ASSESSING THE EFFECTS OF COGNITIVE STYLE, HYPOTHESIS GENERATION, AND PROBLEM COMPLEXITY ON THE PROBLEM SOLVING ABILITY OF SCHOOL-BASED AGRICULTURAL EDUCATION STUDENTS: AN EXPERIMENTAL STUDY

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Abstract: Problem solving is one of the most important cognitive abilities possessed by people. Further, the ability to solve problems is one of the most important characteristics of potential employees sought by employers in the agriculture industry. The purpose of this study was to assess the effects of cognitive style, hypothesis generation, and problem complexity on the problem solving ability of students in Agricultural Power and Technology courses in Oklahoma. Specifically, students were asked to troubleshoot a small gasoline engine with a known fault. Kirton's Adaption-Innovation Inventory was used to determine students' cognitive style as *more adaptive* or *more innovative*. This study employed a CRF–22 design where students were assigned randomly by cognitive style to treatment groups. The treatment was complexity of the problem, either *simple* or *complex*. Students received instruction in small gasoline engines from their respective agriculture teachers, who had attended a small gasoline engines workshop, prior to troubleshooting. Additionally, students were required to generate a written hypothesis over their assigned problem. Students' content knowledge was assessed using a criterion-referenced test. A two-way independent ANOVA was calculated and no statistically significant differences in knowledge existed based on cognitive style and hypothesis generation. A three-way independent ANOVA was utilized to determine if statistically significant differences existed in students' time to solution based on the independent variables. The three-way interaction effect was not statistically significant. The two-way interaction effect of problem complexity and cognitive style was not statistically significant. Likewise, the two-way interaction effect of hypothesis generation and cognitive style was not statistically significant. It was concluded that students can solve problems regardless of their cognitive style. The two-way interaction effect of problem complexity and hypothesis generation was statistically significant. This finding indicated that the students who generated a correct hypothesis solved their problems more efficiently, regardless of complexity. It was recommended that agriculture teachers teach their students to generate hypotheses when solving problems. Additionally, it was recommended that further research be conducted to clarify the relationship of content knowledge, hypothesis generation, and cognitive style on the ability of students to solve problems of varying complexities.

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CHAPTER I

INTRODUCTION

Background

"The central point of education is to teach people to think, to use their rational powers, [and] to become better problem solvers" (Gagné, 1980, p. 85). Problem solving is one of the most important outcomes of learning that people use in their everyday and professional lives (Jonassen, 2000). In fact, the ability to solve problems has been identified consistently as an essential skill needed for entry-level employment in the agricultural industry (Alston, Cromartie, Wakefield, & English, 2009; Graham, 2001; Robinson, 2009; Robinson & Garton, 2008; Robinson, Garton, & Terry, Jr., 2007). Employers desire employees who are creative, inventive, and can think on their feet and solve problems (MacPherson, 1998; Robinson & Garton, 2008; Robinson, Garton, & Vaughn, 2007; Robinson, 2009). As such, problem solving skills have been regarded as imperative in the workplace (Johnson, 1988). The need exists for people to be able to "solve critical, complex problems, in challenging environments" (Kirton, 2003, p. 1).

The ability to solve problems is one of the most important cognitive processes people possess (Schunk, 2008). A problem is "a situation in which you are trying to reach some goal, and must find a means for getting there" (Chi & Glaser, 1985, p. 229). People encounter problems on a daily basis, whether solving a puzzle, budgeting money, or controlling inflation. Problems can range in difficulty from simple to complex and everything in between (Chi & Glaser, 1985).

Jonassen (2000) listed various types of problems on a continuum from well-structured to ill-structured. Well-structured problems are found commonly in school settings and consist of a well defined initial state, a known goal, and known operational constraints (Jonassen, 2000). Ill-structured problems, however, are problems encountered normally in everyday life (Jonassen, 2000). Another distinguishing characteristic of ill-structured problems is that, typically, these types of problems require the integration of several content domains (Jonassen, 2000).

All problems have an initial state, a goal, functions to perform, and operational constraints (Chi & Glaser, 1985). The initial state encompasses the person's level of knowledge or status regarding the problem (Schunk, 2008). From the initial state, individuals must create and define the problem space (Newell & Simon, 1972). Problem space is also referred to as mental models, which are constructed from the person's knowledge (Jonassen, 2000). Problem solvers utilize their previous knowledge and information gathered from the initial state to formulate hypotheses (Johnson, 1988). Next, goals are divided into sub-goals that are mastered sequentially, ending in the attainment of the goal (Schunk, 2008). Performing operations on the initial state to achieve the goal leads to the problem being solved (Chi & Glaser, 1985).

Historically, agricultural education has embraced problem solving as a method of teaching students (Parr & Edwards, 2004). Researchers have argued that the philosophical foundation of problem solving in agricultural education is merely a "historical accident," occurring only because the passage of the Smith-Hughes Act in

1917 coincided with the height of John Dewey's career (Moore & Moore, 1984, p. 5). However, the adoption of the problem solving approach by agricultural education was not the work of Dewey alone (Lass & Moss, 1987). Although, Dewey may have planted the seed, his followers and subsequent agricultural educators cultivated, nurtured, and cared for the problem solving approach as it grew into what is recognized today (Lass & Moss, 1987). Nevertheless, problem solving and the problem solving method of teaching continue to serve as cornerstones of school-based agricultural education programs because of the influence of Dewey (Phipps, Osborne, Dyer, & Ball, 2008). Today, problem solving is defined in terms of the scientific method with the steps: "a) recognizing and defining the problem, b) clarifying the problem, c) identifying possible solutions, d) testing a solution or plan, and e) evaluating the results" (Phipps et al., 2008, p. 239).

Specifically, Dewey's concept of reflective thinking provided the basis for the problem solving approach to teaching agriculture (Phipps et al., 2008). Although Dewey (1910/1997) did not use the term *problem solving,* he outlined steps for reflective thinking that are somewhat analogous to the scientific method. The steps included "a felt difficulty, its location and definition, suggestion of possible solutions, development by reasoning of the bearings of suggestion, [and] further observation and experiment leading to its acceptance or rejection" (p. 72).

Numerous agriculture teachers and teacher educators were influenced by the work of John Dewey (Lass & Moss, 1987). The educational views of John Dewey permeated agricultural education and are still influencing agricultural education today. When describing agricultural education as a context for learning, Roberts and Ball (2009) discussed the importance of problem solving as being an important skill, especially for productive citizens who are agriculturally literate. Problem solving is also needed by those students who seek employment in the agricultural industry (Alston et al., 2009; Graham, 2001; Robinson & Garton, 2008; Robinson et al., 2007).

Agricultural education consists of three integral components: classroom and laboratory instruction, Supervised Agricultural Experience (SAE), and the National FFA Organization (Baker, Robinson, & Kolb, 2012; Phipps et al., 2008). These three components serve as the conceptual foundation of agricultural education (Jenkins, 2008). Students are guided through the cycle of the experiential learning theory (ELT) within each element and throughout the total program (see Figure 1). According to ELT, knowledge is a result from experiences that have been internalized by the learner (Kolb, 1984).

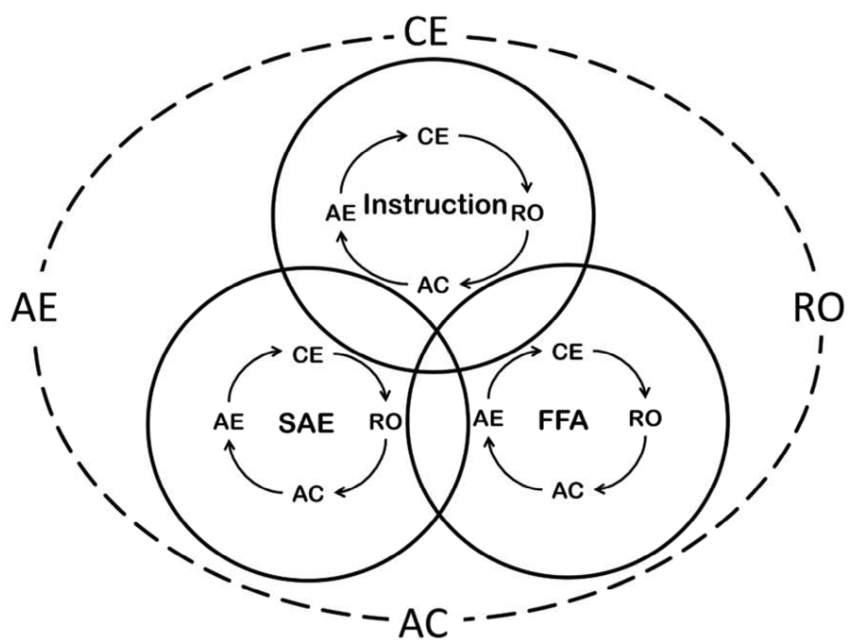

Figure 1. Comprehensive Model for School-Based Agricultural Education. Adapted from "Aligning Experiential Learning Theory with a Comprehensive Agricultural Education Model," by M. A. Baker, J. S. Robinson, and D. A. Kolb, 2012, *Journal of Agricultural*

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Instructional environments in agricultural education are comprised of both traditional classrooms and agricultural laboratories (Newcomb, McCracken, Warmbrod, & Whittington, 2004). Agricultural laboratories are essential to the total agricultural education program by providing a means for students to apply theory learned in the classroom in a controlled setting (Newcomb et al., 2004). These laboratories can include agricultural mechanics shops, greenhouses, school farms, aquaculture centers, and computer-based environments (Newcomb et al., 2004; Shoulders & Myers, 2012).

SAE programs are designed to allow students to have opportunities to apply knowledge learned in the classroom and laboratory in a real-world, experiential manner (Phipps et al., 2008; Ramsey & Blackburn, 2013). The National FFA Organization (FFA) component of the total agricultural education program exists to serve as a laboratory environment for students to acquire and practice skills related to leadership, personal growth, and career success (Newcomb et al., 2004; Phipps et al., 2008). The nature of agricultural education programs ensures that students with a wide range of abilities can achieve success (Phipps et al., 2008). The philosophy of agricultural education is based on solving real problems experienced by individuals involved in all sectors of the agricultural industry (Phipps et al., 2008). The problems-based nature of agricultural education lends itself to instructional strategies that are student-centered, such as inquiry-based learning, the problem solving approach, and experiential learning (Phipps et al., 2008).

Educators, including those in agricultural education, must be aware of personal characteristics that students bring to the learning environment (Brinkman, 1999; Phipps et al., 2008). In the case of problem solving, the concept of cognitive style is an important variable to consider (Brinkman, 1999). Cognitive style, also known as *problem solving style*, is a concept defined by Kirton's (2003) Adaption-Innovation Theory (KAIT) as differences in the ways that individuals attempt to solve problems. Individuals are classified as either *more adaptive* or *more innovative* based on KAI score (Kirton, 2003, p. 47). The more adaptive tend to prefer solving problems that are more structured in nature and have a mindset of "doing things better" (Kirton, 1994, p. 9). More innovative students prefer problems associated with looser structure and have an attitude of "doing things differently" (Kirton, 1994, p. 9). The crux of KAIT is that neither style is superior because all individuals are creative and solve problems every day, but the manner in which people go about solving problems differs (Kirton, 2003).

Statement of the Problem

Problems are encountered every day. The ability to solve problems is one of the most important abilities possessed by individuals (Chi & Glaser, 1985). In addition, potential employers place high value on their employees' abilities to solve problems efficiently and accurately (Billing, 2003). Prospective employees also understand the value of problem solving in the workplace (Robinson & Garton, 2008). The profession of agricultural education has long embraced problem solving, not only as a programmatic goal, but also as a teaching method (Phipps et al., 2008). Numerous agricultural education researchers tout the benefits of problem solving as a teaching method (Boone, 1990; Cano & Martinez, 1991; Dyer & Osborne, 1996a; Flowers & Osborne, 1988;

Phipps et al., 2008). Yet, few studies have assessed problem solving abilities of school-based agricultural education students.

Dyer and Osborne (1996b) found the problem solving approach to teaching agriculture was more effective at increasing the problem solving ability of students than the subject matter approach, regardless of learning style. Pate and Miller (2011a) investigated the small gasoline engine troubleshooting abilities of agriculture and industrial technology students and found no statistically significant differences existed between students who worked independently and those who engaged in the think-aloud peer problem solving (TAPPS) method. Additionally, little research is available investigating the impact of problem complexity, cognitive style, and hypothesis generation on the problem solving performance of individual students. Specifically, MacPherson (1998) expressed concern that few studies investigated the relationship of factors related to problem solving and problem solving ability in authentic settings. Therefore, the principle question that arose from the review of literature was, What effect does problem complexity, hypothesis generation, and cognitive style have on students' ability to solve authentic problems in agriculture?

Purpose of the Study

The purpose of this study was to assess the effect of cognitive style, hypothesis generation, and problem complexity on the problem solving ability of school-based agricultural education students enrolled in agricultural power and technology (APT). The following research questions guided the study:

1. What are the personal and educational characteristics of students enrolled in APT courses in Oklahoma?

2. What differences exist in content knowledge based on cognitive styles and hypothesis generation?
3. What effect does problem complexity have on the amount of time required to solve problems correctly?
4. What effect does students' cognitive style have on the time required to solve problems correctly?
5. What effect does students' hypothesis generation have on the time required to solve problems correctly?
6. What interactions exist between problem complexity, hypothesis generation, and students' cognitive styles on the amount of time required to solve problems correctly?
7. What interactions exist between students' problem complexity and hypothesis generation on the amount of time required to solve problems correctly?
8. What interactions exist between students' hypothesis generation and cognitive style on the amount of time required to solve problems correctly?
9. What interactions exist between students' problem complexity and cognitive style on the amount of time required to solve problems correctly?

The following null hypotheses guided the statistical analyses of the study:

$H_0$1: In the population, there is no statistically significant difference in content knowledge due to cognitive styles ($\mu_{1\ \text{More Adaptive}} = \mu_{2\ \text{More Innovative}}$).

$H_0$2: In the population, there is no statistically significant difference in the time required to solve problems correctly based on problem complexity ($\mu_{1\ \text{Simple}} = \mu_{2\ \text{Complex}}$).

$H_0 3$: In the population, there is no statistically significant difference in the time required to solve problems correctly based on cognitive styles ($\mu_{1\ \text{More Adaptive}} = \mu_{2\ \text{More Innovative}}$).

$H_0 4$: In the population, there is no statistically significant difference in the time required to solve problems correctly based on hypothesis generation ($\mu_{1\ \text{Correct Hypothesis}} = \mu_{2\ \text{Incorrect Hypothesis}}$).

$H_0 5$: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity, hypothesis generation, and cognitive styles ($\mu_{1\text{More Adaptive x Simple x Correct Hypothesis}} - \mu_{2\text{More Adaptive x Simple x Incorrect Hypothesis}} - \mu_{3\ \text{More Adaptive x Complex x Correct Hypothesis}} - \mu_{4\ \text{More Adaptive x Complex x Incorrect Hypothesis}} - \mu_{5\ \text{More Innovative x Simple x Correct Hypothesis}} - \mu_{6\ \text{More Innovative x Simple x Incorrect Hypothesis}} - \mu_{7\ \text{More Innovative x Complex x Correct Hypothesis}} - \mu_{8\ \text{More Innovative x Complex x Incorrect Hypothesis}} = 0$).

$H_0 5$: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and cognitive styles ($\mu_{1\text{Simple x More Adaptive}} - \mu_{2\ \text{Complex x More Adaptive}} - \mu_{3\ \text{Simple x More Innovative}} - \mu_{4\ \text{Complex x More Innovative}} = 0$).

$H_0 7$: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of cognitive styles and hypothesis generation ($\mu_{1\text{More Adaptive x Correct Hypothesis}} - \mu_{2\ \text{More Adaptive x Incorrect Hypothesis}} - \mu_{3\ \text{More Innovative x Correct Hypothesis}} - \mu_{4\ \text{More Innovative x Incorrect Hypothesis}} = 0$).

$H_0 8$: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and hypothesis generation ($\mu_{1\text{Simple x Correct Hypothesis}} - \mu_{2\text{ Simple x Incorrect Hypothesis}} - \mu_{3\text{ Complex x Correct Hypothesis}} - \mu_{4\text{ Complex x Incorrect Hypothesis}} = 0$).

Scope of the Study

This study included students and teachers from seven high schools in the state of Oklahoma. The teachers who participated in this study attended a two-day professional development workshop on small gasoline engines on the campus of Oklahoma State University during June of 2012. Student participants were enrolled in an agricultural power and technology (APT) course taught by a teacher participant during the 2012–2013 academic year. In all, a total of 68 students participated fully in this study, including 34 who were assigned a simple problem to solve and 34 who were assigned a complex problem to solve. Data were collected between October 15, 2012 and March 15, 2013, depending on when the curriculum topic fit into the teachers' schedules.

Assumptions

The following assumptions were made regarding this study:

1. Students performed to the best of their ability when solving problems.
2. Students performed to the best of their ability when completing the content knowledge test.
3. Teachers presented the lessons as they were provided by the researcher.

Delimitations of the Study

The delimitations of the study included a purposeful sample of schools based on teacher participation in a two-day professional development workshop on small gasoline engines held during June of 2012 on the campus of Oklahoma State University. The 68 student participants were assigned randomly to solve either a simple or complex problem in small gasoline engines, a topic relevant to and present in the APT curriculum.

Limitations

The following limitations of this study should be considered:

1. Since random sampling procedures were not utilized to select the participating schools or students, findings from this study should not be generalized beyond the participants of this study. However, study participants were assigned randomly to a level of treatment.
2. Variability, such as time of the day courses, may have existed between schools offering APT courses.
3. Non-treatment related variability, such as prior knowledge or student motivation, may have occurred between the treatment groups.
4. Although each teacher was provided with identical training, curriculum, and resources, variability due to teacher effect may have existed. Variables such as teacher enthusiasm, clarity, length of tenure and knowledge about small gasoline engines may have influenced student performance.

Operational Definitions

Agricultural Education – Systematic instruction related to agriculture, food, and natural resources taught at the secondary level to increase students' agricultural literacy and prepare them for employment in the agricultural industry, and prepare students for postsecondary education (Phipps et al., 2008).

Agricultural Education Teacher – Professional educators trained in both agricultural subject matter and pedagogy who are employed by local school districts to deliver agricultural education content to students in secondary schools.

Agricultural Power and Technology Course – A secondary-level course aimed at developing knowledge and skills regarding, implements, machinery, engines and other related technologies. Major course content includes: (a) use of agricultural power; (b) personal and occupational safety; (c) internal combustion engine principles; and (d) maintenance of internal combustion engines (Oklahoma Department of Career and Technology Education Course Information, 2012a).

Cognitive Style – Differences in the ways that individuals go about solving problems; also referred to as preferred problem solving style (Kirton, 2003).

More Adaptive – An indicator of an individual scoring 95 or below on the Adaption-Innovation Inventory (Kirton, 2003).

More Innovative – An indicator of an individual scoring 96 or higher on the Adaption-Innovation Inventory (Kirton, 2003).

Oklahoma Career and Technology Education (CareerTech) – "provides nationally recognized competency-based curriculum, education, and training for a myriad of specialized and customized courses and training opportunities" (Oklahoma Career and Technology Education, 2012a, About CareerTech, para. 3)

Problem – Situation where individuals or group are attempting to reach a goal (Chi & Glaser, 1985).

Problem Complexity – the number of issues, functions, or variables involved in the problem (Jonassen, 2000).

Problem Solving – Finding a means to achieve a goal (Chi & Glaser, 1985).

Problem Solving Ability – Whether or not students were able to solve their assigned problem.

Time to Solution – The amount of time required for successful identification of the assigned problem.

Troubleshooting – Specialized subset of general problem solving where the problem is ingrained in a real-life situation (Custer, 1995; MacPherson, 1998).

CHAPTER II

REVIEW OF LITERATURE

Introduction

Chapter II contains a review of relevant literature related to this study as well as the variables in question. This chapter is comprised of the following sections: student learning and problem solving, historical overview of school-based agricultural education, historical influences of problem solving research, expert and novice problem solving, mechanical problem solving, technical troubleshooting, troubleshooting research, an overview of cognitive styles, problem solving in agricultural education and agricultural mechanics, theoretical framework, conceptual framework, and chapter summary. The review of literature provides a synthesis of major themes that have influenced problem solving research within educational psychology, agricultural education, and other educational disciplines. This chapter addresses literature related to the selection of the variables of interest for the current study.

Student Learning and Problem Solving

The fundamental goal of education is to foster student learning. There is no doubt that learning is important, but throughout the history of educational research, scholars have disagreed on the causes, processes, and consequences of learning (Schunk, 2008). One accepted general definition of learning is that it “is an enduring change in behavior, or in the capacity to behave in a given fashion which results from practice or other forms of experience” (Schunk, 2008, p. 2). Learning is as difficult to measure as it is to define. It is evaluated, generally, on what people say, write, and do. An additional difficulty of determining how much a person has learned is the change in capacity associated with learning and that an individual may not demonstrate new knowledge, skills, or behaviors that are learned in close proximity to the time when the learning occurred (Schunk, 2008).

Research on learning has been a topic of discussion of scholars for decades (Schunk, 2008). Numerous variables of interest have been studied, but learning styles continue to be of interest to researchers (Sternberg & Grigorenko, 1997). Learning style is defined broadly as the manner in which individuals prefer to learn material (Kirton, 2003; Schunk, 2008). Dunn and Dunn (1979) discussed three broad types of learning styles, consisting of visual, auditory, and kinesthetic. These authors posited that between 20 and 30 percent of students prefer to learn in an auditory manner, while 40 percent of students prefer to learn visually. The remaining 30 to 40 percent of students are kinesthetic learners (Dunn & Dunn, 1979). Visual learners prefer to see the information, either through graphical representations or via reading text, while auditory learners prefer to hear information; they learn best in lectures and discussions (Fleming & Mills, 1992). Kinesthetic learners, on the other hand, touch and manipulate objects in addition to seeing or hearing information (Dunn & Dunn, 1979; Fleming & Mills, 1992).

The fact that students hold diverse learning styles has great implications for the manner in which teachers deliver instruction. Traditional, teacher-centered instructional strategies, such as lecture, have been the dominant method in which material is presented to students (Moore & Moore, 1984). Lecture, or even lecture-discussion, forces students to learn material auditorily. Therefore, it is not a surprise that sometimes students struggle to find success in teacher-centered classrooms (Dunn & Dunn, 1979).

The experiential philosophy of school-based agricultural education allows for teachers of agriculture to cater to the diverse learning styles of students (Phipps et al., 2008). Agricultural education's three component philosophy of classroom and laboratory instruction, experiential learning, and leadership education through the National FFA Organization enables students with diverse learning styles to find success (Phipps et al., 2008).

Although learning is not synonymous to problem solving, the two are highly connected (Jonassen, 2000; Schunk, 2008). A key to effective problem solving lies in students' ability to become self-regulated learners (Schunk, 2008). Problem solving skills develop early in childhood (Ellis & Siegler, 1994). As children mature, "their ability to effectively regulate their cognitive activities becomes increasingly central to their problem solving" (Ellis & Siegler, 1994, p. 341).

Progressing through school affords children the opportunity to interact with a broad range of individuals and experience diverse situations, which increase the students' capacity for solving problems (Ellis & Siegler, 1994). Research has indicated that children begin to develop capacity for recognizing problem space and creating mental models for problem solving as early as four years of age (Halford, 1993). Problem space and mental model representation are key processes for problem solving (Jonassen, 2000; Newell & Simon, 1972).

