

An Investigation of Factors that Influence the Hypothesis Generation Ability of Students in School-Based Agricultural Education Programs when Troubleshooting Small Gasoline Engines

J. Joey Blackburn¹ & J. Shane Robinson²

Abstract

The purpose of this study was to determine if selected factors influenced the ability of students in school-based agricultural education programs to generate a correct hypothesis when troubleshooting small gasoline engines. Variables of interest included students' cognitive style, age, GPA, and content knowledge in small gasoline engines. Kirton's Adaption-Innovation Inventory was employed to assess cognitive style and a researcher developed criterion-referenced test was utilized to determine small gasoline content knowledge. Students were assigned randomly, by cognitive style, to generate a hypothesis for either a simple or complex small gasoline engine problem. A similar number of students were able to correctly hypothesize the fault in their assigned engine regardless of cognitive style. However, differences were noted between the more adaptive and more innovative students. A binary logistic regression revealed that as cognitive style score increased, the odds of generating a correct hypothesis decreased. Additionally, older students were more likely to generate an incorrect hypothesis. Teachers should encourage students to hypothesize when engaged in problem solving activities, but should be aware of individual differences such as cognitive style.

Keywords: Troubleshooting; problem solving; cognitive style; hypothesizing;

Introduction and Literature Review

There is no argument that problem solving is an important component of human existence. Kirton (2003) referred to problem solving as the key to life, and Popper (1999) wrote a book titled, *All Life is Problem Solving*. There is, however, debate in the literature as to the definition of problem solving, the processes of problem solving, and whether problem solving is an educational goal or a method of instruction (van Merriënboer, 2013). Chi and Glaser (1985) defined problem solving as, "a situation in which you are trying to reach some goal, and must find a means for getting there" (p. 229). Further, Jonassen (2000) added that there must be social, cultural, or intellectual value to serve as motivation for solving problems.

Problems differ in complexity, which is a function of the number of issues and variables present, how connected the variables are to one another, and how stable they are over time (Funke, 1991). Additionally, problems vary in structure. Well-structured problems are typical of those found in schools. These problems feature (a) known rules, (b) constraints, (c) principles the

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problem solver utilizes to achieve the goal, and (d) normally have a single correct answer (Jonassen, 2000). Ill-structured problems, on the other hand, tend to be more complex and occur in everyday and professional life (Jonassen, 2000). Often, these do not have well defined goals, operations, and constraints, and may not have a single correct answer (Jonassen, 1997). They also may require the problem solver to employ knowledge across more than one content domain (Jonassen, 2000). Problems often are defined as being domain-specific, meaning that problems may require a certain type of knowledge to solve (Hegarty, 1991). According to Jonassen (2001) real-world problems are typically situated within a specific context and are considered ill-structured. Troubleshooting is one example of problem solving that is situated in a specific context (Jonassen, 2000).

Troubleshooting is a subset of 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). Simply, troubleshooting is the attempt to locate the reason for a malfunction in a given system (Morris & Rouse, 1985). On the continuum, troubleshooting occurs between well-structured and ill-structured problems (Jonassen, 2000). Troubleshooting is primarily a cognitive task that requires the troubleshooter to process a multitude of information while he or she searches for one or more faults in a system (Jonassen & Hung, 2006; Schaafstal & Schraagen, 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) while using their “creativity, ingenuity, and inventive thought processes” (MacPherson, 1998, p. 1).

Knowledge is a prerequisite of problem solving (Gitomer, 1988; Hegarty, 1991; Johnson, 1988; 1989; Jonassen, 2000; 2001; Larkin, McDermott, Simon, & Simon, 1980; Nickerson, 1994; Schunk, 2008; Simon, 1979; Zimmerman & Campillo 2003). There are, however, several types of knowledge that influence an individual’s ability to solve problems. Domain knowledge refers to basic, theoretical knowledge about the system to be troubleshot (Jonassen & Hung, 2000). Domain knowledge is an important condition of the beginning troubleshooter and assists the experienced troubleshooter in developing deep connections among systems (Johnson, Flesher, & Chung, 1995; Jonassen & Hung, 2006; MacPherson, 1998). However, research has indicated that domain knowledge alone is not an effective predictor of troubleshooting performance (Johnson, Flesher, Jehng, & Ferej, 1993). Further, Johnson et al. (1993) reported no statistically significant differences between post-test examination scores between high and low performing troubleshooters. Similarly, Schaafstal and Schraagen (2000) determined that an instructor of radar theory was an ineffective troubleshooter of radar systems, further perpetuating Jonassen and Hung’s (2006) fundamental question of “what kinds of knowledge do novices need to construct during the transition from novice to competent performer?” (p. 80).

