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EFFECT OF INSTRUCTIONAL STRATEGY ON CRITICAL THINKING AND CONTENT KNOWLEDGE: USING PROBLEM-BASED LEARNING IN THE SECONDARY CLASSROOM

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Abstract

The purpose of the study was to determine the effect of problem-based learning (PBL) on critical thinking ability and content knowledge among selected secondary agriculture students in Missouri. The study employed a quasi-experimental, non-equivalent comparison group design. The treatment consisted of two instructional strategies: problem-based learning and supervised study. The target population was identified as secondary agriculture students in Missouri. Twelve secondary agriculture teachers were selected based on criteria established by the researcher. Intact classrooms were randomly assigned to a level of the treatment. The resulting sample (n = 140) consisted of 77 students in the problem-based learning treatment group and 63 students in the supervised study treatment group. Analysis of covariance indicated a treatment effect on critical thinking ability and content knowledge.

Introduction and Theoretical Framework

"Whether our focus is on classical education, the new math, or basics, the ultimate goal of education has been to teach children to think critically and independently" (Sternberg & Baron, 1985, p. 40). The origins of critical thinking can be traced to the early philosophies of Plato and Aristotle. The importance of critical thinking was evident in the beginning of the modern era of education in the writings of Dewey (1909/1997), who described the ability to think critically as a way to find meaning in the world in which we live.

Reform initiatives in education have further solidified the concept of critical thinking as a requisite goal of education. *A Nation at Risk* (National Commission on Excellence in Education, 1983) sounded an alarm at our faltering attempts to foster critical thinking, higher-order thinking and problem solving in our nation's schools. The Secretary's Commission on Achieving Necessary Skills (1991) ranked competencies in critical thinking, decision making, problem solving, and reasoning as imperative for high performing workplaces. An emphasis is now being placed on the ability to understand and use information, not just merely possess it (Richardson, 2003).

Almost unanimously, educators believe the development of critical thinking ability should be a primary goal of education (Pithers & Soden, 2000). However, the actions of educators would suggest otherwise. "Three-quarters of a century of educational literature suggests the main emphasis in schools has been teaching students facts, even though teachers and curriculum designers have attested to the importance of teaching students to think" (Cano & Newcomb, 1990, p. 46). While the importance of acquisition and recall of basic knowledge remains important, the development of critical thinking has emerged as equally important. Can we find a balance with instructional strategies that facilitate the acquisition of basic knowledge yet develop and nurture critical thinking?

Driscoll (1994) provided a conceptual framework for distinguishing theories of instruction from theories of learning. Driscoll stated that while the two must be compatible, they represent different views of learning outcomes. According to the model (Figure 1), learning theories attempt to explain the interaction of required learning conditions and outcomes of learning. A foundational assumption is that learning occurs when conditions are ripe. In contrast to learning theories, instructional theories account for “a deliberate arrangement of learning conditions to promote the attainment of some intended goal” (Driscoll, p. 332).

Problem-based learning (PBL) is a constructivist approach to instruction that revolves around a real-world, ill-structured problem (Jonassen, 1997). PBL promotes both the acquisition of content knowledge and the development of thinking skills and strategies. Teachers typically take on the role of the facilitator and students become responsible for information learned. This method typically ends with a presentation of solutions and an evaluation of the process used in solving the problem. PBL was pioneered as a method of instruction in medical programs and was designed with several important goals. It was designed to help students construct an extensive and flexible knowledge base; develop effective problem-solving strategies; develop self-directed, lifelong learning skills; become effective collaborators; and become intrinsically motivated to learn (Barrows & Kelson, 1995). In recent years, PBL gained in popularity at the collegiate and secondary levels as well.

Studies have explored the outcomes related to PBL at virtually all levels of education. There is agreement on the contribution of PBL to factors such as knowledge retention, student satisfaction, motivation, and critical thinking. There is much less agreement on the role of PBL in knowledge acquisition. Vernon and Blake (1993) concluded that PBL students are at a disadvantage when compared to traditional students on content knowledge. Albanese and Mitchell (1993) were much less confident, asserting that PBL students are at a disadvantage sometimes, but not always. Albanese and Mitchell attributed the disparity to the variation in which PBL was implemented. Others (Alleyne, et al., 2002; Dods, 1997; Leiux, 1996) found no difference in the content knowledge of students exposed to PBL compared to traditional instructional strategies.