Jonassen (2000) conducted a review of the problem solving literature and discerned variations in types of problems, such as their structure, complexity, and domain-specificity. Problems can be classified as well-structured or ill-structured (Jonassen, 1997). Well-structured problems are the most common type of problems students face in school settings and are a type of application problem. Well-structured problems provide the problem solver a defined initial state, a known goal, and known operational constraints (Jonassen, 1997). Ill-structured problems, however, are those that people are likely to encounter in their everyday and professional lives (Jonassen, 2000). Ill-structured problems are likely to be situated in more than one domain. For example, an ill-structured problem may require the individual to employ concepts from mathematics, science, and psychology (Jonassen, 2000). Ill-structured problems may not have a clearly defined initial state, may have unknown elements, or they have more than one potential solution (Johnassen, 1997).

Another variation in problem typology is problem complexity. "Problem complexity is defined by the number of issues, functions, or variables involved in the problem (Jonassen, 2000, p. 67). Often, complex problems are situated in dynamic environments (Jonassen, 2000). Problem difficulty is a function of complexity, but the two are not synonymous (Jonassen, 2000). Typically, problem complexity and problem structure are related. Ill-structured problems are likely to be more complex than well-structured problems (Jonassen, 2000).

The third classification of problems is by their domain specificity. Research often defines problems as being domain-specific, meaning that problems may require certain type of knowledge to solve (Hegarty, 1991). According to Jonassen (2001) real-world problems are normally situated within a specific context and are likely ill-structured. These ill-structured problems require domain-specific knowledge are said to be *situated* in a context (Jonassen, 2000). Well-structured problems, on the other hand, are not context specific, normally. These types of problems require the problem solver to be proficient at general problem solving skills (heuristics) and are considered *abstract* in nature (Jonassen, 2000).

Overview of the History of School-Based Agricultural Education

Public secondary education was serving less than 15 percent of the school-aged population at the turn of the 20th century (Gordon, 2003). The 1906 Douglas Commission report stated that 25,000 Massachusetts students between the ages of 14 and 16 dropped out of school to enter the workforce (Wirth, 1972). More alarming was the anecdotal report from school administrators that thousands of students remained in school physically but had dropped out mentally because there was “nothing else to do” (Wirth, 1972, p. 78). These students found little value in the liberal education of the time and were of the age that they believed they were old enough to earn a living (Wirth, 1972). The findings of this report prompted the recommendation for schools to incorporate elements of industrial (vocational) education (Wirth, 1972).

The Douglas Commission’s recommendation led to the formation of two distinct schools of thought regarding how vocational education should be implemented. The first view of vocational education, led by David Snedden and Charles Prosser, was grounded in social efficiency (Gordon, 2003). The supposition of social efficiency is that “schools should prepare individuals for occupations at which they excelled” (Gordon, 2003, p. 27). Snedden and Prosser argued for a dual system of education where vocational education would be separate from the common schools (Gordon, 2003). In other words, vocational education schools should be like work, and students should develop and acquire specific skills needed for a particular occupation (Roberts & Ball, 2009).

The opposing viewpoint of vocational education, led by John Dewey, was grounded in the belief that education should aid in the development of democratically minded students. Dewey (1938) believed there should be no distinction made between the education of future workers and those who would be leading companies (Gordon, 2003). Dewey (1938) argued that vocational education should not focus on the attainment of specific skills, but rather vocational exploration where students would "acquire practical knowledge, apply academic content, and examine occupational and societal value" (Gordon, 2003, p. 32). Students should focus on acquiring general skills through quality experiences that would be transferrable to either higher education or the workforce (Dewey, 1938; Gordon, 2003).

In the end, policymakers and industry favored the views of Snedden and Prosser, who influenced the writing and passage of the Smith-Hughes Act of 1917 (Roberts & Ball, 2009). The Smith-Hughes Act was the first piece of legislation targeted at vocational education at the secondary level (Gordon, 2003). It provided Federal funds for the vocational education areas of agriculture, home economics, and industrial education. Additionally, it required states to establish separate state boards of vocational education (Gordon, 2003). In the end, the Smith-Hughes Act solidified the views of Snedden and Prosser and set the course that vocational education followed for most of the 20th century. At the time, agricultural education, in schools, was known as vocational agriculture, where boys learned how to be better farmers with the goal of returning to the family farm after graduation.

Little change occurred regarding the basic vocational mission of agricultural education until the 1980s when declining enrollment forced the profession to rethink its purpose (National Research Council [NRC], 1988). In response to the changing times, the NRC published a report that called for vocational agriculture to broaden its scope and include additional content areas in the curriculum than simply those needed to train students for on-farm jobs only. The NRC (1988) listed other sectors of agriculture, such as agribusiness, marketing, and policy, as areas that needed to be integrated into the curriculum. In addition, the NRC (1988) emphasized the need to teach science in the context of agriculture. In 1988, vocational agriculture formally changed its name to agricultural education to reflect a new mission of educating students *about* agriculture versus educating students for careers *in* agriculture (NRC, 1988). This shift in mission and philosophy reopened the Snedden/Prosser and Dewey debate (Roberts & Ball, 2009).

Roberts and Ball (2009) outlined the two major philosophies of agricultural education. The first is that agricultural education exists for educating and preparing students for agricultural careers (Phipps et al., 2008). Students who complete agricultural education programs should develop the knowledge and skills needed for employment in various sectors of the agricultural industry (Phipps & Osborne, 1988). Several researchers in agricultural education have described problem solving as a skill desired by employers (Alston et al., 2009; Graham, 2001; Robinson & Garton, 2008; Robinson et al., 2007). The core of this view of agricultural education is rooted in the philosophy of early leaders in vocational education, such as Charles Prosser and David Snedden

(Roberts & Ball, 2009). Prosser and Snedden viewed the purpose of vocational education, including agricultural education, as training workers based on industry standards and needs (Roberts & Ball, 2009).

The competing philosophy is based on the work of John Dewey and calls for an integrated curriculum where both academic and vocational content are taught (Roberts & Ball, 2009). In this view, students learn core content such as mathematics or science in the context of agriculture, to "develop transferrable life skills" (Roberts & Ball, 2009, p. 82). Problem solving is one of the transferrable life skills advocated by agriculture as a context philosophy.

Roberts and Ball (2009) suggested a blended philosophy of agricultural education where the outcomes are both a "skilled agricultural workforce" and "successful lifelong learners that are agriculturally literate citizens" (p. 87). This dual-purpose model of agricultural education described the two outcomes as not being mutually exclusive and that students may transition between the outcomes throughout their lives (see Figure 1). Regardless of philosophical underpinning, teaching students to solve problems, both well-structured and ill-structured, is an important outcome of the program.

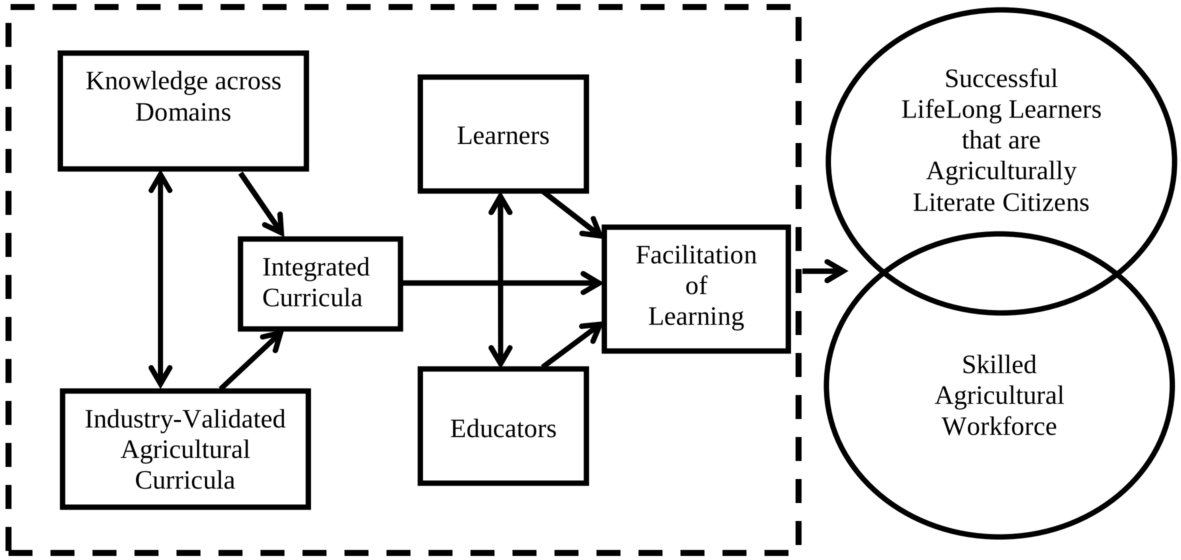

Figure 2. Conceptual model for agriculture subject matter as a content and context for teaching. Adapted from "Secondary Agricultural Science as Content and Context for Teaching," by T. G. Roberts, and A. L. Ball, 2009, *Journal of Agricultural Education, 50*(1), p. 87. Copyright 2009 by the American Association for Agricultural Education. Reprinted with permission.

Historical Influences of Problem Solving Research

Problem solving has been a topic of interest of scholars for years (Schunk, 2008). Three themes have influenced the current body of literature on problem solving. These three topical areas include trial and error learning, insight, and general problem solving strategies, also known as, heuristics (Schunk, 2008).

Trial and Error Problem Solving

In the early portion of the 20th century, the dominating theoretical perspectives on how people learn were the conditioning theories, also known as behaviorism. One of the early leaders in the field of educational psychology was E. L. Thorndike (Schunk, 2008). Thorndike's view of learning, called connectionism, was a dominant school of thought during the first one-half of the 20th century. Thorndike (1923) postulated that learners form connections between sensory experiences (stimuli) and responses that are then manifested as behaviors.

Thorndike operationalized problem solving as trial and error behavior (Schunk, 2008). Much of Thorndike's (1923) research was on animals in problem situations, such as cats escaping from a cage. Thorndike (1923) observed that, ultimately, after a series of random behaviors, cats would stumble onto the correct solution and open the cage door successfully. When the experiments were repeated, the cats made fewer errors before escaping. These experiments with cats led Thorndike to view problem solving as a gradual process where unsuccessful solutions were "stamped out" and successful solutions "stamped in" (Dominowski & Bourne, 1994, p. 25). Trial and error is utilized occasionally by educators and learners, but often it is not reliable or effective (Schunk, 2008).

Insight

The second major historical influence on problem solving research is insight, or the sudden awareness of a solution (Schunk, 2008). In several experiments in which apes were presented a piece of fruit that was out of reach, Kohler (1925; as cited in Dominowski & Bourne, 1994) observed that the apes began generally by employing direct, yet futile attempts to obtain the food. Kohler (1925; as cited in Dominowski & Bourne, 1994) reported that after a period of time, the ape, purposefully, would use objects provided, such as a short stick, to obtain the fruit. This led Kohler and other researchers to theorize and research the concept of insight.

A leader in the study of insight and problem solving was Graham Wallas who studied great problem solvers and devised a four-step model based on his observations. The first step, preparation, is a time to learn about the problem and gather information that might be relevant to its solution. Incubation is the second stage of insight. It is a period of thinking about the problem, which may also include putting the problem aside for a time. The next step, illumination, is a period of insight when a potential solution suddenly comes into awareness. The final step, verification, is a time to test the proposed solution to ascertain whether the potential solution is correct (Wallas, 1926). Although these stages were never verified empirically, Wallas (1926) believed that much of human learning was insightful. In this view, learners think about solving the problem; then, the solution comes to mind, spontaneously (Wallas, 1926).

Like Wallas (1926), the Gesalt psychologists of the time believed learning and problem solving were based on insight, although the term *productive thinking* was penned to describe this phenomenon (Schunk, 2008). When faced with a new problem, learners often experience an *Aha!* moment after a period of time (Davidson, 2003). In the Gesaltist view, productive thinking allows learners to move beyond old knowledge and experiences and view the problem in a new way (Schunk, 2008). When a solution to the problem cannot be found, it is usually the result of the problem solver's inability to move beyond his or her past associations (Davidson, 2003). This mental block is known as functional fixedness (Schunk, 2008). An example of functional fixedness can be seen in the box problem described by Dunker (1945). In this problem, participants were asked to mount a candle to serve as a reading lamp, given three cardboard boxes, matches, candles, and thumbtacks. The solution to the problem involved employing the box for a purpose other than being a container (Dunker, 1945). Those who could not solve the problem were fixated on using the box for its common purpose, unable to move beyond their prior knowledge and experiences (Davidson, 2003).

Heuristics

Problem solving strategies are either general or specific (Schunk, 2008). General problem solving strategies, also referred to as heuristics, are useful in a variety of situations, while specific strategies are domain specific (Hegarty, 1991). The term heuristic is derived from the Greek word meaning "serving to find out or discover" (Todd & Gigerenzer, 2000, p. 738.) In the context of problem solving, heuristics are general strategies employed to solve a wide range of problems (Abel, 2003). In other words, heuristics are "rules of thumb" people use when solving problems (Abel, 2003, p. 53). These general problem solving strategies enable people to overcome problems to reach a goal (Ellis & Siegler, 1994). One useful general strategy to solving problems is creating sub-goals. When employing the heuristic of creating sub-goals, problem solvers identify the end goal, then the break problem into manageable sub-goals. When all the sub-goals are completed, the individual will have reached the overall problem goal (Schunk, 2008).

Often, general problem solving strategies are employed in situations where the solution is not recognized immediately (Schunk, 2008). Several general strategies, such as generate-and-test, means-ends analysis, analogical reasoning, and brainstorming are described in the literature. The generate-and-test strategy is useful in situations where a limited amount of possible solutions can be tested. This strategy is appropriate in situations where the individual is not a content knowledge expert, but has some familiarity with the subject. Basic knowledge of the problem situation allows individuals to organize information and possible solutions hierarchically so that the most likely solutions are tested first. Schunk (2008) cited an example of walking into a room and turning on the light switch only to discover that the light did not come on. Several possible solutions exist. Perhaps a faulty socket in the lamp existed, the switch malfunctioned, the circuit breaker flipped, a short in the wiring occured, or the light bulb was burned out. Individuals who are familiar with this situation would generate the most likely solution, a burned out bulb, then test the solution by replacing the bulb. If bulb replacement did not solve the problem, the next most likely solution could be tested, and so on. Basic content knowledge establishes the hierarchy of solutions, but current knowledge of the situation influences the selection of possible solutions (Schunk, 2008).

Means-ends analysis involves comparing the initial state of the problem to the goal state and eliminating the differences between the two (Hunt, 1994). The means-ends approach can be very successful, unless the problem is so complicated that the problem solver loses track of the sub-goals (Schunk, 2008). Losing track of necessary sub-goals can hinder goal attainment. There are two basic methods of the means-ends problem solving strategy, which are working forward and working backward. It involves working from the initial state to the goal (Hunt, 1994). Working forward is most appropriate for expert problem solvers. Experts are able to classify problems better than novices and can proceed with solving the problem (Hunt, 1994). Novices may veer off the problem solving course or arrive at a dead end due to poor problem classification and hierarchy of thought (Schunk, 2008). Working backward involves beginning at the desired goal, then working toward the initial state to determine operations that must be performed to remove the differences (Schunk, 2008).

The third general problem solving strategy is analogical reasoning, where individuals generate an analogy between the target (problem) and a base (familiar situation) (Chen, 1999; Hunt, 1989; Schunk, 2008). This strategy works best when underlying features or principles of the problem and base are similar, even if the context of the problem is very different (Schunk, 2008). This strategy relies on the individual's ability to transfer applications from one situation to another. Analogical reasoning is most effective when the problem solver has knowledge of the problem and base contexts; this allows cognitive transfer to occur more readily. Individuals lacking knowledge in the base domain are unlikely to make needed connections between it and the familiar problem (Schunk, 2008).

Another general strategy of problem solving is brainstorming. Brainstorming is useful when several possible solutions are needed (Schunk, 2008). Four basic steps of brainstorming include a) defining the problem, b) generating mass ideas for possible solutions, c) selecting criteria to evaluate possible solutions, and d) employing selected criteria to determine the best solution. Brainstorming, like analogical reasoning, is most successful when participants have knowledge in the problem domain (Schunk, 2008). Criticism of ideas should be withheld until the generation of ideas is complete; this encourages participants to discuss even unusual ideas (Schunk, 2008). Knowledge in the problem domain, coupled with the freedom to discuss atypical ideas, helps ensure the success of brainstorming sessions (Schunk, 2008).

Expert and Novice Problem Solving

There is little doubt of the importance of domain-specific knowledge when solving problems (Nickerson, 1994). The degree to which an individual is knowledgeable in the problem domain impacts how the problem is understood and what possible solutions are generated (Jonassen, 2000). It is unrealistic to expect an individual without knowledge of chemistry to think deeply or solve problems of a chemical nature; heuristics would not suffice (Nickerson, 1994). Research has indicated differences in problem solving performance of experts and novices. These differences have influenced debate among scholars as to whether students should be taught problem solving skills separately from content or if the two should be integrated (Nickerson, 1994).

Previous research has focused on differences in problem solving abilities of experts and novices. Some authors define an expert as having high competence in problem solving and novices as being familiar with problem solving, but exhibiting poor performance (Schunk, 2008). Others, however, have described experts and novices as differing in domain-specific knowledge (Simon, 1979). In fact, some researchers suggest experts do not possess greater knowledge of problem solving strategies than novices (Zimmerman & Campillo, 2003). Larkin, McDermott, Simon, and Simon (1980) asserted that experts' knowledge was organized in such a way that access to relevant information was almost instantaneous.

What is agreed on in the literature, however, is that there are clear differences in problem solving abilities between experts and novices. First, experts tend to recognize patterns and underlying principles within a problem (Zimmerman & Campillo, 2003). Novices, on the other hand, are likely to classify problems based on "surface features of the task" (Zimmerman & Campillo, 2003, p. 236). Chi, Feltovich, and Glaser (1981) investigated differences in problem solving ability in physics among experts and novices. These researchers found novices were likely to categorize problems based on the type of apparatus employed, while experts tended to group problems based on the underlying physics principle. Experts were able to recognize underlying patterns within the physics problems because they organized their knowledge more hierarchically (Chi et al., 1981; Schunk, 2008). Additionally, experts tend to utilize strategies, such as creating sub-goals to break up the problem into manageable tasks, while novices attempt to tackle the problem as a whole (Zimmerman & Campillo, 2003).

Mechanical Problem Solving

An additional subset of problem solving research is focused on problems of a mechanical nature. Problems are considered mechanical, generally, when forces are applied to objects causing movement (Hegarty, 1991). As with all forms of problem solving research, one theme related specifically to mechanical problems is knowledge of the problem solver. Hegarty (1991) listed two broad types of knowledge, general and specific, that influence an individual's ability to solve mechanical problems. General knowledge is described as being useful to all types of problem solving, while specific knowledge is useful in the mechanical domain. General knowledge can include heuristics, such as identifying a goal state and eliminating differences between it and the current situation (Hegarty, 1991).

Specific knowledge is most useful in semantically rich domains, such as those found in mechanics (Hegarty, 1991). Specific knowledge can be divided into conceptual knowledge and procedural knowledge. Conceptual knowledge is described as an understanding of "items of knowledge" (McCormick, 1997, p. 143). When students are able to make and understand the connection of knowledge items, it is said they have a "conceptual understanding" (McCormick, 1997, p. 143). For example, for students to have a conceptual understanding of gearing, they should be able to see the relationship among concepts such as torque, speed, and directional rotation (McCormick, 1997). In contrast, procedural knowledge can be thought of as knowing *how* to perform tasks (Hegarty, 1991; McCormick, 1997). Problem solving, therefore, is a higher-order type of procedural knowledge (McCormick, 1997).

Although problem solving is considered a type of procedural knowledge, the idea that individuals can be trained to solve problems easily may be false (McCormick, 1997). General problem solving strategies, such as heuristics, are an intriguing idea, but research has indicated that successful problem solving relies on the relationship between conceptual and procedural knowledge (Glaser, 1984; McCormick, 1997). The possession of conceptual knowledge allows individuals to utilize procedural knowledge, such as problem solving, effectively (Glaser, 1984).

Technical Troubleshooting

Troubleshooting, or technical problem solving, is a specialized subset of general problem solving where the problem is ingrained in a real-life situation and the troubleshooter engages in diagnosing a fault (Custer, 1995; Jonassen, 2000; MacPherson, 1998). More simply, troubleshooting is the attempt to locate the reason for a malfunction in a given system (Morris & Rouse, 1985). On the continuum of problem structure, troubleshooting is in the middle of the road between well-structured and ill-structured (Jonassen, 2000). Individuals engaged in troubleshooting must have the ability to use symptom information to generate and test possible hypotheses about the faulty system (Jonassen, 2001). The ability to troubleshoot systems “encourages creativity, ingenuity, and inventive thought processes,” which are characteristics sought after highly by potential employers (MacPherson, 1998, p. 1). Successful troubleshooting is often measured as efficiently identifying the fault in a system (Jonassen, 2000).

Newell and Simon (1972) classified problems based on the notion of problem space. Problem space is described as the problem context and the resources, solutions, and all processes utilized to solve the problem (Newell & Simon, 1972). Problem space is also known as the mental model of the problem solver and is comprised of conceptual knowledge, functional knowledge, and declarative knowledge (Jonassen, 2000). Using the idea of problem space as a foundation, Custer (1995) described the uniqueness of technical problem solving. Specifically, problem space includes "resources, primary processes, and goal thrust" (Custer, 1995, p. 233). Resources include everything the problem solver utilizes to solve the problem, including physical, psychological, and knowledge resources. Primary processes are the activities employed to solve the problem. Finally, goal thrust is the motivation to solve the problem. Custer (1995) argued that the primary distinguishing characteristic among various types of problem solving is the goal thrust component. Therefore, the construction of problem space is key to successful problem solving (Jonassen, 2000).

Johnson (1989) developed a model of technical troubleshooting to depict how individuals utilize cognitive processes to solve technical problems (see Figure 2). This model is comprised of two phases. The first, hypothesis generation, is when the troubleshooter seeks and interprets information with the goal of formulating a hypothesis. The information sought is derived from both internal and external sources (Johnson, 1989). Internal information includes both declarative and procedural knowledge within long-term memory (Schunk, 2008). Troubleshooters must possess and be able to utilize these types of knowledge. Additionally, Jonassen (2001) listed system knowledge, procedural knowledge, and strategic knowledge as requirements of troubleshooters. System knowledge is the basic understanding of how the system operates, procedural knowledge is achieved when the troubleshooter knows how to perform tests and employ problem solving procedures, and strategic knowledge is when the troubleshooter comprehends how and when to employ procedures (Jonassen, 2001). External information is gathered from sources such as job aids, technical support and evaluations, and sensory evaluation (Johnson, 1989). After the necessary information is gathered, the troubleshooter determines whether or not hypotheses can be made (Johnson, 1989).

If the troubleshooter is able to generate a hypothesis, he or she then transitions into the hypothesis evaluation phase of the model. Additional information, if necessary, is gathered so that the troubleshooter can evaluate the hypothesis (Johnson, 1989). Once the hypothesis is evaluated, the troubleshooter makes a decision to confirm or disconfirm the hypothesis. If the hypothesis is confirmed, then the troubleshooter pursues a course of action to correct the problem. If the hypothesis is disconfirmed, the troubleshooter cycles back to the first phase of the model and generates a new hypothesis to evaluate (Johnson, 1989, see Figure 2). More successful troubleshooters are able to generate accurate hypotheses to solve problems quickly (Vasandani & Govindaraj, 1991).

