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Problem-Solving in the Preparation of Teachers for Agricultural Education: A Mixed Methods Study Investigating the Effect of Metacognitive Awareness and Cognitive Ability on Students Enrolled in an Introductory Agricultural Mechanics Course

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PROBLEM-SOLVING IN THE PREPARATION OF TEACHERS FOR AGRICULTURAL EDUCATION: A MIXED METHODS STUDY INVESTIGATING THE EFFECT OF METACOGNITIVE AWARENESS AND COGNITIVE ABILITY ON STUDENTS ENROLLED IN AN INTRODUCTORY AGRICULTURAL MECHANICS COURSE

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ABSTRACT

Cognitive and metacognitive ability have been identified as a critical factor that influences individuals to successfully problem-solve. However, recent research has indicated that students do not have the necessary 21st-century skills to be successful in the workplace. This issue has been confounded by the lack of school-based agricultural education (SBAE) teachers' limited knowledge regarding effectively teaching decision-making skills and the use of teaching methods that promote problem-solving. Therefore, this study sought to understand the effect that cognitive and metacognitive ability had on the problem-solving of students who are enrolled in an Introduction to Agricultural Mechanics course at Louisiana State University. All 28 students in this course participated in both the quantitative and qualitative phases of this study. Therefore, to accomplish the objectives of this study, we utilized an embedded mixed-methods design to gain a deeper understanding of the phenomenon; specifically, the qualitative phase was used to triangulate and provide more insight into the findings of the quantitative measures. The quantitative results of this study found no difference between content knowledge, time to solution, hypothesis generation, problem-solving behavior, and metacognitive ability on cognitive diversity and problem-solving ability. However, statistically significant differences were found between course motivation and cognitive diversity. Further, the multiple regression analysis revealed that the lower-level thinking skills predicted 93% of the total variance in overall problem-solving ability, which indicated that students struggled to utilize their higher-order skills. Finally, upon qualitative analysis, three themes emerged: (a) navigating troubleshooting, (b) cognitive supports, and (c) thinking-about-thinking. Thus, the findings from this study provided insights into the factors associated with students' problem-solving ability.

CHAPTER I. INTRODUCTION TO RESEARCH

Background

In the U.S., school-based agricultural education (SBAE) provides crucial instruction in the avenues of food, fiber, construction, manufacturing, and STEM to almost 12 million secondary and post-secondary students every year (Advance CTE, 2022; NAAE, 2023). SBAE allows students to explore opportunities in a multitude of domains and gain skills critical to the global workforce. The workforce in the 21st Century has evolved from only requiring basic knowledge and skills to a more integrated system that calls for individuals to have more advanced problem-solving skills, communication, teamwork, and critical thinking in a multitude of domains (Jacobson-Lunddeberg, 2016; Lumina, 2018; Rotherham & Willingham, 2010). These skills have become necessary for individuals to locate problems, find solutions, and implement plans successfully (Allen et al., 2011; Hanson, 2006; Jonassen, 2001). However, students' attainment of these skills has been compounded by the rapid advancement and availability of technology and a lack of secondary education's ability to integrate such into their curriculum (Pate & Miller, 2011b; Ulmer & Torres, 2007)

From the inception of SBAE, higher-order thinking skills have been considered one of the most effective methods of instruction (Phipps & Osborne, 1988). Many of the instructional strategies utilized in SBAE provide individuals with real-world experiences that require them to use previous knowledge to effectively problem solve. The most prominent method of instruction to achieve this is experiential learning (EL). EL positions learners to actively participate in real-world experiences while allowing them to collaborate and reflect (Kolb, 1984). Although EL has been the primary pedagogy used in SBAE classrooms, educators have a plethora of other active learning methods to differentiate instruction including problem-based learning (PBL) and inquiry-based learning (IBL). PBL primarily utilizes problems in a specific area of interest and has defined solutions (Yew & Goh, 2016). In contrast, IBL has multiple problems and solutions that allow the group to analyze information and choose which problem to solve (Ernst et. al, 2017). Both methods rely primarily on collaboration, integrating problem-solving, and critical thinking skills into situated problems. Further, research has shown that collaborative learning environments ultimately encourage the development of students' cognition, problem-solving skills, and ability to actively reflect (Felder & Brent, 2009; McCubbins et al., 2016).

To foster the growth of these critical skills, it has become increasingly necessary for teachers to be aware of the elements that influence students' problem-solving ability, particularly their cognitive style and metacognition (Figland et al., 2020). Cognitive style is a person's preferred method of learning (Kirton, 2003). An individual's cognitive style directly relates to how they retrieve, retain, and organize information when dealing with a problem to solve (Keefe, 1979) and is a key factor in individuals' effectiveness in accomplishing such (Jonassen, 2000). However, previous studies have indicated that most individuals are relatively unaware of their cognitive style preference (Kirton, 2003). Ultimately, this can lead the learner to be unable to effectively problem solve (Kirton, 2003). Therefore, understanding the impact cognitive style has problem-solving could pave the way for students and educators to better develop experiences that build problem-solving skills (Figland et al., 2019).

However, an individual's metacognitive ability has also been shown to play a critical role in the problem-solving process (Zimmerman & Risemberg, 1997). Metacognition is the process by which the problem solver utilizes problem-solving strategies to form schemas or patterns of directed thought (David & Sternberg, 1998). As such, this process reflects how an individual *thinks about thinking* – a concept called the regulation of learning (Cross & Paris, 1998; Flavell, 1979; Martinez, 2006; Rhodes & Tauber, 2011). Specifically, metacognition is knowing what, how, and when to use the skills, strategies, and resources required to solve a problem (Dimmitt & McCormick, 2012). However, developing metacognitive skills can be slow and often does not begin until the age of seven (Flavell, 1985). Previous research has indicated that targeted instruction in a content-specific domain can foster the development of metacognitive skills and enhance the effectiveness of problem-solving for most individuals (Pintrich, 2002; Rhodes & Tauber, 2011; Schraw, 1998).

Further, the type of knowledge (conceptual or procedural) and the ability of the individual to utilize that knowledge not only affects cognition and metacognition but also overall problem-solving ability (Hegarty, 1991). Apart from the type of knowledge required, it is also important that an individual be able to troubleshoot a problem that is situated in real life (Custer, 1995; Jonassen, 2000). Most of these problems are considered ill-structured in context and are defined by a singular domain. However, the majority of these problems are the hardest to solve because they often have multiple solutions (Jonassen, 2000). Due to the complexity of solving these problems, researchers (Johnson & Fleshner, 1993; Jonassen, 2003) have suggested that individuals should possess multiple types of knowledge and be able to identify, select, and implement a correct solution.

Research on problem-solving has reported differences between troubleshooters of varying expertise when they were tasked with troubleshooting a problem (Blackburn et al., 2014; Pate et al., 2004). Specifically, the largest difference between these two groups was their ability to construct problem-solving solutions and utilize multiple sources of information (Dixon & Johnson, 2011). However, it should be noted that a novice’s ability to construct solutions when problem-solving has been found to exhibit statistically significant relationships with individuals’ lack of knowledge and experience in a domain (Dixon & Johnson, 2011). Therefore, a key implication from the study was that a lack of knowledge and skills in a given domain did not mean the individuals exhibited less effective problem-solving ability; instead, they simply needed more content knowledge and practical skill-building opportunities to successfully master the content and be able to engage higher order thinking skills while problem-solving (Dixon & Johnson, 2011).

Similar work has been advanced in agricultural education. For example, Parr et al. (2006) called for educators to use problem-solving in ways that could foster the development of students' higher-order thinking skills (Parr et al., 2006). To achieve such, Pashler et al. (2007) explained that agricultural educators could integrate opportunities for students to ask, provide, and explain their thought processes to develop better metacognitive functions that could improve their problem-solving skills. As such, it has become apparent that SBAE teachers need to modify their curriculum and methods of teaching to meet the needs of the current workforce (Chumbley et al., 2018). Despite these calls, problem-solving implementation has remained a persistent problem in SBAE classrooms because agricultural education teachers have not historically integrated such skills into their curriculum (Chumbley et al. 2018; Ulmer & Torres, 2007).

Consequently, the following question has persisted: *Are teachers not using problem-solving as a method of instruction in SBAE because they do not understand how to integrate the method of instruction into their curriculum due to the lack of exposure during their teacher preparation?* In response, the current investigation sought to examine a problem-solving approach that was embedded into an introductory to agricultural mechanics course at Louisiana State University that required students to draw on lower and higher-order thinking skills as well as motivation, cognition, and metacognition to successfully solve a problem. Through exposure to this approach, our intent was twofold: (1) encourage the greater problem-solving development of students enrolled in the course, and (2) expose the students to a method of instruction they could use to encourage the problem-solving skill development of their future SBAE students.

Conceptual Framework

For this investigation, I developed a conceptual model to illustrate how an individual progresses through the problem-solving process, called Figland's model of problem-solving behavior. Specifically, this model was used to understand the level of problem-solving ability when individuals engage in troubleshooting. The intent of the model was that it could be used to guide preservice teachers as they sought to enhance their problem-solving ability while in a teacher preparation program. Through this enhanced knowledge and skill, I postulated that agricultural education majors would gain greater problem-solving skills and be more inclined to use such an approach with their future SBAE students as a teacher.

Foundationally, the model was based on Zimmerman's (1997) self-regulated learning theory. This theory opines that for an individual to maximize their critical thinking ability, they must be able to regulate their learning. In self-regulated learning theory, there are three main categories including (a) metacognition, (b) cognition, and (c) motivation. Metacognition reflects the knowledge of regulation and knowledge of learning, while cognition represents the individual's problem-solving and critical thinking strategies. Finally, motivation plays an important role as it influences individuals' self-esteem and epistemological beliefs. Therefore, an individual's maximum critical thinking ability lies at the intersection of metacognition, cognition, and motivation. This is the point at which an individual can self-regulate their learning and problem-solve at their highest level. An illustrative case has been provided next to demonstrate the model's relevance.

An individual servicing a lawnmower realizes that there is a puddle of fluid underneath the motor. For the individual to be able to successfully problem solve, they must first be able to regulate their learning. Per the model, this would mean they must have the ability to identify and select problem-solving strategies related to the problem. In this example, the individual would utilize previous small engines knowledge and begin to brainstorm possible problems that could be associated, such as knowing if gas is leaking it is either a fuel tank/line leak or a carburetor problem.

Although they organize their problem-solving strategies and try to find a solution, the individual must also have the ability to regulate their metacognitive activities. Specifically, the individual must reflect on their decisions and be able to work through their thinking processes. Such may appear as an individual going back over the engine and problem identifiers to ensure they have identified, selected, and evaluated correctly. Finally, for these processes to happen, the individual must find value in the problem and have positive self-efficacy. A positive motivation for this individual to fix this problem may be because they need the lawnmower to mow their lawn and do not want to purchase a new one. This motivation provides the individual with the needed focus to fix the problem. Once the individual has regulated their learning, they can now move through the problem-solving behaviors.

As the learner engages with a real-world situated problem, they begin to move through the learning process which in this model draws on Bloom's taxonomy (2001) to articulate the level to which the individual solves problems. Using the above example, in the lower levels of Bloom's taxonomy (remember and understand), the individual may only be able to list parts and recall facts within that system. Specifically, they would need to be able to identify the carburetor and the fuel tank. However, at the highest level of Bloom's, the learner could generate a new hypothesis and correct the problem, which leads to the learner being able to successfully solve it. In this example, that may be the individual being able to state, “If I take the carburetor apart and the float is stuck/upside down, then I should inspect the internal components and either replace the float or flip it to the correct side.” Within the highest levels of thinking, the individual would have been able to correctly fix the carburetor problem. If the learner can successfully create a solution to the problem, then they have completed the problem-solving process. It is important to note that the problem-solving process should be considered non-linear, and the learner can enter the process at any given point – as illustrated by the double-ended arrows in Figure 1.

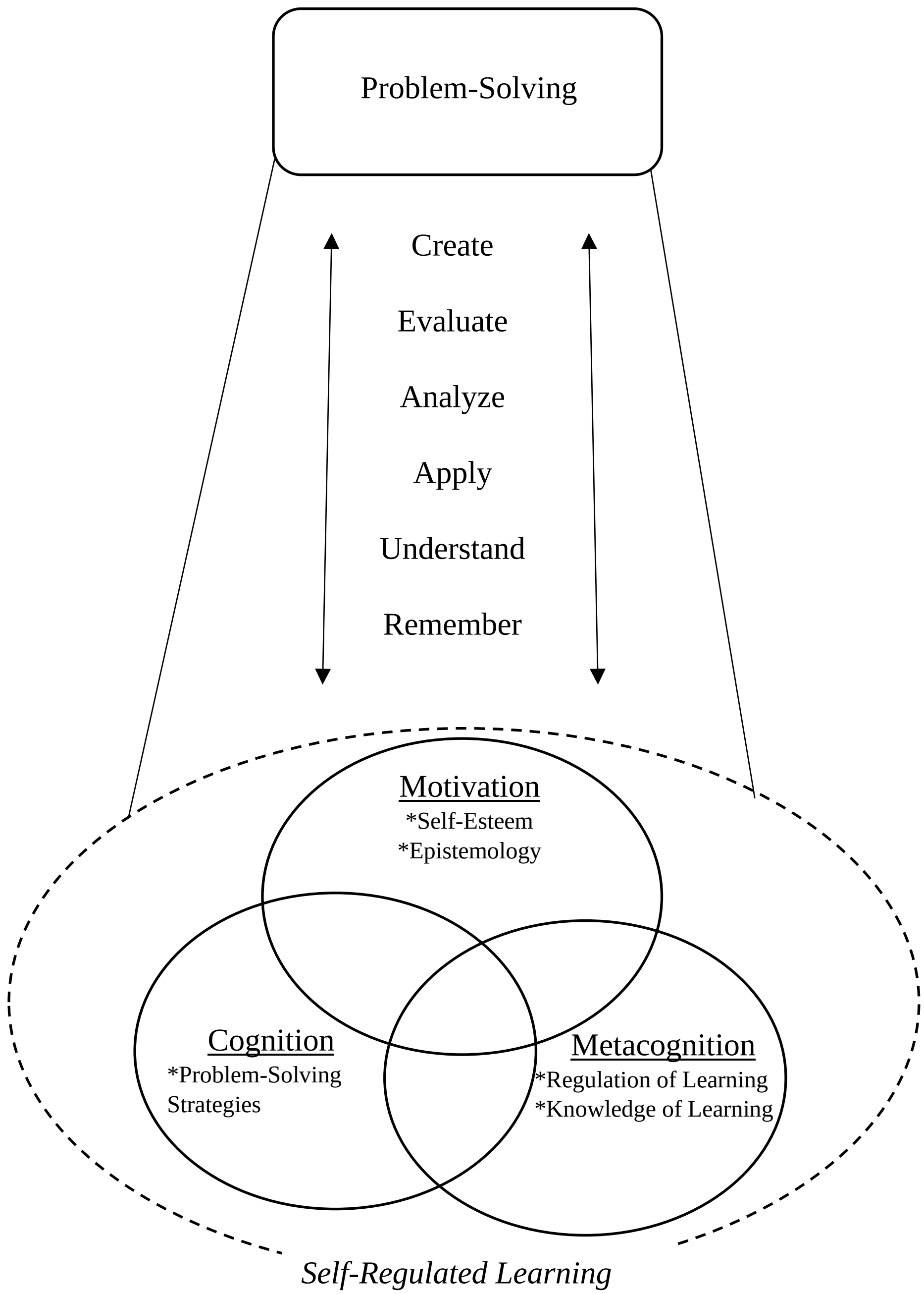

Figure 1. Figland's model of problem-solving behavior. Note. Adapted from Zimmerman's (1997) self-regulated learning theory and Bloom's taxonomy of learning (2001).

Need for the Study

In our day-to-day life, we come across a multitude of problems that require us to utilize multiple knowledge sources, cognitive functions, and metacognitive activities to problem-solve effectively (Jonassen, 2000; Parr et al., 2006). Meanwhile, the need for skilled workers who possess the ability to solve complex problems effectively and efficiently has drastically increased in the last two decades (Alston et al., 2009; Lumina, 2018; Robinson & Garton, 2008). Nevertheless, many students in secondary education have not been asked to develop skills that increase their higher-order thinking skills (Jonassen, 2000). To combat this issue, career and technical education (CTE) has been identified as a critical component in secondary education to foster the development of these needed skills by tailoring curriculum for students to solve real-world problems and engage in experiential learning (Pate & Miller, 2011a).

In SBAE, research on problem-solving, cognition, and metacognition has suggested that educators should tailor curriculum and utilize instructional methods that help to develop their student's problem-solving skills (Parr et al., 2006; Pashler, 2007). In particular, Pashler et al. (2007) advocated for educators to provide students with probing questions that required them to explain their reasoning to promote metacognition and build problem-solving skills. Similarly, Edwards (2004) reiterated that SBAE programs should be incorporating problem-solving skills into their curriculum to build cognitive and metacognitive skills.

Nevertheless, this problem has been compounded by the lack of problem-solving skill development opportunities in the SBAE curriculum, which has left students without the necessary problem-solving skills (Ulmar & Torres, 2007). According to the Lumina Foundation (2018) and the Partnership for 21st Century Learning (Battelle for Kids, 2020) the most important workplace skills students need to possess are skills in problem-solving, collaboration, and communication. For students to be able to develop imperative problem-solving skills, educators must help students develop their 21st-century skills by utilizing diverse learning methods in their curriculum, which are targeted to such factors (Blackburn et al., 2014; Chumley et al., 2018; Fuhrmann & Grasha, 1983; Jonassen, 2000; Lamm et al., 2011; Ulmar & Torres, 2007; Weeks, 2020). Thiel and Marx (2019) stated that SBAE teachers can develop problem-solving skills by utilizing active teaching methods like inquiry-based instruction, experiential learning, and problem-based learning. Empirical research has postulated that active learning environments enhanced student learning and lead to student's academic success (Bloom, 1974; Darling-Hammond & Falk, 1997; Dewey, 1944; Kolb, 1984; McCubbins et al., 2018).

However, research in agricultural education has indicated that in-service and preservice teachers do not possess the proper higher-order thinking skills themselves to be able to implement those skills into their classrooms (Smalley et al, 2019; Weeks et al., 2020). Weeks et al. (2020) ascertained that within 21st-century skills, preservice SBAE teachers needed the most assistance with teaching students how to think critically. Similarly, Smalley et al. (2019) identified that teaching decision-making skills was a professional development need expressed by SBAE teachers, which aligned with previous research (Joerger, 2002; Layfield & Dobbins, 2002). Moreover, current SBAE and preservice SBAE teachers have indicated they need professional development in technical agriculture areas, such as agricultural mechanics (McCubbins et al., 2017; Smalley et al., 2019; Tummons et al., 2017). Further, the demand for qualified candidates to possess adequate problem-solving and critical-thinking skills is on the rise, especially in technical areas (Bancino & Zevalkink; 2007; Jacobson-Lunddeberg, 2016; Lumina, 2018; Rotherham & Willingham, 2010). Therefore, it has become increasingly important that teacher preparation programs begin to focus on the ability of their preservice teachers to successfully implement problem-solving strategies and utilize problem-solving as a method of instruction in their future classrooms.

Purpose of the Study

The overall purpose of this study was to investigate the effects of an individual's metacognitive and cognitive processes on their ability to problem solve in an introductory to agricultural mechanics course at Louisiana State University (LSU).

Research Objectives

1. Describe the level of metacognitive awareness, cognitive diversity, content knowledge, motivation, problem-solving behavior, time to solution, and hypothesis generation among the students in AEEE 2003 – *Introduction to Agricultural Mechanics*.
2. Determine the effect cognitive diversity has on metacognitive awareness when troubleshooting a small gasoline engine.
    a. Null hypothesis: No differences will exist between cognitive diversity and metacognitive awareness when troubleshooting a small gasoline engine.
3. Determine the effect cognitive diversity has on content knowledge of students enrolled in an introductory to agricultural mechanics' course.
    a. Null hypothesis: No differences will exist between cognitive diversity and small engines content knowledge of students enrolled in an introductory agricultural mechanics' course.
4. Determine the effect cognitive diversity has on motivation of students enrolled in an introductory agricultural mechanics' course.
    a. Null hypothesis: No differences will exist between cognitive diversity and motivation of students enrolled in an introductory agricultural mechanics' course.

5. Determine the effect problem-solving behavior has on metacognitive awareness when troubleshooting a small gasoline engine.
    a. Null hypothesis: No differences will exist between problem-solving behavior and metacognitive awareness when troubleshooting a small gasoline engine.
6. Determine if problem-solving behaviors are significant predictors of time to solution when troubleshooting a small gasoline engine.
7. Determine if problem-solving behaviors are significant predictors of hypothesis generation ability when troubleshooting a small gasoline engine.
8. What are the processes that students utilize when troubleshooting a small gasoline engine?

Limitations of the Study

The following limitations were associated with this study:

1. The population for this study was limited to students enrolled at Louisiana State University in *AEEE 2003 - Introduction to Agricultural Mechanics* course.
2. Findings from this study cannot be generalized past the bounds of this study.
3. Video and audio recordings from the qualitative phase were not utilized due to a lack of audio quality.
4. Course motivation (CIS) was not collected pre/post; therefore, we do not know the effect of the treatment on course motivation.

Assumptions

The following assumptions were made for the purpose of this study:

1. All participants were students at LSU and enrolled in *AEEE 2003 – Introduction to Agricultural Mechanics*.
2. All students provided accurate and true information throughout data collection.

Operational Definitions

The following terms were utilized for the duration of this study. For reference, each term has been defined with how it was operationalized throughout this study.

Agricultural Education's Comprehensive, Three-Circle Model – An interconnected model of agricultural educations program three components: (a) classroom/laboratory instruction, (b) SAE, and (c) FFA (Talbert et al., 2013). In this model, classroom/laboratory instruction is where students develop a foundation for agricultural topics through contextualized learning. Supervised agricultural experiences allow students to apply what they have learned in the classroom to a real-world setting. FFA is an intracurricular student-led organization that promotes premier leadership, personal growth, and career success.

