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Investigating the Effects of Cognitive Style Diversity on the Hypothesis Generation and Troubleshooting Ability of Undergraduate Students Enrolled in an Introductory Agricultural Mechanics Course at Louisiana State University

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Abstract

Problem solving has been regarded as one of the most important cognitive skills in everyday life. The complexity of problem solving in technical areas is a critical component to developing the problem solving abilities of agricultural education students. This study grounded in Kirton's Adaptation-Innovation Theory (A-I Theory), sought to identify the effects of cognitive style diversity on the time to solution and hypothesis generation ability of undergraduate students enrolled in an agricultural mechanics course at Louisiana State University during the spring semester of 2018 (n = 17) and spring semester of 2019 (n = 15). Students were divided into three groups based on their Kirton's Adaptation-Innovation Inventory (KAI) scores into three cognitive style diversity groups including (a) homogenous innovative, (b) homogenous adaptive, and (c) heterogenous. Overall, the more heterogeneous cognitive style diversity group was able to solve the problem more quickly as well as being the most successful group to hypothesize correctly, with the homogeneous innovator group being the slowest to reach conclusion. From the results of this study, it is recommended that educators consider cognitive styles when grouping students in undergraduate courses that are heavily laboratory based.

Keywords: problem solving; troubleshooting; agricultural mechanics; hypothesis generation

Introduction

Problem solving is defined as "any goal-directed sequence of cognitive operation" (Anderson 1980, p. 257) and has been regarded as one of the most important cognitive skills in everyday life (Jonassen, 2000). We encounter and solve problems daily as part of a routine that is integrated into our personal and professional lives. This ability has been identified as a critical skill for employment in the agricultural industry, specifically within technical areas (Alston et al., 2009; Graham, 2001; Robinson & Garton, 2008; Robinson et al., 2007). Despite the importance of problem solving, students today often do not solve meaningful problems as a part of their curricula (Jonassen, 2000). For problem solving to develop successfully, there must be social, cultural, and/or intellectual value placed upon the task (Jonassen, 2000).

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One of the most commonly experienced types of problem solving we encounter, especially within the realm of technical education, is troubleshooting (Jonassen, 2003). Troubleshooting can be broadly defined as determining what causes a malfunction in a machine or process where the problem is situated into a real-world situation (Herren, 2015; Morris & Rouse, 1985). In order for a troubleshooter to be successful, he/she must be able to apply domain knowledge and utilize cognitive skills to identify and repair faults in a system (Custer, 1995; Jonassen, 2000; Jonassen & Hung, 2006; Schaafstal et al., 2000). Specifically, troubleshooting requires the individual to employ prior knowledge and experiences to interact with the complex system effectively (Johnson & Flesher, 1993).

However, problem solving and troubleshooting is not as straight forward as whether an individual can or cannot solve complex issues. Individual differences, such as cognitive style, technical knowledge, and problem solving methods employed can influence an individual's ability to successfully solve problems (Jonassen, 2000). Dyer and Osborne (1996) researched the use of teaching methods on ability of students with varying learning styles to solve problems. This study indicated students who were taught using the problem solving approach had significantly higher problem solving ability than those taught through the subject matter approach (Dyer & Osborne, 1996). While no statistically significant differences were present within this study between students with similar learning styles, all benefited from the problem solving approach. Similarly, Torres and Cano (1994) found learning style had an effect on students being successful in specific situations and environments.

Within agricultural education, an area that is heavily focused on hands-on learning and problem solving in a multitude of authentic learning environments, researchers have investigated students' problem solving in a variety of contexts. Pate et al. (2004) and Pate and Miller (2011) investigated agriculture students' abilities to solve small gasoline engines related problems when implementing Think-Aloud Paired Problem Solving (TAPPS) and reported no statistically significant differences. Similarly, Blackburn and Robinson (2016) found the greatest difference in time to solution among high school students troubleshooting small gasoline engines was their ability to hypothesize correctly. They further analyzed differences in problem solving ability and reported no differences based on students' cognitive style (Blackburn & Robinson, 2016). Blackburn et al. (2014) reported differences in problem solving ability of students based on the cognitive style and problem complexity. Additionally, Lamm et al. (2012) conducted a qualitative analysis of undergraduate agriculture students who had completed an international experience in Costa Rica. Upon returning to the U.S., the students were grouped purposely by cognitive style and tasked with solving a complex, ill-structured problem. Overall, it was reported that the students' ability to solve the problem differed depending on the cognitive style diversity of the groups.