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 context. 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” that leads to “conceptual understanding” (McCormick, 1997, p. 143). In contrast, procedural knowledge assumes knowing *how* to perform tasks (Hegarty, 1991; McCormick, 1997).

Other research in the troubleshooting ability of individuals has focused on differences between expert and novice problem solvers and differences in individual characteristics. Johnson (1989) described differences in the performance of experts and novices on troubleshooting tasks

related to gasoline powered electric generators. Experts tended to seek specific information through technical evaluation, and novices tended to seek superficial, sensory information. Gitomer (1988) utilized three experiments to determine individual differences in the troubleshooting ability of expert and novice troubleshooters regarding electronics. Overall, Gitomer (1988) concluded that the experts were able to develop mental models that represented systems much more accurately than the novices, who tended to become distracted by trivial features of the problem (Gitomer, 1988). The experts utilized prior knowledge gained from past experiences in fault diagnosis (Jonassen & Hung, 2006; Konradt, 1995).

Problem Solving Research in Agricultural Education

Scholars in agricultural education have conducted research to understand problem solving and troubleshooting better. Friedel, Irani, Rhoades, Fuhrman, and Gallo (2008) explored the relationships between critical thinking and problem solving in the context of Mendelian genetics involving undergraduate students. In their study, the cognitive style of the students was assessed using the Kirton Adaption-Innovation Inventory (KAI). However, neither critical thinking disposition nor cognitive style was related to problem solving level (Friedel et al., 2008).

Using Kirton's (2003) Adaption-Innovation theory and Bransford's (1984) IDEAL problem solving model as a frame, Lamm et al. (2012) conducted focus group interviews to investigate how cognitive style influenced group problem solving of students who attended a study abroad course in Costa Rica. The authors concluded that the homogenous adaptor group was unable to solve the problem because they spent so much time focused on the details of the problem. The homogenous innovator group was able to solve the problem, but not in a linear fashion. Instead, they tended to act out on potential ideas before thinking them through thoroughly. Finally, the heterogeneous group of adaptors and innovators was able to work together to identify key problem aspects, create goals as a group, and think about ideas prior to acting them out, which is as an attribute of adaptors and innovators working together and achieving balance (Lamm et al., 2012).

Pate, Wardlow, and Johnson (2004) conducted an experimental study to investigate undergraduate students' ability to troubleshoot small gasoline engines when utilizing the think-aloud pair problem solving (TAPPS) technique. They reported no statistically significant differences in time to solution between those who employed the TAPPS technique and the control group (Pate et al., 2004). Pate and Miller (2011a) sought to determine the effects of TAPPS on secondary students enrolled in either agricultural or industrial education courses focused on small gasoline engine technology. Their results indicated no statistically significant differences existed in the problem solving success of students who utilized the TAPPS technique versus those who worked independently. Further, Pate and Miller (2011b) conducted an interpretive analysis of audio recording of students who utilized the TAPPS technique. It was compared the metacognitive statements of students who solved a compression related small gasoline engine problem successfully using TAPPS, with those who were unsuccessful. They concluded that the TAPPS technique was inappropriate for use with secondary students because of their lack of domain specific knowledge (Pate & Miller, 2011b).

Blackburn, Robinson, and Lamm (2014) conducted a study to investigate the problem solving ability of undergraduate students enrolled in a small gasoline engines course. The KAI was employed to determine the cognitive style of the students as being either *more adaptive* or *more innovative*. The authors found the more innovative students who were assigned the simple problem were the most efficient problem solvers, and the more innovative students assigned the complex problem were the least efficient.

