Liquid gasoline does not burn. What must happen to liquid gasoline so it can be burned in the combustion chamber?
- A. cooled
  - B. diluted
  - C. **vaporized**
  - D. none of the above
27. What is used to ignite the fuel-air mix in the combustion chamber?
- A. Compression
  - B. **Electricity**
  - C. Heat
  - D. Pressure
28. Which of the following is the LEAST likely cause of pre-ignition?
- A. Incorrect spark plug heat range
  - B. Excessive carbon build up
  - C. **Synthetic oil**
  - D. Narrow valve margins
29. What is the main purpose of the cooling fins on the outside of the cylinder?
- A. Decrease surface area to help heat the engine
  - B. **Increase surface area to help cool the engine**
  - C. Make the engine more aerodynamic
  - D. Make the engine look good
30. Which of the following are symptoms of a partially sheared flywheel key?
- A. Noticeable misfire
  - B. Backfire
  - C. Out of time
  - D. **All of the above**

**APPENDIX F. COURSE INTEREST SURVEY**

**AEEE 2003**

**Course Interest Survey Pre & Posttest**

**Directions: There are 34 statements in this questionnaire. Please think about each statement in relation to the instructional content you are about to study, and indicate how true it is. Circle the answer that truly applies to you, and not what you would like to be true.**

<b>Item</b>	<b>Not True</b>	<b>Slightly True</b>	<b>Moderately True</b>	<b>Mostly True</b>	<b>Very True</b>
<b>Circle</b> the answer that truly applies to you					
1. The instructor knows how to make us feel enthusiastic about the subject matter of this course	1	2	3	4	5
2. The things I am learning in this course will be useful to me	1	2	3	4	5
3. I feel confident that I will do well in this course	1	2	3	4	5
4. This class has very little in it that captures my attention	1	2	3	4	5
5. The instructor makes the subject matter of this course seem important	1	2	3	4	5
6. You have to work too hard to succeed in this course					
7. I have to work too hard to succeed in this course	1	2	3	4	5
8. I do <b>NOT</b> see how the content of this course relates to anything I already know	1	2	3	4	5
9. Whether or not I succeed in this course is up to me	1	2	3	4	5
10. The instructor creates suspense when building up to a point	1	2	3	4	5
11. The subject matter of this course is just too difficult for me	1	2	3	4	5

<b>Item</b>	Not True	Slightly True	Moderately True	Mostly True	Very True
<b>Circle</b> the answer that truly applies to you					
12. I feel that this course gives me a lot of satisfaction	1	2	3	4	5
13. In this class, I try to set and achieve high standards of excellence	1	2	3	4	5
14. I feel that grades or other recognition I receive are fair compared to other students	1	2	3	4	5
15. The students in this class seem curious about the subject matter	1	2	3	4	5
16. I enjoy working for this course	1	2	3	4	5
17. It is difficult to predict what grade the instructor will give my assignments	1	2	3	4	5
18. I am pleased with the instructor's evaluations of my work compared to how well I think I have done	1	2	3	4	5
19. I feel satisfied with what I am getting from this course	1	2	3	4	5
20. The content of this course relates to my expectations and goals	1	2	3	4	5
21. The instructor does unusual or surprising things that are interesting	1	2	3	4	5
22. The students actively participate in this class	1	2	3	4	5

<b>Item</b>	Not True	Slightly True	Moderately True	Mostly True	Very True
<b>Circle</b> the answer that truly applies to you					
23. To accomplish my goals, it is important that I do well in this course	1	2	3	4	5
24. The instructor uses an interesting variety of teaching techniques	1	2	3	4	5
25. I do <b>NOT</b> think I will benefit much from this course	1	2	3	4	5
26. I often daydream while in this class	1	2	3	4	5
27. As I am taking this class, I believe that I can succeed if I try hard enough	1	2	3	4	5
28. The personal benefits of this course are clear to me	1	2	3	4	5
29. My curiosity is often stimulated by the questions asked or the problems given on the subject matter in this class	1	2	3	4	5
30. I find the challenge level in this course to be about right: neither too easy nor too hard	1	2	3	4	5
31. I feel rather disappointed with this course	1	2	3	4	5
32. I feel that I get enough recognition of my work in this course by means of grades, comments, or other feedback	1	2	3	4	5
33. The amount work I have to do is appropriate for this type of course	1	2	3	4	5
34. I get enough feedback to know how well I am doing	1	2	3	4	5







Engine Troubleshooting Packet

1. Hypothesis #3:

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2. Engine Symptoms:

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3. Troubleshooting Process:

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4. Was your hypothesis correct?

- Yes
- No

**\*If no, create a new hypothesis sheet and proceed with the steps again!\***

## VITA

Whitney Lynn Figland was born in 1995 and was raised on a small family farm in rural Iowa. Whitney is an avid advocate for agriculture, enjoys being outdoors, and teaching students about agriculture, especially agricultural mechanics. She gained her bachelor's degree in Agricultural and Life Sciences Education from Iowa State University in the spring of 2017. Shortly after graduation, she moved to Louisiana to pursue her master's degree in Agriculture and Extension Education from Louisiana State University. After, the conclusion of her masters, she plans to become a high school agriculture teacher/FFA advisor.