Theoretical/Conceptual Framework

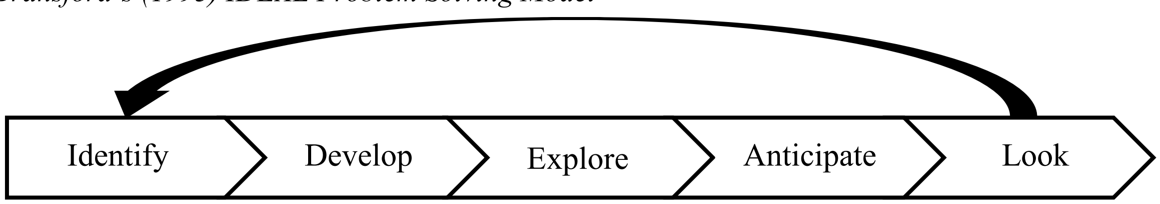
The theoretical framework for this study was grounded in Kirton's (1976, 2003) Adaptation-Innovation Theory (A-I Theory). This theory is founded on the belief that every individual is creative and can solve problems (Kirton, 2003); however, it is important to note that the A-I theory is only concerned with the *how* an individual solves problems. This theory allows an individual to understand their cognitive style and how they go about solving everyday problems (Kirton, 2003). According to Kirton (2003) cognitive style is "the preferred way to which people respond to and seek to bring about change" (p. 43), therefore resulting in problem solving and cognitive style differences between individuals. Foundationally, the A-I theory presumes individual cognitive style is predetermined from the early stages of life and remains stable, regardless of a person's previous experiences or age.

According to this theory, individual cognitive style falls between adaptation and innovation on a continuum from 32–160 as measured by Kirton's Adaption-Innovation Inventory (KAI; Kirton, 2003). This type of scale does not allow any individual to be purely an adaptor or purely an innovator. Kirton (2003) identified key distinctions in preferred problem solving style between the more adaptive and more innovative individuals. Specifically, individuals whose tendencies were more adaptive preferred a more structured environment when solving problems. However, more innovative individuals preferred an environment that allowed them to think more fluidly.

When solving problems individually, people are able to rely on their preferred style to accomplish the task at hand. However, once individuals are placed into a group or team to problem solve, they soon face what Kirton (2003) calls the *Problem A and Problem B Situation*. Essentially, Problem A is the task at hand, whether it be creating a presentation or troubleshooting a small engine. Problem B, however, is the cognitive style differences that are present in the group. Homogenous groups of adaptors or innovators have to the ability to easily cope with minimal cognitive style differences and can be quite successful completing small-scale, narrow projects (Kirton, 2003; Lamm et al., 2012). Heterogenous teams of adaptors and innovators have the greatest potential of success with large-scale projects due to their diverse cognitive styles, however, if the group is unable to manage and cope with these differences, Problem B can grow larger and overshadow Problem A (Kirton, 2003). Individuals with KAI scores that are less than 10 points apart have a better chance that Problem B will not be an issue, however, as score differences increase, the cognitive style diversity can become an issue if they are unable to cope or if bridgers are absent (Kirton, 2003). Per Kirton, 2003, a *bridger* is an individual whose KAI score falls between the others in the group, they can have the ability to bridge the cognitive gap between individuals with different styles to help complete Problem A (Kirton, 2003).