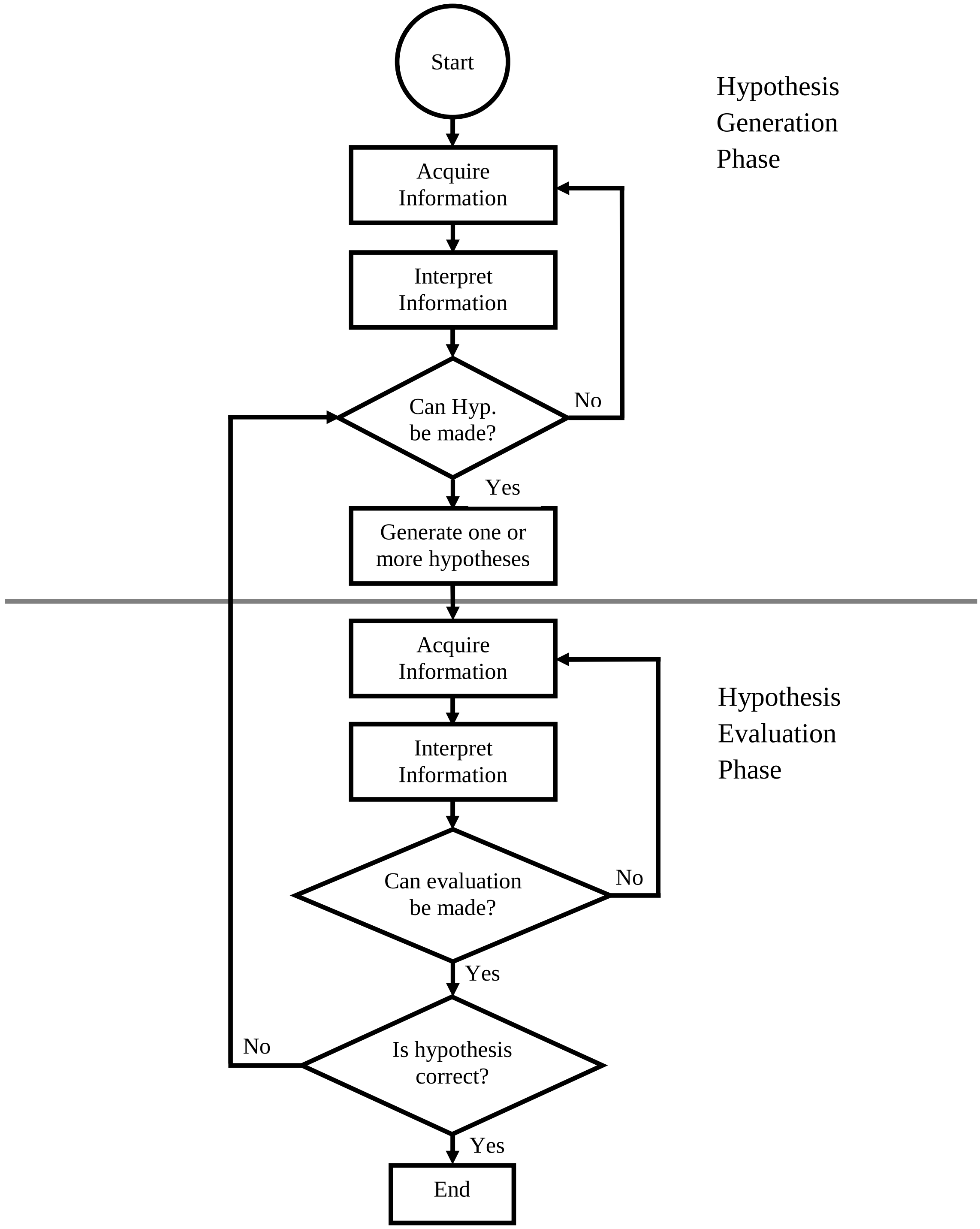

Figure 2. Technical Troubleshooting Model. Adapted from "A description of expert and novice performance differences on technical troubleshooting tasks" by S. D. Johnson, 1989, *Journal of Industrial Teacher Education, 26*(3), p. 20. Copyright 1989 by *Journal of Industrial Teacher Education.* Reprinted with permission.

Troubleshooting Research

Research in the troubleshooting ability of individuals has focused on differences between expert and novice problem solvers and differences in individual characteristics. Using the technical troubleshooting model as a frame, Johnson (1989) described differences in the performance of experts and novices on troubleshooting tasks related to gasoline powered electrical generators. In that study, five novice troubleshooters were identified as individuals who were enrolled in a training course related to the generators. Five expert troubleshooters were selected from technician trainers, engineering troubleshooters, and troubleshooters from the manufacturing facility which produced the generators. Both the experts and novices were directed to solve two problems, one mechanical in nature and one electrical. The groups were provided generators with set faults and instructed to attempt to start the engine to identify the problem. Troubleshooting success, time to solution, and procedural skill were measured directly. All experts were able to troubleshoot successfully both the mechanical and electrical faults. The novices, however, were not 100 percent successful. Three novices found the mechanical fault, while only two solved the electrical problem (Johnson, 1989).

Regarding time to solution, the novices were able to solve the mechanical problem faster than the experts. The experts, however, were able to solve the electrical problem nearly five times quicker than those novices who were able to identify the fault successfully. Johnson (1989) also observed the type of procedures utilized to solve the problems. The experts utilized correct mechanical and electrical test procedures, but the novices did not. All experts utilized electrical tests to solve the electrical problem, yet only 88 percent of the tests implemented by the novices were electrical in nature

(Johnson, 1989). Information related to the technical troubleshooting model were measured indirectly and included the types of information sought, relevance of the information, and success experienced in obtaining information (Johnson, 1989). Experts tended to seek specific information through technical evaluation, and the novices tended to seek superficial, sensory information. Specifically, related to the electrical problem, only 61.4 percent of the novice group sought relevant information. Overall, Johnson (1989) concluded that the greatest difference in the troubleshooting performance of experts and novices was quality of information acquired and hypotheses generated.

Gitomer (1988) utilized three experiments to determine individual differences in the electronics troubleshooting ability of expert and novice troubleshooters. The three experiments were designed to compare the experts' and novices' abilities to construct accurate mental models, differentiate troubleshooting procedures, and identify sources of procedural skill errors. Differences were identified in the mental models of expert and novice troubleshooters. The novices' mental models tended to reveal misconceptions stemming from multiple sources. Additionally, the expert troubleshooters were more proficient in procedures employed when troubleshooting. Novices were more likely to resort to guessing when attempting to identify the problem. Errors committed by the experts tended to be computational in nature. However, novices exhibited conceptual, knowledge-based errors. Overall, Gitomer (1988) concluded that there are clear differences in the troubleshooting abilities of experts and novices. Specifically, the experts were able to develop mental models that represented systems much more accurately than the novices, who tended to become distracted by superficial features of the problem (Gitomer, 1988).

Johnson (1988) conducted a study to compare the difference between experts and novices during an electronics troubleshooting task. During the troubleshooting task, participants were required to think aloud. Thinking aloud enabled the researchers to determine how the experts and novices worked through the problem space (Newell & Simon, 1972). Johnson (1988) reported three types of information the troubleshooters gathered as they worked through the problem space. First, problem formation involves searching through the problem space for the initial information of a system fault. Experts were to gain better information in this first stage than the novices (Johnson, 1988).

The second type of information reported was problem space representation (Johnson, 1988). In this stage, the troubleshooter generated hypotheses that could potentially identify the fault in the system. In all, the experts involved in that research study generated a total of 24 hypotheses. Johnson (1988) reported that only two of the hypotheses generated by the experts were irrelevant. The novices, however, generated 36 irrelevant hypotheses out of a total of 61 hypotheses. The third type of information was problem solution sequence (Johnson, 1988). Experts were able to reduce the problem space by proceeding through a more efficient order of operations that allowed them to identify the fault in the system. This was accomplished by obtaining better information and formulating relevant hypotheses (Johnson, 1988).

Johnson (1988) concluded that the experts held a greater understanding of the technical system than the novices. The deeper understanding enabled the experts to sort through the information and generate relevant hypotheses that took them closer to identifying the fault. Additionally, the experts possessed more knowledge of electronic systems, and their knowledge was organized better from their experiences. This organization of knowledge is referred to as a mental model (Johnson, 1988). The novices did not possess the same level of system knowledge, but an even greater hindrance to troubleshooting was poor organization of their knowledge.

Overview of Cognitive Style

A plethora of literature exists responding to: how do students learn best. Terminology such as cognitive style, learning style, intellectual style, and thinking style are used to describe how students prefer to receive information (Kirton, 2003; Schunk, 2008; Sternberg & Grigorenko, 1997; Zhang & Sternberg, 2005). Cognitive styles have been described as "preferences or attitudes that determine a person's cognitive function in a wide variety of behaviors such as perception, remembering, thinking, and problem solving" (Swinnen, Vandenberghe, & Van Assche, 1986, p. 51). Although numerous definitions of cognitive style exist, one characteristic of cognitive styles is it is a relatively stable characteristic that is developed early in life (Kirton, 2003; Rouse & Rouse, 1982). Several researchers have hypothesized that cognitive styles influence an individual's ability to solve problems; however, it is important to note that cognitive styles are a reflection of how individuals prefer to receive information, and are not a measure of intelligence (Kirton, 2003; Schunk, 2008; Sternberg & Grigorenko, 2005).

Numerous instruments exist that attempt to capture and measure various definitions of cognitive style. In fact, Zhang and Sternberg (2005) reviewed 10 style conceptualizations and arranged them to create a threefold model of intellectual styles. These style models were classified as "trait versus state, value laden versus value free, and different style constructs versus similar constructs with different style labels" (Zhang & Sternberg, p. 37). The cognitive style models chosen met the criteria of (a) being influential in the literature, (b) being defined and operationalized by construct, and (c) having each style was tested against at least one other style. Examples of cognitive style models reviewed were the Group Embedded Figures Test (GEFT) (Witkin, Moore, Goodenough, Cox, 1977), Matching Familiar Figures Test (MFFT) (Rouse & Rouse, 1982), Adaption-Innovation (Kirton, 1976; 2003), and the Myers-Briggs Type Indicator (Myers & McCaully, 1988).

Troubleshooting and Cognitive Style

Research has been conducted to identify relationships between individuals' cognitive style and their ability to perform troubleshooting tasks. Common measures of cognitive style found in the troubleshooting literature are field-dependent and field-independent, as measured by the GEFT, and Reflectivity-Impulsivity, as measured by the MFFT. Field-dependent learners are highly tuned to their environment, tend to prefer to take more of a spectator role in learning, and are motivated extrinsically (Witkin et al., 1977). Field-dependent learners prefer when teachers provide structure for learning, and they tend to have difficulty solving problems (Witkin et al., 1977). In contrast, field-independent learners tend to prefer individualized learning activities, are motivated intrinsically, and are less concerned with social reinforcement. Additionally, the field-independent learners prefer less provided structure and have less difficulty solving problems (Witkin et al., 1977).

The MFFT dichotomizes learners as either reflective or impulsive by the amount of time they take to answer test items. Impulsive individuals respond quickly, often committing errors. The more reflective individuals tend to utilize more time to make a decision, and commit fewer errors in the process (Messer, 1976).

Rouse and Rouse (1982) conducted a study to determine the relationship of two measures of cognitive style, the GEFT and MFFT, with performance on two simulated troubleshooting tasks. The researchers reported statistically significant, negative relationships between MFFT response time and MFFT errors, which indicated that the more time it took the participants to complete the MFFT, the fewer errors they committed. Additionally, the researchers reported statistically significant, positive relationships between GEFT times and GEFT errors, mean that me more time it took participants to complete the instrument, the more errors they made. The researchers concluded that the difference in relationship directionality between the two instruments was attributable to how the instruments measure style. The MFFT measures time to first response, while the GEFT measures time to correct response (Rouse & Rouse, 1982).

Additionally, Rouse and Rouse (1982) sought to determine the relationships that existed between the measures of cognitive style and troubleshooting performance. The authors reported statistically significant, positive relationships between the MFFT error score and both troubleshooting tasks. Only a single statistically significant relationship between the GEFT and one of the troubleshooting tasks was reported. It was concluded that reflective troubleshooters tended to commit significantly fewer errors (Rouse & Rouse, 1982).

Henneman and Rouse (1984) conducted a study to determine predictors of troubleshooting performance on two simulated tasks. Cognitive styles, as measured by the GEFT and MFFT, were utilized as predictor variables. The researchers determined that cognitive styles were good predictors of troubleshooting performance, with correlation coefficients around the .40 level (Henneman & Rouse, 1984).

MacPherson (1998) sought to determine the predictive relationship of factors that affect cognitive transfer during troubleshooting. Specifically, the predictor variables were cognitive skills, such as knowledge, years of experience, cognitive style, as measured by the GEFT, critical thinking, and problem solving style, as measured by Personal Problem Solving Inventory – Technological (PSI-Tech). MacPherson (1998) reported that the strongest predictor of cognitive transfer of troubleshooting skills was years of experience, followed by cognitive skills and critical thinking. Cognitive style was determined to be an ineffective predictor, and problem solving style was the least important predictor of cognitive transfer. MacPherson (1998) concluded that no evidence suggested that one cognitive style is superior when troubleshooting, and individuals with a wide range of cognitive styles can solve problems.

Problem Solving and Troubleshooting in Agricultural Education

Historically, agricultural education has aligned itself with the work of John Dewey (Phipps et al., 2008). Traditionally, the profession of agricultural education has also focused on problem solving as both an outcome of the program and a method of instructing students (Parr & Edwards, 2004; Phipps et al., 2008). Much of the problem solving literature in agricultural education has focused on the merits of utilizing the problem solving method of teaching. Recently, however, researchers have begun to investigate problem solving ability of students and their cognitive style preference for solving problems (Pate & Miller, 2011a, Lamm et al., 2012).

Problem Solving as a Teaching Approach

The effectiveness of the problem solving approach to teaching has been of interest to agricultural education scholars for decades. However, the overall body of literature has been described as “limited in scope with inconclusive results as to its effectiveness” (Dyer & Osborne, 1996a, p. 44). The available literature on problem solving as a teaching approach has focused primarily on student achievement and student problem solving ability. Additionally, Lamm et al. (2011) identified cognitive style, specifically problem solving style, as an important variable for educators to consider when attempting to increase student achievement.

Dawson (1956) evaluated the effect of the problem solving approach to teaching a college course in agronomy at the introductory level at Cornell University. The study sought to determine if the problem solving approach was more effective than traditional lecture and recitation. Effective learning was measured as student achievement on tests and problem solving ability. Regarding student achievement, no statistically significant difference existed in the test scores of those taught by traditional lecture and those who received instruction via the problem solving approach. However, students taught through the problem solving approach were able to solve practical, in-the-field problems more effectively than those taught with the lecture method. A statistically significant difference was reported in favor of students who were taught by means of the problem solving approach on tests involving problem solving (Dawson, 1956).

Thompson and Tom (1957) compared an experimental, student-centered (problem-solving) approach to teaching agriculture with the conventional teacher-centered method. The results from this early work indicated the problem solving ability of students did not differ based on teaching approach. However, a statistically significant difference was reported regarding students’ ability to recall knowledge. Students who were taught via the problem solving approach to teaching scored higher on the content knowledge test than their counterparts who were taught with the conventional technique (Thompson & Tom, 1957).

Crunkilton (1984) touted the problem solving approach to teaching, referring to it as “the culminating step in a sequence of learning theories that can be traced to the early beliefs in learning styles and to the pioneer findings of the initial stimulus—response scientific experiments” (p. 14). Further, Crunkilton (1984) opined that the problem solving approach to teaching was the best method to capture all elements of education. Therefore, teachers who utilize the problem solving approach will encourage the development of reasoning and hone the problem solving skills of their students (Crunkilton, 1984).

Flowers and Osborne (1988) sought to determine the effects of the problem solving and subject matter approaches to teaching agriculture on achievement and knowledge retention of students enrolled in an introductory agriculture course in Illinois. Achievement was measured on a 25-item test in the problem area, and student knowledge retention was measured by calculating the difference between the test and a deferred post-test. No statistically significant differences were found between the problem solving and subject matter approaches to teaching regarding student achievement or overall knowledge retention. Students taught via the problem solving approach had slightly higher knowledge retention of items that were deemed higher level in nature than those taught via the subject matter approach (Flowers & Osborne, 1988).

Boone (1990) conducted a research study to investigate the effect of the problem solving approach to teaching agriculture on achievement and retention of knowledge of students in Ohio. Students of teachers who did an exemplary job of employing the problem solving approach, as defined by university faculty and state instructional staff, served as the sample for the study. Student achievement was operationalized as the difference between pre-test and post-test scores on one of two instructional units, either preparing beef for exhibition or controlling weeds in corn production. Student retention of agricultural knowledge was measured by calculating the difference between the post-test and deferred post-test. The major findings of this study were that the problem solving approach to teaching increased student retention of agricultural knowledge in both instructional units. Student achievement was affected by the students' prior knowledge, but the problem solving approach did have a positive effect (Boone, 1990).

Dyer and Osborne (1996a) studied the effects of teaching approach on student achievement in regard to differing learning styles. The sample included 258 secondary students and six agriculture teachers in Illinois. In the experimental design, one group of students received all instruction via the problem solving approach, while the other group received instruction through the subject matter approach. Achievement was measured by differences in the pre-test and post-test scores on two content knowledge tests. Student learning styles were assessed by the Group Embedded Figures Test (GEFT). The GEFT classifies students on a scale from 0 to 18, with scores ranging from 0 to 8 being field-dependent, nine to 11 being field-neutral, and 12 to 18 being field-independent. Overall, students taught via the problem solving approach showed higher mean scores on achievement than those taught by the traditional subject matter approach; however, the researchers performed an analysis of covariance on the pre-test scores and found no statistically significant differences existed (Dyer & Osborne, 1996a).

When taking into account student learning styles, the researchers reported an interaction effect with both achievement tests (Dyer & Osborne, 1996a). The field-neutral learners taught by the problem solving approach scored significantly higher than their counterparts who were taught using the subject matter approach. Field-dependent learners also showed somewhat higher mean scores when taught through the problem solving approach, although the results were not statistically significant. There were almost no differences in the mean scores of field-independent learners regarding teaching approach (Dyer & Osborne, 1996a).

Dyer and Osborne (1996b) utilized the same sample of secondary students and agriculture teachers to determine the effects of teaching approach on the problem solving ability of students with differing learning styles. Problem solving ability was measured by a 10-point instrument created by the researchers. Student learning styles were assessed using the GEFT. The overall conclusion of the study was that, regardless of learning style, the problem solving approach to teaching agriculture was more effective at increasing the problem solving ability of students than the subject matter approach. Each learning style experienced a gain in problem solving ability, leading the researchers to conclude that students can be taught to solve problems (Dyer & Osborne, 1996b).

Friedel, Irani, Rhoades, Fuhrman, and Gallo (2008) conducted a study to explore the relationships between critical thinking and problem solving in the context of Mendelian genetics of undergraduate students at the University of Florida. In addition, the problem solving style of the students was assessed using the Kirton Adaption-Innovation Inventory (KAI). The KAI measures cognitive style on a continuum ranging from adaptive to innovative (Kirton, 2003). The KAI utilizes three constructs to measure cognitive style, which are sufficiency of originality (preference for forming solutions), efficiency (preference to strategy in problem solving) and rule/group conformity (preference for structure when problem solving) (Kirton, 2003). Critical thinking disposition was measured using the University of Florida Engagement, Maturity, and Innovativeness test (UF-EMI). The UF-EMI measures three constructs of critical thinking which are "engagement–anticipating situations to use critical-thinking skills, maturity–being aware of own values an biases, and innovativeness–being intellectually curious to find truth (Friedel et al., 2008). The researchers operationalized problem solving level as the final grade in an undergraduate agriscience course. No relationships were found between critical thinking skill and total cognitive style or critical thinking disposition. Critical thinking disposition, however, showed a moderate and positive relationship with one construct of cognitive style, sufficiency of originality. Additionally, critical thinking disposition was negatively related to the cognitive style construct of efficiency. Critical thinking disposition showed no relationship to problem solving level. Finally, cognitive style was not related to problem solving level (Friedel et al., 2008).

Lamm et al. (2011) investigated the relationships between critical thinking disposition, problem solving (cognitive) style, and learning styles of University of Florida undergraduates who participated in a study abroad program in the Fall Semester of 2009. The UF-EMI, KAI, and Kolb's (1984) Learning Styles Inventory (LSI) were utilized to measure critical thinking disposition, cognitive style, and learning styles, respectively. No relationship was found between cognitive style and learning styles of the students. A low, positive relationship was found between cognitive style and critical thinking disposition. No relationship was found between overall critical thinking disposition and overall learning styles; however, a relationship between the LSI construct of active experimentation and critical thinking existed (Lamm et al., 2011).

Using Kirton's (2003) Adaption-Innovation theory and Bransford's (1984) IDEAL problem solving model as a frame, Lamm et al. (2012) investigated how cognitive style influenced group problem solving of students who attended a study abroad course in Costa Rica. The IDEAL problem solving model is a sequential method of problem solving comprised of five stages: Identify, Develop, Explore, Anticipate, and Look. Focus groups were conducted with a homogenous, adaptor group; a homogeneous, innovator group; and a heterogeneous group consisting of both adaptors and innovators. Group sessions were recorded, transcribed, and coded. Coded data were then compared to Bransford's (1984) IDEAL problem solving model.

The homogeneous, innovator group progressed through all stages of the IDEAL problem solving model. This group excelled in identifying the problem and looking back (reflection) portions of the IDEAL model. The innovators were weakest in developing understanding and anticipating before implementing action.

The homogeneous, adaptor group did not progress through all stages of the IDEAL model, and spent most of their time in the anticipating before acting stage. This group was unable to solve the problem at a high level because of the focus on one stage and "never created a high quality product, and was embarrassed by their results" (Lamm et al., 2012, p. 27).

Like the homogeneous, innovator group, the heterogeneous group was able to progress through all stages of the IDEAL model, but not in a linear fashion (Lamm et al., 2012). This group combined the stages by reflecting throughout the IDEAL process. This group worked together during the entire process of problem solving, from identifying the problem, through anticipating what others would think, to creating a solution. The group members revealed that their process was not how they would prefer to work typically. Lamm et al. (2012) reported this as an attribute of adaptors and innovators working together and achieving balance.

Problem Solving and Troubleshooting in Agricultural Mechanics

One of the conceptual goals of laboratory instruction in agricultural education is developing students' problem solving abilities (Phipps et al., 2008). Previous research on problem solving in agricultural mechanics has focused on mathematics problem solving during the FFA Career Development Event (CDE) for agricultural mechanics and metacognition during troubleshooting tasks. Buriak, Harper, and Gliem (1986) analyzed data from the National FFA Agricultural Mechanics CDE from 1979 to 1984. At the time, the CDE was divided into five categories consisting of written examination, problem solving, construction and maintenance skills, power and machinery skills, and electric power and processing skills. The researchers reported aggregated scores for each area of the CDE and found that problem solving had the second highest mean score. Problem solving also showed the highest unique contribution to total score when simultaneous regression techniques were employed (Buriak et al., 1986).

In similar studies, Johnson (1991) and Johnson (1993) investigated student achievement factors during agricultural mechanics CDEs in Mississippi. Johnson (1991) reported that mathematical problem solving was "especially low" (p. 27). Similarly, a three-year trend of scores at the FFA agricultural mechanics CDE in Mississippi revealed the area of problem solving was the lowest score category when data were aggregated (Johnson, 1993). Franklin and Miller (2005) conducted an ex post-facto study of the 2004 agricultural mechanics CDE in Arizona and also found students scored lowest on the problem solving portion of the event. Specifically, contestants in Arizona scored below 50 percent on two out of three problem solving activities, agricultural power and machinery and agricultural energy systems. The third problem solving area was structural systems, and students' average score was 52 percent (Franklin & Miller, 2005).

In an evaluation study, Wells and Parr (2011) sought to determine what mathematical competencies existed within the agricultural mechanics CDE in Alabama. The researchers evaluated scores from 2008 to 2010 and determined the CDE was conducive to mathematics integration. Specifically, four out of five contest activities were reported to represent state mathematics competencies related to problem solving (Wells & Parr, 2005).

