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Determining the Effects of Cognitive Style, Problem Complexity, and Hypothesis Generation on the Problem Solving Ability of School-Based Agricultural Education Students

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Abstract

The purpose of this experimental study was to assess the effects of cognitive style, problem complexity, and hypothesis generation on the problem solving ability of school-based agricultural education students. Problem solving ability was defined as time to solution. Kirton's Adaption-Innovation Inventory was employed to assess students' cognitive style as either more adaptive *or* more innovative. *Students were assigned randomly, by cognitive style, to solve either a simple or complex problem in small gasoline engines. A three-way independent analysis of variance revealed that a statistically significant interaction effect between the independent variables did not exist. Additionally, the two-way interactions between cognitive style and problem complexity, and cognitive style and hypothesis generation were not statistically significant. A statistically significant interaction effect did exist, however, between problem complexity and hypothesis generation. A simple main effects test revealed the students who hypothesized their problem correctly were the most efficient at solving the problem. Future research should require students who generate an initial incorrect hypothesis to re-hypothesize prior to attempting to solve the problem. Educators should encourage students to engage in metacognitive activities, such as hypothesizing, prior to engaging in problem solving activities.*

Keywords: agricultural education; agricultural mechanics, cognitive style; problem solving; hypothesis generation; problem complexity

Introduction and Literature Review

"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 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 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 those who are creative, inventive, and can think on their feet and solve problems (MacPherson, 1998; Robinson, 2009; Robinson & Garton, 2008; Robinson, Garton, & Vaughn,

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2007). To be successful, people need to be able to "solve critical, complex problems, in challenging environments" (Kirton, 2003, p. 1).

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). Problems can be classified as well-structured or ill-structured (Jonassen, 1997). Well-structured problems are common in school settings and provide the problem solver a (a) defined initial state, (b) known goal, and (c) known operational constraints (Jonassen, 1997). In contrast, ill-structured problems may (a) not have a clearly defined initial state, (b) consist of unknown elements, (c) have more than one potential solution, and (d) be situated in more than one domain (Jonassen, 1997). Another variation in problem typology is complexity, which is defined by the "number of issues, functions, or variables involved in the problem" (Jonassen, 2000, p. 67). Problem difficulty is a function of complexity, but the two are not synonymous. Typically, problem complexity and problem structure are related; ill-structured problems tend to be more complex than well-structured problems (Jonassen, 2000).

The fundamental goal of education is to foster student learning. 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). Research has indicated that children begin to develop capacity for recognizing problem space and creating mental models for solving problems as early as four years of age (Halford, 1993). Problem space, or mental model representation, is a key process for problem solving, especially regarding technical problems (Jonassen, 2000; Newell & Simon, 1972).

Technical problem solving, or troubleshooting, 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). Prior research in troubleshooting has investigated the problem solving differences between experts and novices. Johnson (1988) and Gitomer (1988) found that experts constructed better mental models of a troubleshooting task than their novice counterparts. Similarly, Johnson (1989) reported differences in troubleshooting ability were attributed to the variety of information acquired. Other researchers have investigated the influence of individual characteristics, such as cognitive style, in the troubleshooting process. Henneman and Rouse (1984) reported cognitive styles to be good predictors of troubleshooting ability. Conversely, MacPherson (1998) reported that cognitive style was an ineffective predictor of problem solving performance.

Agricultural education scholars have also investigated problem solving, troubleshooting, and cognitive styles. Pate, Wardlow, and Johnson (2004) conducted an experimental study to investigate troubleshooting performance when utilizing the think-aloud pair problem solving (TAPPS) technique. Students who utilized TAPPS were more successful; however, no differences in time to solution were reported. Similarly, Pate and Miller (2011) conducted an experimental study to determine the effects of TAPPS on secondary students enrolled in small gasoline engine technology courses. There were no statistically significant differences found in problem solving success of students who utilized the TAPPS technique and those who worked independently. Blackburn, Robinson, and Lamm (2014) sought to determine if student's cognitive style, as defined by Kirton's (2003) Adaption-Innovation (KAI) theory, and problem complexity affected problem solving ability in the context of small gasoline engines. No statistically significant differences in time to solution were found based on cognitive style. However, a statistically significant difference in time to solution based on problem complexity was detected (Blackburn et al., 2014).