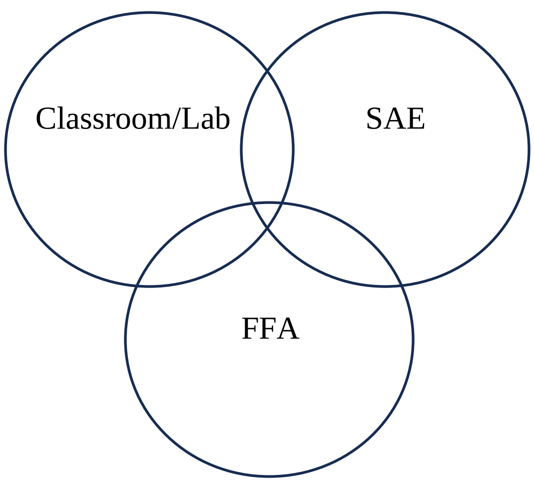

Figure 2. A model of agricultural education's comprehensive three-circle model. Adapted from "The foundations of agricultural education" by Talbert et al., 2008, p. 107.

Career and Technical Education (CTE) – Provides rigorous and relevant career for a wide range of high-wage, high-skills, and high-demand training to youth and adults (Association for Career & Technical Education, 2023).

Cognition – Cognition is the act of all forms of knowing and awareness, which includes, perceiving, conceiving, remembering, reasoning, judging, imagining, and problem-solving (American Psychological Association, 2023).

Cognitive Skill Acquisition – The ability to solve problems in intellectual tasks, where success is determined more by subjects' knowledge than by their physical prowess (VanLehn, 1996).

Hypothesis Generation Ability – The ability of the individual to create a correct hypothesis; regardless of number of times needed to generate a correct hypothesis (Figland, 2019).

Metacognition – "[t]he knowledge and control children have over their own thinking and learning activities" (Martinez, 2006, p. 131).

Method of Instruction – A specific technique utilized to facilitate student learning and meet educational objectives (Phipps et al., 2008).

Pedagogy – Strategies utilized to organize a lesson to meet educational objectives; more commonly referred to as the art and science of teaching (Phipps et al., 2008).

Problem-Solving – "any goal-directed sequence of cognitive operation that has cultural, social, and intellectual value to the learner" (Jonassen, 2000, p. 256).

Problem-Solving Ability – A student's ability to correctly identify and solve a given problem (Figland, 2019, pg. 10).

School-Based Agricultural Education (SBAE) – "a systematic program of instruction available to students in schools desiring to learn about the science, business, and technology of plant and animal production and/or about the environmental and natural resource systems" (The National Council for Agricultural Education, 2017, p. 1).

Student-Centered Instruction - Provides students the opportunities to interact with real-world contextual problems (Allen et. al, 2011).

Teacher Preparation – A program that prepares students to teach agricultural education programs at various levels (National Center for Education, 2023).

Team-Based Learning – Integrates student collaboration and problem-based learning, while utilizing prior concepts to solve problems situated in the real world and providing them with conceptual knowledge and procedural skills (Michealsen & Sweet, 2008).

Time to Solution – The time required by teams to correctly identify and solve the problem (Figland, 2019, pg.10).

Troubleshooting – Identifying a problem within a process or machine (Herren, 2015; Jonassen, 2000).

CHAPTER II. LITERATURE REVIEW

Overview of School-Based Agricultural Education and Career and Technical Education

In the U.S., there are approximately 12 million career and technical education (CTE) students enrolled in secondary and postsecondary education programs. When looking specifically at Louisiana, there are approximately 201,142 students enrolled in public education and of those, there are 163,158 enrolled in a secondary CTE cluster, which means that 83% of students participate in some aspect of CTE in high school (Advance CTE, 2022). Further, at the postsecondary level, there are 37,095 students enrolled in a CTE program (Advance CTE, 2022). Therefore, it is apparent that CTE plays a major role in the educational system on a national and state levels.

CTE provides students in secondary and postsecondary education with the academic and technical skills needed to enter careers and become lifelong learners (Advance CTE, 2022). However, the CTE we know today is the product of several decades of extensive advancements and evolution. Specifically, in the late 19th Century, vocational education experienced a pivotal turn with the advancement of the Smith-Hughes Act of 1917. Not only did this foundational act provide funding for the advancement of secondary vocational education, but it also paved the way for the development of SBAE as we know it today (Steffes, 2018). This push for vocational education was a product of the U.S. experiencing a large societal shift due to accelerated advancements in technology, which were incurred from the industrial revolution (Gordon, 2014). Due to the paradigm shift, there was a need for individuals who were skilled in specific domains (Roberts & Ball, 2009). This need steered the passing of the Smith-Hughes Act and, subsequently, many others, which have paved the way for school-based agricultural education (SBAE) and CTE.

Many of the current CTE clusters are provided through SBAE programs. Those clusters include agriculture, food and natural resources, construction and architecture, manufacturing, and science, technology, engineering, and mathematics (STEM) (Advance CTE, 2022). SBAE provides avenues for students to explore the many opportunities that CTE has to offer and develop imperative workforce skills. It is evident that without the passing of these foundational Act's, the current state of SBAE and CTE could have been greatly altered.

Problem-Solving Within School-Based Agricultural Education

Since the inception of SBAE, the foundation of student learning has been built on using problem-solving as a method of instruction (Parr & Edwards, 2004; Talbert et al., 2007). This method has been considered the most integral piece of SBAE because it provides students with the tools needed to solve real-world problems that are often integrated into agriculture (Parr & Edwards, 2004; Sibley & Ostafichuk, 2015). It is believed that this method was chosen due to the paradigm shift that the U.S. was experiencing at the time and was believed by many scholars to fit with the purpose of agricultural education (Boone, 1990; Cano & Martinez, 1989; Conroy et al., 1999; Crunkilton & Krebs, 1982; Dyer & Osborne, 1996; Flowers & Osborne, 1988; Hammonds, 1950; Krebs, 1967; Newcomb et al., 1993; Phipps & Osborne, 1988).

Therefore, the problem-solving approach emerged as cornerstone the of many pedagogies that educators use to guide instructional objectives. These pedagogies include inquiry-based learning, experiential learning, and problem-based learning (Ernst et al., 2017; Kolb, 1984; & Yew & Goh, 2016). Each of these pedagogies focuses on the integration of higher-order thinking skills by allowing students to apply their knowledge to real-world situations. However, even though they all focus on problem-solving development, they each have distinct strengths and weaknesses as pedagogies.

Problem-Solving Based Pedagogies

Problem-Based Learning (PBL). This method of instruction allows students to become the focal point of learning by having them actively engage in a collaborative learning environment (Yew & Goh, 2016). Within this environment, learning is triggered by a problem that needs to be solved. Often these problems are constructed to be limited to a particular content area and have limited solutions. As a pedagogy, it is appealing to educators because it supports active group collaboration, which is based on the premise that students construct ideas through social interaction and self-instructed learning (Yew & Goh, 2016).

Inquiry-Based Learning (IBL). IBL is similar to PBL; however, instead of the problem being solved, the students are able to choose which aspects they want to learn more about (Ernst et. al, 2017). Thus meaning, that the scenario or event that the students will be exploring will have more than one problem to solve. Ernst et al. (2017) described that for each scenario, there should be five to 15 problems for students to solve. Then, the collaborative group explores their options and selects the problem they will address. As a pedagogy, this method of instruction appeals to educators because it allows the students to broadly explore a given topic, actively collaborate with their group, and then actively reflect on their solution.

Experiential Learning (ELT). This method of instruction allows students to actively engage in a real-world experience (Kolb, 1984), while also utilizing previous knowledge, cognitive skills, and building active reflection (McCarthy, 2016). Kolb (1984) defined his theory as “the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience” (p. 41). As a pedagogy, this method is appealing because it can be implemented as groups or as individuals, which allows for more flexibility and differentiation between individuals.

In agricultural education, these pedagogies rose to the forefront because of their flexibility, student-centered approach, and problem-solving skills development, which aligned with the focus of agricultural education in the 21st Century. This new focus helped slingshot agricultural education into preparing students with the skills necessary to be competitive in today's workforce (Allen et al., 2011; Baker & Robinson, 2012; Retallick & Miller, 2005).

Student-Centered Classrooms

The driving principle of any student-centered learning environment is to shift instruction from traditional lecture format to one that is more open, and student-driven. As such, students become the focus of their own learning while the teachers move into a facilitation role, which develops a learning environment that provides students the opportunities to interact with real-world contextual problems (Allen et al., 2011). These classrooms come in many different formats, including flipped classrooms, team-based learning, problem-based learning, experiential learning, and more. Therefore, student-centered classrooms can transform the traditional classroom into a collaborative student-centered environment.

Of those predominant student-centered learning environments, team-based learning incorporates learning conceptual and procedural knowledge, with collaboration and problem-solving (Michealsen & Sweet, 2008). Michealsen and Sweet (2008) created team-based learning to bring together student collaboration and problem-based learning while utilizing prior concepts to solve problems situated in the real world while still providing them with conceptual knowledge and procedural skills. Similar to student-centered approaches, TBL is formatted so students learn conceptual knowledge in a specific domain before the scheduled class, and during class, they actualize that knowledge (Michealsen & Sweet, 2008; Wallace et. al, 2014). However, to design a TBL formatted course, there are four key elements: (a) group formation and management, (b) student accountability, (c) timely feedback, and (d) assignment design (Michealsen & Sweet, 2008). Using these elements, the classroom is organized into modules that last one to two weeks (Michealsen et al., 2004). These modules are designed for students to learn the necessary conceptual knowledge outside of classroom instruction and be prepared to engage in class application activities.

During instruction, students are expected to come prepared to take their individual test or Individual Readiness Assurance Test (IRAT). The IRAT is developed to gauge conceptual knowledge retention over the materials presented in the module that the student was expected to learn outside of classroom instruction. Once the IRATs have been completed, the students will move into taking their Team Readiness Assurance Test TRAT, which is the same exam but now all members of the team can discuss the questions and collectively decide on answers. From this point, the students will receive immediate feedback on the questions that they got wrong on both exams and can provide a rebuttal to their answers by providing written responses supported by information found in the materials provided. Allowing the individuals and teams to discuss the incorrect items and have the opportunity to rebuttal their answers, which provides them with the ability to collaborate and think critically and enhances their problem-solving ability. Finally, any remaining time is committed to integrating the learner's new knowledge into real-world experiences (Michealsen et al., 2004).

Effectively designing these real-world application exercises is a critical component of the TBL method. These application exercises allow students to engage in problem-solving by creating solutions to real-world situations. Application exercises should be developed using the 4S framework, which reflects that the exercise entails a significant problem, same problem for each group, requires the group to make a specific decision, and employs the same reporting format for each team (Michealsen et al., 2004). As an example, each team is given a troubleshooting scenario that is directly related to an engine bug. As a group, they analyze, evaluate, and select a solution based on their previous conceptual knowledge. Once consensus has been reached, they will then report their decisions in the same time frame.

TBL can develop a classroom environment that is more productive and conducive to developing problem-solving skills, but it must be designed and executed properly (Sibley & Ostafichuk, 2015; Michaelsen & Sweet, 2008). However, there are few research studies on the use and effectiveness of TBL, especially in agricultural education. Research by McCubbins et al. (2016) examined student perceptions of TBL and found that overall students in the course were highly motivated by the teaching method. These results indicated that students who work in a collaborative environment held higher motivations during the course (McCubbins et al., 2016). Similarly, a study conducted by Figland et al. (2019) found complementary results in which students indicated were very satisfied with the TBL course and perceived that TBL promoted the development of positive team collaboration skills, increased problem-solving skills, and self-efficacy. Finally, McCubbins et al. (2018) assessed student engagement in relation to the TBL-designed capstone course at Iowa State University and concluded that TBL had a positive impact on the development of higher-order thinking skills.

Problem-Solving

In our day-to-day life, we encounter and are asked to solve a plethora of problems that range from simple to complex. Problem-solving has been defined as “any goal-directed sequence of cognitive operation that has cultural, social, and intellectual value to the learner” (Jonassen, 2000, p. 256). Simply, the learner must find value in the problem being solved for them to be able to successfully problem solve. However, it has been noted that curriculum today does not include the necessary components for real-world problem-solving, which means students are not problem-solving those situated concepts (Jonassen, 2000). Without those critical skills being taught in the modern curriculum, students lack the foundation necessary to be able to be effective and efficient critical thinkers and solve real-world issues (Alston et al., 2009; Graham, 2001). This is especially true in technical areas, such as agriculture and other CTE-related fields (Robinson & Garton, 2008; Robinson et al., 2007). For individuals to be able to problem solve they must understand the type of problem they have encountered and utilize a plethora of knowledge.

As we encounter these real-world problems, they are often not uniform activities (Jonassen, 2000). Meaning that two individuals may encounter the same problem but engage in the experience differently, which leads to an altered way of problem-solving. However, most real-world problems are situated between two distinct categories: ill-structured or well-structured depending on the overall outcome (Jonassen, 2000). Ill-structured problems are those situations that do not have defined boundaries or are undefined. These problems often require knowledge from multiple domains and are the most common type of problem-solving because they are situated in the real world (Jonassen, 2000). For a problem to be identified as ill-structured, it must include: (a) unknown key pieces, (b) require the use of knowledge in multiple domains (c) have multiple paths to solution, and (d) require the problem solver to reflect on their solution (Jonassen, 2000; Wood, 1983). For example, in crop production, solving an insect infestation in sugarcane would be considered an ill-structured problem because it requires the learner to utilize multiple domains of knowledge, make judgments, and evaluate the situation. Opposite of ill-structured problems are well-structured problems. Well-structured problems are those that are goal-oriented, have all key elements, and contain a logical order to solution or indicators to solution (Greeno, 1991; Jonassen, 2000). Most of these problems are found in schools and universities for teaching and research purposes because these problems are limited to one or two solutions. For example, troubleshooting a 4-cycle engine in the real world would be an ill-structured problem because there are no constraints on context; however, within a teaching environment, it becomes a well-structured problem because the students will be given a specified context and domain to work inside.

Therefore, in order for individuals to solve problems they must possess the ability to manage their cognitive and metacognitive ability. Specifically, they must have an awareness of how they prefer to solve problems in order to make decisions on how to solve the problem. Meaning that in order for individuals to begin to solve ill or will-structured problems they must understand how they acquire and utilize information, which is cognition.

Cognition

Cognition is the act of all forms of knowing and awareness, which includes, perceiving, conceiving, remembering, reasoning, judging, imagining, and problem-solving (American Psychological Association, 2023). Simply, cognition is all the conscious/unconscious process by which we acquire knowledge. For example, when an individual is taking apart a small gasoline engine, they are making conscious decisions about the order parts should be disassembled in real time based on the experience, while simultaneously making unconscious decisions about the experience, like knowing which size ratchet to take a bolt off without trying different ones.

In educational psychology, cognition plays a major role in an individual's ability to solve a plethora of problems. Specifically, it has a major effect on individual cognitive skill and cognitive style (Greeno et al., 1996). Whereas cognitive style is how an individual goes about solving problems. Therefore, an individual's cognitive style influences their cognitive skill acquisition. However, it is important to note that cognitive skills and functions can be learned and acquired; therefore, sharpening their overall ability to problem solve.

Cognitive Skill Acquisition

By definition, cognitive skill acquisition is the learner's ability to solve problems determined by the amount and level of knowledge in a specific domain (VanLehn, 1996). Meaning that problem-solving effectiveness depends more heavily on the knowledge of the learner, rather than on procedural ability. Because cognitive skill acquisition is heavily embedded into the problem-solving process, much of the research has focused on problem-solving progression from simple to complex, the problem-solving ability of novices and experts, and how people acquire expertise. Therefore, determining how people acquire knowledge is an important consideration when trying to understand the problem-solving process.

Early research done by Fitts (1964), on cognitive skill acquisition, determined that there were three phases including (a) early, (b) intermediate, and (c) late. In the early phase, the learner is trying to understand the domain-specific knowledge without applying the new knowledge. Usually in this phase, knowledge is obtained from books, infographics, discussions, debates, etc. In the intermediate phase, the learner then begins to solve problems. However, in this phase, the learner is acquiring problem-solving knowledge by utilizing previous example problems outlined in curricular materials. The learner still has a very cerebral view of problem-solving, but now has a basic understanding of the knowledge needed to solve the problem and the types of problems encountered. In the final phase, the learner continues to improve on accuracy and efficiency in solving problems, but their understanding and why to solve problems remains very basic and stagnant. Further, the more hands-on and heuristic knowledge gained increases the overall effectiveness and efficiency of problem-solving. Nevertheless, cognitive skills allow individuals to acquire knowledge and process information to become more effective problem solvers (VanLehn, 1996).

Cognitive Style

Regarding an individual's cognition, cognitive style provides information on how the learner utilizes problem-solving strategies; specifically, how they recall, retain, and utilize organizational schemas to solve problems (Keefe, 1996). By definition, cognitive style is the learner's more favorable way of solving problems (Keefe, 1979; Kirton, 2003). Simply, how are the problem solvers utilizing and organizing knowledge to be successful. Further, for an individual to be a successful problem solver, they must be aware of how they solve problems (Jonassen, 2000). However, an individual's cognitive style is not a defined construct, meaning that learners can vary between cognitive styles depending on the type of task and information acquired (Kirton, 2003). It should be noted that an individual's cognitive style is related to the patterns of thinking or how an individual organizes information. Therefore, an individual can learn different problem-solving strategies that would ultimately change their reasoning and allow them to move between the different cognitive styles, but the individual always has a preferred cognitive style which they would initially default.

Research regarding cognitive style has been conducted for some time and overwhelmingly conveyed its importance on the individual's overall problem-solving ability (Blackburn & Robinson, 2016, 2017; Figland et al, 2021, 2022, 2023; Myers & Dyer, 2006; Parr & Edwards, 2004; Thomas, 1992; Torres & Cano, 1995; Witkin et al., 1977). Of such, in early 1976, Kirton developed the adaptive-innovative theory to help explain the different cognitive styles concerning problem-solving, diversity among teams, and organizational leadership change (Aritzeta et al., 2005; Buffington et al., 2002; Talbot, 1997; & Kirton, 1976, 2003). Among such, Buffington et al. (2005) focused research around cognitive styles within teams; specifically, within the cognitive gaps between the members of the team. This research concluded three main benefits of teams recognizing differing cognitive styles including conformity and consensus, relevance, and conflict. Kirton (2003) explained the importance of "bridgers" in team dynamics. Bridgers are those individuals who "reach out to the people in the team and help them to be part of it some they may contribute even if their contribution is outside of the mainstream" (p. 247). Kirton (2003) concluded that leaders who act as bridgers can understand each team member's cognitive style and help to narrow cognitive gaps and better facilitate the problem-solving process.

Further, recent research within agriculture has utilized cognitive style instruments in a plethora of studies to examine the effects of cognitive style on problem-solving, hypothesis generation, and team dynamics (Blackburn & Robinson, 2016, 2017; Blackburn et al., 2014; Figland et al., 2021; Friedel et al., 2008; Lamm et al., 2011). Regarding cognitive style and problem-solving ability, a study conducted by Friedel et al. (2008) examined the relationship between the factors and found that there was no relationship. Further, Blackburn and Robinson (2016, 2017) reported no differences between a student's cognitive style, the type of problem being solved, and the ability to correctly generate a hypothesis. However, Figland et al. (2021) conducted a study to understand the effect cognitive diversity has on problem-solving ability; specifically, on time to solution and hypothesis generation ability. These results showed that there was a statistically significant relationship between groups that were homogenous innovative compared to the heterogenous groups in regard to effectiveness and efficiency (Figland et al., 2021). This study supported a previous notion advanced by Kirton (2003) that suggested that groups who can overcome cognitive style gaps and integrate their perspectives are more efficient and effective problem solvers. Regardless, these previous findings support the findings from Kirton (2003) and the overall purpose of the KAI.

Early knowledge of individual learning style revealed it as a factor that has a direct influence on the development of cognitive skill acquisition (VanLehn, 1996). Many researchers believed that learning styles had a critical influence on an individual's ability to think critically (Claxton & Murrell, 1987; VanLehn, 1996). One of the most prominent learning style theories was developed by psychologist Neil Fleming. Fleming developed the VARK Theory, which identified that there were four main learning styles (a) verbal, (b) auditory, (c) verbal, and (d) kinesthetic (Fleming, 1987). Through this lens, visual learners are those who prefer to utilize maps, pictures, and organizers to understand information. Just the opposite, auditory learners prefer to learn by listening and speaking in discussions and lectures. Verbal learners prefer to learn by words and writing, while kinesthetic learners like to learn through contextual activities.

Similar to Flemings's VARK Theory, the Gregorc Style Delineator (GSD) assists individuals in identifying their primary style for processing information. The GSD postulates that an individual's learning style lies in two dimensions including perception and sequence (Gregorc, 1982b). Within those dimensions, the individual will fall into one of the four combinations: (a) concrete sequential (CS), abstract sequential (AS), abstract random (AR), and concrete random (CR) (Gregorc, 1982b). An individual's cognitive style or learning style the GSD closely aligns with other inventories including Kolb's learning style inventory and the KAI and has been widely used to illuminate preferred learning styles by individuals.

Metacognition

Metacognition has been identified as an important aspect of individual learning since the early 20th Century. One of the first to conceptualize metacognition was a Soviet psychologist Lev Vygotsky, who developed the idea of zone of proximal development. Vygotsky (1978) argued that the zone encompasses what the individual can learn on their own and what they can achieve with guidance; therefore, allowing the learner to eventually be able to regulate their own learning process. As we understand metacognition today, this transition of learning that Vygotsky noted, would be metacognition.

Metacognition is the process of thinking about one's learning (Flavell, 1979). Specifically, it is the individual's ability to learn specified material and then be able to transition that learning and regulate that new knowledge. However, a common definition of metacognition has yet to be established. Flavell (1979), a lead psychologist who was the first to coin the term, defined metacognition as the ongoing active process of monitoring and regulation of cognitive processes in relation to some tasks. Cross and Paris (1988) reiterated a similar definition as "[t]he knowledge and control children have over their own thinking and learning activities" (p. 131). More recently, Martinez (2006) defined metacognition as "[t]he monitoring and control of thought" (p. 696). Therefore, broadly, metacognition can be defined as simply ones "thinking about thinking." (Martinez, 2006, p. 696).