Pate, Wardlow, and Johnson (2004) conducted an experimental study to investigate troubleshooting performance of undergraduate students at the University of Arkansas when utilizing the think-aloud pair problem solving (TAPPS) technique. TAPPS is designed to increase student metacognition by requiring the problem solver to verbalize his or her thought process as a listener (Lochhead, 1987). Pate et al. (2004) utilized small gasoline engines as the context for the problem. Each engine was set, purposefully, with an identical fault in the electrical system. In the control group, individual students were assigned a faulty engine and instructed to identify the problem, then repair and test run the engine. In the experimental group, students were assigned an engine with an electrical system fault and a member of the control group served as the listener. The dyad's task was to identify and repair the fault, then run the engine to test if the repair was correct. Time to complete the task was the dependent variable measured for both groups. All students were pre-tested to determine if any statistically significant differences regarding content knowledge existed between the groups. No statistically significant differences were found. A second round of troubleshooting was then completed with students reversing roles from control group to experimental group. During this second round of troubleshooting, students were assigned an engine with a fault in the air/fuel delivery system. Students in the experimental group who utilized the TAPPS technique to troubleshoot were more successful than those in the control group in both rounds of the study. There were, however, no statistically significant differences in the time to complete the task between the groups (Pate et al., 2004).

Pate and Miller (2011a) conducted an experimental study to determine the effects of TAPPS on secondary students enrolled in either agricultural education or industrial education courses focused on small gasoline engine technology. Students were provided instruction in the major engine systems required for operation, as well as techniques of troubleshooting. The experimental group consisted of a problem solver instructed to verbalize the process of troubleshooting and a listener instructed only to ask questions. The control group was assigned an engine to troubleshoot individually. Both groups received an engine with an identical fault in the compression system. Time to identify the fault was the dependent variable measured. There were no statistically significant differences found in problem solving success of students who utilized the TAPPS technique and those who worked independently. Although there was no statistically significant difference in time to complete the task between the groups, students who utilized TAPPS needed four additional minutes (Pate & Miller, 2011a).

Further, Pate and Miller (2011b) conducted an interpretive analysis of audio recording of students who utilized the TAPPS technique. The overall purpose of this study was to compare the metacognitive statements of students who solved a compression related small gasoline engine problem successfully, using TAPPS, with those who were unsuccessful. The recordings were transcribed, and analyzed for metacognitive level of the statements. Working/short-term memory statements were coded level one, nonverbal, sensory information statements were coded level two, and "metacognitive statements involving planning, monitoring, and evaluating" were coded level three(Pate & Miller, 2011b, p. 110).

Within each code, levels were differentiated by whether the statement was positive or negative. The researchers concluded the only difference in statement level of successful and unsuccessful students was with "level three negative self-assessment and level three negative problem assessment" (p. 116). Those students who completed the problem successfully did not express negative level three statements. In fact, unsuccessful students stated nearly twice the amount of total negative statements compared to those who completed the problem successfully. After analysis of the audio transcriptions, the researchers concluded that the TAPPS technique was inappropriate for use with secondary students because of their lack of domain specific knowledge (Pate & Miller, 2011b).

Pate and Miller (2011c) conducted a study to determine if regulatory self-questioning would improve the problem solving ability of secondary career and technical education students. Regulatory self-questioning was assessed with a checklist of questions students answered as they solved electrical problems. Regulatory self-questioning was deemed as the method of improving students' metacognitive abilities. Iowa students enrolled in industrial and agricultural education courses with a focus on electrical concepts were assigned to a treatment or control group randomly. All students received instruction in electricity, specifically in the area of Ohm's Law. Both groups were assigned identical electrical problems based on Ohm's Law. After receiving instruction, the control group was given a demonstration on using Ohm's Law, completed a worksheet of example problems, and then solved two circuit problems independently. In contrast, the experimental group received instruction on how to use the regulatory checklist to regulate their thinking. Next, the experimental group was taught Ohm's Law and were allowed to practice on a problem-solving worksheet. Finally, the experimental group was given the task of solving the same two circuit problems as the control group. After completing the practice problems, students from both groups were administered a test to measure their performance. On average, students who performed regulatory self-questioning scored 10 percentage points higher than their counterparts in the control group (Pate & Miller, 2011c).

Theoretical Framework

The theoretical framework employed in this study is the cognitive information processing theory (CIPT). CIPT postulates that learners are not passive absorbers of knowledge, but rather active seekers of knowledge and information (Schunk, 2008). A common metaphor used to describe CIPT is the personal computer. Like the computer, humans receive information, which is stored in their memory, and retrieved whenever needed (Schunk, 2008). There are, however, differing views of how accurate the computer metaphor represents human learning.

Mayer (1996) differentiated between two views of information processing. These views are literal and constructivist. The literal interpretation of the CIPT views a "cognitive process as a discrete procedure in which information is input, operators are applied to the input information resulting in the creation of new information and the new information is output" (Mayer, 1996, p. 156). In this view, the computer is analogous to human learning, and some researchers utilize the computer to simulate human learning (Schunk, 2008). Mental representations, or memory, are simply pieces of information for the brain to code and store for later use (Mayer, 1996). Cognitive processes are simply a "mental computation" (Mayer, 1996, p. 156).

The constructivist interpretation of the CIPT, however, regards memory as knowledge instead of bits of information (Mayer, 1996), in which the computer is nothing more than a metaphor (Schunk, 2008). In this view, learners search actively for knowledge and understanding. "Three basic processes in active learning are selecting relevant incoming experiences, organizing them into coherent representation, and integrating them with existing knowledge" (Mayer, 1996, p.156). Cognitive processes are not simply mental computations, but rather a "coordinated collection of processes aimed at making sense of incoming experiences" (Mayer, 1996, p. 156).

One of the most important aspects of CIPT is the cognitive process of problem solving (Schunk, 2008). In fact, instructional designs associated with CIPT are often centered on solving structured problems (Jonassen & Land, 2000). Although problem solving and learning are not always synonymous, Schunk (2008) stated that problem solving is a key process in learning. A problem can be described as finding a means to achieve a goal (Chi & Glaser, 1985). All problems, regardless of context or complexity, have common attributes (Schunk, 2008). All problems have an initial state, which involves the condition of the problem itself, as well as the problem solvers' current knowledge of the problem (Chi & Glaser, 1985; Schunk, 2008). Problems also have a goal which, typically, is broken into sub-goals that, when mastered, lead to the goal being achieved (Schunk, 2008). Problems also require operations to be performed on the initial state and sub-goals to reach the end goal (Chi & Glaser, 1985; Schunk, 2008). Finally, there are constraints, or rules about allowable operations that problem solvers must abide by when solving problems (Chi & Glaser, 1985). For example, chess has often served as a context for solving problems; a basic constraint in chess is the acceptable movements for each game piece (Chi & Glaser, 1985).

Conceptual Framework

Conceptually, this study was underpinned by Kirton's (1976; 2003) Adaption-Innovation (A-I) theory. The foundation of the A-I theory is that all people are creative and solve problems; however, the focus of A-I theory is the various preferences for which people solve problems (Kirton, 2003). Specifically, A-I theory is concerned with "individual differences in the way humans solve problems" (Kirton, 2003, p. 1). These individual differences are known as cognitive style (Kirton, 2003).

Cognitive style is a "strategic, stable characteristic – the preferred way in which people respond to and seek to bring about change" (p. 43). The A-I theory assumes that cognitive style remains stable regardless of age or experience. In other words, individuals will always have a preferred approach to solving problems (Kirton, 2003).

The term *preferred* is used purposefully to indicate a difference between cognitive style and the behavior of solving a problem. Cognitive style thereby influences the behavior of the problem solver. There is also a sharp distinction between cognitive style and cognitive capacity. Cognitive capacity is divided into two components, which are potential capacity and learned levels. Potential capacity includes characteristics such as intelligence or talent, while learned levels can include any learned skill or competency (Kirton, 2003).

The preferences for which people solve problems are located along a normally distributed continuum, ranging from highly adaptive to highly innovative (Kirton, 2003). Kirton (2003) utilized terms “more adaptive” and “more innovative” (p. 47) to indicate this continuum and stress the idea that people are not strictly adaptive or innovative. There are, however, common characteristics of individuals that are more adaptive and more innovative.

The more adaptive people prefer problems that are more structured and tend to work in the boundaries of the current paradigm (Kirton, 2003; Kirton, Bailey, & Glendinning, 1991). The more adaptive people prefer technical solutions (Lamm et al., 2012) and tend to have the mindset of “doing things better” (Kirton, 1994, p. 9). The more adaptive “produce a sufficiency of original ideas and concentrate on increasing efficiency and conforming to established organizational rules and authority” (Kirton & Pender, 1982, p. 883).

On the opposite end of the continuum, innovators prefer problems that are less structured and they tend to become frustrated by boundaries (Kirton et al., 1991). The more innovative are less concerned with technical solutions (Lamm et al., 2012); rather, they tend to focus on novel ideas and "doing things differently" (Kirton, 1994, p. 9). The more innovative "proliferate ideas, try to implement them despite organizational resistance and are more concerned with the 'broad sweep' of tasks than with day-to-day precision" (Kirton & Pender, 1982, p. 883).

Kirton (2003) described three constructs captured within overall cognitive style. These three are Sufficiency of Originality (SO), Efficiency (E), and Rule/Group Conformity (RG). These subgroups were obtained through a factor analysis, and each construct possessed an internal reliability of roughly .80. SO deals with an individual's preference in forming solutions to a problem. The more adaptive prefer fewer ideas that they view as practical, sound, and appropriate to the situation, while the more innovative proliferate ideas, often bucking the norm to shift the current paradigm.

E is equal to the preferred method of solving problems to which adaptors and innovators align themselves with naturally. The innovative will push, or even break, boundaries when solving problems, while the more adaptive prefer to work within boundaries. Within organizations, the more adaptive problem solver's ideas are usually more accepted (Kirton, 2003).

The final construct, RG, has to do with individuals' preference relating to structure, also known as conformity. Kirton (2003) differentiated between two types of conformity to structure, formal/impersonal rule and personal/informal group. The more adaptive tend to provide cohesiveness when working in a group by generating acceptable ideas within the group structure. The more innovative tend to bring up ideas outside the box that challenge or shake up the group, which is sometimes needed (Kirton, 2003).

Summary

Problem solving is an important outcome of the learning process that people utilize everyday (Jonassen, 2000). Problem solving has been identified consistently as a highly important skilled needed for entry-level employment in the agricultural industry (Alston et al., 2009; Graham, 2001; Robinson & Garton, 2008; Robinson et al., 2007). Specifically, potential employers want employees that are creative, inventive, and can think on their feet to solve problems at the workplace (MacPherson, 1998; Robinson & Garton, 2008; Robinson, Garton, & Vaughn, 2007, Robinson, 2010). These are reasons that agricultural education has embraced problem solving as both a teaching approach and as a programmatic outcome (Parr & Edwards, 2004; Phipps et al., 2008).

A number of factors that influence people's ability to solve problems have been identified. Commonly, researchers have discussed the role of knowledge in the problem solving process (Chi, Feltovich, & Glaser, 1981; Glaser; 1984; Hegarty, 1991; Jonassen, 2000; Larkin et al., 1980; McCormick, 1997; Nickerson, 1994; Simon, 1979; Schunk, 2008; Zimmerman & Campillo, 2003). Specifically, researchers have investigated general and domain-specific knowledge (Glaser, 1984; Hegarty, 1991; Nickerson, 1994; Jonassen, 2000; Simon, 1979), conceptual and procedural knowledge (McCormick, 1997), and knowledge organization (Larkin et al., 1980). Often, knowledge differences between expert and novice problem solvers have been examined (Chi et al., 1981;

Knowledge of the problem solver appears to influence how individuals work through problem space to develop mental models (Jonassen, 2000; Newell & Simon 1972). Problem space is comprised of conceptual knowledge, functional knowledge and declarative knowledge and is responsible for the mental models that problem solvers are able to create (Jonassen, 2000). The ability to navigate problem space affects the ability of individuals to solve problems of a mechanical nature (Gitomer, 1988; Johnson, 1988).

Related specifically to troubleshooting, Johnson (1988; 1989) examined the hypothesizing ability of expert and novice troubleshooters. In general, experts were not only more accurate in identifying system faults; they were also more efficient in terms of time required. It was concluded that the greatest differences between expert and novice troubleshooters was the quality of information gathered and hypotheses generated.

Other variables researchers have investigated in relation to troubleshooting are cognitive styles and learning styles (Sternberg & Grigorenko, 1997). Learning styles are the manner in which people prefer to learn (Sternberg & Grigorenko, 1997) and cognitive style is the manner in which individuals prefer to solve problems (Kirton, 2003). Research is inconclusive as to what role cognitive styles play in the problem solve process. Kirton (2003) states that everyone can solve problems, only preference for how to go about solving problems differs. Similarly, MacPherson (1998) reported no differences in troubleshooting ability based on cognitive styles as measured by the GEFT or PSI-Tech. Dyer (1996b) reported that regardless of learning style, agriculture students can solve problems if they are taught via the problem solving approach. Using the KAI, Friedel et al., 2008 concluded that cognitive style was not related to problem solving performance. However, other researchers have found that reflective troubleshooters commit fewer errors (Rouse & Rouse, 1982) and that cognitive style is a good predictor of problem solving performance (Henneman & Rouse, 1984). Lamm et al. (2012) utilized the KAI to determine how students solved problems in groups and found that heterogeneous of more adaptive and more innovative students worked through all parts of the IDEAL problem solving model.

CHAPTER III

METHODOLOGY

Introduction

Chapter III provides a description of the methodological approach employed by this research study and an explanation of data collection procedures. This chapter is comprised of: the purpose of the study, a description of the Institutional Review Board requirements, participant recruitment, a description of the professional development workshop provided to the teacher participants, research design, treatment description, an overview of the threats to internal validity, instrumentation, fidelity of the treatment, research procedures, and data analysis. The chapter concludes with a description of how effect size was reported and interpreted.

Purpose of the Study

The purpose of this study was to assess the effect of cognitive style, hypothesis generation, and problem complexity on the problem solving ability of school-based agricultural education students enrolled in agricultural mechanics courses. The following research questions guided the study:

1. What are the personal and educational characteristics of students enrolled in APT courses in Oklahoma?

2. What differences exist in content knowledge based on cognitive styles and hypothesis generation?
3. What effect does problem complexity have on the amount of time required to solve problems correctly?
4. What effect does students' cognitive style have on the time required to solve problems correctly?
5. What effect does students' hypothesis generation have on the time required to solve problems correctly?
6. What interactions exist between problem complexity, hypothesis generation, and students' cognitive styles on the amount of time required to solve problems correctly?
7. What interactions exist between students' problem complexity and hypothesis generation on the amount of time required to solve problems correctly?
8. What interactions exist between students' hypothesis generation and cognitive style on the amount of time required to solve problems correctly?
9. What interactions exist between students' problem complexity and cognitive style on the amount of time required to solve problems correctly?

The following null hypotheses guided the statistical analyses of the study:

$H_0$1: In the population, there is no statistically significant difference in content knowledge due to cognitive styles ($\mu_{1\ \text{More Adaptive}} = \mu_{2\ \text{More Innovative}}$).

$H_0$2: In the population, there is no statistically significant difference in the time required to solve problems correctly based on problem complexity ($\mu_{1\ \text{Simple}} = \mu_{2\ \text{Complex}}$).

$H_0$3: In the population, there is no statistically significant difference in the time required to solve problems correctly based on cognitive styles ($\mu_{1\text{ More Adaptive}} = \mu_{2\text{ More Innovative}}$).

$H_0$4: In the population, there is no statistically significant difference in the time required to solve problems correctly based on hypothesis generation ($\mu_{1\text{ Correct Hypothesis}} = \mu_{2\text{ Incorrect Hypothesis}}$).

$H_0$5: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity, hypothesis generation, and cognitive styles ($\mu_{1\text{More Adaptive x Simple x Correct Hypothesis}} - \mu_{2\text{More Adaptive x Simple x Incorrect Hypothesis}} - \mu_{3\text{ More Adaptive x Complex x Correct Hypothesis}} - \mu_{4\text{ More Adaptive x Complex x Incorrect Hypothesis}} - \mu_{5\text{ More Innovative x Simple x Correct Hypothesis}} - \mu_{6\text{ More Innovative x Simple x Incorrect Hypothesis}} - \mu_{7\text{ More Innovative x Complex x Correct Hypothesis}} - \mu_{8\text{ More Innovative x Complex x Incorrect Hypothesis}} = 0$).

$H_0$6: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and cognitive styles ($\mu_{1\text{Simple x More Adaptive}} - \mu_{2\text{ Complex x More Adaptive}} - \mu_{3\text{ Simple x More Innovative}} - \mu_{4\text{ Complex x More Innovative}} = 0$).

$H_0$7: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of cognitive styles and hypothesis generation ($\mu_{1\text{More Adaptive x Correct Hypothesis}} - \mu_{2\text{ More Adaptive x Incorrect Hypothesis}} - \mu_{3\text{ More Innovative x Correct Hypothesis}} - \mu_{4\text{ More Innovative x Incorrect Hypothesis}} = 0$).

$H_0$8: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and hypothesis generation ($\mu_{1 \text{Simple x Correct Hypothesis}} - \mu_{2 \text{ Simple x Incorrect Hypothesis}} - \mu_{3 \text{ Complex x Correct Hypothesis}} - \mu_{4 \text{ Complex x Incorrect Hypothesis}} = 0$).

Institutional Review Board

To comply with federal regulations, all studies involving human subjects must be reviewed and approved by the institution's compliance board. As such, an application was submitted to the Institutional Review Board (IRB) at Oklahoma State University Office of University Research. This application included all documentation required of the research proposal. All requirements of safe and humane treatment of human subjects were met, and the IRB approval needed to conduct the study was (see Appendix A).

Participant Recruitment

All agriculture teachers in Oklahoma were afforded the opportunity to enroll in a two-day small gasoline engine professional development workshop in June 2012 on the campus of Oklahoma State University. A total of 21 teachers attended the workshop. Seven teachers agreed to participate in the study by signing the instructor consent form (see Appendix B). Per IRB regulations, the teachers were also required to obtain permission from school administration to continue in the study (see Appendix C).

After the agriculture teacher recruitment was finalized, students enrolled in each of the seven teachers' Agricultural Power & Technology courses were asked to participate in the study. Following the guidelines set forth by IRB, students were asked to sign a consent form to indicate their willingness to participate in this study (see Appendix D). Additionally, parent/guarding consent was sought for students who were minors (see Appendix E). A total of 68 students agreed to participate in the study.

Professional Development

The professional development workshop on small gasoline engines was conducted June 12 and 13, 2012 on the campus of Oklahoma State University. A grant proposal was written and submitted to Briggs & Stratton® requesting a donation of small gasoline engines. In all, Briggs & Stratton® donated 277 engines valued at over $105,000 for the workshop. Most (246) of the engines were an L-head style engine used commonly to power walk behind lawn mowers. The remaining 31 engines were larger, overhead valve (OHV) engines used commonly to power go-karts. Additional funding in the amount of $3000 was provided by the Oklahoma Department of Career and Technology Education (CareerTech) with a portion ($2,750) of these funds devoted to pay Robert Ortolani, a content expert, to teach the workshop content. At the time of the training, Mr. Ortolani served as the manager for corporate education for Magneto Power, LLC, a distributor of Briggs & Stratton® engines. In addition to providing workshops for career and technical educators, Mr. Ortolani trains new engine technicians for Briggs & Stratton®.

During the first day of the professional development workshop, Mr. Ortolani presented information about the Briggs & Stratton® PowerPortal where teachers located engine information, curriculum, and engine parts online (see Appendix F). Additionally, the teachers were shown how to access materials useful for teaching students, including videos and competency examinations. The teachers were also taught fuel and oil systems and allowed to disassemble and reassemble common carburetors found on Briggs & Stratton® engines.

The second day included information about common electrical systems found in Briggs & Stratton® engines with the teachers receiving the opportunity to dissect various electrical components. Once completed, the teachers were able to practice disassembling an engine to identify and observe internal components of the engine. They then reassembled the engine as Mr. Ortolani described methods of re-calibrating the engine to ensure it would operate correctly. At the conclusion of the workshop, all 21 teachers were given nine L-head engines and one OHV engine to use as teaching aids in their respective schools. In all, 15 hours of professional development were devoted to teachers training over the two-day workshop.

A portion of the remaining funds from CareerTech were used to purchase USB flash drives to provide curriculum to the participating teachers. In addition to engines, the teachers also received ready-made curriculum to teach. The curriculum provided was created by the researcher and based on similar curriculum used in MCAG 3211, the small gasoline engines course at OSU, and information available from Briggs & Stratton®. The curriculum included lesson plans and visual aids relevant to teaching students small gasoline engine content. The OSU Department of Agricultural Education, Communications and Leadership covered the cost of Kirton's Adaption-Innovation (KAI) instrument. Each KAI cost $5.00 to administer. The total cost of the two-day workshop was $3,290.

Research Design

This research study employed a Completely Randomized Factorial 2x2 (CRF-22) designs (Kirk, 1995). CRF designs are appropriate when researchers desire to test the effects of two independent variables, as well as, their combined effects (Ary, Jacobs, &

Razavieh, 2002). According to Kirk (1995) the following assumptions regarding CRF designs must be met:

1. Two or more treatments, with each treatment having two or more levels.
2. All levels of each treatment investigated in combination with all levels of every other treatment. If there are *p* levels of one treatment and *q* levels of a second treatment, the experiment contains *p* x *q* treatment combinations.
3. Random assignment of experimental units to treatment combinations. Each experimental unit must be assigned to only one combination. (p. 365)

The researcher made two site visits to each participating school. The first site visit occurred between October 15, 2012 and February 28, 2013. During this visit, students were administered the personal characteristics questionnaire and Kirton's Adaption-Innovation Inventory (KAI) to determine cognitive style (see Appendices G and H). Students were classified as either *more adaptive* or *more innovative*, based on KAI scores (Kirton, 2003). Students were assigned randomly either a simple or complex engine problem to solve. Additionally, students were asked to develop a hypothesis based on a written scenario that described symptoms the engine would exhibit if starting procedures had been employed.

Dependent variables of this study included problem solving ability and time to solution. Problem solving ability was defined as whether or not the students were able to identify the faulty. Time to solution was operationalized as how many minutes each student required to identify the fault in his or her assigned engine. Time was measured from a designated start time to when each student indicated he or she had identified the problem. Small gasoline engines content knowledge was measured with a 30-item criterion-referenced test, developed by the researcher (see Appendix I).

Treatment

The treatment, or intervention, of this study consisted of small gasoline engines with one of two known faults in which students were required to identify. For safety and time considerations, students were instructed not to attempt to start the engine. Instead, they were given a scenario describing the symptoms the engine would exhibit if they had attempted to start it (see Appendices J and K). The faults were classified as either *simple* or *complex*. The simple fault was within the ignition system of the engine – in particular, a closed spark plug gap. The complex fault was within the fuel delivery system. Specifically, debris was placed in the main jet of the carburetor.

The participating teachers were recruited from a professional development workshop held in June 2012 on small gasoline engines. Upon completion of the workshop, they were provided with engines to use in their respective programs. The engines utilized for the treatment were of the same make and model the teachers received at the professional development and utilized to teach their students. Students at each school were assigned randomly, by cognitive style, an engine with a simple or complex fault. This ensured that all treatment groups were approximately equal in size (see Figure 4).

		Problem Complexity	
		Simple (One)	Complex (Two)
Cognitive Style Group	More Adaptive	Treatment Group A *n* = 19	Treatment Group B *n* = 12
	More Innovative	Treatment Group C *n* = 22	Treatment Group D *n* = 15

Figure 4. The results of random assignment of participants who completed all parts of the study fully into a completely randomized factorial (CRF) 2x2 design.