Blackburn and Robinson (2016) investigated the effects of cognitive style, problem complexity, and hypothesis generation on the small gasoline engines troubleshooting ability of school-based agricultural education students. They reported students who generated correct hypotheses were the most efficient problem solvers, regardless of the complexity of their assigned problem. Regardless of the vast amount of literature on problem solving in agricultural education, there is a lack of information regarding factors that affect students' abilities to generate a correct hypotheses during troubleshooting, which is a key aspect to the problem solving process (Custer, 1995; Jonassen, 2000; MacPherson, 1998).

When dealing with a new situation, problem solvers must use any prior knowledge of the system and gather additional information to formulate hypotheses (Johnson, 1988). Specifically, when individuals engage in solving problems, they must generate and test their hypotheses effectively (Jonassen, 2001). Generating a correct hypothesis helps the problem solver to identify the fault in a system efficiently (Jonassen, 2000).

Theoretical Framework

Situated cognition served as the theoretical framework of this study (Greeno, Collins, & Resnick, 1992). The foundation of situated cognition is that all cognitive processes are situated in contexts, both physical and social (Greeno, 1989; Schunk, 2008). "Situated cognition emphasizes the importance of context in establishing meaningful linkages with learner experience and in promoting connections among knowledge, skill, and experience" (Choi & Hannafin, 1995, p. 54). Additionally, learning is influenced by the interaction of numerous processes (Schunk, 2008). For example, learning is connected with motivation: positive experiences with instruction can increase motivation and learners who are motivated may seek additional instruction (Schunk, 1995). Situated cognition addresses the notion that learning occurs in authentic contexts, and performance assessments should be employed as an authentic measure of student achievement (Greeno et al., 1992; Schunk, 2008).

Situated cognition does not address problem solving as a separate component of the theory; rather, it assumes that problems arise and are situated in specific contexts (Kirsh, 2009). Further, learning experiences, such as problem solving activities, should pique students' interest and hone their ability to reason (Greeno et al., 1992). Additionally, the situated view of problem solving emphasizes the interaction of cognition and various situations, rather than a more mathematical approach, as seen in information processing models (Greeno, 1989). Instead of applying heuristics, the situated context view focuses on the problem solver becoming deeply familiar with the context and structure of the problem at hand, then utilizing the information to derive a solution (Greeno, 1989). Although the situated cognition view of problem solving can be perceived as less linear than other approaches, the process of generating and evaluating ideas and hypotheses of potential solutions remains vital (Kirsh, 2009). The problem context is more important than employing general problem solving skills since it is the context that drives the idea generation process. Therefore, the number of potential ideas or hypotheses the problem solver may generate tends to be context dependent (Kirsh, 2009).

Conceptual Framework

Conceptually, this study was framed using Johnson's (1989) Technical Troubleshooting Model (see Figure 1). The crux of the model is an individual's ability to generate one or more hypotheses. The model is defined by two distinct phases: the hypothesis generation phase and the hypothesis evaluation phase (Johnson, 1989). During the first phase, individuals must acquire and interpret information prior to generating a hypothesis.