Empirical research has indicated that in order for individuals to be able to problem-solve they must possess the proper metacognitive skills (Zimmerman & Risemberg, 1997), which have been identified as skills that allow the learner to form mental schemas of an identified problem, select plans, and overcome an obstacle (David & Sternberg, 1998; Zimmerman & Risemberg, 1997). Further, research in cognitive psychology has also identified that these [metacognitive] skills are also linked to critical thinking, problem-solving, and motivation (Ennis, 1985; Facione, 1990; Halpern, 1998; Paul, 1992; Schneider & Lockl, 2002).

When examining metacognition, there are two main elements: knowledge of cognition and regulation of cognition (Cross & Paris, 1988; Flavell, 1979; Paris & Winograd, 1990; Schraw & Moshman, 1995; Schraw et al., 2006; Whitebread et al., 1990). Knowledge of cognition relates to the awareness of one's cognitive strengths and weaknesses which may affect overall cognition (Flavell, 1979). Within one's knowledge of cognition, there are three types of knowledge:

1. *Declarative Knowledge:* This type of knowledge refers to the learner's knowledge of self. Specifically, the individual's knowledge to know and understand what internal and external factors influence their performance. It can be simply coined as the individual's "world knowledge" (Rathore & Sonawat, 2015, p. 561).
2. *Procedural Knowledge:* Opposite to declarative knowledge, procedural knowledge specifically refers to identifying the individual's knowledge of performing tasks. This knowledge is often the strategy one uses to perform tasks (Rathore & Sonawat, 2015). For example, reassembling a carburetor or installing a light switch.
3. *Conditional Knowledge:* This knowledge is largely related to knowing when to utilize declarative and procedural knowledge (Rathore & Sonawat, 2015).

The other element of metacognition deals with the individuals' ability to monitor, regulate, and evaluate the learner's knowledge of cognition (Cross & Paris, 1988, Schraw et al., 2006; Whitebread et al., 2009). For an individual to be able to regulate their learning they must contain three essential skills including:

1. *Planning:* refers to the ability of the individual to correctly select a strategy and allocate resources. This phase also is a late-developing skill and has been researched and reported to not be seen until the individual is 10 – 14 years old (Flavell, 1979; Schraw & Moshman, 1955; Whitebread et al., 2009).
2. *Monitoring:* This skill is simply the person's awareness of the knowledge and task being completed (Rathore & Sonawat, 2015).
3. *Evaluating:* Finally, evaluating refers to the individual's ability to reflect on the strategies and resources utilized to perform a task. Often this skill is the most looked over and most individuals never evaluate or re-evaluate the strategies used (Rathore & Sonawat, 2015).

Types of Metacognitive Learners

Empirical research has identified specific types of metacognitive learners. These types of categories identify how individuals are aware of their learnings and how they utilize problem-solving strategies to make decisions. Lead psychologist, David Perkins, identified that there were four types of metacognitive learners: (a) tact learners, (b) aware learners, (c) strategic learners, and (d) reflective learners. Tact learners are those who have no specific path or strategy that they use to problem solve; they are unaware of their metacognitive knowledge. Aware learners know specific types of thinking patterns they are generating, but it is not always planned. Opposite to aware learners, strategic learners utilize specific problem-solving strategies and know why they are utilizing them. Finally, the most complex, reflective learners not only know the strategies they are using but can reflect on the experience and make changes as needed. Perkins (1992) stated that metacognitive learning is on a continuum that spans from the lowest level (tact) to the most complex (reflective). He ascertained that to foster metacognitive skills, learners must be aware of their style and educators must be able to plan materials to foster and build those metacognitive skills (Perkins, 1992).

Metacognitive Activities

For educators to develop metacognitive skills, they must be aware of metacognitive activities that affect overall ability. Metacognitive activities relate to regulative strategies and mental schema or learning (Flavell, 1979; Vermunt, 1996). Research conducted by Vermunt (1996) identified three variations of metacognitive activities: (a) cognitive, (b) affective, and (c) regulative. Cognitive activities are how an individual thinks about learning that leads to direct outcomes. For example, relating engine parts and thinking of solutions. Affective activities include being able to regulate your emotions during the learning process. Finally, regulative activities are those that are directed at the regulation of cognition or learning. This domain is targeted for the learner to be able to regulate their cognitive and affective processes to be able to effectively associate with the problem task (Vermunt, 1996). Therefore, these metacognitive processes affect an individual's ability to be a successful troubleshooter. Specifically, if the learner is unable to regulate cognitive and affective activities then they will be unable to successfully utilize troubleshooting strategies.

Troubleshooting

As we go about our day, we are expected to solve a plethora of problems. One of the most common forms of problems we encounter are those that require us to troubleshoot (Jonassen, 2003). Troubleshooting, as encountered in our everyday lives, would be those problems that require us to use a systematic approach. Meaning that we solve the problem in a logical deductive sequence. However, the other side of troubleshooting relates to determining the cause of a malfunction in a process (Herren, 2015), which would include solving problems related to technical applications often which are ill-structured.

Moreover, most of the problems related to technical applications are problems that have multiple solutions and challenges (Blackburn & Robinson, 2014, 2017; Custer, 1995; Jonassen, 2000). Most technical problems have multiple solutions, which makes them particularly difficult to solve. Therefore, the problem solver must have the ability to utilize their previous knowledge, use cognitive skills, and be able to regulate their learning to correctly solve the problem (Jonassen & Hung, 2008).

A critical aspect of troubleshooting lies within the individual's conceptual knowledge (Jonassen, 2001). Of those aspects, a troubleshooter's knowledge in that specific domain is essential. Meaning the troubleshooter must have a basic understanding of concepts in that area. Johnson and Flesher (1993) reiterated this sentiment by concluding that troubleshooters must utilize previous experiences to be able to interact with the problem. For example, when solving a carburetor problem in a 4-cycle engine, the troubleshooter would need to have previous domain knowledge to solve the problem. However, previous research within agricultural education has postulated that domain knowledge has no effect on the ability of the individual to successfully problem-solve (Blackburn, 2013; Figland et. al, 2020).

Novice and Expert Troubleshooters

Literature in technical and mechanical troubleshooting has reiterated that knowledge, skill, and level of experience play a large role in a troubleshooter's ability to solve simple and complex problems (Johnson & Flesher, 1993; Jonassen, 2003). However, a large indicator of ability also lies within the expertise level of the troubleshooter. Johnson (1989) indicated that there are two major level groups: novice troubleshooters and expert troubleshooters. Novice troubleshooters have little to no conceptual or procedural knowledge in the given domain (Johnson, 1989). Whereas expert troubleshooters are just the opposite; they have previous knowledge and interaction in that domain (Johnson, 1989).

The differences between the way novice and expert troubleshooters go about solving the problem are drastically different. Jonassen (2003) indicated that novice troubleshooters often utilize a more linear sequential path when solving problems, which would align with Johnson's (1989) technical troubleshooting model. However, expert troubleshooters tended to deviate from the linear path and construct better mental schema of the problem because of the plethora of prior knowledge (Gitomer, 1993; Johnson & Flesher, 1993; Jonassen, 2003). Johnson (1989) conducted a study that indicated that the primary difference between them was in the ability of the troubleshooter to utilize knowledge and generate a hypothesis. However, this research indicated no differences between those factors and whether they were novice or expert in skill level (Johnson, 1989). Further, this conclusion was also consistent with more recent studies which indicated that content knowledge was not a significant predictor of troubleshooting ability for agricultural education majors interested in pursuing careers as teachers (Blackburn & Robinson 2014, 2016; Figland et al., 2019). Overall, Johnson (1989) concluded that the plethora of knowledge utilized by expert troubleshooters was the biggest difference as compared to novice troubleshooters. However, it should be noted that the main difference between troubleshooters was the inability of novice troubleshooters to identify and select the correct symptoms that were associated with that problem (Johnson, 1989).

Troubleshooting Styles

To understand the behaviors and patterns between experience levels, Johnson and Flesher (1993) conducted a study to pinpoint those characteristics that define an individual's troubleshooting style, which influence their overall ability to effectively troubleshoot. They collected and analyzed data from 50 troubleshooting technicians of varying experience and synthesized the behavior patterns of each. This analysis led them to three main troubleshooting styles including gamblers, testers, and thinkers (Johnson & Flesher, 1993).

Gamblers. Johnson and Flesher (1993) identified gamblers as those individuals who when given a troubleshooting problem rely mainly on luck or probability. Johnson and Flesher (1993) also identified four sub-types within the style of gamblers, including (a) risk-takers, (b) wanderers, (c) swappers, and (d) oddsmakers (Johnson & Flesher, 1993). First, risk takers are problem-solvers who like to experiment with the problem. However, risk-takers were identified as having a high level of knowledge in multiple domains (Johnson & Flesher, 1993). Opposite of risk takers are wanderers. Wanderers are identified as individuals who rely solely on chance to identify a problem and also have very limited knowledge and procedural skills (Johnson & Flesher, 1993). Swappers are problem-solvers who will change the part of what they identified as the fault but tend to replace parts that were not the problem. However, unlike the previous types of troubleshooters, swappers rely on previous knowledge to help them solve the problem (Johnson & Flesher, 1993). Finally, oddsmakers rely on their conceptual and procedural knowledge to locate specific problems. Further, if oddsmakers are not meticulous in swapping, they can fall back and fail to locate the correct malfunction (Johnson & Flesher, 1993). Even though gamblers are considered troubleshooters who are more novices, it does not mean experts cannot fall into one of these sub-categories (Johnson & Flesher, 1993).

Testers. Troubleshooters who were identified as testers were those who relied on previous experiences, domain knowledge, and procedural knowledge to locate malfunctions (Johnson & Flesher, 1993). Johnson and Flesher (1993) identified three subsets of testers, including sensors, tracers, and splitters. Sensors are troubleshooters who utilize their senses to find and fix faults but can easily misinterpret their senses and get lost in the process (Johnson & Flesher, 1993). Tracers are considered mid-level troubleshooters because they utilize schematics and diagrams to help move them through the problem (Johnson & Flesher, 1993). However, they must have the knowledge and skill to be able to effectively read schematics and identify dead ends (Johnson & Flesher, 1993). Finally, Johnson and Flesher (1993) identified the last type of testers are splitters, which tend to divide a particular system and then check for faults individually. This type of troubleshooting was noted as the most highly utilized method, but splitters have a greater rate of getting lost in the problem.

Thinkers. Finally, thinkers are those who utilize a logical deductive sequence to identify problems in a system (Johnson & Flesher, 1993). In the category of thinkers, there were four different subsets that were identified including readers, designers, recallers, and analyzers (Johnson & Flesher, 1993). The first identified type are readers, which are the least skilled of any category because they utilize the work of others to locate the problem (Johnson & Flesher, 1993). Secondly, designers utilize a theoretical base to examine a problem. Often these theories come from formal trainings, but they are the least efficient problem solvers outside of fixed situations (Johnson & Flesher, 1993). Johnson and Flesher (1993) identified recallers are those troubleshooters who use extensive previous knowledge and can immediately locate the problem; however, these individuals tend to lose their ability to effectively problem solve because they focus on memory recall. Finally, analyzers, who are much like tracers, utilize their previous knowledge and experiences to work to delineate faults linearly. Further, Johnson and Flesher (1993) identified that the main difference among the troubleshooters were analyzers because they carefully analyze the problem before making decisions on replacing components.

Research in Agricultural Education Examining Problem-Solving

In agricultural education, research investigating problem-solving has been conducted in a variety of settings. As such, Blackburn et al. (2014) conducted a study with preservice agricultural education students enrolled in an agricultural mechanics' course to investigate the effects of cognitive style and problem complexity on problem-solving ability. In this study, the students were purposefully grouped based on cognitive style based on the results from the individual's KAI scores. Therefore, the results stated that there were no differences among the factors on overall problem-solving ability; however, it was noted that the students identified as more innovative, were more advantageous when solving the complex problem (Blackburn et al., 2014). This finding suggested that more innovative individuals should be able to identify and correct a more complex problem.

Similarly, in the same study, the researchers also investigated the effects of hypothesis generation ability on troubleshooting ability (Blackburn & Robinson, 2016). This study found that regardless of problem type (i.e., simple, or complex) the students who were able to generate a correct hypothesis were more effective problem solvers overall. Further, to understand the associated factors that affected the student's ability to correctly hypothesize, the researchers investigated cognitive style, GPA, age, and content knowledge in that domain. The findings from this study suggested that, regardless of these factors, almost all students correctly hypothesized. However, students who were more adaptive problem solved better when given the simple tasks and the students were more innovative had an easier time solving the complex tasks (Blackburn et al., 2017).

Furthermore, Figland et al. (2021) conducted a more recent study with agricultural education students to investigate how cognitive diversity effects hypothesis generation ability and time to solution. In this study, the students were purposely grouped by cognitive style as determined by the KAI. The groups consisted of homogenous adaptive, homogeneous innovative, and heterogeneous. The results from this study indicated that the teams who hypothesized correctly the first time were more efficient and effective problem solvers, regardless of cognitive diversity. However, no differences were found between cognitive diversity and time to solution. Overall, the heterogeneous teams solved the problem faster and hypothesized the least than any other group. Also, the more innovative teams were the least successful problem solvers overall (Figland et al., 2021).

Moreover, the researchers also investigated the effect of cognitive diversity and content knowledge on troubleshooting ability (Figland et al., 2022). Similar to previous studies, the results did not find significant differences between cognitive diversity and content knowledge on problem-solving ability (Figland et al., 2022). Regardless of content knowledge and cognitive diversity, those teams who were able to hypothesize correctly were the most effective problem-solvers.

Research has also been conducted examining the association of critical thinking style, learning style, and problem-solving style on the decision-making process of agricultural education majors. Specifically, a pair of researchers created and implemented a protocol called think-aloud-pair-problem-solving or (TAPPS) (Lochhead & Whimbey, 1987). The primary purpose of TAPPS is to encourage students to vocalize their thoughts while working toward a solution. This method, however, requires that there be at least two problem solvers who can collaborate and collectively work together to solve a problem and that one person be the solver and their partner be the listener (Lochhead, 2001; Pate & Miller, 2011a). TAPPS has been utilized to help problem solvers develop and regulate their metacognitive processes (Pate & Miller, 2011a, 2011b), which has helped the students in successfully identifying and repairing faults, specifically in troubleshooting; however, there were no differences found between individuals who utilized TAPPS and those who did not (Johnson & Chung, 1999; Pate et al., 2004). Further research has also indicated problem solvers who utilized TAPPS were less likely to complete the task and those who did complete the task took four minutes longer on average (Pate & Miller, 2011a).

Conceptual Framework

Conceptually, the foundation of this study was built upon Figland's problem-solving behavior model, which describes the processes agricultural education majors undergo when engaging in problem-solving. Specifically, this model drew upon Zimmerman's (1994) self-regulated learning theory and Bloom's (2001) taxonomy of learning. Therefore, when viewing problem-solving through this lens, understanding the processes that students use to regulate their learning – motivation, cognition, and metacognition – as well as their level of thinking (higher order versus lower order) is critical (Stizmann & Ely, 2011; Zimmerman, 2000). For example, an individual's ability to set goals, apply knowledge, reflect, and maintain positive motivation in the learning environment all affect their ability to interact with a problem (Lord et al, 2010; Zimmerman, 2000).

However, some theories of self-regulated learning differ based on the wide range of disciplines and research focused on self-regulated learning. They all share the same four common assumptions. First, self-regulated learning must include that the individual is active in the learning experience. Meaning they must be cognitively, metacognitively, and motivationally invested in the experience or must find value (Zimmerman, 2001). For example, in a small engine unit, all learners would be engaged in disassembling and reassembling a 4 – cycle motor. Secondly, self-regulated learning is a constant feedback loop. Specifically, how the learner is monitoring their progress, in terms of goals and external feedback (Zimmerman, 2001). Therefore, active reflection is an integral piece in the regulation process. The third assumption is the ability of the learner to focus on their goals and use relevant strategies to solve problems (Sitzmann & Ely, 2011). For example, understanding when to utilize concept mapping to organize previous information to locate a fault. Finally, the fourth assumption lies within the learner's motivation to the task (Schunk & Zimmerman, 2008). Specifically, does the learner find enough value in the task that they are intrinsically or extrinsically motivated to be able to complete the problem by regulating their learning. Therefore, it is integral to the model that the learner be able to engage in all pieces of the self-regulated learning process to problem-solve effectively and efficiently, which is why the process is positioned at the bottom of the model. If a learner is unable to regulate their learning, they will be unable to successfully move through the problem-solving ladder. In this model, the problem-solving ladder is depicted by Bloom's (2001) taxonomy of learning.

Bloom's (2001) taxonomy of learning was first developed by Benjamin Bloom in 1956 and later revised by a group of cognitive psychologists, and curriculum/instructional theorists in 2001. The primary objective of Bloom's was to be able to describe the cognitive processes learners think, develop, and structure knowledge when encountering tasks. Specifically, there are six levels including:

(a) Remember – Learner’s ability to recognize and recall basic information;

(b) Understand – Learner’s ability then interpret that information;

(c) Apply – Learner’s ability to successfully implement knowledge;

(d) Analyze – Learner’s ability to organize information;

(e) Evaluate – Learner’s ability to reflect on the process;

(f) Create – Learner’s ability to generate or produce a hypothesis.

For a learner to successfully problem solve they must engage with each level at some point. However, it is important to remember that a learner may enter the problem-solving process at any point and move throughout at different stages, which is depicted by the double-ended arrows on each side. Further, within this model, Bloom’s taxonomy was specifically utilized to illustrate the level of problem-solving. Specifically, to what level did each of the troubleshooting teams attain when posed with the troubleshooting problem. If the learners are able to regulate their learning and move through the problem-solving process, then they will be able to successfully problem-solve and complete the process. Therefore, identifying them as effective and efficient problem solvers (see Figure 1).

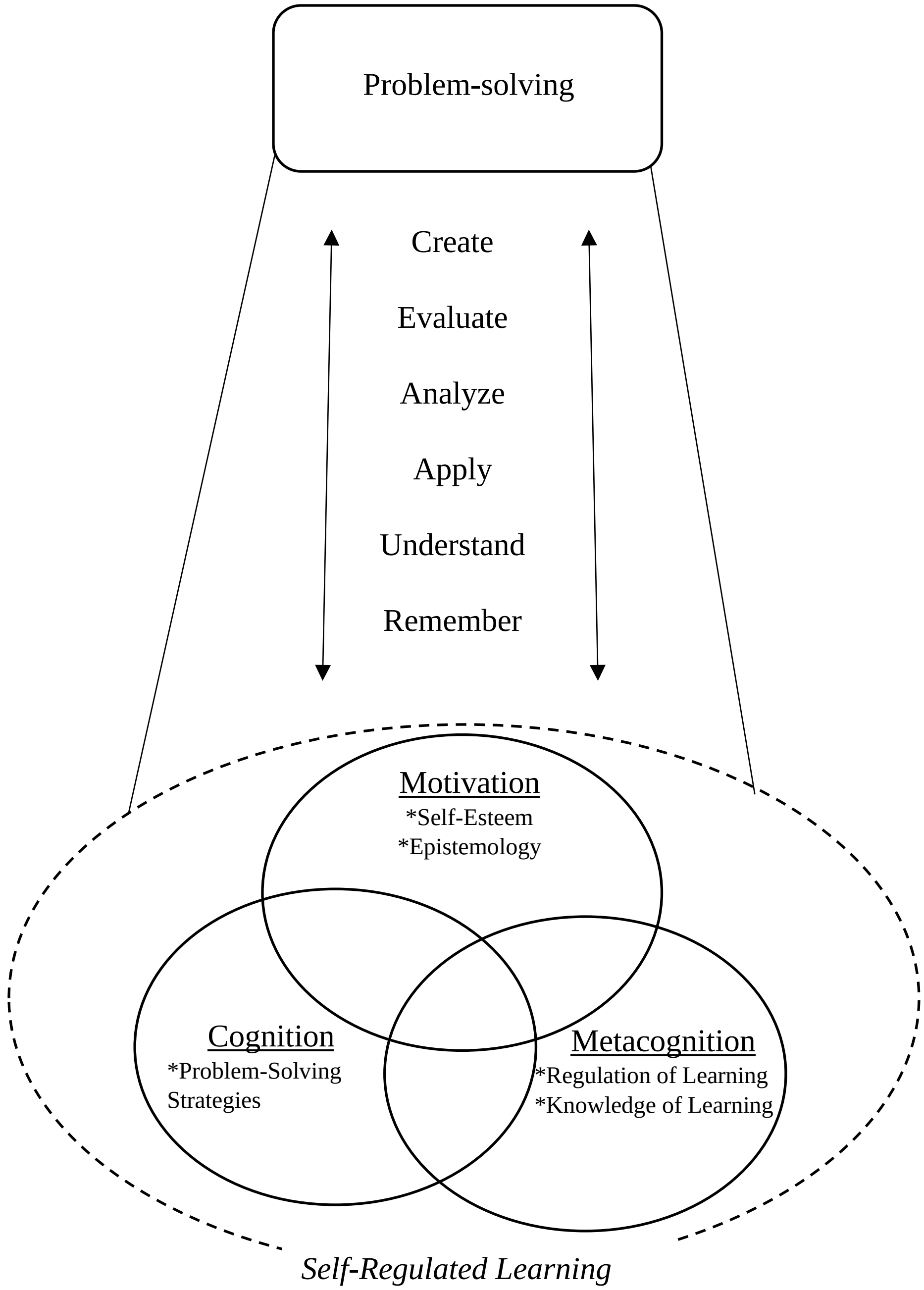

Figure 1. Problem-Solving Behavior Model. Adapted from Zimmerman's (1997) Self-regulated learning theory and Bloom's taxonomy of learning (2001).