Evidence suggests PBL can help promote critical thinking skills. Studies investigating problem-solving, a component of critical thinking, have found that students exposed to PBL consistently display growth in problem-solving skills (Ball & Knobloch, 2004; Hmelo, 1998). Additionally, students in PBL programs showed an increase in transfer and application of knowledge (Norman & Schmidt, 1992) and in analysis and application required in clinical trials (Albanese & Mitchell, 1993), each considered essential to problem-solving. PBL has been found to be effective in promoting higher-order thinking (Albanese & Mitchell; Cockrell, Caplow, & Donaldson, 2000; Dods, 1997; Vernon & Blake, 1993).

The literature additionally suggests a general consensus regarding a positive impact of PBL on student dispositions. PBL has been found to improve student motivation and interest (Gordon, Rogers, Comfort, Gavala, & McGee, 2001; Herman & Knobloch, 2004; Norman & Schmidt, 1992). In addition to motivation, students indicate more satisfaction with PBL than with traditional methods of instruction (Albanese & Mitchell, 1993; Ball & Knobloch, 2004; Cockrell et al., 2000; Gordon et al.; Vernon & Blake, 1993).

While there are elaborate descriptions of using PBL in various settings, there is little empirical evidence as to what students are learning and how (Hmelo-Silver, 2004). Herman and Knobloch (2004) recommended future studies investigate the use of constructivist PBL approaches to determine effects on learning outcomes in agriculture classrooms.

Agricultural education has long valued the importance of problem solving (Brown, 1998). In turn, the problem-solving approach has been touted as the most effective method for teaching (Osborne & Hamzah, 1989). Research validating this claim has been inconclusive. While the problem-solving approach and problem-based learning share common educational goals, the two have very different philosophical origins. Few studies (Herman & Knobloch, 2004) have sought to identify the impact of PBL in secondary agriculture classrooms.

Research on critical thinking has linked the development of critical thinking skills to instructional design. Lundy et al. (2002) concluded critical thinking was a skill that can be acquired and developed in all students by utilizing critical thinking instructional techniques. Instructional design has been found to improve critical thinking through active learning strategies (Burbach, Matkin, & Fritz, 2004) and contextual applications (Elliot, Oty, McArthur, & Clark, 2001) in college students. In a study of 5th and 6th grade students, Mabie and Baker (1996) concluded that experiential learning activities can lead to increased critical thinking skills. Less information is available on the role PBL plays in the critical thinking development of secondary students.

Results from this study will serve to answer these concerns, in part, and contribute to the knowledge base of teaching and learning as a process in education in general and specifically in the field of agricultural education. Furthermore, findings from this research will inform practicing teachers of alternative strategies that can be used to meet the expectations established at the state and national level as well as help inform teacher preparation programs as to what instructional strategies should be taught to pre-service teachers.

Purpose and Objectives

The purpose of this study was to determine the effect of problem-based learning (PBL) on critical thinking ability and content knowledge. The following research objectives and hypotheses were generated to focus and guide the direction of the study.

1. Describe students on gender, grade classification, and academic aptitude.
2. Describe the critical thinking ability of students before and after instruction in a quail management unit.
3. Describe the content knowledge of students before and after instruction in a quail management unit.
4. Compare the effect of instructional strategy (problem-based learning versus supervised study) with regard to secondary agriculture students' critical thinking ability and content knowledge.

H_1: Students taught using the problem-based learning instructional strategy will demonstrate a greater improvement in critical thinking than students taught using the supervised study instructional strategy.

H_2: A significant difference exists in content knowledge for students taught using the problem-based learning instructional strategy and students taught using the supervised study strategy.

Methods and Procedures

A quasi-experimental, non-equivalent comparison group design was utilized. The design included both pre-test and post-test data gathered on the same unit making it a dependent samples design. Campbell and Stanley (1969) advocated the use of both pre-test and post-test when the groups are similar, but not so similar that a pre-test is unnecessary. Using both a pre-test and a control group allows for greater ease in examining threats to internal validity (Shadish, Cook, & Campbell, 2002).

The target population for the study was identified as secondary agriculture students in Missouri. Subjects in the study were part of a purposive sample. Selection was determined by criteria of the instructors. Twelve teachers were selected based on characteristics of their teacher preparation program. All selected teachers had been exposed to a similar pre-service departmental philosophy of education, completed similar requirements for teacher certification, and received similar instruction in teaching methodology. Teachers were included in the study based on their ability to include the Quail Management Unit in their Ag Science II or Natural Resource/Conservation class. Each intact classroom was randomly assigned to the supervised study treatment or the PBL treatment. Subjects were part of the intact classrooms of the selected teachers. The resulting sample (n = 140) consisted of 77 students in the PBL treatment and 63 students in the supervised study treatment.