Friedel, Irani, Rhoades, Fuhrman, and Gallo (2008) sought to explore the relationships between critical thinking and problem solving in the context of Mendelian genetics. No statistically significant relationships were found between critical thinking skill and total cognitive style or critical thinking disposition. Critical thinking disposition showed no statistically significant relationship to problem solving level, nor was cognitive style found to be related to problem solving level (Friedel et al., 2008). Lamm, Rhoades, Irani, Unruh Snyder, and Brendemuhl (2011) investigated the relationships between critical thinking disposition, problem solving style, and learning styles of undergraduates who participated in a study abroad program. 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.

Using KAI (Kirton, 2003) theory and Bransford's (1984) IDEAL problem solving model as a frame, Lamm et al. (2012) explored how cognitive style influenced group problem solving of students who attended a study abroad course. Focus groups were conducted with a homogenous, adaptor group; a homogeneous, innovator group; and a heterogeneous group consisting of both adaptors and innovators. The homogeneous, innovator group progressed through all stages of the IDEAL problem solving model. 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. The heterogeneous group was able to progress through all stages of the IDEAL model, but not in a linear fashion (Lamm et al., 2012).

Theoretical Framework

This study was underpinned using Kirton's Adaption-Innovation (A-I) theory (Kirton, 1976; 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 the preference for the approach people take when solving a problem. It remains stable regardless of age or experience (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. Cognitive style is located along a normally distributed continuum, ranging from highly adaptive to highly innovative (Kirton, 2003). Individuals are neither completely adaptive nor completely innovative; however, there are common characteristics of each cognitive style. The *more adaptive* prefer problems that are more structured. They tend to work in the boundaries of the current paradigm, and prefer technical solutions (Kirton, 2003; Kirton, Bailey, & Glendinning, 1991; Lamm et al., 2012). On the opposite end of the continuum are the *more innovative* who prefer problems that are less structured. These individuals tend to become frustrated by boundaries and are less concerned with technical solutions (Kirton et al., 1991; Lamm et al., 2012).

Conceptual Frame

The conceptual framework employed in this study was Johnson's (1989) model of technical troubleshooting (see Figure 1). 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. 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). Individuals engaged in troubleshooting must have the ability to use symptom information to generate and test possible hypotheses about the faulty system (Jonassen, 2001).