Summary

Over the last decade, the demand for trained workers who possess 21st-century skills has been highly sought after (Weeks et al., 2018). These skills have built a critical foundation for individuals to be able to locate, select, and solve a multitude of problems (Allen et al., 2011; Alston et al., 2009; Zimmerman & Risemberg, 1997; Robinson & Garton, 2008). However, in educational settings, students are not being challenged to develop their problem-solving skills, which is in part due to the lack of secondary education teachers' inability to integrate problem-solving skills into their current teaching methods (Jonassen, 2001; Ulmer & Torres, 2007; Pate & Miller, 2011b).

In education, SBAE and CTE have been considered the optimal places to promote problem-solving skills development because of the variety of active teaching methods that are utilized within the field (Phipps & Osborne, 1988). Those active teaching methods, like experiential learning, problem-based learning, and inquiry-based learning, all predominately provide students with real-world hands-on experiences (Kolb, 1984; Yew & Goh, 2016). All of these teaching pedagogies allow the focus of the classroom to shift away from the teacher and put more emphasis on student-centered instruction, which promotes students' collaboration and critical thinking skills development (McCubbins et al., 2016). Even though these pedagogies naturally integrate some problem-solving skills, many educators are unaware of student's cognitive style and metacognitive abilities that affect the overall problem-solving process (Ulmer & Torres, 2007; Pate & Miller, 2011b).

Within the problem-solving process, cognitive and metacognitive ability play a key role in overall problem-solving ability (Zimmerman, 1994). Specifically, metacognitive skills promote the development of mental schemas, which allow the learner to be able to identify, select, and implement a plan to overcome an obstacle (Zimmerman, 1994; Zimmerman & Risemberg, 1997). Similarly, cognitive ability and cognitive style affect the problem-solving process because they deal with an individual's knowledge base and how they prefer to learn (Kirton, 2003). Therefore, metacognitive and cognitive functions play a crucial role in the development of problem-solving skills and ability.

Along with cognitive and metacognitive factors, the type and domain of a problem are also strong indicators of problem-solving ability (Jonassen, 2001) because problem solvers must possess a multitude of domain-specific knowledge to troubleshoot a problem (Jonassen & Hung, 2006). The lack of content knowledge in a domain leads the troubleshooter to struggle to identify and select appropriate solutions to problems because of the lack of schema development (Halpern, 1984; Zimmerman & Risemberg, 1997). However, Pate et al. (2004) indicated that in troubleshooting the biggest difference between problem solvers has been the ability of individuals to utilize knowledge, identify problems, and create solutions.

Empirical research in agricultural education has examined the impact of cognitive diversity, problem-solving style, and metacognition has on the problem-solving process for quite some time and have found relationships among a person's cognitive style, type of problem-solving task, ability to generate a correct hypothesis, and efficiency in solving problems (Blackburn et al., 2014, 2016; Boone, 1990; Figland et al., 2020, 2021; Friedel et al., 2008; Cano, 1993, 1999; Dyer & Osborne, 1996; Garton et al.,1999; Lamm et al., 2011, 2014; Myers & Dyer, 2006; Parr & Edwards, 2004; Rudd et al., 1998; Torres & Cano, 1994, 1995a). Therefore, based on the review of literature, it is imperative that teacher preparation sites emphasize the importance of understanding the effect cognitive and metacognitive ability have on the overall problem-solving process.

CHAPTER III. METHODS

In order to uphold federal and ethical standards, all studies including human subjects must be approved by the institutional review board (IRB). For the current study, an electronic application, including all documents for the proposal, were submitted to the Institutional Review Board (IRB) at Louisiana State University AgCenter for review and approval. The IRB for the current study was approved (AG-22-0082) on September 19, 2022 (See Appendix A).

Role of the Researcher

As the primary researcher, my interaction with each stand of data changed throughout the duration of this study. Even though data for each strand was collected concurrently, the implementation, data collection, and data analysis changed. For instance, in the quantitative strand, I utilized standard procedures to implement the instruments, analyzed the data utilizing SPSS, and checked the instruments for content validity and reliability. Meanwhile, in the qualitative strand, I facilitated focus groups where participants were asked to write about their experience and engagement in the problem-solving activity.

It is important to own my biases and previous experience, which may have had an impact on this study and the subsequent results. Previously, I was a SBAE teacher for three years where I taught agricultural mechanics courses. I primarily utilized an active learning environment that drew upon team-based learning with all my laboratory-based courses. Further, the majority of my graduate studies, both master’s and doctoral, have been dedicated to understanding the effects of cognitive style and metacognition on problem-solving ability and how secondary agricultural education can foster the development of problem-solving skills in their curriculum. Also, it should be noted that I was the primary instructor of the course involved in this research and had a great deal of interaction with the participants. Therefore, it is possible that my interaction with them could have influenced their overall responses.

Research Design

This study used an embedded mixed methods design, which combines the data of both the quantitative and qualitative approaches (Creswell & Plano Clark, 2018). In this design, data collection of each strand occurs concurrently; however, priority is given to either the quantitative or qualitative strand. In this study, the primary approach is quantitative, but the qualitative data was being used to support the interpretation and validation of the quantitative strand. However, it should be noted that although each strand was collected and analyzed separately, they were mixed for interpretation (Creswell & Plano Clark, 2018). This approach allowed me to gain a holistic understanding of the effect cognition and metacognition had on the problem-solving ability of students enrolled in an introductory to agricultural mechanics course. This design was chosen to gain a deeper understanding of the interaction between metacognition and problem-solving ability. Therefore, I wanted to mix the findings from each stand of data and depict a more holistic understanding of the interaction between cognitive ability, metacognition, and problem-solving ability.

This design has distinct strengths and weaknesses that should be considered. The advantages include (a) it does not require extensive time or resources, (b) it utilizes different methods to address different research questions, (c) data can be published separately, and (d) it is appealing to funding agencies (Creswell & Plano Clark, 2018). Further, the limitations of this design include (a) the researcher must have expertise in both domains, (b) it must specify the purpose of collecting qualitative data as part of a larger study, (c) challenges to knowing when to collect the data, and (d) it is difficult to integrate the results (Creswell & Clark, 2018).

When examining each of these considerations, it is important for the researchers to utilize a pragmatist worldview. This view allows the researchers to focus on the primary research questions and use multiple forms of data to understand a phenomenon (Creswell & Clark, 2018). This design is oriented toward practice and understanding of what will work (Creswell & Clark, 2018).

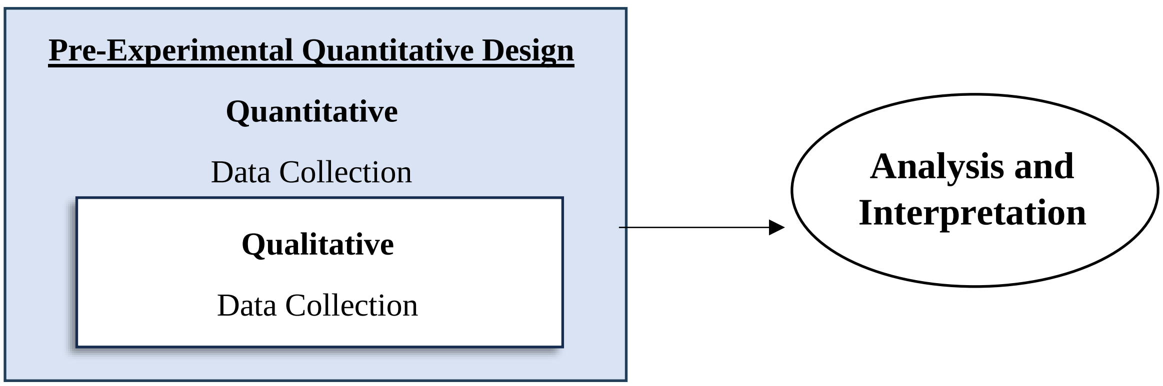

Figure 3. Depiction of the Embedded Mixed Methods Study Design.

Background of the Study

To achieve an active learning environment, during the spring of 2023 I used a modified team-based learning (TBL) format to conduct AEEE 2003 - *Introduction to Agricultural Mechanics*. This format was adapted from the guidelines of Michealsen and Sweet (2008) to fit the objectives of the course and facilitate a student-centered learning environment that gave the students more time in the lab to use the skills they had learned in the lecture. All the course materials, including (a) course readings, (b) videos, (c) handouts, and (d) Individual Readiness Assurance Tests (IRATs)/Team Readiness Assurance Tests (TRATs), I developed utilizing the *Agricultural Mechanics Fundamentals and Applications* by Herren (2015), *Small Engines* by Radcliff (2016), and *Small Engine and Equipment Maintenance* by London (2003) (Figland, 2019, pg. 53).

To facilitate the research process, at the beginning of the Spring 2023 semester, the 28 participants were purposefully grouped into seven equal teams of four based on cognitive style score, collected using Kirton's (2003) Adaptation-Innovation Inventory (KAI). They remained in the teams for the entirety of the course and all subsequent activities. All members were also asked to complete the metacognitive awareness inventory (MAI), which consisted of 45 items directed to assess their metacognitive processes.

The course comprised of four modules including, (a) safety, (b) agricultural structures (construction), (c) electricity, and (d) small gasoline engines (Figland, 2019, pg. 53). For this study, data was collected within the small gasoline engine unit, consisting of five individual modules, 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 (Figland, 2019, pg. 53). At the beginning of each module, the students would engage in learning the material before class. All the modules consisted of a short reading and supplemental material that was aimed to help the students be prepared to come to class ready to take their IRAT. After a review discussion, the individuals would then complete their individual test. After the IRAT, the teams would gather and complete the TRATs. The TRATs were designed to generate collaboration and teamwork amongst members on items that were difficult or were incorrect on their IRATs. The TRAT ensures that all members are participating equally and promotes content mastery.

After the formative assessments, the remainder of the session was spent in the laboratory where the students engaged in their application exercises. The application exercises were designed to incorporate each student's conceptual knowledge and procedural knowledge in hands-on activities. Students remained in their teams and were directed to collaborate with those members as a first line of action while completing all course activities. This was done to keep the format of the course and promote collaboration and teamwork, which promoted problem-solving skills development and built metacognition.

Population and Sample

The population of this study was students enrolled in AEEE 2003 – *Introduction to Agricultural Mechanics* at Louisiana State University during the spring of 2023 (N = 28). Per the IRB, students were notified of the study on the first day of class by reviewing the participation and consent form (see Appendix B). For this study, all students participated and there was no mortality; therefore, the total sample was 28.

Due to the students not being randomly assigned to treatment groups, there were no sample procedures utilized. The students were purposively put into groups, which were obtained from the KAI; determined the student's cognitive style. Therefore, due to the lack of random assignment, no generalization past the population in this study can be made. Demographically, most students enrolled in AEEE 2003 were 20 years old (f =10, 35.7%) and female (f =18, 64.3%). Regarding academic classification, most of the students were also juniors (f = 13, 46.3%; see Table 1).

Table 1. Demographic Characteristics of Students Enrolled in AEEE 2003 (N = 28)

Variable	*f*	%
Age		
18	1	3.6
19	4	14.3
20	10	35.7
21	5	17.9

(table cont’d)

Variable	*f*	%
22	5	17.9
23	1	3.6
25	1	3.6
26	1	3.6
Gender		
Male	10	35.7
Female	18	64.3
Academic Classification		
Freshman	1	3.6
Sophomore	9	32.1
Junior	13	46.4
Senior	4	14.3
5th Year Senior	1	3.6

The students were also asked to identify the quantity of agricultural mechanics courses they participated in during high school. Most students reported never having taken any courses dedicated to agricultural mechanics in high school ($f = 22$, 78.6%; See Table 2).

Table 2. Quantity of Agricultural Mechanics Courses Participated in During High School ($N = 28$)

Number of Courses	*f*	%
0 Courses	22	78.6
1 Course	0	0

(table cont'd)

Number of Courses	*f*	%
2 Courses	0	0
3 Courses	4	14.3
4 Courses	1	3.6
5+ Courses	1	3.6

Quantitative Strand

Team Cognitive Diversity Treatment

To ensure cognitive diversity, all individuals were placed into their respective teams based on the scores from the KAI. Each of the seven teams consisted of four members of either like-minded or opposite-minded individuals (i.e. more adaptive or more innovative). Development of each team was given on the first day of the semester. The team formation consisted of three homogeneous adaptive teams, two homogeneous innovative teams, and two heterogeneous teams (see Table 3).

Table 3. Cognitive Diversity Scores of Students Enrolled in AEEE 2003 by Team (*N* = 28)

Team	Individual 1	Individual 2	Individual 3	Individual 4
Team 1-Homogeneous Adaptive	85	77	84	76
Team 2-Homogeneous Innovative	96	100	97	107
Team 3- Homogeneous Adaptive	93	84	92	80
Team 4-Homogeneous Innovative	104	116	101	108

(table cont'd)

Team	Individual 1	Individual 2	Individual 3	Individual 4
Team 5-Homogeneous Adaptive	94	73	92	88
Team 6-Heterogeneous	116	110	93	94
Team 7-Heterogeneous	98	101	65	74

In team one, individual scores tallied from 76 to 85 with a nine-point cognitive style score gap and were all homogeneous adaptive. All members of team two were considered more innovative, with scores ranging from 96 to 107. Team two had an 11-point separation. Students in team three were all homogenous adaptive, with scores ranging from 80 to 93 and a 13-point dispersion. Team four consisted of members with scores from 101 to 116 and a 15-point gap. Members of team five were all considered homogeneous adaptive and had scores ranging from 73 to 94 with a 21-point spread. Team six was considered heterogeneous with scores ranging from 93 to 116 with a 23–point difference between members. Finally, team seven consisted of member scores ranging from 65 – 101 with a 36–point separation. Team seven was also considered heterogeneous. To eliminate any conflict during the problem-solving process, homogeneous teams were purposefully assigned to no more than a 20-point cognitive style gap (Kirton, 2003). However, because of the limited number of participants, one of the homogeneous teams had a point gap of 21. Alternatively, the heterogeneous teams were purposefully created to have more than a 20-point gap to ensure problem-solving differences between adaptors and innovators.

Small Gasoline Engine Team Treatment

To create a more positive working environment and eliminate frustration, the members of each team were put into pairs to complete the small gasoline engine unit. This was done to prevent four people from working on one engine. The small gasoline engines unit was the last topic of the semester and lasted for approximately eight weeks. Each team was further divided into dyads or Group A and Group B. The groups were created with the same cognitive style points difference as the large teams, to keep equal treatments throughout (see Table 4).

Table 4. Cognitive Diversity Scores for Small Gasoline Engine Sub-Groupings

Teams	*Small Gasoline Sub-Grouping*			
	Group A		*Group B*	
	Individual Group Member KAI Scores			
Team 1	85	76	77	84
Team 2	96	100	97	107
Team 3	93	84	92	80
Team 4	104	101	116	108
Team 5	64	92	73	88
Team 6	116	93	110	94
Team 7	98	65	101	74

Small Gasoline Engine Troubleshooting Fault

For the final treatment, each 4-cycle gasoline engine was treated with one known fault. Meaning that all 14 subgroups received their engines with the same fault to troubleshoot on the day of data collection. It is important to note that each group received the same engine that they had been working on in the previous weeks and all of them were in proper working order (i.e. running with no problems).

On the day of the data collection, each 4-cycle engine was topped with fresh oil and fuel. All teams were instructed to start their motors to diagnose any symptoms that may be present. Also, each team was given a troubleshooting scenario that was directly related to the problem with their motor. The fault for each 4-cycle gasoline engine was within the fuel/carburetor system; specifically, the float in the carburetor was flipped upside down. Therefore, once the individuals tried to start the motor the engine's carburetor was almost instantly flooded, which would hinder the motor from starting properly.

Instrumentation

Metacognition Instrument

Students' metacognitive ability was determined by utilizing the Metacognitive Awareness Inventory (MAI) (Appendix D), which was developed for use in educational psychology (Schraw & Dennison, 1994). This instrument posed a series of 52 items on a continuous 100-point bipolar scale that assesses an individual's metacognitive awareness. The right end of the scale indicates whether the statement is false about the individual; while the left end of the scale indicates whether the statement is true. In the MAI there are eight constructs including: (a) declarative knowledge, (b) procedural knowledge, (c) conditional knowledge, (d) planning, (e)information management strategies, (f) monitoring, (g) debugging strategies, and (h) evaluation. Therefore, the higher the number in each construct, the better the person's ability in that category and overall metacognitive awareness.

Cognitive Style Instrument

In order to identify the students' cognitive styles and to purposefully organize them into teams, I used Kirton's Adaptation-Innovation Inventory (KAI) (Kirton, 2003). This instrument posed a series of questions on the individual's preferred mode of learning (see Appendix E).

After the students completed the KAI, they received a score that ranged from 32 to 160. Scores that ranged from 32 to 95 were considered more adaptive, and scores that ranged from 96 to 160 were more innovative. It should be noted that according to Kirton (2003), the theoretical mean is 96; therefore, for this study, anything above 96 was considered innovative. Based on that score, students were purposefully placed in seven teams to complete the rest of the semester.

Course Motivation Survey

To investigate how motivated the students were before completing the troubleshooting task, all students completed the Course Interest Survey (CIS) developed by Keller (2006) (see Appendix K) to assess their motivation. The instrument consisted of 34 items on a five-point Likert-tyle scale from 1 = not true to 5 = very true. This instrument is comprised of four ARCS subscales (Attention, Relevance, Confidence, and Satisfaction). All the students received the CIS instrument via paper format before they engaged in the small gasoline engine modules and completed the troubleshooting tasks.

Table 5 highlights each measure of the ARCS scale housed within the overall CIS instrument. This table provides a depiction of the scoring guide utilized to attain each measure and overall CIS score (Keller, 2006, p.4). It is important to note that some items on the instrument were written inversely; therefore, they were entered into SPSS in *reverse* (Keller, 2006).

Table 5. Scoring Guide Developed for the Course Interest Survey (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

(table cont'd)

Attention	Relevance	Confidence	Satisfaction
21	20	17 (reverse)	18
24	22	27	19
26 (reverse)	23	30	31 (reverse)
29	25 (reverse)	34	32
	28		33

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Criterion-Referenced Pre and Post-Test

To accomplish the research objectives of this study, it was critical to determine the students' content knowledge covering 4 – cycle gasoline engines before and at the conclusion of the module to determine if there was any effect from the treatment. To determine content knowledge, I developed a 30–item criterion-referenced exam that presented a series of items about small gasoline engines. To ensure clarity and reliability of the exam, half of the items were modified from another small gasoline engines assessment developed by Blackburn (2015), and the other 15 were developed from a series of popular small gasoline engines textbooks, including (a) *Small Engines* by Radcliff (2016), (b) *Briggs & Stratton Small Engines and Equipment Maintenance* by London (2003), and (c) Briggs and Stratton Power Portal website (Figland, 2019, pg. 53). To ensure consistency, it was formatted utilizing a standard multiple-choice format (see Appendix F).

Troubleshooting Instrument

To conduct the troubleshooting portion of the study, a troubleshooting packet was developed based off of the technical troubleshooting model by Johnson's (1989) and Bloom's (2001) Taxonomy of Learning (see Appendix G). The troubleshooting packet comprised of nine items and two categories. The first category was developed using the technical troubleshooting model and asked each group to (a) hypothesize and (b) list all engine symptoms. The second category was the troubleshooting process and it asked seven questions directed at each level of Bloom's taxonomy. At the end of the packet, the groups were asked to identify whether their hypothesis was correct and if not, given a new sheet to restart the process. Each group was given three sets of hypothesis generation sheets to ensure a seamless transition of work if they did not solve the problem correctly on the first attempt. This instrument was qualitative in nature, but to quantify the instrument, a rubric was created to measure the level of learning with each question.

Data Collection

In the quantitative strand of this study, data were collected through a series of instruments including (a) pre/posttest, (b) MAI, (c) Kirton's Adaptation KAI, (d) Course Motivation Survey (e) troubleshooting/problem-solving instrument, and (f) academic and personal characteristics of the students.

To begin the data collection process, all students were notified of the study on the first day of class using the participation in the study and consent form (Appendix B). After I established participant consent, they were asked to complete the online version of the KAI (Appendix E) which was distributed through email and complete a print version of the MAI (Appendix D). Once the initial screenings were complete, the students were purposefully grouped and remained in those groups throughout the semester. In the final phase of the quantitative data collection, the students began the 4 – cycle gasoline engines unit. During the beginning and conclusion of this unit, a criterion-referenced pre/posttest (Appendix F) was given to assess individual knowledge and determine growth in knowledge. Following the pretest, all participants were instructed to complete the course motivation survey (Appendix H) to assess the students' motivations to complete the problem-solving tasks. Finally, data was collected on the final day of the semester through a troubleshooting application. To collect data in this step, a troubleshooting/problem-solving packet (Appendix G) was utilized, which was used to gain a better understanding of the problem-solving process.

Criterion-Referenced Test Reliability

To ensure reliability of the pre/posttest Wiersma and Jurs (1990) was utilized. The guidelines outlined by Wiersma and Jurs (1990) pinpoint eight factors to warrant the reliability of multiple-choice tests. In order to address each factor, Table 6 addresses how each was mitigated.

Table 6. Examples of Wiersma and Jurs's (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	The answer key was developed for accurate assessment

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CIS Validity and Reliability

To assess the validity of the instrument, the CIS was tested with a group of students where their grades and overall GPA were correlated with their CIS Scores (Keller, 2010). After analysis, it was determined that the instrument was a valid measure of motivation and not student learning because all correlations between the CIS and were above the .05 level and no correlations were above .05 between GPA and CIS (Keller, 2010). Cronbach's alpha was utilized to ensure the reliability of the instrument. Further, analysis revealed that each subscale had reliability estimates above .80; with an overall reliability estimate of .95 and therefore, the instrument was deemed reliable.

Metacognitive Awareness Inventory (MAI) Validity and Reliability

The MAI developed by Schaw and Dennison (1994) has been advanced as the only psychometric measure of metacognitive awareness for adults. This instrument has been widely used in reading comprehension and mathematics research to accurately assess metacognitive awareness and has been determined to be a valid and reliable instrument. The validity of this instrument was found to be .90, and the reliability coefficients ranged from .54 to .70. Therefore, the instrument was deemed to be a valid and reliable measure of metacognitive awareness (Schraw & Dennison, 1994).