Students were taught a unit of instruction on quail habitat management developed by the Missouri Department of Conservation. Six of the teachers taught the unit using the supervised study method of instruction as described by Newcomb, McCracken, and Warmbrod (1993). This strategy represents the design of Missouri's recommended curriculum for agriculture classes. The remaining six teachers taught the unit using the PBL strategy of instruction. Both groups received all necessary materials according to their respective strategy. Additionally, a professional development session was conducted to prepare teachers to implement the assigned strategy.

Three data collection instruments were used. Critical thinking ability was determined by the Watson-Glaser Critical Thinking Appraisal® (WGCTA®), Form S. Content knowledge was determined by a score on a quail management test developed by the Missouri Department of Conservation for use with the unit of instruction. Finally, descriptive information of students (gender, grade level, and academic aptitude) was reported by the teacher on a report form developed by the researcher.

The WGCTA® is a standardized, copyrighted assessment tool for assessing the success of programs and courses in developing critical thinking skills (Watson & Glaser, 1994). The instrument includes exercises which are purported to be examples of problems, statements, arguments and interpretations of data which are regularly encountered at work as well as at school and in other activities. The WGCTA® is designed to measure critical thinking as a composite of attitudes, knowledge, and skills. The instrument is available in parallel forms A and B and is also available in an abbreviated version, form S. Form S was used for this study as it is approved for secondary students and can be completed in approximately 45 minutes.

Reliability estimates for Form S of the WGCTA® were reported as a Cronbach's alpha coefficient of .81 (r = .81) (Watson & Glaser, 1994). According to Watson and Glaser (1994), "the content validity of the WGCTA® in classroom and instructional settings may be examined by noting the extent to which the WGCTA® measures a sample of the specified objectives of such learning programs" (p. 35). The statewide objectives of public education in Missouri clearly identify the importance of critical thinking skills as evident by the references to analysis, problem solving, and decision making. The construct validity of the WGCTA® can be evaluated by noting its relationship with other tests. Watson and Glaser reported significant relationships between the WGCTA and test of general intelligence (Otis-Lennon Mental Ability Tests, the California Test of Mental Maturity, and the Wechsler Adult Intelligence Scale Verbal IQ).

Content knowledge was determined by a score for participants on the post-test administration of the quail management test developed in conjunction with the original instructional unit. The test consisted of 50 selected response items related to four unit objectives. The reliability coefficient was determined post hoc to be .85 by assessing the inter-item consistency according to Kuder-Richardson formula 20. The K-R 20 is applicable to tests whose items are scored dichotomously as either right or wrong (Ary, Jacobs, & Razavieh, 2002). The content items on the quail management test were selected by a panel of experts in wildlife management and in agricultural education who developed the original curriculum.

Descriptive data for students in each of the classes were collected on the score report form. Teachers were asked to record these data (gender, classification, and academic aptitude) in the appropriate field of the Score Report Form. That form was returned to the researcher at the conclusion of the unit. Academic aptitude, operationally defined as Missouri Assessment Program (MAP) score, was used as a covariate to control for differences in aptitude in the sample. The MAP is a standardized test designed to assess proficiency in mathematics, science, communication arts, and social studies at a statewide level. Students are assessed on each MAP area once in elementary, middle, and high school grade levels.

Findings

The first objective sought to describe students on gender, grade classification, and academic aptitude (7th grade MAP index). A total of 140 students participated in the study. Approximately two-thirds of the students (65%) were male and approximately one-third (35%) were female. In the problem-based learning (PBL) group (n = 77), just over half of the students were male (n = 44, 58%), while nearly three-fourths of the supervised study treatment group (n = 63) was composed of males (n = 47, 73%). Sophomores represented a majority (n = 79, 56%) of the sample followed by seniors (n = 23, 16.4%), freshmen (21, 15%) and juniors (17, 12%). When distinguished by group, sophomores made up 61.0% (n = 47) of the PBL group and 50.8% (n = 32) of the supervised study group. The PBL group was additionally comprised of 14 seniors (18.2%), 10 freshmen (13.0%), and 6 juniors (7.8%). The supervised study group was represented by 11 freshmen (17.5%), 11 juniors (17.5%), and 9 seniors (14.3%).

Academic aptitude was operationally defined as the scale score on the Missouri Assessment Program (MAP Score). The most recent administration completed by all students in this study was the 7th grade administration. MAP scores were collected in raw score form but were reported categorically by achievement level for descriptive purposes (Table 1). Almost half (44%, n = 46) of the students in the sample were in the *progressing* category. Thirty-two percent (n = 34) of the sample was categorized as nearing proficiency. The remainder of the sample consisted of *step 1* (n = 13, 12%), *proficient* (n = 11, 11%), and *advanced* (n = 1, 1%).