Threats to Internal Validity

Validity of research findings is achieved when data interpretation "matches its proposed use" (Creswell, 2012, p. 159). One of the greatest concerns of researchers who design and conduct experimental research is controlling threats to internal validity (Gay, Mills, & Airasian, 2009). The eight threats to internal validity that should be controlled are: (a) history, (b) maturation, (c) testing, (d) instrumentation, (e) statistical regression, (f) selection, (g) experimental mortality, and (h) selection-maturation interaction (Campbell & Stanley, 1963).

History, as a threat to internal validity, includes events that occur between the beginning and end of the experiment that could possibly influence outcomes (Creswell, 2012). Maturation is changes individuals may experience during the experimental process. Testing, as a threat to internal validity, is associated most commonly with pretest–posttest designs when participants' posttest scores are affected by completing a pretest (Campbell & Stanley, 1963). Statistical regression is an issue when participants are recruited based on extreme scores. Extreme scores tend to regress toward the mean when individuals are retested (Creswell, 2012). Selection of participants can be a threat to internal validity because of *people factors* such as choosing people who are more intelligent or if the research utilizes volunteers (Creswell, 2012). Experimental mortality is losing participants during the course of the experiment (Campbell & Stanley, 1963). Selection-maturation interaction is when factors related to the selection of subjects interact with time (Creswell, 2012). Controlling for these eight threats to internal validity is achieved by random assignment to treatment groups (Gay et al., 2009). In fact, Campbell and Stanley (1963) described random assignment as "the all purpose procedure for achieving pretreatment equality for groups" (p. 6). Specifically regarding the current study, seven of the eight threats to internal validity were either not applicable or were controlled assigning participants to experimental groups randomly. Experimental mortality, however, did impact this study. The entire sample of this study was 77 students from the seven schools; however, only 68 completed all parts of this research study fully.

Instrumentation

Content Knowledge

To determine students' knowledge in small gasoline engine content, the teacher participants tested their students with a 30-item criterion-referenced test developed by the researcher. Test items were based on the curriculum in MCAG 3211, the engines and power course at OSU, as well as information available on the Briggs & Stratton ® PowerPortal website. The format chosen for this criterion-referenced test was multiple-choice. Each test item was comprised of one correct answer and three distracter options.

The criterion-referenced test was evaluated for face and content validity by a panel of experts, consisting of three OSU agricultural education faculty members and one faculty member in Biosystems and Agricultural Engineering (BAE). At the time of the study, the BAE faculty member instructed the undergraduate small gasoline engines course at OSU and was in his 18th year as the instructor of record for that course. The panel of experts reviewed the instrument for semantics, ease of reading, content, and general construction of questions. All recommended changes to the instrument were made prior to administering it to students.

The eight guidelines described by Wiersma and Jurs (1990) to ensure reliability of criterion-referenced tests were followed. Table 1 lists the eight factors as well as the researcher's attempts to address each.

Table 1

Examples of how the Eight Factors, Identified by Wiersma and Jurs (1990), Necessary for Establishing Reliability of Criterion-referenced Tests, were Addressed

Factor	How Factors were Addressed
1. Homogeneous items	Items included in the instrument were of the same font size and style to ensure consistency.
2. Discriminating items	Items of varying difficulty were included within the test.
3. Quantity of items should	The test included 30 multiple-choice items
4. High quality test	Attention was paid to the formatting of the test, as verified by the panel of experts. The test was copied on a laser printer.

(*Table 1 continues*)

(*Table 1 continued*)

Factor	How Factors were Addressed
5. Clear directions	Directions were read aloud and were also printed at the top of the tests provided to students.
6. Controlled environment	The test was administered by the students' respective teacher in their normal classroom setting.
7. Participant motivation	Students were informed by their respective teacher if she or he was opting to use the test as a part of the course grade.
8. Scorer directions	An answer key was developed to ensure the questions were assessed accurately.

There is much debate in the literature regarding the use of internal reliability estimates, such as Cronbach's Alpha or Kuder-Richardson's 20, for criterion-referenced tests. Popham and Husek (1969) argued that because criterion-referenced tests compare individuals to specified criteria, internal reliability estimates are inappropriate. In their view, internal reliability estimates should be employed only when instruments compare individuals to other individuals.

Other researchers, however, have argued that internal consistency is an extremely important issue for criterion-related tests. Kane (1986) argued that criterion-referenced tests with internal reliability greater than $\alpha = 0.50$ would reflect students' collective mean scores accurately. Due to this debate in the literature, the Kuder-Richardson (KR-20) formula was calculated to determine reliability of the instrument.

A total of 33 undergraduate students enrolled in MCAG 3211, Engines and Power, a course offered at OSU, were utilized to pilot test the instruments utilized in this study. Students were administered this instrument after completing the engines and power course. Results from the pilot study yielded a reliability coefficient of 0.74. Additionally, a post-hoc KR-20 was employed to calculate reliability coefficient resulting in a 0.80 for the instrument after it was administered to the secondary students who served as the sample for the current study. Therefore, the instrument was deemed reliable.

Cognitive Style

Kirton's Adaption-Innovation Inventory (KAI) was used to determine students' cognitive style (Kirton, 1976). The KAI consisted of 32 items and scores range from 32 to 160, with a theoretical mean of 96 (Kirton, 2003). The KAI requires participants to compare themselves to each item (Kirton, 2003). However, Kirton (2003) reported that after analyzing research from 10 countries with a total sample of nearly 3,000 individuals the effective range was 40–150, with a mean that "hovers around 95 (+/- 0.5) with a standard deviation around 17 for all samples" (p. 67). According to the theory, scores of 95 and below are considered more adaptive, while scores 96 and higher are considered more innovative (Kirton, 2003). In each of the research studies examined, the internal reliability coefficients ranged from 0.84 to 0.89 (Kirton, 2003). The KAI has been utilized successfully to determine cognitive styles of a wide variety of populations, including teenagers (Kirton, 2003).

Problem Solving Ability

Problem solving ability was operationalized as whether or not students were able to identify an engine fault accurately. Additionally, each student was timed as to how long it took them to solve the problem accurately. Students were assigned randomly either a *simple* or *complex* engine problem to solve. The students were provided a problem scenario that informed them of the symptoms the engine would exhibit if they had attempted to start it.

Fidelity of the Treatment

To ensure fidelity of the treatment, teacher participants were provided resources to teach small gasoline engines content. Teachers were asked to teach 4-cycle theory, fuel systems and carburetors, electrical systems, and compression using the curriculum provided. The teachers delivered the small gasoline unit of instruction between the first and second site visit by the researcher. Teachers provided the lesson worksheets to the researcher as evidence that each lesson was taught. Additionally, each teacher was provided nine small gasoline engines to use as teaching aids. Treatment engines were also of this model to ensure students were familiar with the particular design.

Procedures

Participating teachers were provided curriculum to instruct their respective students. The curriculum focused on L-head type engines and was comprised of units on 4-cycle engine theory, fuel and oil systems, compression systems, electrical and charging systems, and governor systems. Each lesson contained a troubleshooting objective that informed the students about potential faults associated with system, as well as symptoms each fault would exhibit. Additionally, Briggs & Stratton ® PowerPortal training modules were embedded within each PowerPoint® presentation provided to the teachers. The modules utilized were fuel systems, compression, ignition systems, carburetion diagnostics, compression diagnostics, and troubleshooting ignition systems.

Between October 15, 2012 and March 15, 2013 the researcher traveled to each participating school to administer the KAI and student personal characteristics questionnaire. The completed KAIs were scored to determine students' cognitive style. Students with scores below the mean were categorized as *more adaptive* and students with scores greater than the mean were classified as *more innovative* (Kirton, 2003).

Approximately two weeks after the initial tests, and receiving notification from the teachers that the curriculum had been taught, the researcher traveled to participating schools to administer the treatment. Prior to arrival at each site, students were assigned randomly to solve either a simple or complex problem in an engine. Students were provided a hardcopy problem scenario that matched their engine. Each scenario was written as if the student had attempted to start the engine but it failed to operate properly. The scenario also contained information that described the symptoms the engine would exhibit. Once students read the scenario, they were directed to develop a written hypothesis of what they believed to be the problem. After all students had written their hypothesis, they were taken to their engine to begin the problem solving activity. The researcher was present at each participating school to read directions to students and designate a common start time for the troubleshooting activity. After students solved the problem, they were instructed to write the clock time at which they finished. Additionally, they were instructed to record their solution to the problem on the scenario sheet. Each student's answer was checked and those who were correct were allowed to go back into the classroom to ensure they did not disturb those still working. If the students were incorrect, they were directed to continue working.

Data Analysis

Data were coded for computer analysis in IBM SPSS Statistics® version 20 for Windows. Research question one asked, “What are the personal and educational characteristics of students enrolled in APT courses in Oklahoma?” Descriptive statistics such as, mean, frequency, and percentage, were utilized to summarize the personal characteristics of students involved in the study.

Research Question Two asked what differences in students’ content knowledge existed based cognitive style and hypothesis generation. A two-way independent analysis of variance (ANOVA) was calculated to determine if a statistically significant difference in content knowledge existed based on cognitive style and hypothesis generation. Additionally, partial eta squared (η^2) was computed to determine effect size for data concerning this research question.

Research Questions Three, Four, and Five asked how problem complexity, cognitive style and hypothesis generation, respectively, effected time to solve problems correctly. A three-way, independent analysis of variance (ANOVA) was computed to determine main effects of each independent variable (Field, 2009). The three-way independent ANOVA allowed for testing of three independent variables on one dependent variable (Field, 2009).

Research Questions Six, Seven, Eight, and Nine asked what interaction effects existed between the independent variables and time to solve problems correctly. Specifically, research question six asked about the interaction of problem complexity, hypothesis generation, and cognitive styles. Research Question Seven asked about the interaction of hypothesis generation and problem complexity. Research Question Eight dealt with the interaction of hypothesis generation and cognitive style. Finally, research Question Nine asked what interactions existed between problem complexity and cognitive styles. The data addressing these research questions were analyzed using a three-way independent ANOVA. Interaction effects determined to be statistically significant were analyzed by employing a test of simple main effects to further interpret the interaction (Kirk, 1995).

Both statistical and practical significance were reported for this study. To determine statistical significance, an *a priori* alpha level of .05 was set. This alpha level was utilized to determine whether to reject the null hypotheses (Kirk, 1996). Effect size, specifically partial eta squared (η^2), was utilized to determine practical significance of this research study. Practical significance indicates whether the sample mean differences are “large enough to be useful in the real world” (Kirk, 1995, p. 64). Partial η^2 was interpreted using the guidelines described by Cohen (1988). These guidelines indicate that 0.0099 is a *small* effect size, 0.0826 is a *medium* effect size, and 0.20 is a *large* effect size. Cohen’s *d* statistic was calculated to determine practical significance of the simple main effects tests. Cohen’s *d* was interpreted through the following guidelines reported by Cohen (1988) where 0.20 is a *small* effect size, 0.50 is a medium effect size, and 0.80 is a large effect size.

CHAPTER IV

FINDINGS

Introduction

Chapter IV provides the results of the data collection in both narrative and tabular format. The chapter includes the purpose of the study and findings organized by research question.

Purpose of the Study

The purpose of this study was to assess the effect of cognitive style, hypothesis generation, and problem complexity on the problem solving ability of school-based agricultural education students enrolled in agricultural mechanics courses. The following research questions guided the study:

1. What are the personal and educational characteristics of students enrolled in APT courses in Oklahoma?
2. What differences exist in content knowledge based on cognitive styles and hypothesis generation?
3. What effect does problem complexity have on the amount of time required to solve problems correctly?

4. What effect does students' cognitive style have on the time required to solve problems correctly?
5. What effect does students' hypothesis generation have on the time required to solve problems correctly?
6. What interactions exist between problem complexity, hypothesis generation, and students' cognitive styles on the amount of time required to solve problems correctly?
7. What interactions exist between students' problem complexity and hypothesis generation on the amount of time required to solve problems correctly?
8. What interactions exist between students' hypothesis generation and cognitive style on the amount of time required to solve problems correctly?
9. What interactions exist between students' problem complexity and cognitive style on the amount of time required to solve problems correctly?

The following null hypotheses guided the statistical analyses of the study:

$H_0$1: In the population, there is no statistically significant difference in content knowledge due to cognitive styles ($\mu_{1\ \text{More Adaptive}} = \mu_{2\ \text{More Innovative}}$).

$H_0$2: In the population, there is no statistically significant difference in the time required to solve problems correctly based on problem complexity ($\mu_{1\ \text{Simple}} = \mu_{2\ \text{Complex}}$).

$H_0$3: In the population, there is no statistically significant difference in the time required to solve problems correctly based on cognitive styles ($\mu_{1\ \text{More Adaptive}} = \mu_{2\ \text{More Innovative}}$).

$H_0$4: In the population, there is no statistically significant difference in the time required to solve problems correctly based on hypothesis generation ($\mu_{1\ \text{Correct Hypothesis}} = \mu_{2\ \text{Incorrect Hypothesis}}$).

$H_0$5: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity, hypothesis generation, and cognitive styles ($\mu_{1\text{More Adaptive x Simple x Correct Hypothesis}} - \mu_{2\text{More Adaptive x Simple x Incorrect Hypothesis}} - \mu_{3\ \text{More Adaptive x Complex x Correct Hypothesis}} - \mu_{4\ \text{More Adaptive x Complex x Incorrect Hypothesis}} - \mu_{5\ \text{More Innovative x Simple x Correct Hypothesis}} - \mu_{6\ \text{More Innovative x Simple x Incorrect Hypothesis}} - \mu_{7\ \text{More Innovative x Complex x Correct Hypothesis}} - \mu_{8\ \text{More Innovative x Complex x Incorrect Hypothesis}} = 0$).

$H_0$6: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and cognitive styles ($\mu_{1\text{Simple x More Adaptive}} - \mu_{2\ \text{Complex x More Adaptive}} - \mu_{3\ \text{Simple x More Innovative}} - \mu_{4\ \text{Complex x More Innovative}} = 0$).

$H_0$7: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of cognitive styles and hypothesis generation ($\mu_{1\text{More Adaptive x Correct Hypothesis}} - \mu_{2\ \text{More Adaptive x Incorrect Hypothesis}} - \mu_{3\ \text{More Innovative x Correct Hypothesis}} - \mu_{4\ \text{More Innovative x Incorrect Hypothesis}} = 0$).

$H_0$8: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and hypothesis generation ($\mu_{1\text{Simple x Correct Hypothesis}} - \mu_{2\ \text{Simple x Incorrect Hypothesis}} - \mu_{3\ \text{Complex x Correct Hypothesis}} - \mu_{4\ \text{Complex x Incorrect Hypothesis}} = 0$).

Student Personal and Educational Characteristics

Research Question One asked how student characteristics, such as sex, age, academic classification, grade point average, number of agricultural education courses completed, number of agricultural mechanics courses completed, and ethnicity, affected the amount of time required to solve problems correctly. These students were enrolled in Agricultural Power & Technology at their respective high schools during the 2012–2013 academic year. A total of 77 students completed the student personal characteristics questionnaire; however, 68 students completed all parts of this study fully. As such, the personal characteristics of n = 68 students are reported. Measures of variability (i.e., frequency and percentage) were used to analyze the data.

In all, 59 (86.76%) students were male and nine were female (13.23%). Regarding age of the students, 17 (25.00%) were 15 years old, 19 (27.94%) were 16 years old, 14 (20.59%) indicated 17 as their age, 17 (25.00%) were 18 years of age, and one (1.47%) student indicated he or she was 19 years of age (see Table 2). Regarding academic classification, one (1.47%) student was a freshmen, 33 (48.53%) were sophomores, eight (11.76%) were juniors, and 26 (38.24%) were senior level students. Caucasian was the most frequently selected ethnicity with 59 (86.76%) students, eight (11.76%) self-selected Native American their ethnicity, and one (1.47%) indicated he or she was Hispanic.

Table 2

Selected Personal and Educational Characteristics of Oklahoma Secondary Students Enrolled in Agricultural Power & Technology (n = 68)

Variable		*f*	%
Sex			
	Male	59	86.76
	Female	9	13.23
Age			
	15	17	25.00
	16	19	27.94
	17	14	20.59
	18	17	25.00
	19	1	1.47
Academic Classification			
	Freshman – 9th Grade	1	1.47
	Sophomore – 10th Grade	33	48.53
	Junior – 11th Grade	8	11.76
	Senior – 12th Grade	26	38.24
Ethnicity			
	Caucasian	59	86.76
	Native American	8	11.76
	Hispanic	1	1.47

Students were asked to identify the number of agricultural education courses, including the current class, in which they had enrolled (see Table 3). The greatest number of students (*n* = 23; 33.82%) indicated they had completed two courses in agricultural education. The fewest students (*n* = 1; 1.47%) indicated they had completed seven courses.

Table 3

Number of Agricultural Education Courses in Which Students Had Enrolled (n = 68)

Number of Courses	*f*	%
1 Course	8	11.76
2 Courses	23	33.82
3 Courses	14	20.59
4 Courses	8	11.46
5 Courses	9	13.24
6 Courses	3	4.41
7 Courses	1	1.47
8 Courses	2	2.94

Note. Includes current school year.

Students were also asked to identify how many of their agricultural education courses had focused on agricultural mechanics. The greatest number (*n* = 48; 70.59%) of students indicated they had enrolled in one agricultural mechanics courses (see Table 4). The fewest number (*n* = 3; 4.41%) indicated they had enrolled in four agricultural mechanics courses.

Table 4

Number of Agricultural Mechanics Courses in Which Students Had Enrolled (n = 68)

Number of Courses	*f*	%
1 Course	48	70.59
2 Courses	12	17.65
3 Courses	5	7.35
4 Courses	3	4.41

Note. Includes current school year.

Students' cognitive style was measured using Kirton's (2003) Adaption-Innovation inventory (KAI). Table 5 lists the cognitive styles of the students who participated fully (*n* = 68) in this study. Thirty-one students (45.59%) scored a 95 or lower and were classified as more adaptive. Thirty-seven students (54.41%) scored 96 or higher and were classified as more innovative.

Table 5

Cognitive Styles of Oklahoma Secondary Students enrolled in Agricultural Power & Technology (n = 68)

Item	*f*	%
More Adaptive	31	45.59
More Innovative	37	54.41

Note. KAI score range 32 to 95 = more adaptive; 96 to 160 = more innovative

Table 6 lists students' self-reported mean grade point average (GPA) by cognitive style. The mean self-reported GPA of these students was 3.38, with a minimum score of

2.50 and a maximum score of 4.00. The self-reported mean GPA of the more adaptive students was 3.47, with a minimum score 2.50 and a maximum score of 4.00. The self-reported mean GPA of the more innovative students was 3.31, with a minimum score of 2.50 and a maximum score of 4.00 (see Table 5).

Table 6

Self-Reported Mean Grade Point Averages by Cognitive Style

Cognitive Style	Minimum GPA	Maximum GPA	Mean GPA
More Adaptive	2.50	4.00	3.47
More Innovative	2.50	4.00	3.31
Total	2.50	4.00	3.38

Note. KAI score range 32 to 95 = more adaptive; 96 to 160 = more innovative

Content Knowledge

After completing the small gasoline engines curriculum, but prior to the troubleshooting portion of this study, students were administered a 30-item criterion-referenced test to assess their overall knowledge of the content of the curriculum taught. Table 7 lists the content knowledge test scores by hypothesis generation and cognitive style. The overall mean test score was 18.63 (62.01%; *SD* = 5.29) out of a possible score of 30. The overall mean test score for the more adaptive students was 18.55 (61.83%; *SD* = 5.70) out of 30 items. The more adaptive students who hypothesized their assigned problem correctly had a mean score of 18.68 (62.27%; *SD* = 6.37), while those who generated an incorrect hypothesis had a mean score of 18.22 (60.73%; *SD* = 3.90) out of a possible 30.

The overall mean score of the more innovative students was 18.70 (62.33%; *SD* = 5.00) out of 30 items (see Table 7). The more innovative students who generated a correct hypothesis had a mean test score of 19.89 (66.30%; *SD* = 4.70) out of 30. The more innovative students who hypothesized their assigned problem incorrectly had a mean test score of 17.44 (58.13%; *SD* = 5.13).

Table 7

Mean Content Knowledge Test Scores by Hypothesis Generation and Cognitive Style (n = 68)

Hypothesis Generation	Cognitive Style	*M*	%	*SD*	*n*
Correct	More Adaptive	18.68	62.27	6.37	22
	More Innovative	19.89	66.30	4.70	19
	Total	19.24	64.13	5.63	41
Incorrect	More Adaptive	18.22	60.73	3.90	9
	More Innovative	17.44	58.13	5.13	18
	Total	17.70	59.00	4.69	27
Total	More Adaptive	18.55	61.83	5.70	31
	More Innovative	18.70	62.33	5.00	37
	Total	18.63	62.01	5.29	68

A two-way independent analysis of variance (ANOVA) was employed to determine if a statistically significant difference in content knowledge existed based on cognitive style and hypothesis generation. Prior to employing the ANOVA, Levene's test for equality of error variance was utilized to ensure that error variances were equal (Field, 2009). Specifically, the Levene's test was determined not to be statistically significant ($p = 0.08$) at the 0.05 level; therefore, equality of error variances was assumed. The ANOVA yielded a $F(1, 64) = 0.53$, $p = 0.47$, and power = 0.11 for the interaction effect of hypothesis generation and cognitive style (see Table 8). An analysis of the main effects was necessary due to the lack of statistical significance of the main effect (Kirk, 1995). Regarding the main effect of cognitive style, the ANOVA yielded a $F(1, 64) = 0.025$, $p = 0.87$, and power = 0.53. The main effect of hypothesis generation yielded a $F(1, 64) = 1.13$, $p = 0.29$, and power = 0.18. As such, the researcher failed to reject the second null hypothesis.

Table 8

Analysis of Variance Summary Table for the Effect of Hypothesis Generation and Students' Cognitive Style on Content Knowledge

Source	*SS*	*df*	*MS*	*F*	*p*	Partial η^2
Hypothesis Generation	31.98	1	31.98	1.13	0.29	0.017
Cognitive Style	0.72	1	0.72	0.025	0.87	0.000
Cognitive Style * Hypothesis Generation	14.97	1	14.97	0.53	0.47	0.008
Error	1818.56	64	28.42			
Total	25486.00	68				

Hypothesis Generation

Prior to completing the troubleshooting task, students were asked to develop a written hypothesis regarding what they believed was the fault described in the scenario. Table nine indicates the number and percentages of students who hypothesized the simple problem scenario by cognitive style correctly and incorrectly. In all, 20 (58.82%) students generated a correct hypothesis for the simple problem, and 14 (41.18%) hypothesized incorrectly. Of the 19 more adaptive students, 14 (73.68%) generated a correct hypothesis for the simple problem scenario and five (26.32%) generated an incorrect hypothesis. Of the 15 more innovative students, six (40.00%) generated a correct hypothesis and nine (60.00%) generated an incorrect hypothesis (see Table 9).

Table 9

Hypothesis Generation for the Simple Problem Scenario by Cognitive Style (*n* = 34)

Cognitive Style	Correct	*%*	Incorrect	*%*
More Adaptive	14	73.68	5	23.32
More Innovative	6	40.00	9	60.00
Total	20	58.82	14	41.18

Note. KAI score range 32 to 95 = more adaptive; 96 to 160 = more innovative

Table 10 indicates the number and percentages of students who hypothesized the complex problem scenario correctly. In total, 21 (61.76%) of the students generated a correct hypothesis, and 13 (38.24%) hypothesized the complex problem incorrectly. Of the 12 more adaptive students, eight (66.67%) hypothesized the complex problem correctly, and four (33.33%) generated an incorrect hypothesis. Regarding the 22 more innovative students, 13 (59.09%) generated a correct hypothesis for this scenario and nine (40.91%) generated an incorrect hypothesis (see Table 10).