KAI Validity and Reliability

Due to the widespread use of the KAI, there are multiple studies from varying disciplines to determine the validity and reliability of the instrument and its use to accurately assess cognitive style (Bailey & Glendinning, 1991; Hammond, 1986; Kirton, 2003; Taylor, 1993; & Selby et al., 1993). Regarding the validity of the instrument, those studies have determined that the evaluation yielded correlations ranging from .40 to .80 (Kirton, 2003). Through those studies, the reliability of the instrument was also measured, and those reliability coefficients ranged from .83 to .91. Therefore, the instrument was deemed reliable (Kirton, 2003).

Troubleshooting Instrument Reliability

To quantify the level of problem-solving ability, I created a rubric to assess the level of learning based on the questions asked in the troubleshooting/problem-solving instrument. The rubric was based on a 0 to 1 point scale with zero meaning the group did not attain the desired level of learning based on the answers given in their troubleshooting packet and a one identifying that they did achieve that level. To ensure the reliability of this measure, three raters were utilized. All the raters had experience teaching SBAE for at least three years and an emphasis in agricultural mechanics instruction. Further, an interrater reliability coefficient was established at .80; therefore, the instrument was deemed a reliable measure of problem-solving behavior.

Data Analysis

To address research question one, descriptive statistics were utilized to report frequencies, percentages, means, and standard deviations. For research question two, an independent samples t-test was utilized to examine if there was a relationship between cognitive diversity and metacognitive awareness. Further, post-hoc tests were conducted to identify if there were any relationships between the cognitive diversity groups and metacognitive awareness. For research questions three and four, independent sample t-tests were employed to determine the relationship between cognitive diversity, content knowledge, and motivation. To address research question five, I utilized a one-way ANOVA to determine if problem-solving behavior had an effect on metacognitive awareness. Finally, for research questions six and seven, a multiple regression analysis was performed to determine if problem-solving behaviors were significant predictors of hypothesis generation ability and students' time to solution.

Qualitative Strand

Instrumentation

Troubleshooting Instrument. During the troubleshooting activity, students were asked to verbalize and narratively respond to a series of questions to better contextualize the problem-solving process. First, the groups were asked to write down any symptoms and then write a hypothesis. These two questions were asked to follow Johnson's (1989) technical troubleshooting model (Appendix G). The following section asked questions pertaining to each level of Bloom's (2008) taxonomy of learning. As the students progressed through the application activity, they discussed the questions with their partners and answered each question in the troubleshooting packet.

Self-Reflection Packet. After the troubleshooting application, all students in this course were asked to complete a self-reflection packet about their experience. These reflection questions placed emphasis on how the groups communicated about solving the problem during the troubleshooting exercise. Therefore, the questions pertained to challenges, communication, areas of strength, and evaluation. These questions were asked to gain a holistic understanding of the problem-solving process and its complex nature (see Appendix I).

Data Collection

As previously noted, there were no random sampling techniques utilized; therefore, all groups were purposely created based on cognitive style score to establish cognitive diversity. As such, all students in AEEE 2003 - *Introduction to Agricultural Mechanics* course (N = 28) participated in the written reflection questions. Further, during the troubleshooting application, students were recorded using Zoom as another form of data to capture any interactions that occurred with their partner during the problem-solving process. However, due to large noise interference, the audio from the videos were inaudible. Therefore, the videos were not used, which is a limitation of the study.

The structured set of reflection questions (Appendix K) was written to gain a more holistic understanding of the overall problem-solving process. All teams were further split into dyads to complete the small engine unit. At the conclusion of the application activity, each student responded to the reflection questions individually in which they were asked to focus on the troubleshooting process that they just completed with their partner. These six questions were related to challenges, strengths, weaknesses, overcoming obstacles, communication, and reflection on the entire experience regarding what they would do differently if faced with the same problem again. In the directions, each student was asked to write five complete sentences. This was done to make sure we gained a deep understanding of each question. After the participants completed the reflection questions the data were coded for further analysis.

Data Analysis

After reflection questions were completed, the initial analysis of the responses began by utilizing Saldaña's (2021) coding suggestions. To gain a deeper understanding of the phenomena, I utilized three first-round coding types including (a) structural, (b) in-vivo, and (c) process. The first type of coding I employed was structural because it allowed me to initially categorize the data by commonalities (Saldaña, 2021). Thereafter, I employed in-vivo coding to gain a deeper understanding of the views of the participants and their experiences (Saldaña, 2021). Finally, to illuminate the process that participants engaged in during the experience, I employed process coding. Process coding can be utilized to search for routines as well as "changing and repetitive forms of action-interaction plus the pauses and interruptions that occur when persons act or interact for the purpose of reaching a goal or solving a problem" (Corbin & Strauss, 2015, p. 173).

After the first cycle of coding, I engaged in second round coding; specifically, axial coding. Axial coding is utilized to reassemble data that may have been split and "aims to link categories with subcategories and ask how they are related" (Charmaz, 2014, p. 148). Therefore, axial coding will illuminate the dominant characteristics of the overall problem-solving process that may have been missed in the quantitative data strand. Finally, the data were presented through themes in the findings section.

Qualitative Quality

To build quality into the study, Tracy (2010) established eight criteria to judge validity and reliability. The eight criteria that Tracy (2010) outlines are (a) worthy topic, (b) rich rigor, (c) sincerity, (d) credibility, (e) resonance, (f) significance, (g) ethical, and (h) meaningful coherence. Table 7 outlines each criterion and the strategies that were used to ensure qualitative quality.

Table 7. Plan for Building Quality into the Study

Criteria Categories	Strategies
Worthy Topic	• Provided statement and need of the study • Collected data in the semester
Rich Rigor	• Provided detailed data collection and analysis plans • Collected research over 16 weeks • Fully described participants and settings
Sincerity	• Provided a self-reflexivity statement • Outlined limitations

(table cont'd)

Criteria Categories	Strategies
Credibility	• Triangulated qualitative and quantitative data • Gave thick, rich descriptions within themes • Conclusions reflect themes and previous literature
Resonance	• Provided a rich and thorough description of the participants • Defined the parameters of the study
Significant Contribution	• Developed a conceptual framework to understand the problem-solving process
Ethical	• Gained IRB approval to work with human subjects
Meaningful Coherence	• Stated purpose and objectives • Utilized a mixed methods design to fit objectives • Triangulated research findings with literature and interpretation

Summary

Chapter III provided an overview of the study's design, population, demographic information of the sample, and instruments used to collect data. It also outlined the collection and data analysis procedures for each data strand and the validity and reliability were discussed for each instrument utilized in the quantitative strand, along with discussing qualitative quality for the qualitative strand. Next, chapter IV will illustrate the results from the quantitative and qualitative strands.

CHAPTER IV. FINDINGS

In this chapter, the quantitative findings are presented first followed by the qualitative. In the quantitative findings, participants' cognitive style, metacognitive awareness, problem-solving behavior, content knowledge, course motivation, time to solution, and hypothesis generation ability were described to explain the population by utilizing frequencies, percentages, means, and standard deviations. Next, relationships among the students' metacognitive awareness, cognitive diversity, problem-solving behaviors, time to solution, and hypothesis generation were described. Finally, the qualitative interpretation was described to gain a better understanding of the problem-solving process amongst participants and help to support the quantitative findings.

Research Objectives

1. Describe the level of metacognitive awareness, cognitive diversity, content knowledge, motivation, problem-solving behavior, time to solution, and hypothesis generation among the students in AEEE 2003.
2. Determine the effect cognitive diversity has on metacognitive awareness when troubleshooting a small gasoline engine.
    a. Null hypothesis: No differences will exist between cognitive diversity and metacognitive awareness when troubleshooting a small gasoline engine.
3. Determine the effect cognitive diversity has on content knowledge of students enrolled in an introductory to agricultural mechanics' course.
    a. Null hypothesis: No differences will exist between cognitive diversity and small engines content knowledge of students enrolled in an introductory agricultural mechanics' course.

4. Determine the effect cognitive diversity has on motivation of students enrolled in an introductory agricultural mechanics' course.
    a. Null hypothesis: No differences will exist between cognitive diversity and motivation of students enrolled in an introductory agricultural mechanics' course.
5. Determine the effect problem-solving behavior has on metacognitive awareness when troubleshooting a small gasoline engine.
    a. Null hypothesis: No differences will exist between problem-solving behavior and metacognitive awareness when troubleshooting a small gasoline engine.
6. Determine if problem-solving behaviors are significant predictors of time to solution when troubleshooting a small gasoline engine.
7. Determine if problem-solving behaviors are significant predictors of hypothesis generation ability when troubleshooting a small gasoline engine.
8. What are the processes that students utilize when troubleshooting a small gasoline engine?

Quantitative Findings

Research Question One

The first research objective sought to describe the cognitive and metacognitive processes of the students enrolled in AEEE 2003 – *Introduction to Agricultural Mechanics*. Specifically, I sought to describe their level of metacognitive awareness, cognitive diversity, problem-solving behavior, time to solution, and hypothesis generation ability. To gain a more holistic understanding of students' metacognitive processes, Tables 8 and 9 describe the items associated with each construct for the MAI instrument. The items in the first construct, knowledge of cognition, sought to understand the students' declarative, procedural, and conditional knowledge.

Among the items in this construct, the most frequently selected by students were "I try to use strategies that would have worked in the past" and "I learn best when I know something about the topic," both selected by 100% of participants. The two lowest reported items in the construct were: "I find myself using helpful learning strategies automatically" (*f* = 16, 57.1%) and "I am good at remembering information" (*f* = 14, 50%).

Table 8. Metacognitive Awareness Inventory Knowledge of Cognition Construct Items Frequencies and Percentages of Students Enrolled in AEEE 2003 (*N*=28)

Items	*f*	%
Declarative Knowledge		
I learn more when I am interested in the topic.	27	96.4
I have control over how well I learn.	23	82.1
I am a good judge of how well I understand something.	23	82.1
I understand my intellectual strengths and weaknesses.	21	75
I know what kind of information is most important to learn.	19	67.9
I am good at organizing information.	17	60.7
I know what the teacher expects me to learn.	17	60.7
I am good at remembering information.	14	50.0
Procedural Knowledge		
I try to use strategies that would have worked in the past.	28	100
I have a specific purpose for each strategy I use.	23	82.1
I am aware of what strategies I use when I study.	18	64.3
I find myself using helpful learning strategies automatically.	16	57.1
Conditional Knowledge		
I learn best when I know something about the topic.	28	100
I can motivate myself to learn when I need to.	24	85.7
I use my intellectual strengths to compensate for my weaknesses.	24	85.7
I know when each strategy I use will be most effective.	18	64.3

Note. Knowledge of cognition consists of declarative, procedural, and conditional knowledge. Scores range from 0 – 16.

The other construct, regulation of cognition, consisted of items asking about planning, comprehension monitoring, information management strategies, debugging strategies, and evaluation. For this construct, the highest reported items were: "I try to translate new information into my own words" and "I stop and reread when I get confused" (*f* = 28, 100%). There was a three-way tie for the lowest reported items, which only 15 (53.6%) of the students indicated that was true of them. Those items included: "I know how well I did once I finish a test," "I organize my time to best accomplish my goals," and "I pace myself while learning in order to have enough time." The lowest reported item was "I ask myself questions about the material before I begin," which only 10 (35.7%) students reported was true of them.

Table 9. Metacognitive Awareness Inventory Regulation of Cognition Construct Items Frequencies and Percentages of Students Enrolled in AEEE 2003 (*N*=28)

Items	*f*	%
Planning		
I read instructions carefully before I begin a task	23	82.1
I think of several ways to solve a problem and choose the best one	21	75
I think about what I really need to learn before I begin a task	20	71.4
I set specific goals before I begin a task	20	71.4
I pace myself while learning in order to have enough time	15	53.6
I organize my time to best accomplish my goals	15	53.6
I ask myself questions about the material before I begin	10	35.7
Information Management Strategies		
I try to translate new information into my own words	28	100
I slow down when I encounter important information	25	89.3
I focus on the meaning and significance of new information	25	89.3
I create my own examples to make information more meaningful	25	89.3
I consciously focus my attention on important information	23	82.1
I draw pictures or diagrams to help me understand while learning	21	75

(table cont'd)

Items	*f*	%
I ask myself if what I'm reading is related to what I already know	20	71.4
I try to break studying down into smaller steps	20	71.4
I focus on overall meaning rather than specifics	18	64.3
I use the organizational structure of the text to help me learn	17	60.7
Debugging Strategies		
I stop and reread when I get confused	28	100
I re-evaluate my assumptions when I get confused	26	92.9
I stop and go back over new information that is not clear	26	92.9
I change strategies when I fail to understand	25	89.3
I ask others for help when I don't understand something	24	85.7
Comprehension Monitoring		
I ask myself questions about how well I am doing while I am learning something new	24	85.7
I consider several alternatives to a problem before I answer	24	85.7
I ask myself periodically if I am meeting my goals	19	67.9
I periodically review to help me understand important relationships	19	67.9
I find myself analyzing the usefulness of strategies while I study	18	64.3
I ask myself if I have considered all options when solving a problem	17	60.7
I find myself pausing regularly to check my comprehension	16	57.1
Evaluation		
I ask myself how well I accomplish my goals once I'm finished	25	89.3
I ask myself if there was an easier way to do things after I finish a task	25	89.3
I ask myself if I learned as much as I could have once I finish a task.	24	85.7
I summarize what I've learned after I finish	19	67.9
I ask myself if I have considered all options after I solve a problem	17	60.7
I know how well I did once I finish a test	15	53.6

Note. Regulation of cognition consists of planning, comprehension monitoring, info. management strategies, debugging, and evaluation. Scores range from 0 – 32.

Table 10 describes each team's time to solution. All teams had 60 minutes to complete the troubleshooting task. At the end of the 60 minutes, if they had not correctly identified and corrected the problem, they timed out and received a time of 60 minutes. Overall, there were seven teams with each team having been divided into two groups to complete the troubleshooting application. Team one comprised of homogeneous adaptive individuals, and they completed the task in 30 minutes 32 seconds and 60 minutes, respectively. Team two was identified as homogeneous innovative and Group A completed the task in 15 minutes eight seconds, while Group B completed the task in 56 minutes 17 seconds. Group A and Group B in team three both timed out of the activity and received times of 60 minutes. Team four, which was homogeneous innovative, recorded completion times of 19 minutes, 17 seconds and 48 minutes, 59 seconds. The final homogeneous adaptive team had a time of 60 minutes and 39 minutes, 52 seconds. Teams six and seven consisted of individuals who were heterogeneous. In team six, Group A had a time of 50 minutes 55 seconds and Group B had a time of 35 minutes and 53 seconds. Finally, team seven recorded times of 24 minutes, 34 seconds, and 40 minutes 23 seconds.

Table 10. Small Engine Teams Time to Successful Completion of the Troubleshooting Problem (*N* = 28)

Small Engines Teams	*Group A*	*Group B*
	Time to completion	
Team 1-Homogeneous Adaptive	30 minutes 32 seconds	60 minutes*
Team 2-Homogeneous Innovative	15 minutes 8 seconds	56 minutes 17 seconds
Team 3-Homogenous Adaptive	60 minutes*	60 minutes*
Team 4-Homogeneous Innovative	19 minutes 17 seconds	48 minutes 59 seconds
Team 5-Homogeneous Adaptive	60 minutes*	39 minutes 52 seconds
Team 6-Heterogeneous	50 minutes 55 seconds	35 minutes 53 seconds
Team 7-Heterogeneous	24 minutes 34 seconds	40 minutes 23 seconds

*Note. A * represents the group timed out of the activity*

To better understand the role of cognitive diversity of students' problem-solving abilities, all teams were compressed into either heterogeneous, homogeneous innovative, or homogeneous adaptive. In all, the heterogeneous group consisted of teams six and seven and had an average time to solution of 37 minutes 41 seconds. Next, the homogeneous adaptive group consisted of teams one, three, and five and had a mean time to solution of 51 minutes 42 seconds. Finally, the homogeneous innovative group, which consisted of teams two and four, had a mean time of 34 minutes 25 seconds (see Table 11).

Table 11. Average Time to Solution by Cognitive Diversity (*N* = 28)

Groups	Mean Time to Solution
Heterogeneous	34 minutes 25 seconds
Homogeneous Adaptive	51 minutes 42 seconds
Homogeneous Innovative	37 minutes and 15 seconds

Along with recording the group's time to solution, they were also asked to develop a hypothesis based on the troubleshooting application. Table 12 outlines each cognitive diversity group's ability to generate a correct hypothesis. Overall, the homogeneous innovative group had a 75% success rate on the hypothesis, while the homogeneous adaptive group only had a success rate of 66.7%. Further, the heterogeneous group had a 100% success rate on hypothesis generation. In total, 22 of 28 (78.6%) participants were able to create a correct hypothesis.

Table 12. Ability to Create a Correct Hypothesis based on Cognitive Diversity Groups (N = 28)

Cognitive Diversity	*Hypothesis Generation Ability*	
	f	%
Homogeneous Innovative	6	75
Homogeneous Adaptive	8	66.7
Heterogeneous	8	100
Total	22	78.6

Note. Hypothesis generation was recorded as 1=correct or 2=not correct.

While the students were asked to hypothesize a correct solution, they were simultaneously asked a series of six items based on Bloom's (2008) taxonomy of learning. These six items were completed by students during the application process to better understand their problem-solving behaviors. After analysis, the means were interpreted using the following real limits, which indicated that means from .00 - .29 were *poor*, .30 - .59 were *weak*, .60 – .89 were *good*, and .90 – 1.00 were *excellent*.

In the first level of Bloom's, remember, 16 (57.1%) of the students had a mean of 1.00 and were interpreted as *excellent*, 12 (42.9%) had a mean of .67 or *good*. In the second stage of *understanding*, the students were asked to identify the system to which the part at fault belonged. Overall, the majority of students were able to answer this item correctly, M = 1.0, f = 16, 92.9%. In the application phase of Bloom's taxonomy, the students were asked to explain the steps they took to correct the problem they identified. Of those students, 16 (57.1%) had a mean score of 1.00, four (14.3%) had a mean score of .67, six (21.4%) had a mean score of .33, and two (7.1%) had a mean score of 0. Further, in the analysis phases of Bloom's taxonomy, the students were asked "what is the function of that part within its system?" Overall, six (21.4%) had a mean score of 1.00, eight students (28.6%) had a mean score of .67 and .33, respectively, while 14 (50%) of students had a mean score of 0 or poor. In the evaluation construct, of the 28, only four (14.3%) had a mean score of 1.00, while the majority had a mean score of .33 (*f* = 10, 35.7%). For the final phase of Bloom's taxonomy, the participants were asked to identify if they had created a correct hypothesis and solved it effectively. Of the participants, six (21.4%) had a mean score of 1.00 interpreted as *excellent*, 10 (35.7%) had a mean score of .67 or *good*, two (7.1%) had a mean score of .33 or *weak*, and 10 (35.7%) had a mean score of 0 interpreted as *poor*.

Table 13. Problem-Solving Behaviors of Students Enrolled in AEEE 2003 (*N* = 28)

Constructs	M	*f*	%
Remember			
What is the name of the part you have identified as the fault?			
	1.0	16	57.1
	.67	12	42.9
Understand			
What system does that part belong to?			
	1.0	26	92.9
	.67	2	7.1
Apply			
What steps did you take to correct the problem?			
	1.0	16	57.1
	.67	4	14.3
	.33	6	21.4
	.00	2	7.1
Analyze			
What is the function of that part within its system?			
	1.0	6	21.4
	.67	4	14.3

(table cont'd)

Constructs	M	*f*	%
	.33	4	14.3
	.00	14	50.0
Evaluate			
Why is your hypothesis supported?			
	1.0	4	14.3
	.67	6	21.4
	.33	10	35.7
	.00	8	28.6
Create			
Did you create a correct hypothesis?			
	1.0	6	21.4
	.67	10	35.7
	.33	2	7.1
	.00	10	35.7

Note. Scale – Poor (.00 - .29), Weak (.30 - .59), Good (.60 - .89), Excellent (.90 – 1.0).

In order to determine the level of content knowledge in small gasoline engines, all students completed a multiple choice pre/posttest at the start of the module and the conclusion of the final module. Table 14 below describes the content knowledge of the students enrolled in this course based on their cognitive diversity grouping (i.e. homogeneous or heterogeneous groups). As such, the average pretest score, regardless of diversity group, was 12.75 out of 30 (42.5%) and the average posttest score was 17.89 out of 30 (59.7%). When examining each diversity group further it was determined that on the pre-test homogeneous groups scored an average of 10.5 out of 30 (35%) and the heterogeneous groups scored 14.43 out of 30 (48.1%). Finally, after the unit, the posttest scores determined that the homogeneous group scores averaged 18.08 (60.3%) and the heterogeneous group scores averaged 17.75 (59.2%). Therefore, the homogeneous groups scored 7.58 points better on the posttest, while the heterogeneous groups scored on average 3.32 points higher.

Table 14. Small Gasoline Engines Content Knowledge Scores of Students' Enrolled in AEEE 2003 (*N* = 28)

Item	*f*	*M*	*SD*	%	Minimum	Maximum
Overall Pretest Score	28	12.75	5.64	42.5	0	25
Overall Posttest Score	28	17.89	5.35	59.7	0	26
Pre-test						
Homogenous Groups	12	10.50	6.52	35	0	22
Heterogeneous Groups	16	14.43	4.36	48.1	7	25
Posttest						
Homogeneous Groups	12	18.08	7.27	60.3	0	26
Heterogeneous Groups	16	17.75	3.59	59.2	9	25

After the completion of the pre/posttest, the participants were also given a course motivation survey prior to engaging in the problem-solving activity. Table 15 below describes the overall motivation scores and then subsequent cognitive diversity groups. Overall, the average motivation score, regardless of diversity group, was 3.46 out of 4.00. When examining each group, it was determined that the homogeneous groups had an average score of 3.19, and the heterogeneous groups had an average score of 3.66. Further, each individual construct was examined for each cognitive diversity group. Within the *attention* construct, the homogeneous groups had a mean score of 2.84, and the heterogeneous groups had a mean score of 3.52. In the construct, *relevance,* the heterogeneous groups averaged 3.74, while the homogeneous groups averaged 3.33. Further, within *satisfaction*, the homogeneous groups had a mean of 3.56, and the heterogeneous groups had a mean of 3.93. Finally, within the construct of *confidence*, the heterogeneous had an average score of 3.43 and the homogeneous diversity groups had an average score of 3.04.