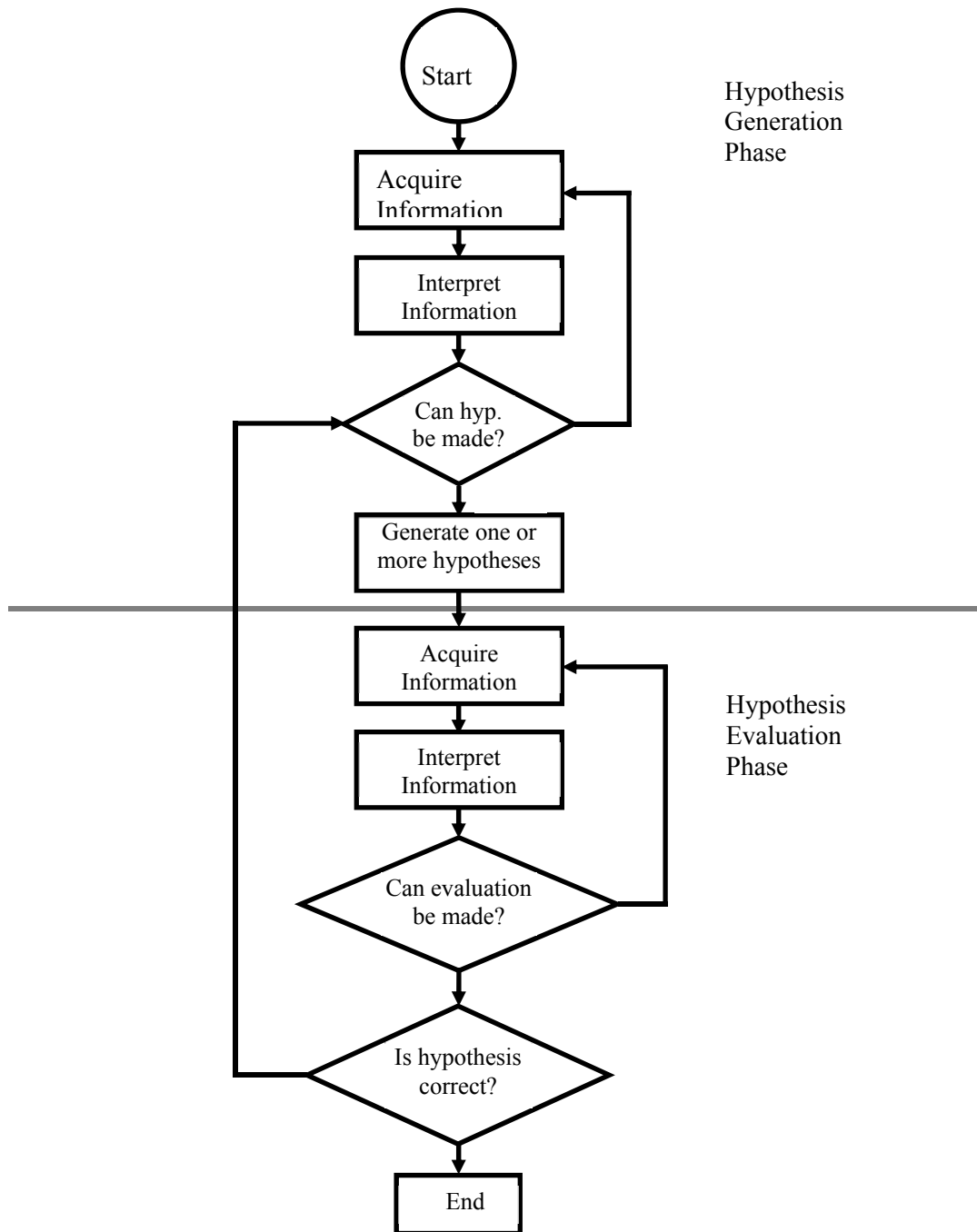


Figure 1. Technical Troubleshooting Model. Adapted from “A description of expert and novice performance differences on technical troubleshooting tasks” by S. D. Johnson, 1989, *Journal of Industrial Teacher Education*, 26(3), p. 20. Copyright 1989 by *Journal of Industrial Teacher Education*. Reprinted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

Both internal and external sources of information are utilized to generate hypotheses (Johnson, 1989). Declarative and procedural knowledge within long-term memory comprise the internal information (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 a system operates, procedural knowledge is achieved when the troubleshooter knows how to perform tests and employs problem solving procedures, and strategic knowledge is when the troubleshooter comprehends how and when to employ said procedures (Jonassen, 2001). The troubleshooter must then synthesize the information and determine if hypotheses can be generated (Johnson, 1989). Once a hypothesis has been generated, it must be evaluated. Hypothesis evaluation occurs through acquiring and interpreting additional information. Once the hypothesis is evaluated, the troubleshooter makes a decision to confirm or disconfirm the hypothesis. If the hypothesis is confirmed, 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). The ability to generate accurate hypotheses quickly is a characteristic of successful troubleshooters (Vasandani & Govindaraj, 1991).