Conceptually, this study was underpinned by Bransford's (1984) IDEAL problem solving model. At the foundational level, this model draws focus on the importance of how an individual utilizes information to build new tools that will help the individual solve problems (Bransford, 1993). More specifically, this model can be utilized to address individual awareness on the problem solving process and therefore, allow the individual to reflect and analyze. The model, developed by Bransford (1986), has five essential steps (a) Identify, (b) Define or Develop goals, (c) Explore, (d) Anticipate or Act, and (f) Look and Learn and is utilized to understand how individuals move through the problem solving process (see Figure 1).

Figure 1
Bransford's (1993) IDEAL Problem Solving Model



Note. Adapted from "The Influence of Cognitive style diversity on Group Problem Solving Strategy" by AJ Lamm, C Shoulders, GT Roberts, TA Irani, LJ Snyder, & J Brendemuhl, 2012, *Journal of Agricultural Education, 53*(1), p.19. Copyright 2012 by Journal of Agricultural Education. Reprinted with Permission.

Problem solving and troubleshooting have been researched in agricultural education for some time. Researchers have utilized the TAPPS method (Pate et al., 2004; Pate & Miller, 2011) and cognitive styles (Blackburn & Robinson, 2016) to explain differences in problem solving ability, with no differences reported. However, Lamm et al. (2012) reported differences, qualitatively, in problem solving based on cognitive style diversity groups and Blackburn and Robinson (2016) reported that hypothesis generation had an effect on time to solution of individual students. Therefore, the principle question that arose after the review of the literature was: What effect does cognitive style diversity have on undergraduate students' ability to hypothesize and solve a small gasoline engines problem while working in a team?

Purpose and Objectives

The primary purpose of this study was to investigate the effects of cognitive style diversity on hypothesis generation and troubleshooting ability of undergraduate students enrolled in an agricultural mechanics course at Louisiana State University while working in a team. This research supports the American Association of Agricultural Education's National Research Agenda Priority 4: Meaningful, Engaged Learning in All Environments. Specifically, this research addresses question three, "How can delivery of educational programs in agriculture continually evolve to meet the needs and interests of students?" (Edgar et al., 2016, p. 39). The following objectives guided this study:

1. What effect does team cognitive style diversity have on the hypothesis generation ability of undergraduate students enrolled in an introduction to agricultural mechanics course when solving small gas engine problems?
2. What effect does team cognitive style diversity have on the troubleshooting ability, as measured by time to solution, of undergraduate students enrolled in an introduction to agricultural mechanics course to solve a small gasoline engine problem correctly?

Methods

This research study was completed as part of a larger research project that investigated the effect of cognitive style diversity on students' abilities to solve problems related to small gasoline engines. This portion of the research project is focused specifically on the effect of cognitive style diversity on the hypothesis generation and troubleshooting ability of students to solve a small engines problem correctly. Because of the nature of this study, a preexperimental one-group pretest-posttest was utilized to collect data (Campbell & Stanley, 1963; Salkind, 2010). Preexperimental research methodology is commonly used in educational research when random sampling is not possible (Campbell & Stanley, 1963). In this approach, all individuals are assigned to the experimental group and are observed at two time points (Campbell & Stanley, 1963; Salkind, 2010). Changes from the pretest to the posttest determine the results from the intervention.

Population/Sample

The population of this study was all students enrolled in an introductory agricultural mechanics course at Louisiana State University during the spring semester of 2018 (n = 17) and spring semester of 2019 (n = 15). Overall, one student in the spring semester of 2018 did not complete enough course material to be included in the study, therefore, the accessible population totaled n = 31. In compliance with the Institutional Review Board (IRB), students were notified of this research on the first day of class and were given the opportunity to not participate. All students in this research study were over the age of 18 and provided signed consent to participate in this research. Demographically, the majority of the participants were 19–21 years of age (n = 25, f = 80.6%) and female (n = 54.8, f = 17). Also, the majority of them were classified as sophomores (n = 13, f = 41.9) and majored in Agricultural and Extension Education (n = 13, f = 41.9).

