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ABSTRACT

A randomized post-test-only experimental design with a counter-balanced internal replication was used to determine the effects of thinking-aloud pair problem solving (TAPPS) on the troubleshooting performance of college students in a power technology course. The experimental results were stable across two troubleshooting tasks. Students who participated in the pair problem solving groups were significantly more successful ($p \leq .05$) at troubleshooting engine faults than were students in the control groups. Among students who successfully completed the troubleshooting tasks across both groups, there were no significant differences in time required for completion. These findings indicate that the use of pair problem solving may be an important step in the development of metacognitive skills among students in technological troubleshooting.

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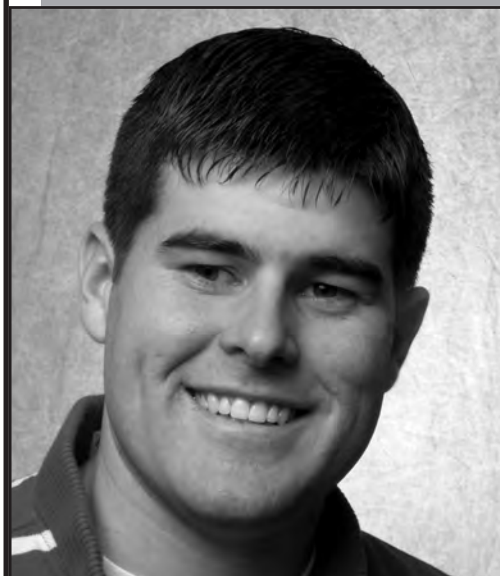
MEET THE STUDENT-AUTHOR



Michael L. Pate

I am a native of Fayetteville, Ark., and a December 2003 Graduate of the Dale Bumpers College of Agricultural, Food, and Life Sciences where I majored in Agricultural Education, Communication and Technology. I have received scholarships from the University of Arkansas Band, Gamma Sigma Delta, Mr. & Mrs. Cy Carney, Daughters of Demeter, and the Dale Bumpers College of Agricultural, Food, and Life Sciences. I am involved with Alpha Tau Alpha the Agricultural Education Honor Fraternity, Collegiate FFA/4H, Gamma Sigma Delta honor society, Alpha Zeta Honor Society, Phi Kappa Phi Honor Society, and the Agricultural and Extension REPS. I am also a Dale Bumpers Alumni Senior Ring Scholar Recipient.

I am currently completing certification to teach Agricultural Education in the state of Arkansas and attending Graduate School here at the University of Arkansas for a Masters of Science in Agricultural Education.

This has been a valuable, and educational experience. I worked on this project with my faculty advisors Dr. Don Johnson and Dr. George Wardlow. We submitted the paper to the Southern Region of Agricultural Education Researchers Association Conference 2004, and the National Agricultural Education Researchers Association Conference 2004 where it was accepted as the only undergraduate research project at the conferences.

I hope to pursue a Doctorate in Agricultural Education at The Ohio State University. I am very grateful to Dr. Johnson and Dr. Wardlow for their assistance and guidance with the project.

INTRODUCTION

All students, including those enrolled in colleges of agriculture, will encounter problems of increasing technological complexity over the course of their lives. The ability to effectively and efficiently solve these problems will become increasingly important. How efficient are undergraduate agriculture students in solving technological problems? Are problem-solving strategies overtly used by students in courses? Are there teaching and learning practices that enable students to more effectively solve technical problems?

The theoretical framework for this study was built around metacognition, technical troubleshooting as a specialized problem-solving process, and the thinking-aloud pair problem-solving approach as a mechanism to promote cognitive self-awareness and monitoring. Relevant literature from each of these areas was reviewed to inform this study.

Metacognition

According to Sternberg (1983), metacognitive skills are the executive thinking skills used by individuals to develop strategies for problem resolution. Flavell (1976) described metacognition as "the active monitoring and consequent regulation and orchestration of these [cognitive] processes in relation to… some concrete goal or objective" (p. 232). Berardi-Coletta, et al. (1995) stated that metacognition is "an active reflective process that is explicitly and exclusively directed at one's own cognitive activity. It involves the self-monitoring, self-evaluating, and self-regulation of ongoing tasks" (p.206).

Technical Troubleshooting

According to Holyoak (1995), "A problem arises when we have a goal—a state of affairs we want to achieve—and it is not immediately apparent how the goal can be achieved" (p. 118). Given this definition of a problem, problem solving is simply the process of finding the best solution that allows movement from the present state to the goal state (Gobert and Simon, 1996).

Halpern (1984) further described the dimensions of problem solving by stating that problems have an anatomy consisting of (a) the initial state; (b) the goal state; and (c) the problem space, which contains all of the possible paths whereby one can move from the initial state to the goal state. According to Halpern (1984), the key to effective problem solving is the ability to recognize and select the most efficient solution path from the myriad of potential solution paths present in the solution space.