The purpose of this research aligns closely with the AAAE National Research Agenda, specifically Research Priority Area 3: Sufficient Scientific and Professional Workforce that Addresses the Challenges of the 21st Century (Roberts, Harder, & Brashears, 2016). Problem solving has been identified consistently as a skill employers desire from new employees (Association of Career and Technical Education, 2010; Slusher, Robinson, & Edwards, 2011; Stripling & Ricketts, 2016). Deepening our understanding of factors that may influence school-based agricultural education students' ability to develop hypotheses when troubleshooting will help address this research priority area.

Purpose and Objectives

The purpose of this study was to determine if selected factors influenced school-based agricultural education students' ability to generate a correct hypothesis when troubleshooting small gasoline engines. Specifically, the factors of interest included (a) age, (b) grade point average (GPA), (c) cognitive style, and (d) performance on a content examination. The following research objectives guided the study.

1. Describe the small gasoline engines content knowledge of school-based agricultural education students.
2. Describe the hypothesis generation ability of school-based agricultural education students based on cognitive style.
3. Explain the influence of age, GPA, cognitive style, and performance on a content examination on school-based agricultural education students' ability to generate a correct hypothesis.

Methods

The data associated with this study were collected as a component of a larger research project that sought to determine if differences existed in problem solving ability of school-based agricultural education students in the area of small gasoline engines (Blackburn, 2013). Secondary agricultural education programs were selected based on teacher participation in a two-day small gasoline engines workshop held on the campus of Oklahoma State University in June 2012. Teachers who participated in the workshop were given an opportunity to volunteer to participate in this study. Nine teachers agreed to participate and seven completed all parts of the study.

During the workshop, the teachers were engaged in approximately 12 hours of small gasoline engines instruction provided by a Briggs & Stratton® technician trainer. At the completion of the workshop, each teacher was provided nine small gasoline engines and curriculum. The curriculum was comprised of four lessons including (a) 4-cycle theory, (b) fuel systems and carburetors, (c) electrical systems, and (d) compression. These lessons were based on information from the Briggs & Stratton® PowerPortal webpage and curriculum from the small gasoline engines course at Oklahoma State University. A troubleshooting objective was included in each lesson to ensure students were familiar with identifying engine fault states. Additionally, the teachers provided completed lesson worksheets and quizzes as evidence the content was taught (i.e., fidelity of the treatment).

Once the semester began, two site visits were made to each school. During the first site visit, Kirton's Adaption-Innovation Inventory (KAI) was administered to determine the cognitive style of the students. Also, student personal and educational characteristics were collected using a researcher created questionnaire. The second site visit was conducted after the teachers had taught the curriculum to their students. During this visit, a 30-item researcher created criterion-referenced test was administered to students to determine their content knowledge in small gasoline engines. The students were then assigned to either the simple or complex problem group, and were provided a scenario that described engine symptoms that would occur if they had tried to start it. Specifically, the simple problem was a closed spark plug gap, and the complex problem was debris within the carburetor's main jet. Oklahoma State University IRB approved this study under the condition that the students would not actually start the engines. The students were required to generate a written hypothesis on the scenario sheet regarding which engine system was at fault. Students were not told whether their hypothesis was correct, but were allowed to engage in the problem solving activity regardless. Later, the statements were coded as correct or incorrect, based on information on the Briggs & Stratton® PowerPortal webpage.

The study utilized a completely randomized factorial (CRF) 2x2 design where students ($n = 77$) were assigned randomly to generate a hypothesis for either a simple or complex small gasoline engine problem. In all, 68 students enrolled in courses taught by the volunteer teachers completed all parts of the study. A total of 41 students completed the simple problem, and 27 completed the complex problem. A discrepancy existed in the number of students completing the simple and complex problems due to students missing portions of the treatment intervention and/or being absent during the troubleshooting activity.

Instrumentation

The instrumentation consisted of a researcher created demographics questionnaire, the KAI, a 30-item criterion-referenced test, and the students' hypotheses. The demographics section consisted of questions to determine the students' (a) age, (b) grade level, and (c) GPA. The KAI is comprised of 32 items designed to assess cognitive style as more adaptive or more innovative. Scores on the KAI can range between 32 and 160, with lower scores indicating more adaptive and higher scores indicating more innovative. The more adaptive students prefer structure when solving problems. These individuals are able to work efficiently within the bounds of their current paradigm and have a tendency to prefer technical solutions. The more innovative students prefer less structure and can feel constrained when working in a rigid environment (Kirton, 2003). These individuals do not prefer technical solutions and proliferate ideas when engaged in problem solving activities (Kirton, 2003).