To test for homogeneity, independent samples T-tests were employed to determine if statistically significant differences existed between the students enrolled in introductory agricultural mechanics in the spring of 2018 and 2019 semesters based on age (t = 2.197, df = 29, p = 0.596) and cognitive style (t = 0.006, df = 29, p = 0.109). Also, a Chi-Square test was utilized to determine if differences existed between the two semesters based on gender (X^2 = .313, df = 1, p = .576). The analysis revealed that our population from both semesters was homologous and subsequently the data were merged for further analysis.

Course Structure

On the first day of the small gasoline engines unit, the KAI and 30-item pretest were administered to the students. Due to the flipped nature of this course with the incorporation of Team-

Based Learning (TBL) the students were grouped purposively by cognitive style into teams of four for the duration of the unit. The TBL layout described by Michelsen and Sweet (2008) was employed for the course. The course readings, videos, worksheets, and Individual Readiness Assurance Tests (IRATs) and Team Readiness Assurance Tests (TRATs) were all developed by the researcher.

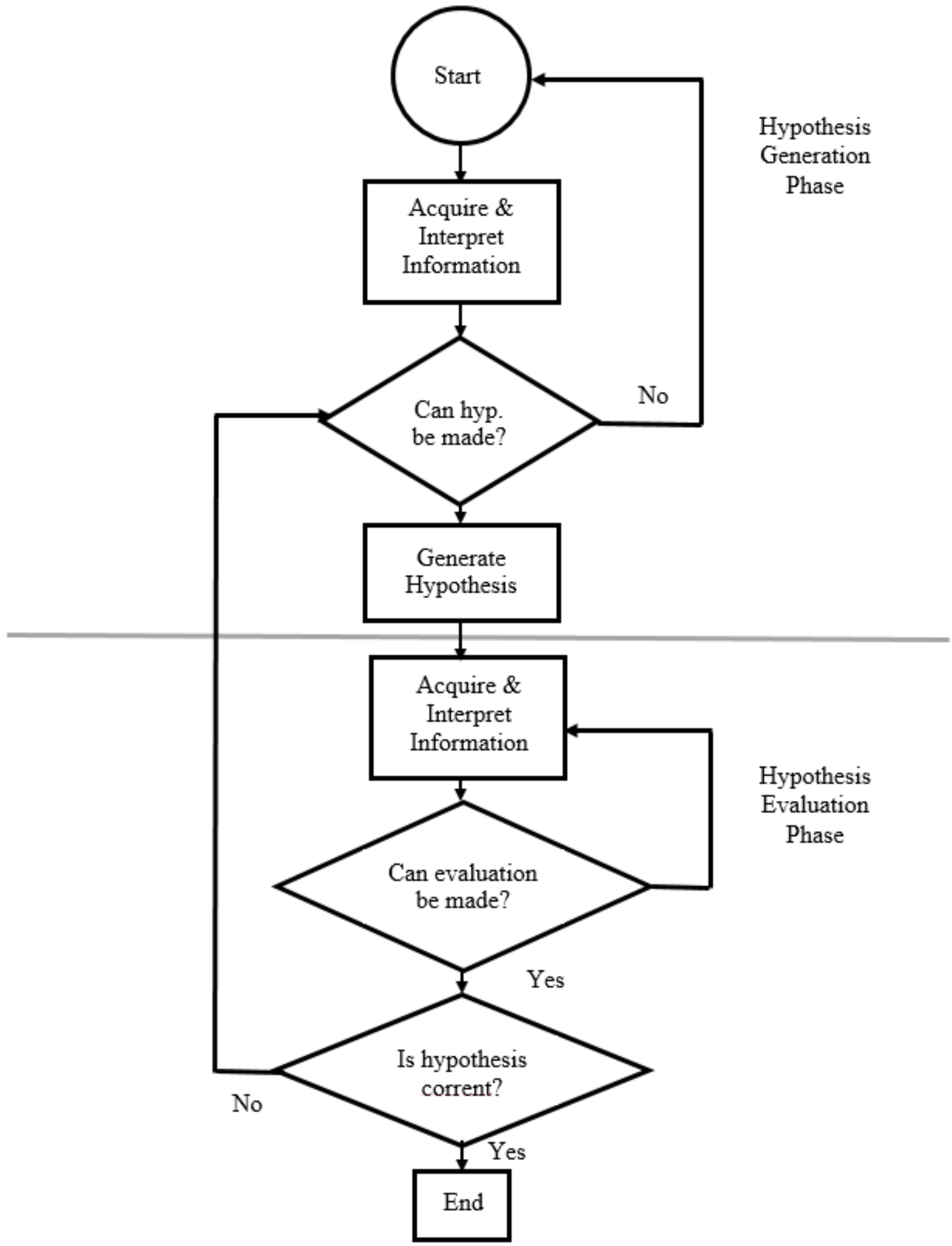
Within the small gasoline foci, five individual modules were constructed including (a) small engine tool and part ID, (b) 4-cycle theory and fuel, (c) ignitions and governor system, (d) cooling/lubrication system, and (f) troubleshooting. After every module, students completed an IRAT to determine their content knowledge retained. After completing the IRAT, the students would then join their assigned team and complete the TRAT. Each team of four would come together during class time to complete the TRATs, where the students were allowed to collaborate with other team members to come to agreements on items they may have gotten incorrect. The goal of completing the IRAT before the TRAT is to ensure that all group members of the team contribute equally. After the TRAT, the remain class time was dedicated to completing laboratory based activities and assignments. For the purpose of laboratory activities, each team of four was further split into dyads (i.e., Team 1A, Team 1B) to complete the hands-on learning activities.