MacPherson (1998), indicated that technical troubleshooting is a special category of problem solving. Morris and Rouse (1985) posited that three skill sets are essential in technical troubleshooting: (a) the ability to make tests, (b) the ability to replace or repair faulty components, and (c) the "ability to employ some kind of strategy [italics in original] in searching for the source" of the fault (p. 504). Jereb (1996) emphasized the importance of strategy in troubleshooting, when he stated that, "The question of how to come from a given starting situation to a desired end situation is usually the essence of each technical problem" (p. 2). This is congruent with the work of Halpern (1984) who indicated that the key component of the problem-solving process was the ability to recognize and select the most efficient solution path from among all possible paths. Morris and Rouse (1985) concluded that identifying and employing an effective strategy was the most difficult skill set for troubleshooters to develop.

Thinking-Aloud Pair Problem Solving

One strategy of interest to educators who seek to improve the acquisition of problem solving strategies is the "thinking aloud" technique. Lochhead and Whimbey (1999) discussed this technique and Narode, et al. (1987), labeled it "pair problem solving" and described the process. The technique focuses on having students express their thoughts aloud while engaging in problem-solving activities in order to externalize the thinking process. This "thinking aloud" gives the speaker, and a student partner as a "listener," oral feedback on what is understood and what is only vaguely processed. These authors claim that thinking aloud in pairs allows for the creation of new ideas by allowing the speaker to listen to what is said in a way that cannot occur when s/he is working quietly and alone.

Some researchers have found the thinking-aloud pair problem solving (TAPPS) process to be an effective strategy in teaching students to think, while others have found different results. Johnson and Chung (1999) conducted a study on the abilities of college students to troubleshoot electronics problems in an aviation technologies program. These authors noted that troubleshooting is a series of cognitive processes that requires combining or managing acquired information with existing knowledge. In this quasi-experimental study, they found that thinking aloud significantly improved troubleshooting abilities. Thinking-aloud pair problem-solving subjects performed at significantly higher levels than a comparison group in their ability to recognize faults and to locate specific faults, and in their ability to correctly evaluate faulty hypotheses they generated.

Hogan (1999) conducted a study on the thinking-aloud technique and its impact on collaborative scientific reasoning among eighth-grade science students.

Thinking-aloud subjects gained in metacognitive knowledge about collaborative scientific reasoning but their performance on problem solving was not significantly different than those who didn't verbalize their thoughts. An earlier study by Flaherty (1975) on overt verbalization and practice in problem solving among high school students found results similar to those of Hogan. This begs the question, "Does thinking-aloud pair problem solving (TAPPS) improve the troubleshooting abilities of students?"

The purpose of this study was to determine if the TAPPS technique improved student success at troubleshooting common problems in small spark-ignition engines, compared with the traditional work-alone technique. The hypotheses tested were as follows:

Ho_1: In an engine electrical system troubleshooting task, there will be no differences in success rate or completion time between the experimental and control groups.

Ho_2: In an engine air/fuel delivery system troubleshooting task, there will be no differences in success rate or completion time between the experimental and control groups.

MATERIALS AND METHODS

This study utilized a post-test only control group design (Campbell & Stanley, 1966) with counter-balanced internal replication. Thirty students in a college course on small power technology during the spring 2003 semester comprised the subjects in the study. Students were randomly assigned to two groups: experimental or control.

Identical small spark-ignition engines were prepared, each with the identical fault to their primary electrical system, for each subject in the study. No clues were given, even about the general engine system in which the fault existed, only that the fault was not an internal component fault. Subjects in the control group were asked to work alone to troubleshoot their respective engines, identify the fault, repair the fault, and test run the engine.

The experimental group participated in the TAPPS treatment. Subjects in the experimental group were presented with an engine and asked to complete the same task. They were assigned a thinking-aloud partner who encouraged them to verbalize their thought processes as they completed the troubleshooting task using such statements and questions as, "What are you doing now?" and "Tell me what you are thinking." Subjects in both groups were audio recorded to insure reliability of the data. Whether or not they were successful at troubleshooting the problem and the time to completion were recorded on a written instrument as measures of the major dependent variables.

While the TAPPS students did have a fellow student to prompt them to talk aloud during the problem solving process, the thinking aloud partner was specifically instructed to only prompt the student to verbalize their thought processes as they attempted to solve the problem. The partner could not assist the problem solver in any other way such as by offering clues or asking leading questions about the specific problem.

For the second round of the study, the groups were reversed. The subjects in the control group became the experimental group, and the experimental group became the control group. The engines were returned to working order and a new fault in the air/fuel delivery system was created in each engine. The subjects in the experimental group completed the troubleshooting activity with a thinking-aloud partner, and the control group completed the task without the aid of a thinking partner. Again, each subject was audio recorded and their success and completion times were recorded.