Table 10

Hypothesis Generation for the Complex Problem Scenario by Cognitive Style (*n* = 34)

Cognitive Style	Correct	%	Incorrect	%
More Adaptive	8	66.67	4	33.33
More Innovative	13	59.09	9	40.91
Total	21	61.80	13	38.24

Note. KAI score range 32 to 95 = more adaptive; 96 to 160 = more innovative

Problem Solving Ability

Problem solving ability was defined as whether or not students were able to identify a set fault in a small gasoline engine. In total, 34 students attempted to solve the simple problem. Of those students, 33 (97.06%) students solved the simple problem successfully, and one (2.94%) was unable to solve the problem (see Table 11). Of the 19 students assigned the simple problem, 18 (94.74%) of the more adaptive students solved the simple problem successfully, and one (5.26%) was unable to solve the problem. All 15 (100.00%) of the more innovative students were able to solve the problem successfully.

Table 11

Ability of Oklahoma Secondary Students to Solve a Simple Small Gasoline Engine Problem (n = 34)

Item	Successful		Unsuccessful	
	f	%	*f*	%
More Adaptive	18	94.74	1	5.26
More Innovative	15	100.00	0	0.00
Total	33	97.06	1	2.94

Note. KAI score range 32 to 95 = more adaptive; 96 to 160 = more innovative

Regarding the problem solving ability of students assigned the complex problem, 28 (82.35%) students were successful and six (17.65%) were unsuccessful (see Table 12). Of the 12 more adaptive students, 10 (83.33%) solved the problem successfully and two (16.67%) were unsuccessful. Of the 22 more innovative students, 18 (81.81%) solve the problem successfully and four (18.18%) were unsuccessful (see Table 12).

Table 12

Ability of Oklahoma Secondary Students to Solve a Complex Small Gasoline Engine Problem (n = 34)

Item	Successful		Unsuccessful	
	f	%	*f*	%
More Adaptive	10	83.33	2	16.67
More Innovative	18	81.82	4	18.18
Total	28	82.35	6	17.65

Note. KAI score range 32 to 95 = more adaptive; 96 to 160 = more innovative

Effects of Problem Complexity, Hypothesis Generation, and Cognitive Style on Time to Solution

Regarding the intervention of this study, students were assigned randomly by cognitive style to solve either a simple or complex problem. Nineteen (27.94%) of the more adaptive students were assigned to the simple problem group and 12 (17.65%) were assigned to the complex problem group. Fifteen (22.06%) of the more innovative students were assigned to the simple problem group, while 22 (32.35%) were assigned to the complex problem solving group (see Figure 4).

Time to solve the problem was recorded for each student who solved the problem successfully. Table 13 reports the mean time to solution for problem complexity and hypothesis generation by cognitive style. Students who hypothesized the simple problem correctly had a mean time to solution of 6.45 (*SD* = 5.66) minutes. Those who generated an incorrect hypothesis for the simple problem required an average of 21.38 (*SD* = 8.04) minutes. Students who hypothesized the complex problem correctly had a mean time to solution of 20.80 (*SD* = 9.04) minutes. Those who generated an incorrect hypothesis for the complex problem required an average of 26.22 (*SD* = 5.47) minutes.

Those students completing the simple problem required a mean time of 12.33 (*SD* = 9.91) minutes. The total time to solve the simple problem for the more adaptive students was 10.06 (*SD* = 8.69) minutes. The more adaptive students who hypothesized the simple problem correctly required an average of 7.43 (*SD* = 6.15) minutes. The more adaptive students who hypothesized the simple problem incorrectly had a mean time to solve the problem of 19.25 (*SD* = 10.91) minutes.

The mean time to solution for the more innovative students assigned the simple problem was 15.07 (*SD* = 10.87) minutes. The more innovative students who generated a correct hypothesis for the simple problem required an average of 4.17 (*SD* = 3.81) minutes. The more innovative students who hypothesized incorrectly the simple problem required a mean time to solution of 22.33 (*SD* = 7.00) minutes.

The mean time to solution for those students completing the complex problem was 22.48 (*SD* = 8.40) minutes. The more adaptive students who completed the complex problem required an average of 22.10 (*SD* = 5.28) minutes. The more adaptive students who generated a correct hypothesis required an average of 22.50 (*SD* = 4.78) minutes to solve the complex problem. A mean time to solution of 20.50 (*SD* = 9.19) minutes was required for the more adaptive students who hypothesized incorrectly.

The more innovative students' mean time to solution for the complex problem was 22.68 minutes (*SD* = 9.78). The more innovative students who hypothesized the complex problem correctly required a mean time of 19.67 (*SD* = 11.10) minutes to complete the task. A mean time to solution of 27.86 (*SD* = 3.44) minutes was required for the more innovative students who generated an incorrect hypothesis.

Prior to employing a three-way independent analysis of variance (ANOVA), Levene's test of error variances was calculated to ensure that the assumption of equal variances was not violated. The Levene's test was not statistically significant at the .05 level, $F(7, 54) = 1.08$, $p = 0.392$. Therefore, ANOVA was utilized to determine main and interaction effects of problem complexity, hypothesis generation, and cognitive style on time to solution. The three-way interaction effect was determined not to be statistically significant at the .05 level (see Table 14). Specifically, the three-way interaction effect of problem complexity, hypothesis generation, and cognitive style yielded an $F(1, 54) = 0.19$, $p = 0.67$, and power = 0.07. Therefore, the researcher failed to reject the fifth null hypothesis. The partial η^2 for the interaction effect was 0.003, indicating negligible effect.

Table 13

Mean Time to Solution for Treatment Conditions Problem Complexity, Hypothesis Generation and Students' Cognitive Style

Problem Complexity	Hypothesis Generation	Cognitive Style	*M*	*SD*	*n*
Simple Problem	Correct	More Adaptive	7.43	6.15	14
		More Innovative	4.17	3.81	6
		Total	6.45	5.66	20
	Incorrect	More Adaptive	19.25	10.91	4
		More Innovative	22.33	7.00	9
		Total	21.38	8.04	13
	Total	More Adaptive	10.06	8.69	18
		More Innovative	15.07	10.87	15
		Total	12.33	9.91	33
Complex Problem	Correct	More Adaptive	22.50	4.78	8
		More Innovative	19.67	11.10	12

(*Table 13 continues*)

(*Table 13 continued)*

Problem Complexity	Hypothesis Generation	Cognitive Style	*M*	*SD*	*n*
Complex		Total	20.80	9.04	20
Problem	Incorrect	More Adaptive	20.50	9.19	2
		More Innovative	27.86	3.44	7
		Total	26.22	5.47	9
	Total	More Adaptive	22.10	5.28	10
		More Innovative	22.68	9.78	19
		Total	22.48	8.40	29

Analyses of the two-way interaction effects were required because of a lack of significance of the three-way interaction effect (Kirk, 1995). Regarding the interaction of problem complexity and hypothesis generation, the ANOVA yielded a $F(1, 54) = 7.07$, $p = .01$, and power = 0.74. As such, the eighth null hypothesis was rejected. The η^2 for the interaction effect of problem complexity and hypothesis generation was 0.116, indicating a practical effect between medium and large.

Regarding the interaction effect for problem complexity and cognitive styles, the ANOVA yielded a $F(1, 54) = 0.28$, $p = .60$, and power = 0.08. Therefore, the researchers failed to reject the sixth null hypothesis. The η^2 for the interaction effect of cognitive style and problem complexity was 0.005, indicating a negligible practical effect. Figure 5 represents the statistically significant interaction effect of problem complexity and hypothesis generation.

Table 14

Analysis of Variance Summary Table for the Effect of Problem Complexity, Hypothesis Generation, and Students' Cognitive Style on Time to Solution

Source	*SS*	*df*	*MS*	*F*	*p*	Partial η^2
Problem Complexity	961.58	1	961.58	17.41	0.00	.880
Hypothesis Generation	902.44	1	902.44	16.34	0.00	.244
Cognitive Style	13.02	1	13.02	0.24	0.63	.004
Problem Complexity * Hypothesis Generation	390.46	1	390.46	7.07	0.01	.116
Problem Complexity * Cognitive Style	15.25	1	15.25	0.28	0.60	.005
Cognitive Style * Hypothesis Generation	188.52	1	188.52	3.41	0.07	.059
Problem Complexity * Hypothesis Generation * Cognitive Style	10.19	1	10.19	.19	0.67	.003
Error	2983.04	54	55.24			
Total	24795.00	62				

The ANOVA yielded and $F(1, 54) = 3.41$, $p = 0.07$, and power = 0.442 for the interaction of cognitive styles and hypothesis generation. As such, the researchers rejected the seventh null hypothesis. The η^2 for the interaction effect of cognitive style and hypothesis generation was 0.059, indicating a small practical effect.

An analysis of the main effect of cognitive style was necessary because no interactions that included the variable were found to be significant at the 0.05 level (Kirk, 1995). The ANOVA yielded an $F(1, 54) = .24$, $p = .63$, and power = .076 for the main effect. Therefore, the researchers failed to reject the third null hypothesis.

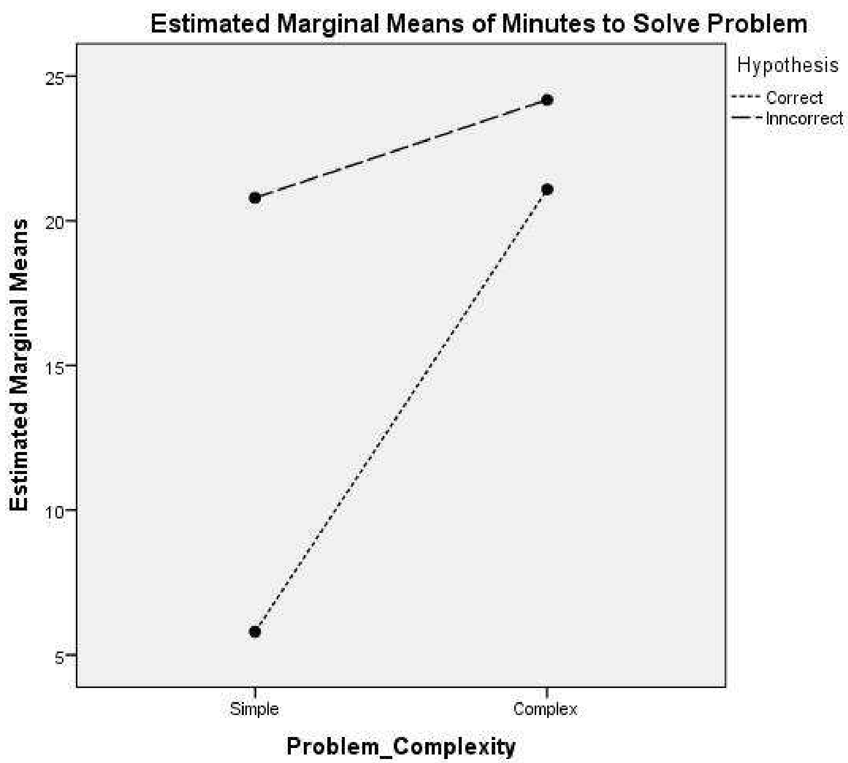

Figure 5. Interaction graph of the independent variables problem complexity and hypothesis generation.

A test of simple main effects was employed to understand the interaction of problem complexity and hypothesis generation better (Kirk, 1995). Simple main effects tests were performed to interpret the interaction based on problem complexity and hypothesis generation. Students who hypothesized the simple problem correctly required an average of 6.45 (*SD* = 5.66) to complete the problem successfully. Those who hypothesized the simple problem incorrectly had a mean time to solution of 21.38 (*SD* = 8.04) minutes. Regarding the complex problem, those who hypothesized correctly required an average of 20.80 (*SD* = 9.04) minutes and those who generated an incorrect hypothesis required 22.48 (*SD* = 8.40) minutes to solve the problem successfully.

Table 15

Mean Time to Solution by Problem Complexity and Hypothesis Generation

		Problem Complexity			
		Simple		Complex	
		M	*SD*	*M*	*SD*
Hypothesis Generation	Correct	6.45	5.66	20.80	9.04
	Incorrect	21.38	8.04	22.48	8.40

Table 16 lists the simple main effects test results for hypothesis generation. The test was statistically significant with a $F(1, 54) = 27.14$, $p = .00$ for the comparison of hypothesis generation within the simple problem. Regarding the complex problem, the test was not statistically significant with a $F(1, 54) = 0.82$, $p = 0.37$.

Table 16

Simple Main Effects Test for Hypothesis Generation

Problem Complexity		*SS*	*df*	*MS*	*F*	*p*	*d*
Simple	Contrast	1500.80	1	1500.80	27.17	.00	2.15
	Error	2983.04	54	55.24			
Complex	Contrast	45.02	1	45.02	.82	.37	0.19
	Error	2983.04	54	55.24			

Table 17 depicts the results of the simple main effects test for problem complexity. The comparison based on hypothesizing correctly was determined to be statistically significant with a $F(1, 54) = 37.90$, $p = .00$. Regarding the incorrect hypothesis comparison, the test was determined to not be statistically significant with a $F(1, 54) = 0.83$, $p = 0.37$.

Table 17

Simple Main Effects Test for Problem Complexity

Hypothesis Generation		*SS*	*df*	*MS*	*F*	*p*	*d*
Correct	Contrast	2093.53	1	2093.53	37.90	.00	1.90
	Error	2983.04	54	55.24			
Incorrect	Contrast	45.70	1	45.02	.83	.37	0.13
	Error	2983.04	54	55.24			

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, IMPLICATIONS, AND DISCUSSION

Summary

The purpose of this study was to assess the effects of cognitive style, hypothesis generation, and problem complexity on the problem solving ability of school-based agricultural education students who were enrolled in Agricultural Power & Technology courses in Oklahoma during the 2012–2013 academic year. After receiving instruction from their respective agriculture teachers, participating students were provided a small gasoline engine with one of two faults. A written problem scenario was provided to each student that outlined symptoms the engine would exhibit if starting procedures were employed. Problem solving ability was operationalized as whether or not the students were able to formulate a solution, as well as the amount of time required to identify the fault correctly. The researcher was present at each data collection site to ensure the students' time to completion was accurate.

Kirton's (2003) Adaption-Innovation Theory (KAIT) served as the conceptual frame for this study. The core of KAIT is that all people are creative and solve problems; however, the manner in which they go about solving problems differs (Kirton, 2003). According to KAIT, some individuals are more adaptive, while others are more innovative. The more adaptive prefer to solve problems that are more structured, they tend work best in the boundaries of the current paradigm, and prefer technical solutions (Kirton, 2003; Kirton et al., 1991; Lamm et al., 2012). In contrast, the more innovative prefer to solve problems that are not limited by a tight structure (Kirton et al., 1991). Additionally, those who are more innovative are less concerned with technical solutions, and they tend to produce novel ideas that push the boundaries of the current paradigm (Kirton et al., 1991; Lamm et al., 2012).

The following research questions guided this study:

1. What are the personal and educational characteristics of students enrolled in APT courses in Oklahoma?
2. What differences exist in content knowledge based on cognitive styles and hypothesis generation?
3. What effect does problem complexity have on the amount of time required to solve problems correctly?
4. What effect does students' cognitive style have on the time required to solve problems correctly?
5. What effect does students' hypothesis generation have on the time required to solve problems correctly?
6. What interactions exist between problem complexity, hypothesis generation, and students' cognitive styles on the amount of time required to solve problems correctly?
7. What interactions exist between students' problem complexity and hypothesis generation on the amount of time required to solve problems correctly?

8. What interactions exist between students' hypothesis generation and cognitive style on the amount of time required to solve problems correctly?

9. What interactions exist between students' problem complexity and cognitive style on the amount of time required to solve problems correctly?

The following null hypotheses guided the statistical analyses of the study:

$H_0$1: In the population, there is no statistically significant difference in content knowledge due to cognitive styles ($\mu_{1 \text{ More Adaptive}} = \mu_{2 \text{ More Innovative}}$).

$H_0$2: In the population, there is no statistically significant difference in the time required to solve problems correctly based on problem complexity ($\mu_{1 \text{ Simple}} = \mu_{2 \text{ Complex}}$).

$H_0$3: In the population, there is no statistically significant difference in the time required to solve problems correctly based on cognitive styles ($\mu_{1 \text{ More Adaptive}} = \mu_{2 \text{ More Innovative}}$).

$H_0$4: In the population, there is no statistically significant difference in the time required to solve problems correctly based on hypothesis generation ($\mu_{1 \text{ Correct Hypothesis}} = \mu_{2 \text{ Incorrect Hypothesis}}$).

$H_0$5: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity, hypothesis generation, and cognitive styles ($\mu_{1\text{More Adaptive x Simple x Correct Hypothesis}} - \mu_{2\text{More Adaptive x Simple x Incorrect Hypothesis}} - \mu_{3 \text{ More Adaptive x Complex x Correct Hypothesis}} - \mu_{4 \text{ More Adaptive x Complex x Incorrect Hypothesis}} - \mu_{5 \text{ More Innovative x Simple x Correct Hypothesis}} - \mu_{6 \text{ More Innovative x Simple x Incorrect Hypothesis}} - \mu_{7 \text{ More Innovative x Complex x Correct Hypothesis}} - \mu_{8 \text{ More Innovative x Complex x Incorrect Hypothesis}} = 0$).

$H_0 6$: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and cognitive styles ($\mu_{1 \text{Simple x More Adaptive}} - \mu_{2 \text{ Complex x More Adaptive}} - \mu_{3 \text{ Simple x More Innovative}} - \mu_{4 \text{ Complex x More Innovative}} = 0$).

$H_0 7$: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of cognitive styles and hypothesis generation ($\mu_{1 \text{More Adaptive x Correct Hypothesis}} - \mu_{2 \text{ More Adaptive x Incorrect Hypothesis}} - \mu_{3 \text{ More Innovative x Correct Hypothesis}} - \mu_{4 \text{ More Innovative x Incorrect Hypothesis}} = 0$).

$H_0 8$: In the population, there is no statistically significant difference in the time required to solve problems due to the interaction of problem complexity and hypothesis generation ($\mu_{1 \text{Simple x Correct Hypothesis}} - \mu_{2 \text{ Simple x Incorrect Hypothesis}} - \mu_{3 \text{ Complex x Correct Hypothesis}} - \mu_{4 \text{ Complex x Incorrect Hypothesis}} = 0$).

Participants

The participants in this study consisted of high school students (n = 68) who attended seven schools throughout Oklahoma. The students were enrolled in Agricultural Power & Technology courses and received instruction in small gasoline engines from their respective agriculture teachers during the 2012–2013 school year. Students were administered Kirton's (2003) Adaption-Innovation Inventory, then assigned randomly by cognitive style to solve either a simple or complex problem.

Design of the Study

A Completely Randomized Factorial 2x2 (CRF-22) design was employed for this research study (Kirk, 1995). CRF designs are best utilized when researchers desire to test the effects of multiple independent variables, as well as their combined effects (Ary et al., 2002). According to Kirk (1995), the following assumptions regarding CRF designs must be met:

1. Two or more treatments, with each treatment having two or more levels.
2. All levels of each treatment investigated in combination with all levels of every other treatment. If there are *p* levels of one treatment and *q* levels of a second treatment, the experiment contains *p* x *q* treatment combinations.
3. Random assignment of experimental units to treatment combinations. Each experimental unit must be assigned to only one combination. (p. 365)

The independent variables of this research study were students' cognitive style, as measured by Kirton's (2003) Adaption-Innovation Inventory (KAI), hypothesis generation, and problem complexity. Students were administered the KAI on the first site visit made by the researcher. Students were classified as either "more adaptive" or "more innovative" based on their KAI score (Kirton, 2003, p. 47). Students were then assigned randomly to solve either a simple or complex small gasoline engine problem. The simple problem consisted of a closed spark plug gap, and the complex problem was a clogged main jet in the carburetor.

The dependent variables of interest were problem solving ability and time to solution. During the second site visit, once the lessons had been taught successfully by the teachers, the researcher provided each student with a small gasoline engine with a set fault. Problem solving ability was operationalized as whether or not the students were able to identify the fault in their assigned engine correctly. Time to solution was assessed based on the number of minutes it took each student to identify the fault in his or her assigned engine. The researcher indicated a common start time at each participating school to ensure accuracy of the data.

Treatment

The treatment, or intervention, of this study consisted of small gasoline engines with one of two known faults in which the students were required to identify. For safety and time considerations, the students were instructed not to attempt to start the engine. Instead, they were provided a scenario describing the symptoms the engine would exhibit if they had attempted to employ starting procedures. The faults were classified as either simple or complex. The simple fault was within the ignition system of the engine – in particular, a closed spark plug gap. The complex fault was within the fuel delivery system. Specifically, debris was placed in the main jet of the carburetor.

The participating teachers were recruited from a small gasoline engines professional development workshop held on the OSU campus in June 2012. Once they completed the two-day training, each teacher was provided with nine engines to use in his or her respective program. For consistency and familiarity, the engines utilized for the treatment were of the same model the teachers received at the professional development. Students at each school were assigned randomly, by cognitive style, an engine with a simple or complex fault to ensure that all treatment groups were roughly equal in size.

Instrumentation

Content Knowledge

To determine students' knowledge in small gasoline engine content, the agriculture teachers tested their students on a 30-item criterion-referenced test created by the researcher. Multiple-choice was the format chosen for this criterion-referenced test, with each test item comprised of one correct answer and three distractor options. Test items were based on the curriculum in Mechanized Agriculture (MCAG) 3211, the engines and power course at OSU, as well as information available on the Briggs & Stratton® PowerPortal website. The criterion-referenced test was evaluated for face and content validity by a panel of experts consisting of three OSU faculty members in agricultural education and one faculty member in Biosystems and Agricultural Engineering (BAE). The BAE faculty member was the instructor of an undergraduate small gasoline engines course at OSU. The panel of experts reviewed the instrument for semantics, ease of reading, content, and general construction of questions. All recommended changes to the instrument were made prior to administering it to students.

A pilot study was conducted to determine reliability of the instrument. Undergraduate students (n = 33) who were enrolled in MCAG 3211 during the Fall Semester of 2012 served as the population of the pilot study. Students were administered the test after completing the course. The Kuder-Richardson (KR-20) formula was employed to calculate a reliability coefficient of 0.74 for the knowledge test. Kane (1986) stated that criterion-referenced tests with an internal reliability above 0.50 would reflect aggregated mean scores. Therefore, this test was deemed reliable and was administered to the secondary students. A post-hoc KR-20 yielded a reliability coefficient of 0.80 for the population of school-based agricultural education students.

Cognitive Style

Kirton's Adaption-Innovation Inventory (KAI) was used to determine students' cognitive style (Kirton, 1976). The KAI consisted of 32 items with a score range from 32 to 160, and a theoretical mean of 96 (Kirton, 2003). According to Kirton (2003), scores of 95 and below are considered more adaptive, while scores 96 and higher fall in the more innovative category. The KAI assesses how participants to compare themselves to each item (Kirton, 2003). However, Kirton (2003) reported that after analyzing research from 10 countries, with a total sample of nearly 3000 individuals, the effective range was 40–150 with a mean that “hovers around 95 (+/- 0.5) with a standard deviation around 17 for all samples” (p. 67). In each of the research studies examined, the internal reliability coefficients ranged from .84 to .89 (Kirton, 2003).

Hypothesis Generation, Problem Solving Ability and Time to Solution

Students were assigned randomly either a simple or complex engine problem to solve. Prior to the problem solving activity, students were provided with a scenario that described symptoms the engine would exhibit if they had attempted to start it. After reading the scenario, students were asked to write a hypothesis that addressed what they believed to be the fault of the engine. Students were instructed to identify which of the four major engine systems was at fault. Problem solving ability was operationalized as whether or not students were able to identify the fault of the engine accurately. Also, each student was timed as to how efficient they were at solving the problem.