Instrumentation

Kirton's Adaptation-Innovation Inventory (KAI) was used to determine the students' cognitive style (Kirton, 2003) and that information was used to group students into teams. The students were grouped, based on their KAI scores into three cognitive style diversity groups including (a) homogenous innovative, (b) homogenous adaptive, and (c) heterogenous. The KAI consists of 32 items that ask specific questions about the individuals preferred way to learn. Per the theory, individuals who score 95 or below are considered more adaptive, while individuals who score is 96 or above are considered more innovative. The internal reliability of this instrument has been measured and collected through multiple studies with individuals from varying backgrounds and demographics. From the wide use of the instrument, internal reliability coefficients have ranged from 0.83 – 0.91 (Kirton, 2003).

In order to collect data on hypothesis generation ability, Johnson's (1989) technical troubleshooting model was utilized as a guide to create the small gasoline engines troubleshooting packet. The packet consisted of three sections that included (a) hypothesis, (b) engine symptoms, and (c) troubleshooting process. Inside each packet were three sets of hypothesis sheets to ensure that if the group hypothesized incorrectly the first time they could use a different sheet to start over. This protocol was developed to follow the technical troubleshooting's model process of hypothesis generation (see Figure 2). One of the researchers kept a master time on a smartphone stopwatch application and recorded time to solution for each team. Time was not stopped and recorded until the students had successfully identified and corrected the fault. Specifically, the fault was an overtightened exhaust valve.

Figure 2
Technical Trouble Shooting Model (Johnson, 1998)



Data Analysis

During the initial data screening it was discovered that data related to the dependent variables were not normally distributed. Due to this violation of statistical assumptions, a Kruskal-Wallis test was employed to compare the effect between cognitive style diversity and time to solution. The Kruskal-Wallis test is a nonparametric test equivalent to a parametric one-way ANOVA. Further, Mann-Whitney U tests were analyzed *post hoc* to determine if differences existed between the cognitive style diversity groups. An *a priori* significance level of .05 was utilized to interpret the statistical significance of the analysis because this study is comparing two independent groups with no control; therefore, no adjustments to the critical value needed to be made (Lewis-Beck et al., 2004). Pearson's correlation coefficient *r* was calculated after the Mann-Whitney U tests to determine the effect size and standardize the measure of the size of effect observed (Field, 2009). Per Field (2011), an *r* value of .10 represents a small effect, which explains only 1% of the total variance. An *r* value of .30 represents a medium effect and explains 9% of total variance. Finally, an *r* value of .50 represents a large effect and accounts for 25% of the variance (Field, 2011)