Table 1
Achievement Categories of MAP Scores by Treatment Group (n = 105)

	Problem-Based		Supervised Study		Total	
Achievement Category	*f*	%	*f*	%	*f*	%
Step 1	7	11.9	6	13.0	13	12.4
Progressing	32	54.2	14	30.4	46	43.8
Nearing Proficiency	16	27.1	18	39.1	34	32.3
Proficient	4	6.8	7	15.2	11	10.5
Advanced	0	0.0	1	2.2	1	0.9
Total	59	100.0	46	100.0	105	100.0

Note. MAP scores were not available for all students.

The second objective sought to describe the critical thinking ability of students before and after instruction in a quail management unit. Summary statistics were calculated for the pre-test and post-test administration of the Watson-Glaser Critical Thinking Appraisal® (WGCTA®) (Table 2). Sample pre-test scores for both groups ranged from 11 to 37 with a mean of 21.3 (*SD* 4.5). Post-test scores for the two groups ranged from 10 to 33 with a mean of 21.4 (*SD* = 4.4). The average pre-test WGCTA® score for the PBL group (n = 77) was 21.1 (*SD* = 4.3) and the post-test score was 21.2 (*SD* = 4.7). Students in the supervised study group (n = 63) achieved an average pre-test WGCTA® score of 21.4 (*SD* = 4.7) and post-test score of 21.6 (SD = 4.1).

Table 2
Critical Thinking (WGCTA®) Scores by Level of Treatment

		Pre-Test			Post-Test		
Treatment	*n*	*M*	*SD*	Range	*M*	*SD*	Range
Problem-Based Learning	77	21.1	4.30	11-37	21.2	4.68	10-33
Supervised Study	63	21.4	4.73	11-34	21.6	4.06	13-32
Total	140	21.3	4.49	11-37	21.4	4.39	10-33

Objective three sought to describe the content knowledge of students before and after instruction in a quail management unit. Content knowledge was determined by the score on a quail management test. Scores were determined by summating the number of correct items resulting in a possible score of 0 to 50. As displayed in Table 3, sample pre-test scores for both groups ranged from 10 to 35 with a mean of 20.4 (*SD* 4.2). Post-test scores for the two groups ranged from 8 to 42 with a mean of 26.4 (*SD* = 6.9). Students in the PBL group (n = 77) correctly identified an average of 20.1 items (*SD* = 4.3) on the quail management test pre-test and 24.2 items (*SD* = 6.1) on the post-test. The average pre-test score for students in the Supervised Study group was 20.8 (SD = 4.1) and the average post-test score was 29.0 (*SD* = 6.9)

Table 3
Content Knowledge Scores by Level of Treatment

		Pre-Test			Post-Test		
Treatment	*n*	*M*	*SD*	Range	*M*	*SD*	Range
Problem-Based Learning	77	20.1	4.3	12-35	24.2	6.1	8-36
Supervised Study	63	20.8	4.1	10-30	29.0	6.9	13-42
Total	140	20.4	4.2	10-35	26.4	6.9	8-42

The fourth objective was to compare the effect of instructional strategy (problem-based learning versus supervised study) with regard to secondary agriculture students' critical thinking ability and content knowledge. The first research hypothesis stated that students taught using the problem-based learning instructional strategy will demonstrate a greater improvement in critical thinking than students taught using the supervised study instructional strategy.

The null hypothesis was tested using ANCOVA to control for critical thinking ability prior to instruction (pre-test WGCTA®) and for academic aptitude (MAP score) (Table 4). The *F*-value ($F_{2,105}$ = 10.96) was significant (p = .01) at the alpha level of .05, established *a priori*, indicating that there was a difference in critical thinking between the level of treatment when controlling for critical thinking pre-test scores and MAP scores. An effect size of .27 was determined. According to Cohen (1977), an effect size greater than .15 is considered "large".

Table 4
Analysis of Covariance (ANCOVA) in Critical Thinking by Instructional Strategy

Source	Sum of Squares	*df*	Mean Square	*F*	*p* - value
Instructional Strategy	505.05	3	168.35	10.96	.01*
MAP	139.24	1	139.24	9.06	.01*
Pre-test	134.98	1	134.98	8.79	.01*
Error	1351.94	105			

Note. Adjusted R Squared = .25
*$p < .05$

The null hypothesis stating that no difference existed between groups on critical thinking scores was rejected. However, treatment group means indicated students in the supervised study group scored higher than students in the PBL group. Therefore, the findings did not support the research hypothesis and favored an alternative explanation.