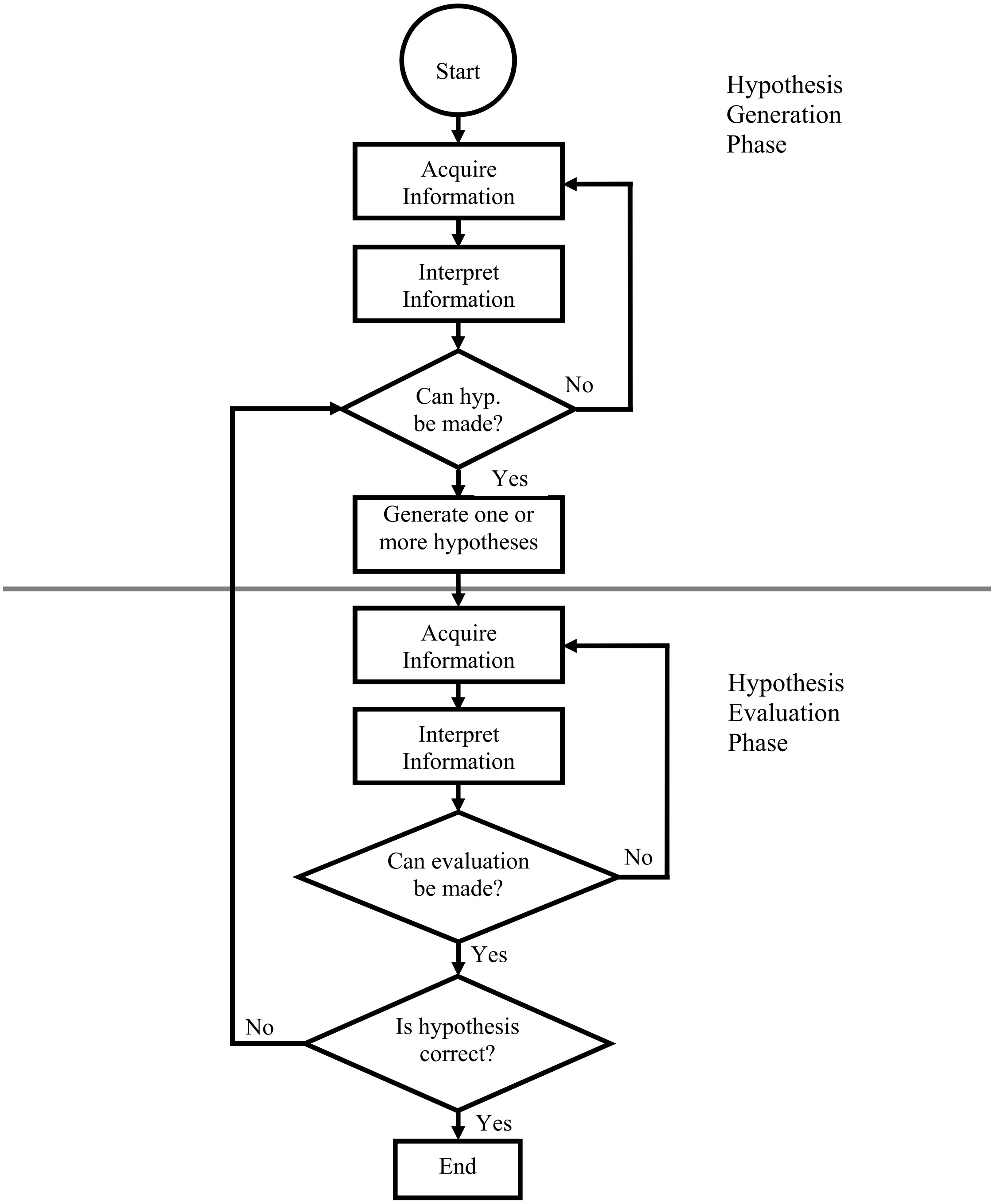

Figure 1. Technical Troubleshooting Model. Adapted from "A description of expert and novice performance differences on technical troubleshooting tasks" by S. D. Johnson, 1989, *Journal of Industrial Teacher Education, 26*(3), p. 20. Copyright 1989 by *Journal of Industrial Teacher Education.* Reprinted with permission.

If the troubleshooter is able to generate a hypothesis, he or she can then transition into the hypothesis evaluation phase of the model. If necessary, additional information 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 (see Figure 2). More successful troubleshooters are able to generate accurate hypotheses to solve problems quickly (Vasandani & Govindaraj, 1991).

MacPherson (1998) expressed concern that few studies investigated the relationship of factors related to problem solving and problem solving ability in authentic settings. Further, Blackburn et al. (2014) recommended that students' ability to generate accurate hypotheses should be investigated to determine their effects on problem solving ability. Therefore, 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 effects of cognitive style, hypothesis generation, and problem complexity on the problem solving ability of school-based agricultural education students who were enrolled in an agricultural power and technology (APT) course. 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 effects exist between problem complexity, hypothesis generation, and students' cognitive styles 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 the time required to solve problems due to the interaction of problem complexity, hypothesis generation, and cognitive styles.

$H_0$2: 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.

$H_0$3: 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.

$H_0$4: 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.