To answer research question one, descriptive statistics, specifically, the frequency and percentage were utilized. Hypothesis generation ability was operationalized as whether or not they correctly hypothesized on the first attempt. Three independent Pearson's Chi-square tests were utilized to determine the relationship between hypothesis generation ability and problem solving ability have on cognitive style diversity. Research question two also utilized descriptive statistics, including mean, frequency, and standard deviation to describe the individual small gasoline engine teams and their time to completion.

Findings

Each of the small gasoline engines groups were given one laboratory period (e.g., 110 minutes) to generate a hypothesis and perform the troubleshooting activity. The teams were asked to hypothesize the possible problem and solution (see Table 1). Hypothesis generation ability was operationalized as correct or not correct on their first hypothesis. The homogeneous innovative cognitive style diversity group consisted of all teams who were more innovative, which included team one. Based on hypothesis generation one, all four individuals hypothesized incorrectly. The homogeneous adaptive cognitive style diversity group consisted of teams who more adaptive, which include team two, team four, team six, and team seven. Within this cognitive style diversity group, seven (41.18%) of the 17 individuals correctly hypothesized and 10 (58.82%) hypothesized incorrectly on hypothesis one. Finally, the heterogeneous cognitive style diversity group consisted of teams who were made up of a more innovative and more adaptive individual, which included team three and team five. Of the members in this cognitive style diversity group, six (60%) hypothesized correctly the first time, while four (40%) hypothesized incorrectly.

Table 1
Hypothesis Generation Ability Based on Cognitive Style Diversity Groups for Students in Introduction to Agricultural Mechanics

Cognitive style diversity	*Hypothesis Generation 1*			
	Correct		*Not Correct*	
	f	*%*	*f*	*%*
Homogeneous Innovative	0	0	4	100
Homogeneous Adaptive	7	41.18	10	58.82
Heterogeneous	6	60	4	40
Overall Total	13	41.94	18	58.06

Three independent Pearson Chi-Square tests were employed to determine the effect that cognitive style diversity had on hypothesis generation ability. The analysis from these tests revealed no statistically significant difference between the homogeneous adaptive cognitive style diversity group and the heterogeneous χ^2 (.894) = 1, *p* = .345. Also, no statistically significant difference was found between the homogeneous adaptive group and the homogeneous innovative group χ^2 (2.471) = 1, *p* = .116. However, a statistically significant difference was found between the homogeneous innovative group and the heterogeneous group χ^2 (4.200) = 1, *p* = .040 based on hypothesis generation ability (see Table 2).

Table 2
Pearson Chi-Square Test Between Cognitive Style Diversity Groups For Students Enrolled In Introduction To Agricultural Mechanics (N=31)

Groups	Value	*df*	*p*
Homogeneous Adaptive vs. Heterogeneous	.894	1	.345
Homogeneous Adaptive vs. Homogeneous Innovative	2.471	1	.116
Homogeneous Innovative vs. Heterogeneous	4.200	1	.040

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

Table 3
Introduction to Agricultural Mechanics Small Engine Sub-Grouping Time to Successful Completion of the Troubleshooting Problem

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

A non-parametric one-way ANOVA (e.g., Kruskal-Wallis) was utilized to determine the statistical significance of the effect cognitive style diversity had on time to solution (see Table 4). The Kruskal-Wallis test determined that there was a statistically significant difference in time to solution by cognitive style diversity, *H* (8.206) = 2, *p* = .017. Effect size was calculated to standardize the measure of the effect observed. The analysis of the effect size revealed an *r* value of .70, which is interpreted as a large effect (*r* > .50).