Table 15. Course Motivation Scores for Students Enrolled in AEEE 2003 (*N* = 28)

Item	*f*	*M*	*SD*	Minimum	Maximum
Overall Course Motivation	28	3.46	.737	0	3.98
Overall Course Motivation by Cognitive Diversity Group					
Homogeneous Groups	12	3.19	1.04	0	3.93
Heterogeneous Groups	16	3.66	.290	2.97	3.98
Individual Construct Course Motivation by Cognitive Diversity Groups					
Attention					
Homogeneous Groups	12	2.84	.995	0	4
Heterogeneous Groups	16	3.52	.345	2.875	4
Relevance					
Homogeneous Groups	12	3.33	1.12	0	4.11
Heterogeneous Groups	16	3.74	.377	2.778	4.11
Satisfaction					
Homogeneous Groups	12	3.56	1.17	0	4.44
Heterogeneous Groups	16	3.93	.401	3	4.44
Confidence					
Homogeneous Groups	12	3.04	1.01	0	3.63
Heterogeneous Groups	16	3.43	.223	3	3.75

At the beginning of the semester, the students were given the KAI and MAI to assess their cognitive style and metacognitive awareness. They were purposely grouped based on cognitive style diversity into homogenous adaptive, homogeneous innovative, and heterogeneous. From those groups, they were divided into dyads to complete the troubleshooting exercise, in which I recorded their time to solution, the correctness of hypothesis generation one, and their problem-solving behaviors. Table 16 describes the mean and standard deviations of each independent variable utilized in this study. On average, the mean cognitive style score was 91.71, which indicated that the majority of students in this population were *more adaptive*. Also, their average metacognitive awareness score was 39.29 out of 52.00, and they had a mean problem-solving behavior of 3.93 out of 6.00. Amongst the groups, the average time to solution was 43 minutes and 15 seconds, and a mean hypothesis generation ability of 1.21 out of 2.00.

Table 16. Overall Means for Students Enrolled in AEEE 2003 (N = 28)

Item	*M*	SD
Cognitive Style (KAI)	91.71	14.17
Metacognitive Awareness (MAI)	39.29	6.25
Course Motivation	3.46	.737
Time to Solution	43.15	16.01
Hypothesis Generation Ability	1.21	.418
Problem-Solving Behavior	3.93	1.45

Note. KAI scores range from 32-160. Scores from 32-95 = more adaptive; 96-160 = more innovative. MAI scores range from 0 – 52.

Research Question Two

Research question two focused on determining if cognitive diversity had any effect on metacognitive awareness. Basic descriptive characteristics of cognitive diversity and metacognitive awareness can be found in Table 8 - 12. To test the hypothesis, an independent sample t-test was conducted and revealed that there were no statistically significant differences between cognitive diversity and metacognitive awareness (t = .274; p = .393) (see Table 17). Further, a test of the effect size revealed that it was a small effect r = .11. Therefore, based on the analysis, we failed to reject the null hypothesis.

Table 17. Independent T-Test for the Effect Cognitive Diversity has on Metacognitive Awareness

F	*df*	*t*	*p*
.707	26	.274	.393

Research Question Three

To determine if cognitive diversity had an effect on content knowledge an independent sample t-test was conducted and revealed that there were no statistically significant differences between cognitive diversity and content knowledge (t = 1.657; p = .055) (see Table 18). Further, a test of the effect size revealed that it was a small effect r = .63. Therefore, based on the analysis, we failed to reject the null hypothesis.

Table 18. Independent T-Test for the Effect Cognitive Diversity has on Content Knowledge (N = 28)

F	*df*	*t*	*p*
9.752	26	1.657	.055

Research Question Four

To determine if cognitive diversity had an effect on course motivation, an independent sample t-test was conducted and revealed that there was a statistically significant difference between cognitive diversity and course motivation (t = -1.707; p = .050) (see Table 19). Further, a test of the effect size revealed that it was a large effect *r* = .71. Therefore, based on the analysis, I rejected the null hypothesis.

Table 19. Independent T-Test for the Effect Cognitive Diversity has on Course Motivation (*N* = 28)

F	*df*	*t*	*p*
2.720	26	-1.707	.050

Research Question Five

The fifth objective sought to determine if overall problem-solving ability had an effect on metacognitive awareness. The one-way ANOVA revealed no statistically significant differences between overall problem-solving ability and metacognitive awareness (p = .945) (see Table 20). Therefore, we failed to reject the null hypothesis.

Table 20. One-Way ANOVA for the Effect Problem-Solving Behavior has on Metacognitive Awareness

SS	*F*	*df*	*p*
127.714	3.27	8	.945

Research Question Six

Prior to the multiple regression analysis, a correlation matrix was used to assess multicollinearity between the variables (see Table 21). Based on the analysis, it revealed that limited multicollinearity existed; therefore, multicollinearity was not considered a concern in this study because the VIF was 1.281. Field (2010) stated that a VIF close to 1 indicates no multicollinearity problems.

Table 21. Relationships between Time to Solution and Problem-Solving Behavior Variables (N = 28)

Variables	1	2	3	4	5	6	7
1. Time	-						
2. Remember	-.610**	-					
3. Understand	-.308	.320	-				
4. Apply	-.545**	.468*	.333	-			
5. Analyze	-.371	.641**	.243	.449*	-		
6. Evaluate	-.249	.611**	.333	.373	.795**	-	
7. Create	-.445*	.683**	.336	.582**	.822**	.881*	-

Note: * p <.05, ** p < .01

To understand the relationship between problem-solving behaviors and time to solution, multiple regression was utilized. Basic descriptive characteristics of the problem-solving behaviors and time to solutions can be found in Tables 10 and 12. The analysis revealed that two of the six predictor variables (remember and apply) entered the model and were statistically significant ($p < .001$). Therefore, the two-predictor models were able to account for 44.4% of the total variance in time to solution, $F = 9.981$, $p <.001$, $R^2 =.444$ (see tables 22 and 23).

Table 22. Multiple Regression Analysis of Time to Solution and Problem-Solving Behaviors ANOVA Summary

ANOVA				
Model	df	MS	F	*p*
Regression	2	1536.647	9.981	<.001
Residual	25	153.957		
Total	27			

Table 23. Multiple Regression Analysis of Time to Solution and Problem-Solving Behaviors Model Summary

Model Summary					
Model	R	R^2	R^2 Change	F Change	Sig. F Change
1	.602	.362	.362	14.758	<.001
2	.666	.444	.082	3.682	.066

Finally, within this model, only two of the six variables entered; therefore, four variables were excluded. Table 24 outlines the excluded variables from the model including their *t* and significance values. Amongst those excluded variables included (a) understand, (b) analyze, (c) evaluate, and (d) create.

Table 24. Excluded Variables from the Regression Model

Excluded Variables	t	*p*
Understand	-.361	.721
Analyze	.609	.548
Evaluate	1.299	.206
Create	.562	.579

Research Question Seven

Prior to the multiple regression analysis for hypothesis generation and problem-solving behaviors, a correlation matrix was used to assess multicollinearity between the variables (see Table 25). Based on the analysis, it revealed that multicollinearity was not a concern because the VIF was 1.114, which indicates collinearity is not an issue (Field, 2010).

Table 25. Relationships between Hypothesis Generation Ability and Problem-Solving Behavior Variables (*N* = 28)

Variables	1	2	3	4	5	6	7
1. Hyp. #1	-						
2. Remember	-.471*	-					
3. Understand	-.679**	.320	-				
4. Apply	-.621**	.459*	.345	-			
5. Analyze	-.381*	.636**	.259	.518**	-		
6. Evaluate	-.527**	.615**	.358	.357	.761**	-	
7. Create	-.480**	.678**	.326	.588**	.836**	.898**	-

Note: * p <.05, ** p < .01

A multiple linear regression was also utilized to determine if problem-solving behaviors were significant predictors of the ability to create a correct hypothesis. Basic descriptive characteristics of problem-solving behaviors and hypothesis generation one can be found in Tables 12 and 13. After analysis, the model revealed that two of the six predictor variables (remember and understand) were statistically significant (p <.001). Therefore, the two-predictor model was able to account for 49.1% of the total variance in hypothesis generation one, F = 12.054, $p < .001$, $R^2 = .491$ (see Tables 26 and 27).

Table 26. Multiple Regression Analysis of Hypothesis Generation and Problem-Solving Behaviors ANOVA Summary

ANOVA				
Model	df	MS	F	*p*
Regression	2	1.157	12.054	<.001
Residual	25	.096		
Total	27			

Table 27. Multiple Regression Analysis of Hypothesis Generation and Problem-Solving Behaviors Model Summary

Model Summary					
Model	R	R^2	R^2 Change	F Change	Sig. F Change
1	.603	.364	.364	14.857	<.001
2	.701	.491	.127	6.250	.019

Finally, within this model, only two of the six variables entered; therefore, four variables were excluded. Table 28 outlines the excluded variables from the model, including their *t* and significance values. Amongst those excluded variables included (a) apply, (b) analyze, (c) evaluate, and (d) create.

Table 28. Excluded Variables from the Regression Model

Excluded Variables	t	*p*
Apply	-1.582	.121
Analyze	.128	.900
Evaluate	-1.087	.288
Create	-1.007	.324

Qualitative Findings

Research Question Eight

To better understand the problem-solving process, participants completed individual self-reflection narratives that prompted them to critically think about the problem-solving process in which they had engaged. After initial data coding, axial coding was utilized, and three themes emerged including, (a) *navigating troubleshooting*, (b) *cognitive supports*, and (c) *thinking-about-thinking*.

Theme 1: Navigating Troubleshooting

The first theme that emerged was barriers to the problem-solving process that participants experienced while troubleshooting their small gasoline engines. Barriers were identified as prolonging obstacles that slowed the progression of problem-solving but did not fully impede the process. For example, many of the teams had difficulty identifying the initial problem but were able to continue through the problem-solving process. However, when attempting to understand the complex barriers that the students endured during the problem-solving process, two sub-categories surfaced: (a) communication barriers and (b) process barriers.

Communication Barriers. Emerging from the analysis, was students' inability to effectively communicate with their partner to solve problems. Some of the teams struggled to communicate throughout the entire process, which caused them to miss steps and not be able to generate ideas. Participant #6 stated, "We talked, but there wasn't much input from her about the issue at hand." Another stated, "We basically communicated by saying as little as possible" (Participant 17). Participant 17 went on to state that it was difficult at times to work on the engine when no one was talking, which led to mistakes. This notion was echoed by Participants 1 and 4, who explained, "[Our] communication was not good, which made it hard to decide on a hypothesis," and "We wasted a lot of time not talking and going back and forth on the issue, which slowed us down." This lack of partner communication led to an inability to effectively problem solve and caused errors throughout the problem-solving process.

I observed this phenomenon throughout the experiment, especially with teams who were homogeneously grouped. In particular, as I observed the groups during the problem-solving exercise, I noted that many of the individuals had a *blank stare* as they were reading through the scenario and materials indicating that they were confused by the problem. When examining such issues through Bloom's (2001) taxonomy of learning, students must have the proper lower-order thinking abilities to be able to remember key facts or information that is important to the task of interacting with a problem. This confusion led those students to rarely give input into the solution. This lack of communication with their partner likely was the major setback of successfully completing the troubleshooting exercise because the channel of communication was broken.

Process Barriers. The second barrier to problem-solving emerged during the participants' troubleshooting. Process barriers were identified as aspects of problem-solving that hindered students' ability to solve problems that were cognitive in nature. Of the process barriers, most of the participants had the most difficulty with identifying the problem. Participant 9 stated: "Overall, figuring out the issue was most challenging." Meanwhile, Participant 18 explained: "determining the issue was the most challenging because there were multiple reasons that could have been the problem." Further, this sentiment was echoed by Participant 17 who said, "determining the issue was difficult because we had to know how the symptoms were affecting the engine." According to Bloom (2008), in order for an individual to identify and decode a problem, they must possess the correct domain-specific knowledge. For example, the students in this study would have had to have had knowledge of small engines and carburetor issues to identify the problem.

However, the participants also expressed issues with understanding and recalling previous information. According to Bloom (2001) for an individual to successfully problem solve they must be able to understand the scenario or problem and then be able to remember domain-specific knowledge by recalling facts and information about the problem. Specifically, many of the participants communicated that it was difficult for them to understand and decode the given troubleshooting scenario to further identify the problem. For example, Participant 2, recalled: "One of the most challenging aspects was understanding the scenario." Further, Participant 3 also stated that understanding the scenario was difficult but elaborated by stating that "the process of symptom elimination was difficult." This sentiment was expressed by Participants 15 and 17, who also had difficulty processing the scenario because the "symptoms were not explicitly written or given."

In my observations, I captured fieldnotes that chronicled how many of the participants struggled with self-doubt and low self-efficacy during the development of their hypothesis. Specifically, many of the individuals expressed they were unsure if their hypothesis was correct and if they would be able to continue to solve the problem correctly. On this point, Participant 11 stated, "it was challenging to figure out the answer because we weren't sure if we correct or not to proceed." This was also reiterated by Participant 15 who said that they felt their own self-doubt got in the way of developing a hypothesis. Participant 28 also reported: "our confidence was the main problem [because of this] we continually second guessed ourselves throughout the process." This lack of self-efficacy could have ultimately had an impact on the participants' abilities to fully regulate their learning. According to Zimmerman (1997), an individual must be able to regulate their emotions during the learning process because they often struggle with being able to fully utilize more complex domains of knowledge.

Theme 2: Cognitive Supports

The second theme, cognitive support, emerged as students described the factors that aided them during the problem-solving process. Therefore, cognitive supports represented the specific resources or services that positively impacted students' problem-solving. One of the largest cognitive supports identified by many of the participants was having a partner to problem solve. One of the participants stated: "having a partner was super helpful [because] the balance of our two brains helped us solve faster" (Participant 10). Participant 12 also stated that having a partner was extremely helpful because "[my partner] helped me talk out possible problems." Further, Participants 5 and 26 expressed that being able to talk through the information in the scenario helped them stay on track. Specifically, for Participant 26 her partner helped, "to get all my ideas out, good or bad." Participant 21 also noted that having a "supportive and willing partner" was the key to success.

In this theme, participants expressed utilizing the troubleshooting materials as helpful. During the application, participants had access to their troubleshooting materials and many of the participants noted that being able to utilize their troubleshooting concept map was helpful in identifying the problem. Specifically, Participant 22 stated: "having the troubleshooting tree was a good reference to help us narrow down the problem." Similarly, Participant 19 said, "the [troubleshooting] tree helped the most in determining the issue [because] it was a good starting point." Further, it was also noted that the troubleshooting curricular materials helped to keep the participants engaged with each other and solving the problem. It should be noted that the troubleshooting materials were developed to help guide students through the situated problem utilizing a structured questioning approach based on the conceptual framework for this study.

Theme 3: Thinking-About-Thinking

In the final theme, thinking-about-thinking, the students expressed their opinions on how they would engage with this problem if they encountered it in the future. The majority of the participants discussed how they would like to have more practice with procedural knowledge, so they are better at applying that knowledge to the task. Specifically, Participant 3 stated: "[I] would like to have more knowledge of the engine components [and also] taking apart the engine a greater number of times." Similarly, Participant 9 reflected: "I would like to have more knowledge of engine components and where they are supposed to go and also take apart the engine several more times."

This led the participants to discuss the diverse ways that they would have solved the carburetor problem differently. Specifically, they illuminated the procedural steps they would have taken differently to make the process easier. For example, Participant 18 explained that they would have just started by taking the carburetor bowl off first, instead of removing the air filter and the entire carburetor. Further, Participant 7 explained that with more knowledge, they would have drained the gas first to be able to work with the carburetor more easily.

Finally, some of the participants discussed that having the ability to reflect on and apply their knowledge to different problem-based scenarios would have been beneficial to their learning. This was expressed by Participant 7 who stated: "[I would have liked to] learn more about different [troubleshooting] scenarios, so I would be better at applying the knowledge." In a similar vein, Participant 2 revealed: "having more experience with troubleshooting scenarios would have made us better."

Summary

The purpose of this study was to understand the effects metacognitive and cognitive processes have on student's ability to solve problems. The quantitative strand reported information associated with each independent and dependent variable in the study to meet the overall objectives. In this study, I failed to reject three of the four null hypotheses, which indicated that there were no differences between cognitive diversity, problem-solving behavior, course motivation, content knowledge, and metacognitive awareness. However, I rejected one of the null hypotheses because there was found to be a statistical significance between cognitive diversity and course motivation. Further, differences did exist between problem-solving behavior, time to solution, and hypothesis generation ability. Subsequently, the qualitative strand revealed three themes regarding students' views on the problem-solving process, which included: (a) *navigating troubleshooting*, (b) *cognitive supports*, and (c) *thinking-about-thinking*. As such, the qualitative strand's findings helped to explain the problem-solving process as the individuals were engaging in a real-world problem. Therefore, the findings from both strands were complementary and illuminated insights into the complex nature of the problem-solving process, which led to the conclusions, implications, discussion, and recommendations outlined in Chapter V.

CHAPTER V. CONCLUSIONS, IMPLICATIONS, & RECOMMENDATIONS

Summary of the Research Problem

The demand for highly trained and competent workers who have the necessary critical thinking skills and ability to collaborate has been on the rise in recent decades (Weeks et al., 2018). These skills build a critical foundation for individuals to be able to define, locate, and solve a variety of problems (Allen et al., 2011; Alston et al., 2009; Robinson & Garton, 2008). However, in the current educational environment, students are not being challenged to develop their higher-order thinking skills, which is in part due to the lack of secondary education teachers' inability to integrate these skills into current teaching methods (Jonassen, 2001; Pate & Miller, 2011b; Ulmer & Torres, 2007).

To address this issue, SBAE teachers and teacher preparation sites have been called upon to integrate critical thinking skills into their curriculum (Chumbley et al., 2018; Pate & Miller, 2001a). In SBAE, research on problem-solving and critical thinking have suggested that educators need to build metacognitive and cognitive functions by continuing to develop opportunities for students to solve real-world problems (Parr et al., 2006; Pasher et al., 2007). However, for current and future SBAE teachers to be able to effectively integrate these skills, it is imperative that they understand cognitive style differences and utilize diverse teaching methods in their curriculum (Blackburn et al., 2014; Chumbley et al., 2018; Lamm et al., 2011; Ulmar & Torres, 2007). Therefore, it is integral that teacher preparation programs promote future SBAE teachers' awareness of cognitive and metacognitive ability, and their ability to successfully develop and implement teaching strategies and materials to promote problem-solving (Blackburn et al., 2014; Chumbley et al., 2018; Lamm et al., 2011).

Chapter I introduced the study's background, need for the study, conceptual framework, purpose, research objectives, limitations, assumptions, and key terms. Chapter II then illustrated the foundations of agricultural education, primary teaching methods, introduced cognition and metacognition, and finished expanding on factors associated with problem-solving and troubleshooting. Chapter III then presented the embedded mixed methods research design associated with the study (Creswell & Clark, 2018), along with both strands' methods and procedures for data collection and analysis. Chapter IV provided the findings of both strands, quantitative and qualitative, of data collected. Finally, Chapter V offers insights into the overall conclusions, implications, and further recommendations regarding this study. A review of the study's findings will be given to discuss the study's results from Chapter IV. Also, to give context to this overall chapter, a review of the study's literature, methods, and purpose and research objectives will be reviewed.

Summary of Research Methods and Procedures

This study utilized an embedded mixed methods design (Creswell & Clark, 2018) to examine the role of cognitive and metacognitive ability on problem-solving ability. As such, data were collected and analyzed separately but mixed for interpretation (Crewell & Clark, 2018). For this study, priority was given to the quantitative strand; however, qualitative data were being used to triangulate the findings from the quantitative strand. All quantitative data were analyzed using SPSS 27 software. Research objective one was addressed using descriptive statistics, while research objectives two, three, and four employed independent sample t-tests. Further, research objective five utilized a one-way ANOVA, and research objectives six and seven employed a multiple regression analysis.

To investigate the qualitative phase of this study, research objective eight sought to determine the processes students utilize when troubleshooting a small gasoline engine. Through the analysis of data, three themes emerged: (a) *navigating troubleshooting*, (b) *cognitive supports,* and (c) *thinking-about-thinking*. These themes provided insight into the study's quantitative findings by explaining the experiences these students were engaged in during the troubleshooting task and illuminating the critical factors affecting the problem-solving process.

Purpose of the Study

The purpose of this study was to investigate the effects of an individual's metacognitive and cognitive processes on their ability to problem solve in an introductory to agricultural mechanics course at Louisiana State University (LSU).

Research Objectives

1. Describe the level of metacognitive awareness, cognitive diversity, problem-solving behavior, time to solution, and hypothesis generation among the students in AEEE 2003.
2. Determine the effect cognitive diversity has on metacognitive awareness when troubleshooting a small gasoline engine.
    a. Null hypothesis: No differences will exist between cognitive diversity and metacognitive awareness when troubleshooting a small gasoline engine.
3. Determine the effect cognitive diversity has on content knowledge of students enrolled in an introductory to agricultural mechanics' course.
    a. Null hypothesis: No differences will exist between cognitive diversity and small engines content knowledge of students enrolled in an introductory agricultural mechanics' course.