Methods and Procedures

Participant Recruitment

All agricultural education teachers in Oklahoma were afforded the opportunity to enroll in a two-day professional development workshop focused on small gasoline engines. The professional development occurred in June 2012 on the campus of Oklahoma State University. A total of 21 teachers attended the workshop. At the conclusion of the workshop, all teachers were provided 10 Briggs & Stratton® engines and researcher developed curriculum, based on the content taught in an undergraduate small gasoline engines course at Oklahoma State University, as well as information available from Briggs & Stratton®. In all, seven teachers agreed to participate in the study by signing the instructor consent form. Per IRB regulations, the teachers also were required to obtain permission from school administration to continue in the study. After the agricultural education teacher recruitment was finalized, secondary students who were enrolled in each of the seven teachers' APT courses were asked to participate in the study. Following the guidelines set forth by IRB, students were asked to sign an assent form indicating their willingness to participate in the study. In addition, parental/guardian consent was obtained for students who were minors. A total of 77 students agreed to participate in the study. Of those, 68 completed all parts of the study and 62 identified the fault in their assigned engine successfully.

Research Design

This research study employed a Completely Randomized Factorial 2x2 (CRF-22) design (Kirk, 1995). CRF designs are appropriate when researchers desire to test the effects of multiple independent variables, as well as their combined effects (Ary, Jacobs, & Razavieh, 2002). Time to solution served as the study's dependent variable and was operationalized as how many minutes each student required to identify correctly the fault in his or her assigned engine.

Teachers were provided curriculum that was developed by the researcher, which was comprised of four lessons: (a) 4-cycle theory, (b) fuel systems and carburetors, (c) electrical systems, and (d) compression. Each lesson was based on curriculum from the small engines course at Oklahoma State University, as well as information available from the Briggs & Stratton® Power Portal webpage. In addition to basic information of each engine system, each lesson contained a troubleshooting objective to inform the students of potential faults associated with each system, as well as symptoms an engine would exhibit if the fault was present. Further, video training modules from Briggs & Stratton® were embedded within each electronic presentation. These modules included (a) fuel systems, (b) compression, (c) ignition systems, (d) carburation diagnostics, (e) compression diagnostics, and (f) troubleshooting ignition systems. Finally, worksheets were provided with each lesson for students to complete. To ensure fidelity, the teachers collected and provided the completed lesson worksheets to the researcher as evidence that each lesson was taught.

To collect data, the researcher made two site visits to each participating school. During the first visit, students were administered the personal characteristics questionnaire and Kirton's (1976) Adaption-Innovation Inventory (KAI) to determine cognitive style. The KAI consisted of 32 items with a score range from 32 to 160. The theoretical mean for the KAI is 96 (Kirton, 2003). According to the theory, scores below the mean are considered *more adaptive*, while scores greater than the mean are considered *more innovative*. Kirton (2003) reported several studies that have been completed to determine the reliability of the KAI. The KAI was developed to be used with adults with work experience, but it has been administered successfully to students as young as 13 years of age (Kirton, 2003). Internal reliability coefficients of the KAI Inventory have ranged from 0.74 to 0.86 in populations of teenagers (Kirton, 2003). Due to the extensive research undertaken to establish the reliability of the KAI, a pilot test was not conducted. However, post-hoc reliability yielded a Cronbach's alpha of .71, indicating acceptable reliability for the population in question.

The researcher made the second site visit to all participating schools once the curriculum had been taught. At that time, students were assigned randomly to treatment groups by cognitive style (see Figure 2). Each student was provided a small gasoline engine with a preset fault and a written scenario describing the symptoms the engine would exhibit if a person 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.

Prior to engaging in troubleshooting, students were required to generate a written hypothesis regarding their perception of the engine's fault on their problem scenario sheet. For consistency, the engines utilized for the treatment of the study were of the same make and model the teachers used at the professional development session.

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

Validity of research findings is achieved when data interpretation “matches its proposed use” (Creswell, 2012, p. 159). One of the greatest concerns of scholars who design and conduct experimental research is controlling threats to internal validity (Gay, Mills, & Airasian, 2009). Seven of the eight threats to internal validity, described by Campbell and Stanley (1963), were not applicable to the study or were controlled for by random assignment. Experimental mortality, however, may have impacted the study. The entire sample of this study was 77 students from seven different schools in Oklahoma; yet, only 68 completed all parts of this research study fully.