Several studies have been conducted to determine the reliability of the KAI. Kirton (2003) reported reliability estimates for populations of teenagers ranging from 0.74 to 0.86. Post-hoc

reliability yielded a Cronbach's alpha of 0.71 for this sample of students. Regarding hypotheses generated by students, they were deemed correct if the major engine system at fault was identified appropriately.

The criterion-referenced test was developed by the researcher based on curriculum from the Oklahoma State University small engines course, as well as information available on the Briggs & Stratton® PowerPortal webpage. The specific format chosen for the test was multiple-choice, consisting of four options. 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 the Eight Factors Necessary for Establishing Reliability of Criterion-referenced Tests, as Identified by Wiersma and Jurs (1990), and How They Were Addressed

| Factor | How Factors were Addressed |
|---------------------------|---|
| 1. Homogeneous items | Items were of the same font size and style. |
| 2. Discriminating items | Varying difficulty of items. |
| 3. Quantity of items | 30 multiple-choice items. |
| 4. High quality test | Format consistency verified by the panel of experts |
| 5. Clear directions | Directions were read aloud and 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. |

The test was evaluated for face and content validity by a panel of experts, including three agricultural education faculty members and one faculty member in agricultural engineering who taught the small gasoline engines course at Oklahoma State University. 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 its administration to students.

Data Analysis

Data associated with objectives one and two were analyzed via descriptive statistics, including means, standard deviations, percentages, and frequencies. Binary logistic regression was

employed to meet the third objective of the study. Binary logistic regression is utilized when the outcome variable is categorical in nature (Field, 2009). Regarding this research study, the outcome variable was whether or not a student generated a correct hypothesis for his or her assigned problem. Nagelkerke's R^2 was calculated to determine the practical significance of the overall regression model. Nagelkerke's R^2 is a useful measure of practical effect of logistic regression because the value ranges between zero and one, making interpretation similar to the classical R^2 utilized to measure effect size in multiple regression (Field, 2009; Nagelkerke, 1991).

Findings

A small gasoline engines test was administered to a total of 68 students after their respective teachers had taught them the content. The overall mean of the test was 18.63 (62.01%) items correct out of a possible 30 (see Table 2). The students with lowest mean ($M = 17.44$; $SD = 5.13$) were the more innovative students who generated an incorrect hypothesis. The more innovative students who hypothesized their assigned problem correctly earned highest mean ($M = 19.89$; $SD = 4.70$).

Table 2

Content Knowledge Test Means 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 |

Note. * Indicates percent correct out of a possible 30 items

In all, 34 students were assigned the simple problem, of which 20 (58.82%) generated a correct hypothesis (see Table 3). Of those who hypothesized the simple problem correctly, 14 (41.18%) were more adaptive and six (17.64%) were more innovative. A total of 14 (41.18%) students generated an incorrect hypothesis. Of those who hypothesized the simple problem incorrectly, five (14.71%) were more adaptive and nine (26.47%) were more innovative (see Table 3).

Table 3

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

| Cognitive Style | Correct | % | Incorrect | % |
|-----------------|---------|-------|-----------|-------|
| More Adaptive | 14 | 41.18 | 5 | 14.71 |
| More Innovative | 6 | 17.64 | 9 | 26.47 |
| Total | 20 | 58.82 | 14 | 41.18 |

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

A total of 34 students were assigned to generate a hypothesis for the complex problem. Overall, 21 (61.80%) students hypothesized the complex problem correctly (see Table 4). Eight (23.53%) more adaptive and 13 (38.24%) more innovative students generated a correct hypothesis. A total of 13 students (38.24%) generated an incorrect hypothesis. Four (11.76%) more adaptive and nine more innovative (26.47%) students hypothesized the complex problem incorrectly (see Table 4).