Procedures

The participating teachers were provided curriculum to instruct their respective students. This curriculum focused on L-head type engines and consisted of units on 4-cycle engine theory, fuel and oil systems, compression systems, electrical and charging systems, and governor systems. Each lesson contained a troubleshooting objective that informed the students about potential faults associated with system, as well as symptoms each fault would exhibit. Additionally, the teachers utilized training modules available online through the Briggs & Stratton® PowerPortal. The modules utilized were fuel systems, compression, ignition systems, carburetion diagnostics, compression diagnostics, and troubleshooting ignition systems.

Between October 15, 2012 and March 15, 2013 the researcher traveled to all seven schools to administer the treatment. Prior to arrival at each site, students were assigned randomly to solve either a simple or complex problem in an engine. Students were provided a hardcopy problem scenario that matched their engine. Each scenario was written as if the student had attempted to start the engine but was unsuccessful to operate it properly. Additional information was provided in the scenario to give clues as to which engine system at fault. Once the students read the scenario, they were directed to hypothesize what they believed to be the problem. Once each student had written his or her hypothesis, they were taken to their engine to begin the problem solving activity. The researcher was present at each participating school to read directions to students and designate a common start time for the troubleshooting activity. Once the students solved the problem, they were instructed to write the clock time at which they completed the activity and have the researcher check their answer. Additionally, they were instructed to record their solution to the problem on the scenario sheet. Those who were correct were instructed to go back into the classroom to ensure they did not disturb those still working or give away the answers to the problems. However, if they students were incorrect, they were directed to continue working.

Data Analysis

Data were coded and analyzed in IBM SPSS® Statistics version 20 for Windows. Research question one asked, "What are the personal and educational characteristics of students enrolled in APT courses in Oklahoma?" Descriptive statistics such as, mean, median, and mode, were utilized to summarize the personal characteristics of students involved in the study.

Research Question Two asked what effect hypothesis generation and cognitive style had on students' content knowledge, as measured by scores on the criterion-referenced test. A two-way independent ANOVA was employed to determine if a statistically significant difference in content knowledge existed between the students based on hypothesis generation and cognitive style. Additionally, partial eta (η^2) was computed to determine effect size for data concerning this research question.

Research Questions Three, Four, and Five asked how problem complexity, cognitive style, and hypothesis generation, respectively, effected time to solve problems correctly. A three-way, independent ANOVA was computed to determine main effects of each independent variable (Field, 2009). The three-way independent ANOVA allowed for testing of three independent variables on one dependent variable (Field, 2009).

Research Questions Six, Seven, Eight, and Nine asked what interaction effects existed between the independent variables and time to solve problems correctly. Specifically research question six asked about the interaction of problem complexity, hypothesis generation, and cognitive styles. Research question seven asked about the interaction of hypothesis generation and problem complexity, research question eight dealt with the interaction of hypothesis generation and cognitive style, and finally, research question nine asked what interactions existed between problem complexity and cognitive styles. The data addressing these research questions were analyzed using a three-way independent ANOVA.

Both statistical and practical significance were reported. To determine statistical significance, an *a priori* alpha level of .05 was set. This alpha level was utilized to determine whether or not to reject the null hypotheses (Kirk, 1995). Effect size, specifically partial η^2, was used to determine practical significance of this research study. Practical significance indicates whether the sample mean differences are "large enough to be useful in the real world" (Kirk, 1995, p. 64). Partial η^2 was interpreted using the guidelines described by Cohen (1988). These guidelines indicate that 0.0099 is a *small* effect size, 0.0826 is a *medium* effect size, and 0.20 is a *large* effect size.

Summary of Findings

Research Question One: Student Characteristics

Regarding sex, 59 (86.8%) of the students who participated in this study were male, and nine (13.2%) were female. Seventeen (25.0%) of the students were 15 years of age, 19 (27.9%) were 16 years of age, 14 (20.6%) were 17 years of age, 17 (25.0%) were 18 years of age, and one (1.5%) student indicated he or she was 19 years old. Sophomore students represented 33 (48.5%) of this research study's population, 26 (38.2%) were seniors, eight (11.8%) were juniors, and one (1.5%) student was a freshman. Caucasian was the ethnicity of 86.8% (n = 59) of the students who participated in this study. Eight (11.8%) of the students self-reported Native American as their ethnicity and one (1.5%) student was Hispanic.

Regarding number of agricultural education courses, 23 (33.8%) indicated they had enrolled in two courses, 14 (20.6%) had enrolled in three courses, nine (13.2%) had enrolled in 5 courses, eight (11.8%) indicated they had enrolled in four courses, and eight (11.8%) also indicated they had enrolled in one course. Three (4.4%) students had enrolled in six courses, two (2.9%) students had enrolled in eight courses, and one (1.5%) indicated he or she had enrolled in seven courses.

Most (*n* = 48, 70.6%) students indicated they had been enrolled in one course focused in agricultural mechanics. Twelve (17.6%) had enrolled in two courses, five (7.4%) had enrolled in three courses, and three (4.4%) indicated they had enrolled in four courses focused in agricultural mechanics.

Research Question Two: Effect of Hypothesis Generation and Cognitive Style on Content Knowledge

In all, 37 (54.4%) scored a 96 or higher on the KAI and were classified as more innovative. Students who scored 95 or lower were classified as more adaptive and represented 31 (45.6%) of the students who participated in this study. The mean content knowledge test score for the more adaptive students was 18.55 out of a possible score of 30. The mean test score of more adaptive students who hypothesized their assigned problem correctly was 18.68, while those who generated an incorrect hypothesis has a mean score of 18.22 out of a possible 30.

The average score for the more innovative students was 18.70. The more innovative students who hypothesized correctly had a mean test score of 19.89, and those who generated an incorrect hypothesis had a mean score of 17.44. A two-way independent ANOVA indicated that a statistically significant interaction effect did not exist based on hypothesis generation and cognitive style, $F(1, 64) = 0.53$, $p = 0.47$, and power = 0.11. An analysis of the main effects of hypothesis generation and cognitive style was required due to the lack of statistical significance of the interaction effect (Kirk, 1995). The main effect of hypothesis generation was determined to not be statistically significant, $F(1, 64) = 1.13$, $p = 0.29$, and power = 0.18. Additionally, the main effect of cognitive style was determined not to be statistically significant, $F(1, 64) = 0.025$, $p = 0.87$, and power = 0.05. As such, the researcher rejected the second null hypothesis.

Research Questions Three, Four, Five, Six, Seven, Eight, and Nine: Interaction Effects

The remaining research questions asked about the main and interaction effects of problem complexity, hypothesis generation, and cognitive styles on time to solution. A statistically significant three-way interaction effect between the three independent variables did not exist at the 0.05 level. Therefore, the researcher failed to reject the fifth null hypothesis.

Analyses of two-way interaction effects were necessary due to the lack of interaction of the three-way interaction effect (Kirk, 1995). Regarding the interaction effect of problem complexity and hypothesis generation, the ANOVA yielded a $F(1, 54) = 7.07$, $p = .01$, and power = .74. As such, the researcher rejected the eighth null hypothesis. The partial η^2 for the interaction effect of problem complexity and hypothesis generation was 0.116, indicating a practical effect between medium and large. A statistically significant interaction effect did not exist at the 0.05 level between problem complexity and cognitive styles. Similarly, the interaction effect of cognitive styles and problem complexity was not statistically significant. Therefore, the researcher failed to reject the corresponding null hypotheses.

An analysis of the main effect of cognitive style was necessary due to the lack of any interaction effects involving that particular variable (Kirk, 1995). The main effect of cognitive style was not statistically significant at the 0.05 level. As such, the researcher failed to reject the second null hypothesis.

Conclusions and Discussion

Student Personal and Educational Characteristics

The typical student participant was Caucasian, male, between 15 and 18 years of age and either a sophomore or senior. Most of the students had enrolled in either two or three agricultural education courses, with one of those courses focused in agricultural mechanics. This profile is consistent with data from ODCTE (2012b) data, which indicated that agricultural mechanics courses were the second most popular type of agricultural education course during the 2010–2011 and 2011–2012 school years in Oklahoma. Over 5,000 students enrolled in courses within the agricultural power and technology career pathway during that time period. Animal science was the only agricultural education career pathway in which more students had enrolled.

The typical student had a GPA of 3.38. The average more adaptive student had a slightly higher GPA (3.47) than the more innovative students (3.31). Regarding cognitive style, a rather equal split of students existed between those who were more adaptive and those who were more innovative. This is consistent with Kirton (2003) who described that the two cognitive styles are distributed evenly across most populations.

Content Knowledge

After completing the small gasoline engines lessons, students were administered a 30-item criterion-referenced test in multiple-choice format. There were no statistically significant differences ($p < 0.05$) in content knowledge based on cognitive styles. Therefore, the first null hypothesis was not rejected. Similarly, Pate and Miller (2011c) concluded that students' content knowledge should not differ if curriculum and instruction by their respective secondary teacher is free from variation.

This conclusion differs from that of Dyer and Osborne (1996a) who found statistically significant differences in achievement based on learning styles as measured by the GEFT. However, this conclusion congruent with other literature that cognitive styles are not a measure of intelligence (Schunk, 2008; Sternberg & Grigorenko, 2005). Specifically, Kirton (2003) posited that cognitive style is not an indicator of cognitive levels, such as intelligence, but rather it is concerned with *how* individuals go about solving problems.

Hypothesis Generation

Prior to beginning the engine troubleshooting portion of this research study, students were asked to develop a written hypothesis based on the information from their respective problem scenario. Regardless of problem complexity, the typical more adaptive student generated a correct hypothesis. The more innovative students were more likely to generate an incorrect hypothesis for the simple problem and a correct hypothesis for the complex problem. This contradicts Johnson (1988) who reported that novice troubleshooters were more likely to generate irrelevant hypotheses than experts. Experts are superior in hypothesis generation due to their ability to gather relevant information to work through the problem space (Johnson, 1988; Jonassen, 2000; Newell & Simon, 1972).

Problem Solving Ability

Students who were assigned the simple problem were able to identify the fault successfully as a closed spark plug gap. Regarding cognitive styles, all of the more innovative students solved the simple problem correctly. Only one more adaptive student was unable to solve the simple problem. Students, regardless of cognitive style, were also able to solve the complex problem by identifying that debris was placed in the main jet of the carburetor. This is consistent with the Adaption-Innovation theory which states that everyone has the ability to solve problems, regardless of cognitive style (Kirton, 2003). This, however, is not consistent with the work of Pate and Miller (2011a) who found that the majority of secondary students were not able to troubleshoot a small gasoline engine compression problem successfully, regardless of whether they worked individually or employed the TAPPS method.

Time to Solution

In all, 33 students solved the simple problem scenario successfully. Students who generated a correct hypothesis solved the simple problem nearly 15 minutes quicker than those who generated an incorrect hypothesis. The typical more innovative student who generated a correct hypothesis was able to solve the problem most efficiently. The typical more innovative student who hypothesized incorrectly was the most inefficient at troubleshooting the simple problem. The more adaptive students who generated an incorrect hypothesis were able to solve the simple problem quicker than their more innovative counterparts.

The most efficient group of troubleshooters assigned the complex problem were the more innovative students who generated a correct hypothesis. The more innovative students who hypothesized the problem incorrectly were the least efficient problem solvers. The more adaptive students who hypothesized the problem incorrectly were able to identify a correct solution more quickly than their counterparts who hypothesized correctly. Overall, this aligns with Johnson (1989) who reported that those who generated relevant hypothesis were able to make better decisions during the troubleshooting process.

A statistically significant three-way interaction effect between problem complexity, hypothesis generation, and cognitive style did not exist ($p > 0.05$). Therefore, the fifth null hypothesis was not rejected. Similarly, the two-way interaction effect between problem complexity and cognitive style was not statistically significant ($p > 0.05$). The two-way interaction effect between hypothesis generation and cognitive styles was also not statistically significant ($p > 0.05$). As such, the sixth and seventh null hypotheses were not rejected. This supports the assertion of Adaption-Innovation theory that all individuals can solve problems regardless of cognitive style (Kirton, 2003).

The two-way interaction effect between problem complexity and hypothesis generation was determined to be statistically significant ($p < 0.05$). Thus, the eighth null hypothesis was rejected. The simple main effects test revealed that students who generated a correct hypothesis were able to solve problems more efficiently than those who generated an incorrect hypothesis. This fact was true for both simple problem and complex problem. This finding is similar to that of Johnson (1988; 1989) who concluded that the greatest difference in troubleshooting performance was attributable to information the problem solvers acquired and hypotheses generated.

An analysis of the main effect of cognitive style was required because no interaction effects that included the variable were found to be statistically significant. The main effect of cognitive style was determined not to be statistically significant ($p > 0.05$). As such, the second null hypothesis was not rejected. This is consistent with the

Kirton's (2003) Adaption-Innovation theory that states cognitive style is not a measure of performance, but rather an indicator of problem solving preference.

Recommendations

Recommendations for Practice

Agriculture has been referred to as the "world's oldest science" (Ricketts, Duncan, & Peake, 2006, p. 48); therefore it is recommended that agricultural educators seek training in teaching methodologies such as inquiry-based learning, experiential learning, or the problem solving approach to teach students how to solve problems. Specifically, agriculture teachers should teach students how to acquire relevant information to formulate hypotheses when solving problems. Students who generated a correct hypothesis were able to solve their assigned problem more quickly, regardless of problem complexity. In the agricultural industry, employers desire entry-level employees who can solve problems (Robinson & Garton, 2008; Robinson et al., 2007). Encouraging students to hypothesize appears to increase students' problem solving efficiency.

Although cognitive style did not have a statistically significant effect on students' ability to solve problems, agriculture teachers should consider this variable when the goal is to increase student achievement or solve problems (Brinkman, 1999; Lamm et al., 2011). Specifically, the results of this study show the more adaptive students were able to solve the simple problem just over five minutes quicker than the more innovative students. Regarding the complex problem, however, there was almost no difference in time to solution between the two cognitive styles.

Additional professional development opportunities in small gasoline engines should be provided for agriculture teachers in Oklahoma. Future professional development should be sustained over time and focus on building a community of practice (CoP) among agriculture teachers. When professional development is of a longer duration, teachers are more likely to implement new strategies in their classrooms (Garet, Porter, Desimone, Birman, & Yoon, 2001). Duration of professional development activities includes contact hours, as well as time span (Garet et al., 2001). CoPs are groups of individuals with similar interests who engage in collective learning (Wenger, 2000). To help facilitate the CoP, agriculture teachers should be allowed to create the unit of instruction as a group, rather than being provided with the curriculum to teach. This would help to bridge the gap between the content and pedagogy by allowing the teachers to engage in active learning (Garet et al., 2001).

Recommendations for Research

Additional research is warranted to further investigate the effect of hypothesis generation and problem complexity on problem solving ability of school-based agricultural education students. The results of this study indicate a statistically significant ($p < 0.05$) interaction effect of hypothesis generation and problem complexity in the context of small gasoline engines. Research should focus on the role of knowledge in hypothesis generation. Johnson (1988; 1989) concluded that successful troubleshooters had greater and better organized knowledge than those who were unsuccessful. Most students did not score well on the content knowledge examination. In fact, the average score on the test was just over 62%, which would be considered barely passing in most school settings.

Replication of this study is needed because teachers were not selected randomly to participate; therefore, it cannot be assumed that the teachers in this study are representative of all agriculture teachers in Oklahoma. Additionally, replications of this study to should occur with larger samples of teachers and students. This would assist in detecting treatment effects through greater statistical power and decrease the chance of committing a Type II error (Kirk, 1995). Variables within the affective domain, such as motivation and interest, should be assessed in future studies to account for additional error variance. Further, students who generate an incorrect initial hypothesis should be required to write alternative hypotheses and test each individually. Additionally, research should investigate mechanical aptitude differences between successful and unsuccessful troubleshooters. The amount of information provided in the problem scenarios could be varied among future research participants to determine how clues affect troubleshooting performance.

Although the results of this study do not indicate that cognitive style has a statistically significant effect on problem solving ability, further research is needed to determine the role cognitive style plays during the problem solving process in agricultural mechanics. Specifically, additional research is needed that assesses the interaction effect of cognitive style and hypothesis generation when troubleshooting problems of differing complexity. Lamm et al. (2011) and Dyer (1996a; 1996b) recommended that teachers should consider students' cognitive styles when trying to increase student achievement and problem solving ability.

Kirton's (2003) Adaption-Innovation theory states clearly that all people can solve problems regardless of cognitive style. However, in situations such as troubleshooting, it may be beneficial for problems to be solved more quickly. Findings from this study indicated differences in time to solution between the more adaptive and more innovative. Future research should focus on these variables. Additionally, research should investigate how teachers' cognitive style impacts the problem solving ability of students.

Much of the literature concerning KAI centers on problem solving among groups. As such, research should be conducted that investigates the role of cognitive style among groups during troubleshooting tasks. Pate et al. (2004) reported that students who utilized the think-aloud paired problem solving (TAPPS) were more successful than those students working individually when troubleshooting small gasoline engines. Research should examine how the interaction of cognitive style and TAPPS affects troubleshooting ability. Specifically, research should investigate how heterogeneous groups, such as a more adaptive student paired with a more innovative student, compare to homogeneous groups, such as amore adaptive student paired with another more adaptive student or a more innovative student paired with another more innovative student when troubleshooting. Employing TAPPS could also allow researchers to gauge the troubleshooters' ability to work in the problem space to develop mental models, which is an important phenomenon to consider when solving problems (Jonassen, 2000; Newell & Simon, 1972).

Limitations

Confounding variables that were outside of the researcher's control contributed to certain limitations of this research study. First, due to the inability to create a set time frame within the school year to collect data, the teachers who volunteered for this study were allowed to teach the small gasoline engines unit of instruction when it fit their schedule most conveniently. As such, five teachers completed the study during the Fall

Semester of 2012 and two during the Spring Semester of 2013. This lack of congruency of the time of the school year when data were collected may have affected the study's outcomes.

Secondly, experimental mortality impacted this study. Experimental mortality is described as losing study participants during the course of the research period (Campbell & Stanley, 1963). Data were collected from a total of 77 students who were enrolled in agricultural mechanics courses across seven different high schools. However, only 68 students completed all parts of the study fully.

Regarding variables within the researcher's control, random selection of teacher participants did not occur. All agriculture teachers in Oklahoma were afforded the opportunity to receive small gasoline engine training held in June 2012 on the OSU campus. Teachers who attended the professional development workshop were not required to participate in this research study. Teachers were provided with a summary of the proposed research and allowed to volunteer for the study. In all, seven teachers out of the 21 in attendance volunteered, completed all required IRB forms, and scheduled the unit of instruction in at a time that allowed the researcher to collect data. As a result of the teacher selection procedure, generalizability of this study suffered.

Implications

For the purposes of this research, problem solving ability was operationalized as whether or not students were able to identify a fault within a small gasoline engine correctly. Overall, 90% of the student participant's were able to solve their assigned problem. This finding aligns directly with Kirton's (2003) Adaption-Innovation theory that states all people solve problems regardless of cognitive style. However, this dichotomous variable may not be an accurate measure of problem solving performance. The amount of time required to solve the problem may be a more accurate assessment. Specifically, individuals who require less time when solving problems are generally considers better problem solvers (Vasandani & Govindaraj, 1991).

Although cognitive style did not have a statistically significant effect on time required to solve problems, there were more than five minutes of difference in the amount time required to solve the simple problem in favor of the more adaptive students. However, the more innovative students who hypothesized the simple problem correctly were able to solve the problem in excess of three minutes quicker than the more adaptive student who hypothesized correctly. Why did these differences exist? Kirton (2003) described that the more adaptive prefer structured problems and produce solutions based on efficiency, while the innovative tend to proliferate ideas and prefer less structure when problem solving. Could it be that the more adaptive students are so structured and methodical that they actually require more time to solve the simple problem? Perhaps there were differences in the mechanical aptitude between the more adaptive and the more innovative.

Johnson's (1989) model of technical trouble shooting indicated that when problem solvers determine their initial hypothesis to be incorrect, they must generate an alternative hypothesis to test. Perhaps the more innovative students who hypothesized incorrectly struggled to formulate an alternative hypothesis. Or, perhaps they generated several hypotheses and were unable to determine which alternative hypothesis to test. Could cognitive styles influence how students work through the problem space to create mental models (Jonassen, 2000; Newell & Simon, 1972)? Perhaps the more adaptive students create structured mental models that enable them to solve problems accurately, yet their methodical nature actually requires them to use additional time to achieve a solution. Further, maybe the more innovative create mental models filled with a plethora of unorganized possible solutions. This could explain why the more innovative students who hypothesized incorrectly required more time to solve the problem.

The interaction effect of hypothesis generation and problem complexity was calculated to be statistically significant with a practical effect between medium and large. Intuitively, it stands to reason that the students required less time to solve the simple problem than the complex problem. Interestingly, for both levels of problem complexity, students who generated a correct hypothesis solved the problem quicker than those who hypothesized more quickly. The literature is clear about the prerequisite of knowledge when problem solving (Gitomer, 1988; Hegarty, 1991; Johnson, 1988; 1989; Jonassen, 2000; 2001; Larkin et al., 1980; Nickerson, 1994; Schunk, 2008; Simon, 1979; Zimmerman et al., 2003). Interestingly, there were no statistically significant differences in content knowledge test scores based on cognitive style or hypothesis generation. However, the overall average test score was just over 62%, which would be considered a very low passing score. Davidson, Deuser, and Sternberg (1994) reported that variations in the quantity and quality of domain-specific knowledge can impact the formulation of problem solutions. Do the poor scores on the content knowledge examination indicate low levels of domain knowledge? If so, why is the interaction effect between hypothesis generation and content knowledge not statistically significant? Johnson (1988; 1989) reported that superior troubleshooters were able to utilize their previous knowledge to generate relevant hypotheses, indicating a relationship between the two variables.

In addition, perhaps there were motivational differences between students. This study did not assess variables within the affective domain, but items such as motivation or interest could have influenced the results. The agriculture teachers were given a choice as to whether or not to count the content knowledge examination as a part of the course grade. Perhaps some teachers elected not use the score as a grade causing students to lack motivation to perform on the test. Some students may have lacked an interest in learning about small gasoline engines. The majority of school-based agricultural education programs in Oklahoma focus on metals and welding within Agricultural Power & Technology (Leiby, Robinson, & Key, 2012). Students may have enrolled in the course to learn about metals and welding and were disengaged during the small gasoline engines unit of instruction.

Perhaps teacher effect impacted the results of this study. Although the agriculture teacher demographics were not a part of this study, there was a range of years of experience. Were the younger teachers able to motivate students better because of age proximity or perhaps the more experience teachers commanded more respect and engaged students better? Do teachers engage students with similar cognitive styles more effectively? Does cognitive style influence teaching methodologies and strategies? Perhaps the seven teachers who volunteer for this study possessed greater knowledge or interest in small gasoline engines than those who elected not to participate in this study.

Major Contributions of this Study

Contributions to Research and Literature

This study employed a completely randomized factorial (CRF) 2x2 design where students were assigned randomly by cognitive style to the treatment groups. This study sought to assess the effects of problem complexity, hypothesis generation, and cognitive style on the problem solving ability of students in enrolled in Agricultural Power & Technology courses. Only seven students out of the 68 that completed all parts of the study fully were unable to solve their assigned problem. Additionally, no statistically significant differences in time to solution were found between problem complexity and cognitive style, or between hypothesis generation and cognitive style. These findings supported Kirton's (2003) Adaption-Innovation theory that all people can solve problems regardless of cognitive style.