Data related to research question one were analyzed using frequencies and percentages. To answer research question two a three-way, independent analysis of variance (ANOVA) was employed to determine the main and interaction effects of the independent variables (Field, 2009). Both statistical and practical significance were reported for this study. An alpha level of .05 was set *a priori* to determine statistical significance. Partial eta squared (η_p^2), was utilized to determine the practical significance of the ANOVA model and was interpreted using the guidelines described by Cohen (1988) where a *small* effect size is 0.0099, a *medium* effect size is 0.0826, and a, *large* effect size is 0.20. Additionally, Cohen’s *d* statistic was calculated to determine practical significance of the simple main effects test and was interpreted as *small* (0.20), *medium* (0.50), and *large* (0.80) effects (Kirk, 1995).

Findings

Research question one sought to identify characteristics of the students enrolled in an APT course at their respective high schools during the 2012–2013 academic year. In all, 59 students were male and nine were female. Regarding age of the students, 17 were 15 years old, 19 were 16 years old, 14 were 17 years old, 17 were 18 years old, and one student was 19 years old. Regarding academic classification, one student was a freshman, 33 were sophomores, eight were juniors, and 26 were seniors. Caucasian was the ethnicity selected most frequently (n = 59). Eight self-selected Native American as their ethnicity and one student indicated he or she was Hispanic.

The second research question sought to determine the effects of cognitive style, problem complexity, and hypothesis generation on time to solution. Regarding cognitive style, 31 (45.50%) of the students were *more adaptive* and 37 (54.41%) were *more innovative*. Prior to the troubleshooting task, students were asked to formulate a hypothesis for what they believed to be the fault. Regarding students assigned randomly to solve the simple problem, 20 generated correct hypothesizes, and 13 hypothesized incorrectly (see Table 1). Regarding students assigned randomly to solve the complex problem, 20 generated a correct hypothesis, and nine (38.24%) hypothesized incorrectly. The most efficient problem solvers were those who generated a correct hypothesis for the simple problem (*M* = 6.45 minutes; *SD* = 5.66). Those who generated an incorrect hypothesis for the complex problem required the longest amount of time to identify the fault (*M* = 26.22 minutes; *SD* = 5.47). Regarding cognitive styles, the more innovative students who generated a correct hypothesis for the simple problem required an average of 4.17 minutes (*SD* = 3.81) to identify the solution. The more innovative students who generated an incorrect hypothesis for the complex problem required an average of 27.86 minutes (*SD* = 3.44).

Table 1

Mean Time to Solution for Treatment Conditions Problem Complexity, Hypothesis Generation and Students' Cognitive Style (n = 62)

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
		Total	20.80	9.04	20
	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

Prior to employing a three-way independent analysis of variance (ANOVA), Levene's test of error variances was calculated to ensure 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. Per the ANOVA test, the three-way interaction effect of problem complexity, hypothesis generation, and cognitive style yielded an F(1, 54) = 0.19, p = 0.67, indicating a lack of statistical significance (see Table 2). Therefore, the researcher failed to reject the first null hypothesis.

Table 2

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*	η_p^2
Problem Complexity	961.58	1	961.58	17.41	0.00	.244
Hypothesis Generation	902.44	1	902.44	16.34	0.00	.232
Cognitive Style	13.02	1	13.02	0.24	0.63	-
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	-
Cognitive Style * Hypothesis Generation	188.52	1	188.52	3.41	0.07	-
Problem Complexity * Hypothesis Generation * Cognitive Style	10.19	1	10.19	.19	0.67	-
Error	2983.04	54	55.24			
Total	24795.00	62				

Analyses of the two-way interaction effects were required because of a lack of statistical 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 second null hypothesis was rejected. The effect size for the interaction effect of problem complexity and hypothesis generation was between medium and large ($\eta_p^2 = 0.116$). Regarding the interaction effect for problem complexity and cognitive styles, the ANOVA yielded a F(1, 54) = 0.28, p = .60. Therefore, the researchers failed to reject the third null hypothesis. Finally, the ANOVA yielded and F(1, 54) = 3.41, p = 0.07 for the interaction of cognitive styles and hypothesis generation (see Table 2). As such, the researchers failed to reject the fourth null hypothesis.