4. Determine the effect cognitive diversity has on motivation of students enrolled in an introductory agricultural mechanics' course.
    a. Null hypothesis: No differences will exist between cognitive diversity and motivation of students enrolled in an introductory agricultural mechanics' course.
5. Determine the effect problem-solving behavior has on metacognitive awareness when troubleshooting a small gasoline engine.
    a. Null hypothesis: No differences will exist between problem-solving behavior and metacognitive awareness when troubleshooting a small gasoline engine.
6. Determine if problem-solving behaviors are significant predictors of time to solution when troubleshooting a small gasoline engine.
7. Determine if problem-solving behaviors are significant predictors of hypothesis generation ability when troubleshooting a small gasoline engine.
8. What are the processes that students utilize when troubleshooting a small gasoline engine?

Quantitative Summary of the Findings

Research Objective One: Demographic Information of Participants

To examine the effect of metacognitive awareness and cognitive style on problem-solving ability, the first research objective aimed to gain imperative demographic and descriptive data regarding metacognitive awareness and cognitive style. Therefore, the participants completed the KAI to determine their preferred learning style, which was subsequently utilized to place them into groups. Overall, it was determined that of the 28 participants, most were *more adaptive,* with an average score of 91.71. Thereafter, the students completed the MAI, which helped to determine metacognitive awareness ability. It was also determined that the students had an average metacognitive awareness score of 39.29 out of 52.00. Students' content knowledge and course motivation were also examined by having them complete a pre/posttest and course motivation survey during the small engine's unit. Overall, the average pretest score amongst groups was 12.75 out of 30.00 (42.5%) and posttest scores averaged 17.89 out of 30.00 (59.7%). Between groups, the average pretest score for homogeneous groups was 10.50 (35%), and heterogeneous groups was 14.43 (48.1%). On the posttest, the heterogeneous groups averaged 17.75 (59.2%), and the homogeneous groups averaged 18.081 (60.3%). The final demographic looked at course motivation, and the overall mean amongst groups was 3.46 out of 4.00. Between groups, the heterogeneous teams averaged a score of 3.66, and the homogeneous teams averaged 3.16.

Further, because of the complex nature of this study, it was critical to identify the time to solution and the ability of each team to create a hypothesis. Overall, the average time to solution among the groups was 43 minutes and 15 seconds, and the average hypothesis generation ability was 1.21 out of 2.00. However, when further examining time to solution, it was determined that the heterogenous groups were the fastest problem solvers with an average time of 34 minutes and 25 seconds, and the homogeneous adaptive groups were the slowest problem solvers with an average time of 51 minutes and 35 seconds. Also, the heterogenous groups were the most efficient at generating a correct hypothesis (100%), and the homogenous adaptive groups were the least efficient at generating a correct hypothesis (66.7%).

Finally, the individual's problem-solving behavior score was identified. This score was identified by utilizing a series of six items related to the tiers in Bloom's taxonomy of learning. The scores for each tier can range from .00 – 1.00. Overall, the average problem-solving behavior score was 3.93 out of 6.00. When examining each individual construct for the instrument, I determined that *understanding* was the highest-rated construct, with 16 (92.9%) of students being able to correctly meet this level. Subsequently, the lowest-rated construct was *analyze,* in which 50% of the students received a score of zero, meaning that the criteria were not met.

Research Objective Two: Effect Cognitive Diversity has on Metacognitive Awareness

Research objective two aimed to determine the effect cognitive diversity had on metacognitive awareness ability. This effect was determined by utilizing an independent sample t-test, which determined that there was not a statistically significant difference between cognitive diversity and metacognitive awareness (t =.274; p = .393). Effect size was also measured and revealed a small effect of .11. Therefore, we failed to reject the null hypothesis.

Research Objective Three: Effect Cognitive Diversity has on Content Knowledge

To further explore the effect cognitive diversity has on content knowledge, an independent sample t-test was employed and revealed no statistically significant difference between the factors (t = 1.478; p = .055). Effect size was also measured and revealed an effect size of .63, which was a medium effect. Therefore, we failed to reject the null hypothesis.

Research Objective Four: Effect Cognitive Diversity has on Course Motivation

Research objective four sought to determine if a difference existed between cognitive diversity and course motivation. Again, an independent sample t-test was utilized and revealed that there was a statistically significant difference between the factors (t = -1.707; p = .050). Further, the effect size was measured and determined to be a medium effect of .65. As such, we rejected the null hypothesis.

Research Objective Five: Effect of Problem-Solving Behaviors has on Metacognitive Awareness

The purpose of research objective five was to determine the effect problem-solving behaviors had on metacognitive awareness. To achieve the goal of this objective a one-way ANOVA was employed and revealed that there was no statistically significant difference between problem-solving behavior and metacognitive ability (p = .945). Therefore, we failed to reject the null hypothesis.

Research Objective Six: Effect Problem-Solving Behavior has on Time to Solution

Research objective four sought to determine if problem-solving behavior was a significant predictor in time to solution. To achieve the aim of this objective, a multiple regression analysis was performed. The regression analysis revealed that two of the six predictors entered the model (remember and apply). The two-predictor model was statistically significant (F = 0.981; R^2 = .444; p < .001) and accounted for 44.4% of the variance. The other four predictors (understand, analyze, evaluate, and create) were excluded from the model.

Research Objective Seven: Effect Problem-Solving Behavior has on Hypothesis Generation Ability

Similarly, research objective five aimed to determine if problem-solving behavior was a significant predictor of hypothesis generation ability. A multiple regression analysis was employed and revealed that two of the six predictors entered the model (remember and understand). The two-predictor model was statistically significant (F = 12.054; R^2 = .491; p <.001) and accounted for 49.1% of the variance. The other four predictors (apply, analyze, evaluate, and create) were excluded from the model.

Qualitative Summary of the Findings

Research Question Eight: Processes of Problem-solving

The final research question aimed to understand the processes the participants underwent when problem-solving. After their troubleshooting activity was completed, all students participated in a written reflection on the processes they used to solve the problem. This instrument consisted of six items that asked questions regarding their challenges, strengths, and communication. After analysis, three themes emerged including (a) *navigating troubleshooting*, (b) *cognitive supports*, and (c) *thinking-about-thinking*.

In the first theme, *navigating troubleshooting*, two sub-categories emerged including (a) communication barriers, and (b) process barriers. In this theme, most of the participants expressed a communication barrier between their partner and themselves, which hindered their ability to be efficient problem solvers by slowing their hypothesis generation ability and subsequent time to solution. Also, the participants expressed that certain process barriers hindered their ability. Specifically, it was noted that having the ability to identify the problem and understand/recall information were the largest challenges. These factors then led participants to struggle with self-doubt and low self-efficacy. Many of the participants expressed difficulty in recognizing if they had identified the correct problem for hypothesis generation one, which led them to rethink the problem and slow the overall process.

In the second theme, *cognitive supports* to the problem-solving process were identified. The students expressed that one of the biggest advantages to successfully problem-solving was having a partner. Specifically, a partner who was willing to contribute and be an active member of the group. Also, participants stated that being able to utilize troubleshooting materials made the processes easier because it gave them a good starting point and helped them narrow down the possibilities. They also stated it helped them to organize their thoughts and stay on track.

In the final theme, *thinking-about-thinking*, participants were given the opportunity to reflect on the problem-solving process. For instance, the participants expressed ways in which they would go about solving the problem differently had they had more conceptual and procedural knowledge. Many of the participants felt that they needed more time to understand how the engine components functioned conceptually. They then followed up by stating they desired additional exposure to troubleshooting scenarios and being able to apply them to different problems.

Conclusions and Implications

Based on the findings from this study, four conclusions were drawn related to the overall purpose and research objectives. It is important to consider any assumptions and limitations associated with this study.

Conclusion 1: Students were aware of their cognitive and metacognitive abilities; however, they lacked the ability to fully regulate their learning.

The first conclusion suggested that students were aware of their own cognitive and metacognitive abilities; including having the ability to regulate their knowledge and learning, but they lacked the ability to fully regulate their learning during the application exercise. Specifically, based on the MAI, the average score was 39.21 out of 52.00, which indicated that students reported they were fairly confident in their ability to regulate their knowledge of cognition. However, during the completed troubleshooting exercise, it was clear that students struggled to fully regulate their learning and successfully reach a solution. Such insights were also corroborated by the qualitative findings. Specifically, students struggled to analyze, evaluate, and create. This indicated that students were struggling to be able to manage their higher-order critical thinking skills. As a result, a discrepancy existed between the students' metacognitive and cognitive beliefs and their ability to apply such to a real-world problem – a notion supported by the work of Roberts et al. (2016, 2017).

Perhaps this chasm was because of cognitive style differences, which was limiting the group's potential to move through the higher-order problem-solving behaviors. Kirton (2003) stated that individuals who were able to overcome cognitive style gaps were more likely to be able to successfully problem solve. Therefore, I conclude that students were unable to integrate their diverse perspectives and manage their problem-solving styles. Perhaps the students who were considered more adaptive had a harder time thinking outside of the given domain and became frustrated with multiple solutions, which impacted their ability to manage their learning (Kirton, 2003; Zimmerman, 1997). Meanwhile, the more innovative individuals struggled to manage their ideas and work within a singular domain, which also impacted their ability to fully regulate their learning (Kirton, 2003). Thus, this supported the work of Kirton (2003), who postulated that cognitive style directly influences how individuals work with each other when faced with a task that needs to be solved (Kirton, 2003).

Further, along with cognitive style differences, this discrepancy could be due to the lack of ability to know *how* and *when* to utilize knowledge or the learner's cognitive skill acquisition. Within the cognitive and metacognitive domains, cognitive skill acquisition allows the learner to acquire, process, and build mental schemas of information to interact with a real-world problem (VanLehn, 1996). However, the type of problem and level of ability have an effect on overall problem-solving ability. Perhaps the students can manage their knowledge of learning but do not have enough knowledge in troubleshooting to be able to problem-solve in that domain. This conclusion was consistent with research in cognitive skill acquisition, which has indicated that novice problem solvers begin by trying to understand the knowledge in the domain and then move to apply that knowledge; however, the learner still has a very cerebral view of the problem being solved (VanLehn, 1997). Nevertheless, this phenomenon has been scantly documented in agricultural education. Therefore, a gap of knowledge has existed on the effect of individuals' cognitive and metacognitive abilities on the problem-solving process when troubleshooting real-world technical problems in the preparation of agricultural education teachers.

Conclusion 2: Students who were in heterogeneous groups were the most successful problem solvers overall.

During the start of the AEEE 2003 course, the participants were purposefully grouped into seven teams of varying cognitive diversity, including (a) homogeneous innovative, (b) homogeneous adaptive, and (c) heterogeneous. In all, 22 of the 28 students were able to correctly diagnose and correct the problem on hypothesis generation one regardless of cognitive style. However, when diving deeper into the cognitive diversity groups, it was identified that heterogeneous groups were able to identify and develop a correct hypothesis generation with 100% accuracy, while the homogeneous groups developed a correct hypothesis with only 75% and 66.7% accuracy, respectively. This finding is consistent with previous research by Blackburn et al. (2017) and Figland et al. (2022), which concluded that those who can identify and develop a correct hypothesis were better problem solvers than those who must hypothesize more than once. Further, this conclusion was consistent with Figland et al. (2022), which also reported that heterogeneous groups were the most effective problem solvers on hypothesis generation one.

Along with collecting the hypothesis generation ability of each team, time to solution was also recorded to establish how efficiently groups could solve problems. Time started as soon as all instructions were given, and students began reading the troubleshooting scenario. Time was stopped and recorded when the teams correctly solved the problem or timed out at 60 minutes. The average time to solve amongst small gasoline engine teams was 43 minutes and 15 seconds; however, it was concluded that the heterogeneous groups were the fastest problem solvers. The heterogenous groups on average solved the problem 10 minutes faster than any other group. Specifically, they were three minutes quicker than the innovative groups and 17 minutes faster than the adaptive groups. This conclusion was consistent with previous research by Figland et al. (2021), which identified that heterogeneous groups were the fastest problem solvers regarding time to solution.

Therefore, this conclusion indicated that individuals placed in heterogeneous groups were more effective and efficient problem solvers than any other group. This was also consistent with previous literature on cognitive diversity, which has suggested that heterogeneous groups perform better because they are able to manage diverse perspectives (Figland et al., 2021; Lamm et al., 2016). Finally, the conclusion also aligned with the A-I theory regarding how teams who can manage large cognitive style gaps and overcome those challenges were more likely to be better problem solvers (Kirton, 2003).

Conclusion 3: Students' problem-solving ability could be conceptualized through Figland's problem-solving behavior model and directly related to the student's ability to regulate their learning and move through the problem-solving process.

The conceptual framework developed for this study aimed to illustrate the critical factors that were associated with students' problem-solving. To understand those relationships, implications of the study's findings for the model have been presented in Figure 1, which illustrates the critical factors associated with problem-solving ability and their relationship to each other. Of note, factors associated with Bloom's taxonomy and metacognition (highlighted in red) emerged as critical barriers to students' problem-solving. Barriers in the study were identified as factors that inhibited the individual from fully utilizing the problem-solving process. Specifically, the students struggled to fully utilize their higher-order thinking skills, including *analyze*, *evaluate*, and *create*. These higher-order thinking skills were identified as being tied to the student's regulation of cognition (i.e., metacognition).

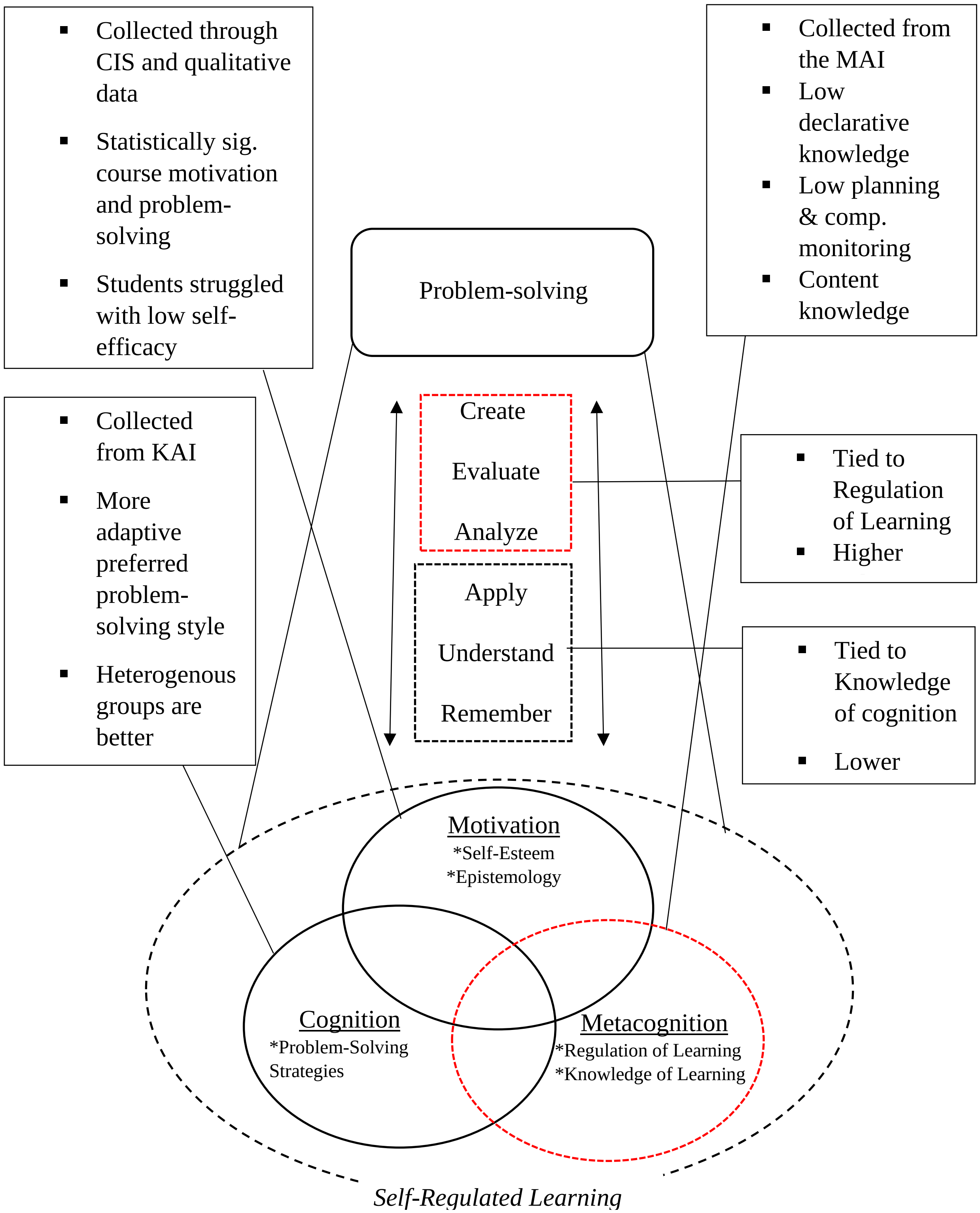

Figure 1. *Figland's problem-solving behavior model. Adapted from Zimmerman's (1997) Self-regulated learning theory and Bloom's taxonomy of learning (2001).*

For instance, based on the multiple regression analysis performed, it was determined that the two largest predictors in students' ability to correctly hypothesize were the ability to *remember* specific domain information and *understand* the given problem, which are the two lowest levels of Bloom's taxonomy and accounted for 49.1% of the variance. This conclusion indicated that within the problem-solving process, students had to successfully utilize previous domain knowledge, organize that information, and understand what the problem was asking to effectively move into higher levels of thinking and create a correct hypothesis. However, this also indicated that students in this study struggled to employ and utilize higher-order thinking skills (*analyze, evaluate, and create*).

Concerning time to solution, the two largest predictors were the ability of the individuals to *remember* domain-specific information and can *apply* that knowledge, which accounted for 44.4%. This conclusion suggested that to problem solve quickly the students had to possess the ability to remember specific information about the problem, in regard to conceptual and procedural knowledge. They also had to have the ability to apply that knowledge to the problem to be efficient. For example, in the troubleshooting problem, the students were required to remember specific conceptual and procedural knowledge associated with carburetors to then be able to utilize that procedural knowledge and correctly fix the upside-down float.

Thus, this conclusion suggested that 93.5% of the total variance in time to solution and hypothesis generation was predicted by the ability of the individual to *remember, understand*, and *apply*. Meanwhile, the factors *analyze*, *evaluate*, and *create* were excluded as variables. This indicated that students' conceptual and procedural knowledge played role in the ability to successfully problem solve in this investigation. This conclusion was consistent with findings advanced by VanLehn (1996), who reported that a primary factor in an individuals' problem-solving ability lies within the amount of knowledge in that domain. However, recent research conducted by Blackburn et al. (2014) and Figland et al. (2022) found that content knowledge was not a statistically significant factor to problem-solving ability. Moreover, the findings indicated that content knowledge does not affect problem-solving ability, but upon further investigation the effect size revealed a medium-large effect, which indicated that this relationship is meaningful in real-world contexts. As such, an implication from this finding was that in real-world contexts, the amount of content knowledge plays a role in the ability of students to problem-solve effectively and be able to self-regulate their learning. As such, this investigation's findings could provide more insight into the critical role of content knowledge on agricultural education majors' problem-solving abilities in real-world contexts.

When looking at the model, perhaps content knowledge influenced problem-solving ability because of the role that cognitive and metacognitive functions have in solving problems. Perhaps the reason the individuals were unable to move fully through the problem-solving process was that they were unable to fully regulate their learning. Specifically, one of the key factors in self-regulated learning lies within the metacognition dimension (Zimmerman, 1997), which is depicted by the dashed red circle in the model. This dimension is the individual's knowledge of cognition including their procedural, conditional, and declarative knowledge; but also, their regulation of cognition (Cross & Parish, 1988; Flavell, 1979; Schraw et al., 2006). Knowledge of cognition and the amount of knowledge in these categories allows the individuals to be able to encode the specific problem. Therefore, perhaps without this knowledge base in small engines, individuals struggled to be able to regulate their cognition or be able to monitor and evaluate the knowledge domain, which made them unsuccessful problem solvers because they were unable to regulate their metacognition.

The findings from this study also suggested that some of the lowest reported metacognitive items from the MAI were within the learner's declarative knowledge, planning, and comprehension monitoring domains. Specifically, declarative knowledge items examined students' knowledge of themselves or their ability to know and understand their strengths and weaknesses that affect their performance (Rathore & Sonawat, 2015). Perhaps this suggests that the individuals in this course struggled to be able to regulate their metacognitive knowledge because they struggled to be able to remember and organize information, which hindered their problem-solving ability. This conclusion was also consistent with the findings from this study, which indicated that students felt they needed more knowledge in the domain; specifically, in small engines and strategies for troubleshooting to be able to interact with the task more effectively and efficiently.

Further, the students also reported that planning and comprehension monitoring were the lowest reported constructs within in regulation of cognition. Specifically, planning referred to the ability of the individual to correctly select a problem-solving strategy and allocate resources prior to problem-solving (Whitebread et al., 2009), while comprehension monitoring reflected the ability of the individuals to assess one's learning or strategies. This indicated that students struggled to decipher the problem and select the appropriate strategy *before* they tried to fix the problem. This conclusion was consistent with the findings from this study that suggested that students struggled to identify the problem and know if their hypothesis was correct. This self-doubt and low self-efficacy seemed to influence the groups to overthink and create too many solutions, which led to mistakes. Perhaps the reason for their low self-efficacy and self-doubt was due to motivation. According to Zimmerman (1997) in order for an individual to fully self-regulate their learning they must find value in the environment and task at hand. Within this model, course motivation was collected at the start of the small gasoline engines module by utilizing the CIS instrument developed by Keller (2006) and there was a statistically significant difference between motivation and problem-solving ($p = .050$). Therefore, this suggested that motivation may play an important role in metacognitive ability and overall problem-solving effectiveness. Perhaps this conclusion implied that students were not reflecting and evaluating their learning regularly enough during the learning process to maximize their metacognitive and cognitive abilities. On this point, Zimmerman (1997) recommended that active reflection during the learning process was a critical component of self-regulating individuals' learning and problem-solving abilities.