Table 4

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

| Cognitive Style | Correct | % | Incorrect | % |
|-----------------|---------|-------|-----------|-------|
| More Adaptive | 8 | 23.53 | 4 | 11.76 |
| More Innovative | 13 | 38.24 | 9 | 26.47 |
| Total | 21 | 61.80 | 13 | 38.24 |

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

Table 5 provides a summary of the predictor variables utilized in the logistic regression. The average age of the students was 16.46 ($SD = 1.13$). The average score on the small engines content knowledge test was 18.63 ($SD = 5.29$) with a range of six to 28 questions correct out of 30. Finally, student's cognitive style ranged from 66 to 119, with an average of 94.60 ($SD = 12.44$). The students' GPA ranged from 2.50 to 4.00, with a mean of 3.38 ($SD = 0.48$) (see Table 5).

Table 5

Summary of Predictor Variables

| Variable | Minimum | Maximum | M | SD |
|---------------------|---------|---------|-------|-------|
| Age | 15 | 18 | 16.46 | 1.13 |
| Test Score | 6 | 28 | 18.63 | 5.29 |
| Cognitive Style | 66 | 119 | 94.60 | 12.44 |
| Grade Point Average | 2.50 | 4.00 | 3.38 | 0.48 |

Prior to interpreting the logistic regression model, the Hosmer and Lemeshow Goodness of Fit (HLGF) test was calculated to determine how well the model fit the data (see Table 6). Specifically, the HLGF ($\chi^2_{HL} = 6.77$) was determined to be not statistically significant ($\alpha > .05$), indicating acceptable fit of the model.

Table 6

Results of the Hosmer and Lemeshow Goodness of Fit Test

| | χ^2 | df | p |
|--------|----------|----|-----|
| Step 1 | 6.77 | 7 | .45 |

Overall, the regression model predicted 81.1% of the cases correctly versus 59.5% predicted correctly in the initial model. Nagelkerke's R^2 was calculated to determine practical significance of the overall regression model. The value of Nagelkerke's R^2 was 0.55. Table 7 depicts the results of the binary logistic regression with correctness of a generated hypothesis as the outcome variable. GPA and test score were determined not to be statistically significant predictors at the $\alpha = .05$ level. The Wald statistics for cognitive style ($Wald = 2.52$; $p = .01$) and age ($Wald = 5.37$; $p = .02$) were found to be statistically significant, indicating the variables were significant predictors in the overall model.

Table 7

Logistic Regression of Hypothesis Generation

| Variable | B | SE | Wald | df | p | Odds Ratio |
|-----------------|-------|------|------|----|-----|------------|
| GPA | -2.94 | 1.85 | 2.52 | 1 | .11 | 0.05 |
| Cognitive Style | -0.13 | 0.05 | 5.93 | 1 | .01 | 0.88 |
| Age | -2.34 | 1.01 | 5.37 | 1 | .02 | 0.10 |
| Test Score | 0.11 | 0.10 | 1.26 | 1 | .26 | 1.12 |

Note. $\alpha = .05$

Discussion and Implications

Hegarty (1991) outlined the importance of various types of knowledge in the mechanical problem solving process. The present study revealed that content knowledge, as measured on the criterion-referenced test, was not a statistically significant predictor of generating a correct hypothesis. This aligns with the study by Johnson et al. (1993) who reported that domain knowledge was an ineffective predictor of electronics troubleshooting ability, with no statistically significant differences between high and low performing troubleshooters. However, in the Johnson et al. (1993) study, both groups had means over 82% on the examination. Regarding the present study, the overall mean on the small engines test would barely be considered passing in most school settings. What, then, is the role of domain knowledge in the problem solving process, specifically when troubleshooting in the mechanical domain? If problem solving is the overarching objective of instruction, should educators even bother teaching theoretical concepts? Perhaps domain knowledge is an important foundation on which to build conceptual and procedural knowledge that is important in the problem solving process (Hegarty, 1991; McCormick, 1997).

From a situated cognition perspective, generating a hypothesis in the context of small gasoline engines would be considered authentic in nature (Greeno et al., 1991; Kirsh, 2009). Nearly equal numbers of students generated correct and incorrect hypotheses for their assigned problem. However, when viewing the data based on cognitive style, the more adaptive were more successful when hypothesizing the simple problem. The more innovative generated more correct hypotheses for the complex problem. The results of this study indicate that over 60% of the students were able to hypothesize correctly.