A simple main effects test was employed to understand the interaction of problem complexity and hypothesis generation better (Kirk, 1995). The comparison based on hypothesizing correctly was determined to be statistically and practically significant with a F(1, 54) = 37.90, p = .00, d = 1.90 (see Table 3). Regarding the incorrect hypothesis comparison, the test was determined not to be statistically significant with a F(1, 54) = 0.83, p = 0.37.

Table 3

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	-
	Error	2983.04	54	55.24			

Conclusions

The typical student participant was Caucasian, male, between 15 and 18 years of age and either a sophomore or senior with a *more innovative* cognitive style. The more innovative students were more likely to generate an incorrect hypothesis for the simple problem and a correct hypothesis for the complex problem. Johnson (1988) 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). Most students were able to solve their assigned problem, regardless of their cognitive style or the complexity of the problem. This is consistent with the A-I theory that states that everyone has the ability to solve problems, regardless of cognitive style (Kirton, 2003). Similarly, Blackburn et al. (2014) reported that most presevice agricultural education teachers were able to solve problems regardless of complexity or cognitive style. However, Pate and Miller (2011) 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.

In all, 33 students solved the simple problem scenario successfully. Students who generated a correct hypothesis solved the simple problem nearly 15 minutes before those who generated an incorrect hypothesis. The students who were *more innovative* and generated a correct hypothesis were able to solve the problem most efficiently. The students who were *more innovative* and hypothesized incorrectly were the most inefficient at troubleshooting the simple problem. In addition, the students who were *more adaptive* and generated an incorrect hypothesis were able to solve the simple problem quicker than their more innovative counterparts. Overall, these findings align with previous research suggesting those who generate accurate hypotheses are able to make better and quicker decisions when solving problems (Johnson, 1989; Vasandani & Govindaraj, 1991).

A statistically significant two-way interaction effect existed between problem complexity and hypothesis generation. On further analysis, 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, regardless of problem complexity. This finding aligns with Johnson (1988; 1989) who concluded that the greatest difference in troubleshooting performance was attributable to information the problem solvers acquired and hypotheses they generated. This supports the importance of students employing metacognitive processes during the problem solving process. The main effect of cognitive style was determined not to be statistically significant. This is consistent with the KAI (Kirton, 2003) theory that states cognitive style is not a measure of performance, but rather an indicator of problem solving preference.

Recommendations for Practice

Employers in the agricultural industry desire employees who can solve problems efficiently and effectively (Robinson & Garton, 2008; Robinson et al., 2007). As such, school-based agricultural educators should encourage students to engage in relevant, hands-on problem solving activities whenever possible. Teachers also should stress the importance of having students hypothesize before they encounter a problem solving activity, as this study supports the notion that generating correct hypotheses affects both efficiency and effectiveness. Teachers who feel uncomfortable teaching problem solving should seek in-service training opportunities that focus on teaching methodologies such as inquiry-based learning, experiential learning, or the problem solving approach to teach students how to solve problems accurately.

Recommendations for Research

Additional research is warranted to investigate further 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 interaction effect exists regarding hypothesis generation and problem complexity in the context of small gasoline engines. Future 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. Therefore, teachers should be prepared to guide students to make better decisions when they are confronted with challenging problems. Specifically, students who generate an incorrect hypothesis initially should be encouraged to write alternative hypotheses and test each individually.

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. In addition, replications of this study 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 considered in future studies to account for additional error variance. Research also 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 to assess the interaction effect of cognitive style and hypothesis generation when troubleshooting problems of differing complexity.

KAI theory states clearly that all people can solve problems, regardless of cognitive style (Kirton, 2003). However, in certain 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 continue to focus on how cognitive style influences the amount of time required to solve problems. 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 within 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 TAPPS method were more successful than those students working individually when troubleshooting small gasoline engines. Therefore, 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 cognitive style groups when troubleshooting. Employing TAPPS could 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).

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