Remember, *understand*, and *apply* were the strongest predictors of problem-solving behavior because they hold a critical foundation in the hierarchy of Bloom's (2008) taxonomy of learning and are lower-order thinking skills. Meaning that for an individual to interact with a problem they must have the ability to remember specific information, understand the problem, and organize and apply that information to correct the problem. Perhaps, it is easier for individuals to attain lower-order thinking skills because they ask the individual to retrieve, comprehend, and apply knowledge (Bloom, 2008); which directly relates to the individual's metacognitive ability. More specifically, these lower-order thinking skills are related to the knowledge of the cognition domain within the MAI. Whereas higher-order thinking skills are tied to the individual's ability to regulate their cognition or plan, monitor, and evaluate their learning process. Within the model, this relationship between metacognition and problem-solving behaviors is depicted by two dashed red squares. Nevertheless, without critical domain-specific knowledge, individuals may struggle to be able to utilize higher-order thinking skills that may ask them to analyze and evaluate their solutions.

Conclusion 4: Students problem-solving ability could be explained by three themes: (1) *navigating troubleshooting*, (2) *cognitive supports*, and (3) *thinking-about-thinking.*

The final conclusion, drawn from the study's qualitative findings, suggested that for individuals to be successful problem solvers, they must be able to achieve self-regulation. This conclusion illuminated critical factors associated with Figland's problem-solving behavior model, which posited students' journey during problem-solving. Therefore, this finding could broaden knowledge on problem-solving and self-regulated learning (Zimmerman, 1997), especially in the context of agricultural education.

When examining the first theme, participants expressed that communication and process barriers were the largest factors that contributed to navigating troubleshooting. Process barriers were identified as aspects of the process that hindered the student's ability to problem solve, which were cognitive in nature. Many of the participants stated that understanding the scenario, identifying the problem, and recalling information were difficult and caused them to struggle during the troubleshooting task. This conclusion indicated that students had difficulty with the lower-order thinking skills components of Bloom's (2001) taxonomy, which directly related to their metacognitive ability. This conclusion supported the quantitative portion of this study, which indicated that 93.5% of the variance in the ability of an individual to be effective and efficient problem solvers was the ability of the individual to utilize their knowledge or remember, understand, and apply. Therefore, if a student does not have the knowledge to interact with the problem, they will be unable to move through the problem-solving behaviors and reach higher-order thinking skills.

However, it was also noted that partners who were unwilling or ineffective at communication caused some of the participants to experience self-doubt because they were unsure if their hypotheses were correct. This undoubtedly caused frustration and self-efficacy issues, which could have caused a lack of motivation to complete the task. As noted previously, motivation plays an important role in the overall regulation of learning and problem-solving ability (Zimmerman, 1994). Perhaps this lack of motivation and self-efficacy was due to cognitive style differences and the inability to overcome differences (Kirton, 2003). This conclusion was consistent with the quantitative CIS instrument findings, which indicated that there was a statistically significant relationship between cognitive diversity and motivation.

Moreover, in the second theme, cognitive supports, the participants indicated that having a communicative and willing partner helped them to decide on a problem and complete a hypothesis, which helped them to be effective and efficient problem solvers. Perhaps this is an important factor because of cognitive style and cognitive diversity grouping. Specifically, Kirton (2003) postulated that for individuals to successfully work together, they must be able to manage their diverse perspectives and be willing and open to new perspectives. Thus, this conclusion provided insight into the importance of having a partner as a form of support because they were able to manage diverse patterns of thinking.

In the final theme, thinking-about-thinking, participants evaluated their troubleshooting processes at the conclusion of the task. All of the participants expressed how they wanted more conceptual and procedural knowledge to be able to be effective and efficient troubleshooters. Even though the quantitative portion of this study did not find any statistical significance in content knowledge, it did provide practical significance in real-world context with a medium effect size of .63. Both of these conclusions were consistent with previous research in cognitive skill acquisition and troubleshooting, which has reported that the more knowledge an individual possesses in a domain, the more likely they are to be better problem solvers (Johnson & Flesher, 1993; Jonassen, 2003; VanLehn, 1991).

Further, per the model, this conclusion indicated that students were putting significant value on lower-order thinking skills or knowledge skills in order to be able to better interact with problems to be solved. Perhaps this is because they have low declarative knowledge utilization and struggle to regulate their knowledge of learning through metacognition (Zimmerman, 1997). Thus, indicating that students felt they needed to have a better understanding of knowledge to regulate their knowledge and their cognitive abilities. This was consistent with research in metacognition that has stated that individuals must have the ability to regulate their knowledge and cognitive abilities to effectively interact with a problem (Cross & Paris, 1988; Stitzman & Elly, 2011; Zimmerman, 1997).

Recommendations

The following recommendations for practice and research emerged from the findings of this study:

Recommendations for Practice

1. Students in agricultural education teacher preparation courses should be assessed and made aware of their preferred cognitive style and metacognitive ability. These factors have been identified as a prerequisite to problem-solving ability and perhaps could also influence the ways in which they teach such content to their students in the future.

2. Students should be purposefully grouped into heterogeneous teams when applicable, especially for laboratory focused courses in the preparation of teachers for agricultural education.
3. Teacher preparation programs for agricultural education should integrate Figland's problem-solving behavior model into their teaching methods courses to assess the level to which students solve real-world problems, especially in laboratory focused courses.
4. Teacher preparation programs for agricultural education should consider focusing on students' abilities to remember, understand, and apply knowledge. Specifically, within their conceptual and procedural knowledge domains.
5. Teacher preparation programs for agricultural education should utilize Figland's problem-solving behavior model so preservice teachers have the opportunity to experience and develop instruction on developing problem-solving ability that can be used in the SBAE classroom to enhance student learning.
6. Troubleshooting concept mapping and problem-solving trees should be shared with teacher educators to assist in developing preservice teachers' problem-solving abilities.
7. Professional development sessions for current SBAE teachers should be developed to demonstrate how to integrate the problem-solving behavior model into their teaching methods, specifically how it can be used and what materials can be developed.

Recommendations for Research

The following recommendations for research emerged from the outcomes of the research questions.

1. Future research is needed to replicate this study in different content areas that are associated with the preparation of SBAE teachers. Specifically, areas such as horticulture, agricultural business, agronomy/soil science, and animal science.
2. Future research is also needed to evaluate current SBAE teachers' cognitive and metacognitive awareness to assess the need for professional development.
3. Further research is needed to understand the cognitive and metacognitive awareness of current SBAE teachers.

However, this also generated questions that could be addressed through further research.

4. Does metacognition, cognitive awareness, and self-efficacy/motivation have an effect on the problem-solving behavior of preservice teachers in agricultural education in other context areas besides agricultural mechanics?
5. How well does metacognition, cognitive awareness, and self-efficacy/motivation predict problem-solving behavior of agricultural education majors?
6. Why are heterogeneous groups more effective and efficient problem solvers in the context of agricultural education?
7. What methods are teacher preparation sites utilizing to assess students' problem-solving ability/behavior?
8. What types of problem-solving strategies are being integrated into the SBAE curriculum?
9. What types of problem-solving opportunities are SBAE preservice teachers engaging in through their coursework?

Discussion

This study demonstrated the factors associated with problem-solving ability related to students in an introductory agricultural mechanics' course regarding their cognitive and metacognitive abilities. Specifically, I examined students' problem-solving behaviors in a real-world setting. The study's findings illuminated the possibility of integrating the problem-solving behavior model into current SBAE teacher preparation programs as a way to understand and develop problem-solving skills for future SBAE teachers.

Since the inception of SBAE, students have been engaging in and solving real-world problems (Phipps & Osborne, 1988). This has been accomplished through the use of many active learning methods that place a high priority on problem-solving (Ernst et al., 2017; Kolb, 1984; & Yew & Goh, 2016). However, many students lack the ability to efficiently and effectively problem solve, which is a critical component of our day-to-day lives (Jonassen, 2000; Ulmer & Torres, 2007; & Pate & Miller, 2011b). It has been documented that problem-solving skills hold a critical foundation in the workforce; therefore, it is critical for teacher preparation sites to begin to understand the problem-solving process. Specifically, the factors that affect problem-solving ability, developing problem-solving skills, and building those skills into the curriculum.

The findings from this study also indicated that heterogenous groups were more advantageous problem solvers in both efficiency and effectiveness. These groups were more likely to overcome their cognitive style differences and integrate their diverse perspectives to successfully problem solve. Perhaps it was because students utilized and organized opposing problem-solving strategies to reach a consensus on the problem. Or maybe it is because students were able to utilize opposing thought processes to help regulate their own learning process, which allows them to constantly reflect on the process and remain in the reflective feedback loop. Regardless, the question still exists: *Why are heterogeneous groups more efficient and effective problem solvers in the context of agricultural mechanics courses designed to prepare teachers of agricultural education?*

Findings from this study also indicated that students were aware of their cognitive and metacognitive abilities but struggled to move through problem-solving behaviors when engaging in real-world situations. Therefore, it is critically important for teacher preparation sites to be aware of these factors and develop processes in their methods of teaching courses to better integrate the problem-solving process. This finding also raised a few questions for agricultural education: *How do we accurately assess a student's problem-solving ability in real-world situations to determine the critical factors associated with the problem-solving process to close knowledge and problem-solving deficiencies?* Moreover, *how can teacher preparation sites utilize this problem-solving behavior model in their current teaching methods?* Lastly, *how do we best prepare preservice agricultural education teachers to utilize and integrate the problem-solving behaviors model into their future instructional practices in SBAE?*

Therefore, for our students both at the secondary and post-secondary levels to be successful in the current workforce it is imperative that teacher preparation sites begin to analyze how they are utilizing problem-solving and develop more targeted learning experiences aimed at developing their skills in this regard. Specifically, using Figland's problem-solving behavior model may be a way for current and future SBAE teachers to understand the problem-solving process from a cognitive/metacognitive perspective. Therefore, Figland's problem-solving behaviors model has the potential to enrich and build rigor into SBAE's current curriculum by illustrating the critical factors associated with problem-solving and deserves more examination and action by researchers in agricultural education.

Moving forward, further examination of the metacognitive instrument (MAI) is also warranted to identify the strongest predictors of problem-solving. Such knowledge could allow researchers to pinpoint critical factors and create targeted curriculum and professional development sessions for preservice teachers, agricultural education teachers, and teacher educators.

Despite the knowledge advanced in this study, several critical questions linger for the refinement of Figland's problem-solving behavior model. In particular, *what is the current knowledge level of SBAE teachers' regarding cognition and metacognition? Further, what are the metacognitive abilities of these SBAE teachers?* Also, further examination of the motivational factors of this population is needed to identify the effect motivation has on the self-regulated learning process. For example, *what motivational factors influence problem-solving ability?* Moreover, *what role does self-efficacy play on motivation and the overall problem-solving process?* Hopefully, the continued development of this model will allow current and future SBAE teachers to have the ability to understand the problem-solving process and also develop a more comprehensive problem-solving curriculum.

APPENDIX A. IRB Approval

LSU AgCenter
Research · Extension · Teaching

TO:	Whitney Lynn Figland LSUAG | Dept | Agricultural and Extension Education and Evaluation | CC00946
FROM:	Michael Keenan Chair, Institutional Review Board
DATE:	19-Sep-2022
RE:	IRBAG-22-0082
TITLE:	Understanding the role of undergraduate students' metacognition when troubleshooting small gasoline engines
SUBMISSION TYPE:	Initial Application
Review Type:	Exempt
Risk Factor:	Minimal
Review Date:	19-Sep-2022
Status:	Approved
Approval Date:	19-Sep-2022
Approval Expiration Date:	18-Sep-2025
Re-review frequency:	(three years unless otherwise stated)
Number of subjects approved:	100
LSU Proposal Number:	
By:	Michael Keenan, Chair

APPENDIX B. Participant Consent Form

Participant Consent and Information Sheet

Project: Investigating the effects of metacognition on the small gasoline problem-solving ability of undergraduate students enrolled in flipped classroom agricultural mechanic's course: A mixed methods study

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

The purpose of this research project is to determine the effects of a student's metacognition on their ability to solve problems related to a small gasoline engine.

Your participation in this study is strictly voluntary and greatly appreciated. Your participation in this study will provide insight into metacognitive processes that my affect how an individual generates solutions to problems. However, this study is being conducted as part of this course, AEEE 2003. As part of the course structure, you will be required to participate in the learning modules as part of your overall course grade. Should you elect to not participate in this study your data will not be included as a part of the aggregate data.

Should you elect to not participate in research study, please see Mrs. Figland or Dr. Blackburn after class, so your name may be documented. However, if you decide to participate in this research study, no further action is required. 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 either Whitney Figland via email at: wfigla2@lsu.edu or Joey Blackburn via email at: jjblackburn@lsu.edu. If you have questions about subjects' rights or other concerns, you may contact the LSU Institutional Review Board, at (225) 578-5983 or www.lsu.edu/irb.

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

APPENDIX C. Demographic Packet

AEEE 2003

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

APPENDIX D. MAI

Directions: There are 52 statements in this questionnaire. Please think about yourself as the learner. Check the answer (true/false) that truly applies to you, and not what you would like to be true.

Item	True	False
1. I ask myself periodically if I am meeting my goals		
2. I consider several alternatives to a problem before I answer		
3. I try to use strategies that have worked in the past		
4. I pace myself while learning in order to have enough time		
5. I understand my intellectual strengths and weaknesses		
6. I think about what I really need to learn before I begin a task		
7. I know how well I did once I finish a test		
8. I set specific goals before I begin a task		
9. I slow down when I encounter important information		
10. I know what kind of information is most important to learn		
11. I ask myself if I have considered all options when solving a problem		
12. I am good at organizing information		
13. I consciously focus my attention on important information		
14. I have a specific purpose for each strategy I use		
15. I learn best when I know something about the topic		
16. I know what the teacher expects me to learn		
17. I am good at remembering information		
18. I use different learning strategies depending on the situation		
19. I ask myself is there was an easier way to do things after I finish a task		
20. I have control over how well I learn		
21. I periodically review to help me understand important relationships		
22. I ask myself questions about the material before I begin		
23. I think of several ways to solve problems and choose the best one		
24. I summarize what I’ve learned after I finish		
25. I ask others for help when I don’t understand something		
26. I can motivate myself to learn when I need to		
27. I am aware of what strategies I use when I study		

Item	True	False
28. I find myself analyzing the usefulness of strategies while I study		
29. I use my intellectual strengths to compensate for my weaknesses		
30. I focus on the meaning and significance of new information		
31. I create my own examples to make information more meaningful		
32. I am good judge of how well I understand something		
33. I find myself using helpful learning strategies automatically		
34. I find myself pausing regularly to check my comprehension		
35. I know when each strategy I use will be most effective		
36. I ask myself how well I accomplish my goals once I'm finished		
37. I draw pictures or diagrams to help me understand while I'm learning		
38. I ask myself if I have considered all options after I solve a problem		
39. I try to translate new information into my own words		
40. I change strategies when I fail to understand		
41. I use the organizational structure of the text to help me learn		
42. I read instructions carefully before I begin a task		
43. I ask myself if what I'm reading is related to what I already know		
44. I reevaluate my assumptions when I get confused		
45. I organize my time to best accomplish my goals		
46. I learn more when I am interest in the topic		
47. I try to break studying down into smaller steps		
48. I focus on overall meaning rather than specifics		
49. I ask myself questions about how well I am doing while I am learning something new		
50. I ask myself if I learned as much as I could have once I finish a task		
51. I stop and go back over new information that is not clear		
52. I stop and reread when I get confused		

APPENDIX E. KAI

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 all find it necessary to present a particular image of ourselves consistently over a long period. In some cases this proves easy as we are like this; sometimes it is very difficult as we are not like this at all.

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 well 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.

ow easy or difficult do you find it to present yourself, onsistently, over a long period as:

	Very Hard	Hard	Easy	Very Easy
A PERSON WHO IS PATIENT.				
A PERSON WHO CONFORMS.				
A PERSON WHO WHEN STUCK WILL ALWAYS THINK OF SOMETHING.				
A PERSON WHO ENJOYS THE DETAILED WORK.				
A PERSON WHO WOULD SOONER CREATE SOMETHING THAN IMPROVE IT.				
A PERSON WHO IS PRUDENT WHEN DEALING WITH AUTHORITY OR GENERAL OPINION.				
A PERSON WHO NEVER ACTS WITHOUT PROPER AUTHORITY.				
A PERSON WHO NEVER SEEKS TO BEND (MUCH LESS BREAK) THE RULES.				
A PERSON WHO LIKES BOSSES AND WORK PATTERNS WHICH ARE CONSISTENT.				
A PERSON WHO HOLDS BACK IDEAS UNTIL THEY ARE OBVIOUSLY NEEDED.				
A PERSON WHO HAS FRESH PERSPECTIVES ON OLD PROBLEMS.				
A PERSON WHO LIKES TO VARY SET ROUTINES AT A MOMENT'S NOTICE.				
A PERSON WHO PREFERS CHANGES TO OCCUR GRADUALLY.				
A PERSON WHO IS THOROUGH.				
A PERSON WHO IS A STEADY PLODDER.				
A PERSON WHO COPES WITH SEVERAL NEW IDEAS AND PROBLEMS AT THE SAME TIME.				
A PERSON WHO IS CONSISTENT.				
A PERSON WHO IS ABLE TO STAND OUT IN DISAGREEMENT ALONE AGAINST A GROUP OF EQUALS AND SENIORS.				
A PERSON WHO IS STIMULATING.				
A PERSON WHO READILY AGREES WITH THE TEAM AT WORK.				
A PERSON WHO HAS ORIGINAL IDEAS.				
A PERSON WHO MASTERS ALL DETAILS PAINSTAKINGLY.				
A PERSON WHO PROLIFERATES IDEAS.				
A PERSON WHO PREFERS TO WORK ON ONE PROBLEM AT A TIME.				
A PERSON WHO IS METHODICAL AND SYSTEMATIC.				
A PERSON WHO OFTEN RISKS DOING THINGS DIFFERENTLY.				
A PERSON WHO WORKS WITHOUT DEVIATION IN A PRESCRIBED WAY.				
A PERSON WHO LIKES TO IMPOSE STRICT ORDER ON MATTERS WITHIN OWN CONTROL.				
A PERSON WHO LIKES THE PROTECTION OF PRECISE INSTRUCTIONS.				
A PERSON WHO FITS READILY INTO 'THE SYSTEM'.				
A PERSON WHO NEEDS THE STIMULATION OF FREQUENT CHANGE.				
A PERSON WHO PREFERS COLLEAGUES WHO NEVER 'ROCK THE BOAT'.				
A PERSON WHO IS PREDICTABLE.				

EASE CHECK THAT YOU HAVE ANSWERED ALL 33 QUESTIONS.

27331

NOT TO BE COPIED IN ANY WAY

APPENDIX F. Pre/Posttest

Name ______________________

<u>Small Engines Test</u>

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 engine 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 G. Troubleshooting Packet

1. Hypothesis #1:

2. Engine Symptoms:

Troubleshooting Process

3. What is the name of the part you have identified as the fault?

4. What system does that part belong to?

5. What steps did you take to correct the problem?

6. What is the function of that part within its system?

7. Why is your hypothesis supported? Justify your answer.

8. Did you create a correct hypothesis and correct the problem?

9. Was your hypothesis correct?
   - ☐ Yes
   - ☐ No

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

APPENDIX H. Troubleshooting Scenario

Troubleshooting Scenario

You have been working for a local mechanic for some time now and the owner has decided to start letting you work on some of the projects by yourself. When you arrive at work, you discover that a John Deere lawnmower had been brought in by an elderly gentleman. This gentleman stated that the mower was in perfect working condition at the end of last year and was properly winterized before being put away. When he pulled the mower out, he filled it with fresh fuel and oil, replaced the fuel filter, and replaced the air filter. He discovered a small puddle under the motor when he tried to start it and it continued to leak after the motor was off. He also said that it ran for a few seconds and then died and would not restart. He stated that it smelled of gas but did not see any noticeable wet areas that it was coming from on the motor itself, but the puddle on the ground was obvious. Before leaving, he also stated that he had replaced the carburetor with a refurbished one before storing it last winter.

APPENDIX I. Troubleshooting Reflection Packet

Directions:

For each question, please focus on the troubleshooting process you and your partner just completed. To receive full credit, you must write a <u>minimum of 5 complete sentences per question.</u>

1. **What were some of the most challenging moments you faced during this activity? (Explain why they were challenging and how did you overcome those challenges).**

2. **What most got in the way of your progress while trying to solve the problem?**

3. **What helped you the most while trying to solve the problem?**

4. What are some things that you would do differently if you approached the same problem again?

5. **How well did you and your partner communicate during the activity?**

6. **How did your partner help you overcome any obstacles, if any?**
    a. **How did that affect your thinking process when you were trying to solve the problem?**

APPENDIX J. Troubleshooting Map

Compression System

Carburetor & Fuel System

Ignition System

Cooling/Lubrication System

Governor System

APPENDIX K. Course Motivation Survey

Item **Circle** the answer that truly applies to you	Not True	Slightly True	Moderately True	Mostly True	Very True
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 **NOT** 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

Item **<u>Circle</u>** the answer that truly applies to you	Not True	Slightly True	Moderately True	Mostlv True	Very True
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

Item **<u>Circle</u>** the answer that truly applies to you	Not True	Slightly True	Moderately True	Mostly True	Very True
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 **NOT** 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

APPENDIX L. Permission of Materials

03/1/2023

Whitney L. Figland

I am completing a doctoral dissertation at Louisiana State University entitled "PROBLEM-SOLVING IN THE PREPARATION OF TEACHERS FOR AGRICULTURAL EDUCATION: A MIXED METHODS STUDY INVESTIGATING THE EFFECT OF METACOGNITIVE AWARENESS AND COGNITIVE ABILITY ON STUDENTS ENROLLED IN AN INTRODUCTORY AGRICULTURAL MECHANICS COURSE."

I would like your permission to reprint the following materials in my dissertation, which is in preparation for my graduation in May 2024:

Figland, Whitney L., "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" (2019). *LSU Master's Theses*. 4880. https://repository.lsu.edu/gradschool_theses/4880, pgs. 53, 67, & 71.

Please contact me with any questions.

Sincerely,

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