A statistically significant interaction effect between hypothesis generation and problem complexity was found. This finding is consistent that of Johnson (1988; 1989), who concluded that major differences in troubleshooting ability were attributable to how the problem solvers utilized information to generate relevant hypotheses. This finding is encouraging because employers in the agricultural industry desire employees that can solve problems (Robinson & Garton, 2008; Robinson et al., 2007). This finding shows that students can solve problems in agricultural mechanics, regardless of complexity, if they are encouraged to generate hypotheses.

Contributions to Practice

Teachers of agriculture should employ teaching strategies that encourage students to generate hypotheses and solve problems. Agriculture teachers should be encouraged that they can help their students become better problem solvers by teaching them to think through a problem and generate hypotheses. Hypothesis generation is common to the scientific method and Dewey's concept of reflective thinking (Phipps et al., 2008). Agricultural educators can help students to become productive citizens who are agriculturally literate by encouraging them to solve practical problems in agriculture (Roberts & Ball, 2009).

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APPENDIX A

Institutional Review Board Approval

Oklahoma State University Institutional Review Board

Date: Wednesday, July 11, 2012

IRB Application No AG1227

Proposal Title: Assessing the Impact of Cognitive Style, Content Knowledge and Problem Complexity on Problem Solving Ability of School Based Agricultural Education Students in Agricultural Mechanics: An Experimental Study

Reviewed and Processed as: Expedited

Status Recommended by Reviewer(s): Approved **Protocol Expires: 7/10/2013**

Principal Investigator(s):

Joey Blackburn	J. Shane Robinson
459 Ag Hall	457 Ag Hall
Stillwater, OK 74078	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:
As soon as you receive signed principal consent forms, send copies to the IRB Office.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North(phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

APPENDIX B

Agriculture Teacher Consent Form

August 1, 2012

Dear Oklahoma Agriculture Teacher,

The Agricultural Education, Communications, & Leadership Department at Oklahoma State University (OSU) would like to invite you to participate in a research study that will provide insight into factors that affect student's ability to solve problems.

Please read this document carefully before you decide to participate in this research study.

Thank you for taking the time to consider participating in this research study. Your participation is completely voluntary; there is no penalty for choosing not to participate. Your decision will not affect your relationship with the department or OSU. The purpose of this study is to examine factors that may potentially affect student problem solving ability. Specifically, this study seeks to determine the impact of content knowledge, problem solving style, and problem complexity on students' ability to accurately solve problems.

If you choose to participate, you will be asked to teach small engine technology curriculum and administer competency examinations created by and available from Briggs & Stratton Corporation. This curriculum and competency examinations were covered during the first day of the small gasoline engines workshop you attended in June 2012 on the OSU campus. The curriculum and competency examinations are available free of charge from Briggs & Stratton's PowerPortal website. The curriculum and competency examinations were created to help entry level technicians learn Briggs & Stratton engines. Topics are divided into basic, intermediate, and advanced categories. All of the instructional topics you will be asked to teach are contained in the basic or intermediate categories.

In addition to teaching the mentioned curriculum, this research study required that I come to your school twice during the fall semester of 2012 to administer instruments and the intervention. Between September 1 and September 15, I will travel to your school to administer a Student Personal Characteristics instrument to collect demographic data. This information will include the student's sex, age, grade level, and number of years in the agriculture program. Additionally, I will administer Kirton's Adaption-Innovation Inventory to assess each student's preferred problem solving style. This information will be used to randomly assign students a problem to solve. These instruments will require approximately 20 – 30 minutes for the students to complete.

The second visit to your school would be between September 15 and October 15. This visit will not occur until after your students have taken the online competency examinations on the Briggs & Stratton PowerPortal Website. As such, please ensure your students have completed the examinations prior to October 10, 2012. During this visit I would administer the treatment intervention to the students. The treatment intervention will be assigned to each student randomly, based on their preferred problem solving style. The treatment intervention will be twofold, the first component is a case study describing a scenario where the students have a start a small gasoline engine that failed to start. The second component is an engine matching the description in the case study. The students will be asked to accurately identify the fault within the engine. Students will be timed to determine how long it takes to solve the problem accurately.

There are no known risks associated with this study. If you choose not to participate, you will not be penalized in any way. However, if you do choose to participate in this research study, please contact Joey Blackburn via email at: joey.blackburn@okstate.edu. You may also contact Dr. Shane Robinson at 405-744-3094 or shane.robinson@okstate.edu with any questions or concerns.

Sincerely,

Joey Blackburn

Assessing the impact of cognitive style, content knowledge and problem complexity on problem solving ability of school-based agricultural education students in agricultural mechanics

Instructor Consent Form

August 2012

Greetings Oklahoma Ag Ed Instructors,

First off let me begin by saying thank you for agreeing to assist us in this study. It is only with your help and dedication that this research project will be a success. This research project is expected to last through the month of October during the fall semester of 2012.

Background Information:

The purpose of this study will be to assess the impact of problem solving style, small engine content knowledge and problem complexity on the problem solving ability of agricultural education students enrolled in Agricultural Power & Technology.

Procedures:

- Provide classroom instruction for the selected course using the curriculum and teaching methods that the teachers(‘s)would normally use.
- Administer small gasoline engine competency examinations developed by and available from Briggs & Stratton Corporation.
- Provide web-based weekly reports over the teachers(‘s) instruction.

Risks and Benefits:

There are no known risks associated with this study that would occur as a result of participation. Perceived benefits include the knowledge of how students with differing problem solving styles solve problems. This could allow teachers to modify curriculum and/or instructional techniques to enhance student learning.

Confidentiality:

Your school can be assured that the records of this study will be kept private and any information obtained relating to you or your students will be kept confidential. Any reports that are generated as a result of this study will remain confidential as well, and not include any identifiers to you or your students. Since this is classified as a voluntary study, your decision to participate will have no bearing on your current or future relationship with OSU.

Contact Information:

If you have any questions now or in the future regarding this study, please do not hesitate to contact myself or the others listed below.

Joey Blackburn
405-744-2972
joey.blackburn@okstate.edu

Dr. Shane Robinson
405-744-3094
shane.robinson@okstate.edu

If you have questions about your rights as a research volunteer, you may contact the Oklahoma State University Institutional Review Board (IRB) Chair, Dr. Shelia Kennison at 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

You will be given a copy of this form to keep for your records.

Statement of Consent:

I have read the above information and freely consent to participate in this study.

Printed Name	Signature	Date
Principle Investigator	Signature	Date

Okla. State Univ.
IRB
Approved 7/11/12
Expires 7/10/13
IRB # AG-12-27

APPENDIX C

School Administrator Consent Form

Problem Solving Ability Research Study
School Principal Consent Form

August 2012

____________________ has agreed to participate in a research study being conducted the Agricultural Education, Communications and Leadership department at Oklahoma State University (OSU). This teacher was purposefully selected because of attendance at the Small Engine Workshop held June 12 and June 13, 2012. We ask that you sign this letter of consent indicating that you are informed about the study and support the teachers' participation in this project.

Background Information:

The purpose of this study will be to assess the impact of problem solving style, small engine content knowledge and problem complexity on the problem solving ability of agricultural education students enrolled in Agricultural Power & Technology.

Procedures: The following requirements have been identified as crucial to this study.

The teacher will:

- Provide classroom instruction for the selected course using the curriculum and teaching methods that the teachers('s)would normally use.
- Administer small gasoline engine competency examinations developed by and available from Briggs & Stratton Corporation.
- Provide web-based weekly reports over the teachers('s) instruction.

Risks and Benefits:

There are no known risks associated with this study that would occur as a result of participation. Perceived benefits include the knowledge that students who possess differing problem solving styles actually solve problems differently. This could allow teachers to modify instructional practices to teach students best.

Confidentiality:

Your school can be assured that the records of this study will be kept private and any information obtained relating to you or your students will be kept confidential. Any reports that are generated as a result of this study will remain confidential as well, and not include any identifiers to you or your students. Since this is classified as a voluntary study, your decision to participate will have no bearing on your current or future relationship with OSU.

Contact Information:

If you have any questions now or in the future regarding this study, please do not hesitate to contact myself or the others listed below.

Joey Blackburn 405-744-2972 joey.blackburn@okstate.edu	Dr. Shane Robinson 405-744-3094 shane.robinson@okstate.edu

If you have questions about your rights as a research volunteer, you may contact the Oklahoma State University Institutional Review Board (IRB) Chair, Dr. Shelia Kennison at 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

Please retain a copy of this form for your records

Statement of Consent:

I have read the above information and support the participation of the teacher in this study.

_______________________ _______________________ __________

Printed Name Signature Date

APPENDIX D

Student Participant Consent Form

Assessing the impact of cognitive style, content knowledge and problem complexity on problem solving ability of students in agricultural mechanics

Students Participant Consent Form

Dear Student,

We are interested in learning about how different problems affect how students your age learn. In order to understand this, we would like you to fill out some forms, take an examination, and try to determine why an engine will not start. Your agriculture teacher will teach you about aspects of small gasoline engines (i.e. push mower engines) over the next couple weeks as a part of the class you are enrolled in. During my next visit, I will ask you to trouble shoot an engine that will not start. I am interested in whether or not you identify the problem with the engine and how long it takes you to do that. We will also need your permission to let us view your examination scores. By signing this form, you are giving us permission to have you fill out our forms and view your examination scores. Your teacher will still teach small gasoline engines in your class whether or not you give us permission to view your scores. Your parent/guardian is aware of this project.

Please understand that you do not have to do this. You do not have to answer any questions that you do not want to. And, you do not have to allow us to view your examination scores. Signing this form (or not signing) will not impact your grade in the course.

Your name will be on the forms you fill out, once the researcher has received your results, your name will be removed and you will be given a number that will be put on your answer sheet so no one will know whose answers they are. If you have any questions about the form or what we are doing, please ask us. Thank you for your help.

Sincerely,

Joey Blackburn
Graduate Student Oklahoma State University

Shane Robinson
Associate Professor Oklahoma State University

I have read this form and agree to help with your project.

____
(your name)

____
(your signature)

(date)

APPENDIX E

Parent/Guardian Consent Form

PARENT/GUARDIAN PERMISSION FORM

OKLAHOMA STATE UNIVERSITY

PROJECT TITLE: Assessing the impact of cognitive style, content knowledge and problem complexity on problem solving ability of school-based agricultural education students in agricultural mechanics: An Experimental Study

INVESTIGATORS: Joey Blackburn, Doctoral Candidate, Oklahoma State University; J. Shane Robinson, Ph. D.

PURPOSE:

The goal of our project is to determine if students with differing cognitive styles solve problem differently. Further, all students will be administered a technical competency exam in agriculture and one instrument designed to identify problem solving style. The results of your child's examination and course interest surveys will only be used for research purposes and will in no way affect your child's outcome in the course. Further, please be advised that no information collected during this research will not be released to the school or any other recipient and will be destroyed at the end of the study.

Your child has been selected because s/he is enrolled in Agricultural Power & Technology and his/her agriculture teacher attended a summer workshop covering small gasoline engines

PROCEDURES:

Your child will complete two questionnaires. One questionnaire will ask about the child's basic personal characteristics such as age, grade level, and gender. The second questionnaire will ask questions that will determine the child's preferred problem solving style. This questionnaire will present the students with a series of statements for the students to the students and asks them to mark how the statement applies to them on a scale from Very Hard to Very Easy.

Additionally, after your child receives instruction in small gasoline engines from the agriculture teacher. Small gasoline instruction is a part of the Agricultural Power & Technology course in which your child is enrolled and will not be affected by the signing of this form. If you elect to give permission for your child to participate, s/he will be asked to complete a competency examination in small gasoline engines and then troubleshoot an engine that failed to start. For safety, the students will not actually attempt to start the engine rather; they will be give a written scenario describing the problem and asked to identify what the problem is. Students will be measured based on whether or not they identified the problem correctly and how long it took them to do so.

RISKS OF PARTICIPATION:

There are no known risks associated with this project which are greater than those ordinarily encountered in daily life.

BENEFITS OF PARTICIPATION:

There is no direct benefit of participation to your child. However, the results of this study will provide information about how students learn and solve problems differently. These results will help teachers to understand how to teach students with differing problem solving styles better. If you are interested, we will send you a copy of the results of the study when it is finished.

CONFIDENTIALITY:

The records of this study will be kept private and confidential, but not anonymous. The child's responses on the two questionnaires will be tracked to match with the problem solving portion of the study. Once all documents and data are collected, names will be removed. Any written results will discuss group findings and will not include information that will identify your child. Research records will be stored securely and only researchers and individuals responsible for research oversight will have access to the records. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research.

COMPENSATION:

Your child will not be compensated for participation in this study. The agriculture teacher may choose to assign grade for portions of the small gasoline engines curriculum not associated with the study. No part of this study (i.e. questionnaires, competency examinations, or problem solving) will affect your child's grade in the course.

CONTACTS:

You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study: Joey Blackburn, Ph.D Candidate., 459 Ag Hall, Dept. of Agricultural Education, Communications, and Leadership, Oklahoma State University, Stillwater, OK 74078, joey.blackburn@okstate.edu (405) 744-2972 or Dr. J. Shane Robinson, Ph.D., 457 AG Hall, Dept. of Agricultural Education, Communications, & Leadership, Oklahoma State University, Stillwater, OK 74078 (405) 744-3094 or shane.robinson@okstate.edu. If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

PARTICIPANT RIGHTS:

I understand that my child's participation is voluntary, that there is no penalty for refusal to participate, and that I am free to withdraw my permission at any time, without penalty.

CONSENT DOCUMENTATION:

I have been fully informed about the procedures listed here. I am aware of what my child and I will be asked to do and of the benefits of my participation. I also understand the following statements:

I have read and fully understand this permission form. I sign it freely and voluntarily. A copy of this form will be given to me. I hereby give permission for my child ______________________ participation in this study.

____

Signature of Parent/Legal Guardian Date

I certify that I have personally explained this document before requesting that the participant sign it.

____
____

Signature of Researcher Date

APPENDIX F

Small Gasoline Engine Workshop Schedule

Small Gasoline Engines
Professional Development Workshop
June 12 & 13
Stillwater, OK

<u>Tuesday, June 12 – Manufacturing Development Laboratory in Old Petroleum Building Classroom</u>

9:00	Introductions & The Power Portal
9:30	Parts Look Up
10:00	Service Bulletin 736 Fuel and Oil
11:00	Lunch on Your Own
12:30	Carburetion/Fuel Systems
4:30	Test
5:00	Request from Joey Blackburn

<u>Wednesday, June 13 – Welding Laboratory Across from Manufacturing Development Laboratory</u>

8:30	Engine Teardown and Reassembly
12:30	Lunch On Your Own
1:30	Electrical
3:30	2012 Briggs & Stratton Update

<u>What to Bring</u>

- Laptop with WIFI access to test on the power portal.
- Basic tools for engine teardown
    - Basic Metric Sockets and/or Wrenches (5 through 15 mm)
    - Basic SAE (Standard) Sockets and/or Wrenches (3/8 through 7/8)
    - Screwdrivers (variety of straight (flat) and Phillips
- Safety Glasses

APPENDIX G

Student Personal Characteristics Questionnaire

Student Personal Characteristics Questionnaire

Name: ____________________ School: ____________________

Directions: Please select the response which best describes you:

1. What is your sex?

€ Female

€ Male

2. What is your age?

€ 14

€ 15

€ 16

€ 17

€ 18

3. What is your current grade level?

€ 8th Grade

€ 9th Grade – Freshman

€ 10th Grade – Sophomore

€ 11th Grade – Junior

€ 12th Grade – Senior

4. What is your current Grade Point Average (GPA)? _____

5. Including your current class, how many agricultural education classes have you taken? ____

6. Including your current class, how many of your agricultural education classes have focused on agricultural power & technology/agricultural mechanics? _____

7. Which of the following ethnicity represents you best?

    € White/Caucasian
    € African-American
    € Asian
    € American Indian/Alaska Native/Pacific Islander
    € Hispanic
    € Other

APPENDIX H

Kirton's Adaption-Innovation Inventory

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.

How easy or difficult do you find it to present yourself, consistently, over a long period as:	Very Hard	Hard	Easy	Very Easy
1) A PERSON WHO IS PATIENT.				
2) A PERSON WHO CONFORMS.				
3) A PERSON WHO WHEN STUCK WILL ALWAYS THINK OF SOMETHING.				
4) A PERSON WHO ENJOYS THE DETAILED WORK.				
5) A PERSON WHO WOULD SOONER CREATE SOMETHING THAN IMPROVE IT.				
6) A PERSON WHO IS PRUDENT WHEN DEALING WITH AUTHORITY OR GENERAL OPINION.				
7) A PERSON WHO NEVER ACTS WITHOUT PROPER AUTHORITY.				
8) A PERSON WHO NEVER SEEKS TO BEND (MUCH LESS BREAK) THE RULES.				
9) A PERSON WHO LIKES BOSSES AND WORK PATTERNS WHICH ARE CONSISTENT.				
10) A PERSON WHO HOLDS BACK IDEAS UNTIL THEY ARE OBVIOUSLY NEEDED.				
11) A PERSON WHO HAS FRESH PERSPECTIVES ON OLD PROBLEMS.				
12) A PERSON WHO LIKES TO VARY SET ROUTINES AT A MOMENT'S NOTICE.				
13) A PERSON WHO PREFERS CHANGES TO OCCUR GRADUALLY.				
14) A PERSON WHO IS THOROUGH.				
15) A PERSON WHO IS A STEADY PLODDER.				
16) A PERSON WHO COPES WITH SEVERAL NEW IDEAS AND PROBLEMS AT THE SAME TIME.				
17) A PERSON WHO IS CONSISTENT.				
18) A PERSON WHO IS ABLE TO STAND OUT IN DISAGREEMENT ALONE AGAINST A GROUP OF EQUALS AND SENIORS.				
19) A PERSON WHO IS STIMULATING.				
20) A PERSON WHO READILY AGREES WITH THE TEAM AT WORK.				
21) A PERSON WHO HAS ORIGINAL IDEAS.				
22) A PERSON WHO MASTERS ALL DETAILS PAINSTAKINGLY.				
23) A PERSON WHO PROLIFERATES IDEAS.				
24) A PERSON WHO PREFERS TO WORK ON ONE PROBLEM AT A TIME.				
25) A PERSON WHO IS METHODICAL AND SYSTEMATIC.				
26) A PERSON WHO OFTEN RISKS DOING THINGS DIFFERENTLY.				
27) A PERSON WHO WORKS WITHOUT DEVIATION IN A PRESCRIBED WAY.				
28) A PERSON WHO LIKES TO IMPOSE STRICT ORDER ON MATTERS WITHIN OWN CONTROL.				
29) A PERSON WHO LIKES THE PROTECTION OF PRECISE INSTRUCTIONS.				
30) A PERSON WHO FITS READILY INTO 'THE SYSTEM'.				
31) A PERSON WHO NEEDS THE STIMULATION OF FREQUENT CHANGE.				
32) A PERSON WHO PREFERS COLLEAGUES WHO NEVER 'ROCK THE BOAT'.				
33) A PERSON WHO IS PREDICTABLE.				

PLEASE CHECK THAT YOU HAVE ANSWERED ALL 33 QUESTIONS.

627295

NOT TO BE COPIED IN ANY WAY

Occupational Research Centre, Cornerways, Cardigan Street
Newmarket, Suffolk CB8 8HZ, United Kingdom
Tel & Fax: [UK] (0) 1638 662704. e-mail: ukinfo@kaicentre.com

Form ref. EL00 R.

Appendix I

Small Gasoline Engines Content Knowledge Test

Small Engines Test

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

1. What is the main purpose of a carburetor?
    A. store fuel
    B. clean the fuel
    C. maintain constant velocity
    D. mix fuel and air

2. What is the term for the hollow tube that houses the piston?
    A. cylinder head
    B. valve cover
    C. cylinder
    D. combustion chamber

3. What attaches the piston to the crankshaft?
    A. connecting rod
    B. crankpin
    C. rod cap
    D. piston rings

4. What three governor types are used in small gasoline engines?
    A. manual, mechanical, automatic
    B. pneumatic, mechanical, electronic
    C. hydraulic, electronic, manual
    D. automatic, pneumatic, mechanical

5. 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

6. 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

7. During which stroke 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

8. 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

9. 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

10. In simple terms, electricity is the movement of which atomic particle?
    A. proton
    B. neutrons
    C. quarks
    D. electrons

11. 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.

12. Which component of the carburetor increases the velocity of air moving through the carburetor?
    A. float
    B. venturi
    C. main jet
    D. needle valve

13. 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

14. What is the term for the pressure that moves electrons?
    A. amperage
    B. voltage
    C. resistance
    D. conductivity

15. 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

16. 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

17. What two engine components are most commonly associated with engines hunting and surging?
    A. carburetor/air filter
    B. governor/compression chamber
    C. spark plug/governor
    D. carburetor/governor

18. 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

19. 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

20. 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

21. 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

22. 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

23. What engine component physically compresses the air-fuel mix in the combustion chamber?
    A. crankshaft
    B. crankpin
    C. intake valve
    D. piston

24. What is the term for electrical current, or the rate of electron flow?
    A. amperage
    B. resistance
    C. voltage
    D. conductivity

25. 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

26. Which carburetor component ensures a constant supply of gasoline in the carburetor bowl?
    A. venturi
    B. main jet
    C. float
    D. throttle plate

27. 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

28. Identify the main structure of an engine designed to support and align internal and external components?
    A. cylinder head
    B. cylinder bore
    C. **engine** block
    D. crankcase

29. 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

30. What is used to ignite the fuel-air mix in the combustion chamber?
    A. compression
    B. electricity
    C. heat
    D. pressure

APPENDIX J

Simple Problem Scenario

Problem Scenario 1

Your neighbor has asked you to mow her lawn while she is away on vacation. She owns her own walk behind lawnmower that she said you can use. You check the oil to ensure proper level and fill the fuel tank with fresh gasoline she provided. You have properly choked the engine and have engaged the safety bail. When you pull the starter rope, the engine turns over but does not start. The mower appears to be in good shape and looks fairly new.

Directions: The engine contains a fault in one of the major engine systems required for operation. Using the information in the scenario, troubleshoot the engine and write the problem below. Also, immediately write down the time when you believe you have identified the problem.

1. Using the information give in the scenario and what you have learned about small gasoline engines, which engine system and component is likely at fault?

2. Write the problem you discovered in the space below:

At what clock time did you identify the fault: ____________________

Researcher Use: ________ minute(s)

APPENDIX K

Complex Problem Scenario

Problem Scenario 2

Your neighbor has asked you to mow her lawn while she is away on vacation. She owns her own walk behind lawnmower that she said you can use. You check the oil to ensure proper level and fill the fuel tank with fresh gasoline she provided. You have properly choked the engine and have engaged the safety bail. You repeatedly pull the starter rope and the engine finally starts. You begin mowing and the engine dies immediately. After several pulls on the starter rope, you are able to re-start the engine, but it dies as soon as you begin mowing. The mower appears to be in good shape and looks fairly new.

Directions: The engine contains a fault in one of the major engine systems required for operation. Using the information in the scenario, troubleshoot the engine and write the problem below. Also, immediately write down the time when you believe you have identified the problem.

1. Using the information give in the scenario and what you have learned about small gasoline engines, which engine system and component is likely at fault?

2. Write the problem you discovered in the space below:

At what clock time did you identify the fault: ____________________

Researcher Use: ________ minute(s)

VITA

John Joseph Blackburn

Candidate for the Degree of

Doctor of Philosophy

Thesis: ASSESSING THE EFFECTS OF COGNITIVE STYLE, CONTENT KNOWLEDGE, AND PROBLEM COMPLEXITY ON THE PROBLEM SOLVING ABILITY OF SCHOOL-BASED AGRICULTURAL EDUCATION STUDENTS: AN EXPERIMENTAL STUDY

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