Table 4
Overall Kruskal-Wallis Test for Differences in Time to Solution by Cognitive Style Group for Students Enrolled in Introduction to Agricultural Mechanics

H	*df*	*p*
8.206	2	.017

In order to compare groups, Mann-Whitney U tests were employed *post hoc* to determine if a difference existed between two independent groups. Three independent Mann-Whitney U tests were conducted between homogeneous adaptive and homogeneous innovative, homogeneous adaptive and heterogeneous, and homogeneous innovative and heterogeneous. The Mann-Whitney U test between homogeneous adaptive and heterogeneous groups determined there was no statistically significant difference between the two groups based on time to solution and cognitive style diversity (*p* = .580), however, a statistically significant difference was found between the homogeneous adaptive and homogeneous innovative group (*p* = .023) and homogeneous innovative and heterogeneous group (*p* = .004) (see Table 5). Effect size was also reported to standardize the measure of the effects observed between all statistically significant cognitive style diversity groups. An *r* value of .61 was revealed between the homogeneous adaptive and homogeneous innovative, which is a large effect (*p* > .50). Also, between the homogeneous innovative and heterogeneous group revealed an *r* value of .63, which is also interpreted as a large effect (*p* > .50).

Table 5
Mann-Whitney U Tests of Differences in Time to Solution by Cognitive Style Diversity Groups for Students Enrolled in Introduction to Agricultural Mechanics (n=31)

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

Conclusions/Discussion

During the troubleshooting exercise, students were asked to create a written hypothesis based on the information they collected when trying to start their respective engines. Regardless of cognitive style diversity, the teams who generated the correct hypothesis on the first attempt were more likely to solve the problem quicker; whereas, the more times the team hypothesized, the more time it took to complete the troubleshooting task. This conclusion is consistent with previous research by Blackburn and Robinson (2016), which indicated that regardless of cognitive style and problem complexity, students who generated a correct hypothesis were more efficient problem solvers. Similarly, Blackburn and Robinson (2017) indicated the majority of students were able to identify and hypothesize regardless of cognitive style, however, more adaptive students were more likely to hypothesize correctly on the simple problem; whereas, the more innovate students were more likely to solve a complex problem. Previous research by Johnson (1989) also concluded that students who generated a correct hypothesis are more likely to be able to correctly solve problems.

Overall, 31 students completed and solved the troubleshooting problem successfully regardless of cognitive style. In terms of group cognitive style diversity, the heterogeneous group solved the problem on average 13 minutes faster than the homogeneous adaptive group and 48 minutes faster than the homogeneous innovative group. The homogeneous adaptor group, however, solved the problem on average 34 minutes and 45 seconds faster than the homogeneous innovator group. Therefore, students in the heterogeneous cognitive style diversity group were more efficient problem solvers. Also, a difference amongst cognitive style diversity groups and time to solution was identified between the homogeneous adaptive and homogeneous innovative groups, as well as the homogeneous innovative and heterogeneous groups. Further analysis revealed the homogeneous adaptive and heterogeneous groups had no differences between cognitive style diversity and time to solution. This conclusion also supports the adaptation-innovation theory that indicates each cognitive style has its own distinct characteristics when problem solving, which can affect how efficiently they are able to solve problems (Kirton, 2003). This finding also supports the findings of Lamm et al. (2012) who reported, qualitatively, that homogeneous innovator groups struggle to solve complex problems, perhaps due to their ability to proliferate ideas.

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

Implications

The heterogeneous cognitive style diversity group was able to solve the problem on average 24 minutes quicker than any of the other groups. However, the homogeneous adaptive group was able to solve the problem almost 35 minutes faster than the homogeneous innovator group. These substantial time differences between cognitive style diversity groups led to further questions about why those differences exist. It is possible that the differences in how each of the cognitive style groups go about solving problems was the primary factor in time to completion. Kirton (2003) stated that groups of homogeneous adaptors tend to excel in problem solving when the problem is structured and has boundaries. Whereas, the more innovative individuals tend problem solve more efficiently with less structure and challenge those set boundaries (Kirton, 2003). However, Kirton (2003) also stated the most successful types of problem solvers are heterogeneous groups who are able to manage their wide variety of cognitive style diversity because they are able to utilize both cognitive styles (Kirton, 2003). Therefore, per the theory, it could be beneficial to purposefully group students based on cognitive style into heterogeneous groups.