The second research hypothesis stated a significant difference exists in content knowledge for students taught using the problem-based learning instructional strategy and students taught using the supervised study strategy. ANCOVA was used to test the null hypothesis that there was no significant difference in content knowledge between groups when controlling for pre-existing knowledge (quail management pre-test) and academic aptitude (MAP score) (Table 5). The ANCOVA resulted in an *F*-value ($F_{2,105}$ = 14.74) for content knowledge that was significant (p = .01) at the alpha .05 level. The effect size (.43) was large (Cohen, 1977). The null hypothesis was rejected in favor of the research hypothesis that, there was a difference between groups on content knowledge scores when controlling for pre-test content knowledge scores and MAP scores. Students taught using supervised study scored higher on content knowledge than students taught using PBL.

Table 5
Analysis of Covariance (ANCOVA) in Content Knowledge by Instructional Strategy

Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Instructional Strategy	1315.99	3	438.66	14.74	.01*
MAP	429.37	1	429.37	14.42	.01*
Pre-test	90.11	1	90.11	3.03	.01*
Error	2678.45	105			

Note. Adjusted R Squared = .31
*$p < .05$

Conclusions/Implications/ Recommendations

In the study, 35% of the students were female and 65% were male. Data from the Missouri Department of Elementary and Secondary Education (DESE, 2005) indicated approximately 30% of students enrolled in secondary agriculture classes for 2003-04 were female and approximately 70% were male. Therefore, it can be concluded that the sample approximates the gender distribution of secondary agriculture students in Missouri. State reports in 2004 indicated the 40% of students state-wide were performing at or above the *nearing proficiency* level on the MAP. Forty-four percent of the students in this study were classified as *nearing proficiency* or higher. The MAP achievement levels imply students in agriculture courses are performing at least as well as the state-wide population of students.

ANCOVA procedures indicated a significant difference between treatment groups on critical thinking ability when controlling for pre-test critical thinking scores and academic aptitude. However, post-test means between the treatment groups differed only by .2. Therefore, it was concluded that there is no practical difference between treatments on critical thinking ability. These findings contrast previous studies (Albanese & Mitchell, 1993; Hmelo, 1998) that concluded students in PBL courses outperformed traditional students in problem-solving ability, a component of critical thinking. An even more direct contrast exists between findings from this study and Burbach et al. (2004). They concluded that instructional strategy resulted in improved critical thinking skills as defined by the Watson-Glaser Critical Thinking Appraisal®.

The lack of change between pre-test and post-test administrations may be attributed to a combination of factors. This study focused on a single unit of instruction implemented over a two-week time period. Most likely, discrepancies between this study and studies that found instructional strategy to effectively increase critical thinking ability (Burbach et al., 2004; Elliot et al., 2001; Lundy et al., 2002; Mabie & Baker, 1996;) can be explained by the relative short treatment length of this study. Treatment lengths in those studies ranged from 10 to 16 weeks. It is likely that the relatively short duration of the treatment was not sufficient to detect any differences likely caused by that treatment. It is possible that extending the length of treatment may yield different results.

From the findings related to content knowledge, it can be concluded that students in supervised study classes tended to score higher on content knowledge assessments than students in PBL classes. Students in the supervised study group scored an average of 5 points higher than students in the PBL group on content knowledge and an average of almost 9 points higher than their pretest scores. Students in PBL classes showed an improvement of just over 4 points of their pre-test scores. These findings are consistent with other studies that found PBL students did not perform as well on knowledge exams (Albanese & Mitchell, 1993; Vernon & Blake, 1993).

Dods (1997) concluded that more traditional approaches to instruction promoted content coverage. This may provide some explanation of the success of those students on assessment items associated with recall and identification of content material. While PBL students may have a deeper understanding of the material, that understanding is not represented at a content knowledge level.

Treatment lengths were equal between groups for this study, yet a significant difference in content knowledge was found. The history of problem-solving in agricultural education is well established, but the use of PBL is a relatively new approach. Students in the PBL classes may have experienced some discomfort in adjusting to a new strategy for instruction. Ryan and Millspaugh (2004), in their model of PBL, describe step 1 of instruction as a description of why PBL is used. It can be argued some time on task was lost due to learning an unfamiliar process. Extended exposure to the treatment may offset this learning process and better detect effects on student outcomes. This study should be replicated with an increased treatment period. Further investigation may provide insight into the effects that instructional strategies can have on student outcomes over a longer duration.

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