The test for differences between groups on the nominal dependent variable, task completion (successful or unsuccessful), was the Chi-square test of association. Independent t-tests were used to determine if there were significant differences in completion times between successful students in the experimental and control groups.

RESULTS AND DISCUSSION

Prior to testing the null hypotheses, student pre-test scores were analyzed to determine if differences existed between the two student groups on their knowledge of basic engine principles and operating theory. No significant differences were found, $\underline{t}\,(28) = 1.35$, $\underline{p} = .19$. Thus, pre-existing differences between groups on level of subject matter knowledge were not assumed to be a confounding factor in this counter-balanced design.

Table 1 presents descriptive statistics on student performance in the electrical troubleshooting task, by group. Students using the TAPPS technique (experimental group) had a significantly higher success rate than did those students who did not use the TAPPS technique (control group), $\chi^2\,(1) = 5.56$, $\underline{p} \leq .02$. Therefore, the first part of Ho_1, positing no relationship between group and task outcome, was rejected. Using the effect size descriptors proposed by Rea and Parker (1992), the magnitude of the phi coefficient ($\phi = .50$) indicated that there was a relatively strong association between group and task outcome.

For those students successfully completing the electrical troubleshooting task, there was no significant difference between groups in the mean time (minutes) required, $\underline{t}\,(19) = -.34$, $\underline{p} \leq .74$. Therefore, the second part of Ho_1, positing no relationship between group and completion time, was not rejected.

Table 2 presents descriptive statistics on student performance on the fuel/intake task by group. Students using the TAPPS technique had a significantly higher success rate than did those students who did not use the TAPPS technique, $\chi^2\,(1) = 4.54$, $\underline{p} \leq .03$. Therefore, Ho_2, positing no relationship between group and task outcome, was rejected. Using the effect size descriptors proposed by Rea and Parker (1992), the magnitude of the phi coefficient ($\phi = .39$) indicated that there was a moderate association between group and task outcome.

For those students successfully completing the electrical troubleshooting task, there was no significant difference between groups in the mean time (minutes) required, $\underline{t}\,(16) = -.45$, $\underline{p} \leq .66$. The second part of Ho_1, positing no relationship between group and completion time, was not rejected.

For both iterations of the study, significantly higher proportions of the subjects in the experimental treatment groups (thinking-aloud pair problem solving) successfully completed the troubleshooting tasks. Effect sizes ranged from moderate to relatively strong. This finding indicates that students engaged in troubleshooting small spark-ignition engine faults are more likely to be successful if they overtly verbalize their cognitive problem-solving processes. This supports assertions by researchers who indicate that the thinking-aloud process assists the problem solver in avoiding skipping steps in reasoning, skipping over important information, or being unaware of getting bogged down in a component of the problem (Heiman & Slomianko, 1987).

However, successful small-gasoline-engine troubleshooters who participated in the thinking-aloud pair problem solving (TAPPS) group were not significantly different in the time it took to complete the tasks compared to successful troubleshooters in the control group. Thus, it can be concluded that the time required to elicit metacognitive skills through verbalization does not adversely affect time for completion. No differences in time required for task completion, coupled with higher success rates for the TAPPS group, indicate that the TAPPS process yields a higher efficiency rate at technical troubleshooting.

Since the control-group subjects in the replication were thinking-aloud participants (experimental group) in the first round of the study and were largely successful in task completion by using overt verbalization, one might assume that the subjects would transfer these skills to their second-round troubleshooting task. This does not appear to be the case. It seems that while students can successfully use problem solving skills when externally prompted, they do not appear to do so when the external prompt is removed.

Further research should be conducted to validate these results. Additionally, if thinking-aloud pair problem solving results in more efficient troubleshooting through the elaboration of thought processes, research is needed to determine strategies to invoke these processes when the external prompt is removed. This would allow students to exhibit true metacognive skills and to become successful, independent problem solvers. More specifically, educators may be able to overtly teach these skills to students.

ACKNOWLEDGMENTS

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Table 1. Student performance on the electrical troubleshooting task by group.

	Task outcome					
	Successful		Unsuccessful		Minutes to completion[z]	
Group	*n*	%	*n*	%	*M*	*SD*
Control (*n* = 12)	5	41.7	7	58.3	33.6	19.8
Experimental (*n* = 18)	16	88.9	2	11.1	30.9	13.6

[z] based only on students with a successful task outcome

Note: χ^2 (1)= 5.56, $p \leq .02$

Table 2. Student performance on the fuel/intake troubleshooting task by group.

	Task outcome				Minutes to completion[z]	
	Successful		Unsuccessful			
Group	*N*	%	*n*	%	*M*	*SD*
Control (*n* = 18)	8	44.4	10	55.6	33.0	18.3
Experimental (*n* = 12)	10	83.3	2	16.7	29.1	18.5

[z] based only on students with a successful task outcome

Note: χ^2 (1) = 4.54, $p \leq .03$