The most successful cognitive style diversity group at hypothesizing correctly on hypothesis one, was the heterogeneous group. The least successful group on a correct hypothesis one, was the homogeneous innovative group. Per the A-I theory, the more adaptive individuals tend to solve problems more effectively that are structured and have boundaries, while the more innovative excel at problems with no boundaries and little structure (Kirton, 2003). Perhaps, the heterogeneous groups were more successful at hypothesis generation because they were able to utilize and manage the wide cognitive style diversity range; therefore, broadening their problem-solving ability scope (Kirton, 2003).

In Johnson's (1989) technical troubleshooting model, the students are required to hypothesize once and if they indicate their initial hypothesis to be incorrect, they are to go back to phase one and hypothesize again. This process is continual until the troubleshooter correctly hypothesizes the fault. It is possible that the homogeneous innovative cognitive style diversity group, were least successful at hypothesizing correctly the first time because they proliferated too many ideas and were unable to identify and recognize the problems; therefore, they struggled to generate a hypothesis (Bransford, 1993; Johnson, 1989; Kirton, 2003) or they generated multiple hypotheses from symptom problems and were then unable to make a decision on the correct one. Pate and Miller (2011) found that students who utilized groups to problem solve, took an average of four minutes longer to solve problems. This could indicate that conflict within groups may can actually hinder the problem solving process when compared to allowing individuals to problem solve independently.

Overall however, the teams who hypothesized correctly on hypothesis one were more likely to have a quicker time to solution. It is possible that the heterogeneous groups were better at problem solving because they solved problems more linearly and were able to utilize all the steps in Bransford's (1993) IDEAL model, allowing them to be efficient problem solvers. Perhaps one of the reasons the homogeneous adaptive and innovative groups were less successful at solving the problem on hypothesis one and had slower times to solution was because they got lost in the details and had a harder time moving through all the steps in the IDEAL model, which created gaps in their problem solving process and led to errors (Brandsford, 1993).

Recommendations for Practice

From the results of this study, it is recommended that educators assess students' cognitive styles and then purposefully group students into heterogeneous cognitive style diversity groups in undergraduate agricultural courses that are heavily laboratory based. Kirton (2003) concluded that heterogeneous groups can be more effective and efficient problem solvers if they are able to manage their wide range of cognitive style diversity. Based on this research, educators should consider adopting active learning environments, like TBL, to help promote the development of problem-solving skills. It has become increasingly important for educators to adapt to new pedagogies in order to meet the demands of the 21st century (Blackburn et al., 2014) because the agricultural industry desires employees who are able to effectively and efficiently problem solve (Robinson & Garton, 2008). Based off the results of this study, the ability for students to hypothesize correctly has increased their problem solving effectiveness and efficiency.

It is also recommended that educators create more questions or application activities that are specifically designed to help develop an individual's procedural knowledge. Much of the literature on troubleshooting reiterates the importance of developing an individual's conceptual and procedural knowledge (Anderson, 1980; Johnson & Flesher, 1993; Johnson, 1989; Jonassen, 2003; Hegarty, 1991, McCormick, 1997). Therefore, it is important for educators to be developing the students *how to* knowledge when dealing with problem solving tasks.

Recommendations for Research

Additional research is warranted to further investigate the effects of cognitive style diversity on hypothesis generation and time to solution on the problem-solving ability of undergraduate students. Specifically, it is recommended that this study be replicated to increase the sample size increase statistical power and, perhaps, normalize the data. Further replication of this study is also warranted to study the effects of cognitive style diversity on hypothesis generation and time to solution. To fully be able to account for extraneous variables, full randomization of treatment and control groups are needed in order to make the findings generalizable to a larger demographic.

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

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

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