Cognitive style and age of the students were determined to be statistically significant predictors in the logistic regression model. Both variables had odds ratios below 1.00, indicating as the predictor increased the outcome likelihood decreased (Field, 2009). In other words, as scores on the KAI increased (i.e., students were more innovative), the chances of generating a correct hypothesis decreased. Kirton (2003) stated that people who are more innovative tend to proliferate ideas in the problems solving process. Kirton (2003) stressed that while neither cognitive style is superior during the problem solving process; the more innovative can struggle when solving simple problems because of the number of ideas that can be generated when hypothesizing. Therefore, perhaps the more innovative students in this study overthought their simple problem by mentally forming multiple hypotheses.

Similarly, as student age increased the likelihood of hypothesizing correctly decreased. Although age has rarely been utilized as a variable in research on problem solving, Johnson (1988) found that the greatest difference in expert and novice troubleshooting was the types of information gathered and hypotheses generated. It is unlikely that any of these students are experts in small gasoline engines; however, older students should have more experiences in school settings and could have been exposed to more problem solving situations. Intuitively, it would be expected that older students would perform better. However, the results of this study do not support this notion.

Scores on the content knowledge examination were not a statistically significant predictor in this model. Previous research has been very clear about the importance of various types of knowledge in the problem solving process (Hegarty, 1991; Larkin et al., 1980; McCormick, 1997; Newell & Simon, 1972; Simon, 1979). It stands to reason that knowledge about a topic would lead to better hypotheses. Yet, the findings of this study do not support this notion.

Recommendations

Additional research is needed to clarify the role of cognitive style in the troubleshooting process, specifically when hypothesizing. Further, requiring students to utilize think-aloud

protocols, as described by Pate et al. (2004), could allow for an estimation of metacognitive procedures utilized when hypothesizing. This would allow for the determination of the types of information sought (Johnson, 1988) and insight as to whether the hypothesis generated is an educated guess or simply a shot in the dark. Additionally, post-troubleshooting reflection sessions should be held in future studies to understand student success and failure more deeply. Further, Johnson (1988) highlighted the importance of the type of information sought during the problem solving process. Utilizing the TAPPS technique in future research could help researchers understand what types of information troubleshooters seek when solving problems.

More research also is needed regarding the influence of content knowledge on troubleshooting. Items on the criterion-referenced test used in this study should be analyzed to determine if differences exist based on higher and lower orders of thinking (Bloom, Engelhart, & Krathwohl, 1956). Further, individual items should be examined to determine if content related directly to the problems' context impacted hypothesizing ability. Items on the test should also be examined to determine the type of knowledge being measured. Prior research has suggested that domain knowledge is an ineffective predictor of troubleshooting ability (Johnson et al., 1993). Additional studies should consider gauging students' procedural knowledge when troubleshooting. Perhaps performance assessments could be employed to assess procedural knowledge rather than domain or conceptual knowledge (Hegarty, 1991).

Additional student characteristics should be collected and added to statistical models. In the present study age was a negative predictor of hypothesis generation ability. Additional variables such as number of agricultural courses completed or critical thinking style improve predictive ability. Student GPA was collected for this study, however students were asked to self-report their GPA and much of the data associated with the variable was missing. Future studies should include GPA obtained from school officials to, hopefully, increase the quantity and quality of data.

Practically, educators should note the importance of hypothesizing in the problem solving process. These metacognitive strategies can greatly impact student learning and critical thinking (Schunk, 2008). Situated cognition stresses the importance that real-life contexts have in motivating students to learn (Schunk, 1995). Employing troubleshooting activities in agricultural education is one such way for teachers to incorporate authentic situations into their curricula. Learners must be allowed to practice their hypothesizing and troubleshooting skills to build and refine their experiential knowledge and move from novices to more capable troubleshooters (Jonassen & Hung, 2006). Even though individual student differences are out of the control of educators, the literature is clear that all students can solve problems, regardless of their cognitive style (Kirton, 2003). Differences do arise, however, in the manner in which students progress through the problem solving process. As such, understanding how students with differing cognitive styles think through problems can assist teachers when working with diverse learners.

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