

The Effect of Vee Maps and Laboratory Reports on High- and Low-Order Content–Knowledge Achievement in Agriscience Education

Andrew C. Thoron

Eric D. Rubenstein

University of Florida

Abstract

Instruction in the laboratory is essential to the success of a total agricultural education program. The development of students' critical thinking, argumentation skills, technical skills, reasoning ability, and engagement are all found within the agriscience laboratory. Yet, utilizing the laboratory setting to its maximum potential is challenging for the instructor. The development of sound research-based assessment tools that enhance high-order thinking and are easily incorporated are needed in secondary agriscience education. This quasi-experimental study investigated the effect of two formative assessment tools on student high- and low-order content knowledge achievement. The Vee map was compared to the standard laboratory report in six different secondary schools across the state of Illinois. Utilizing student pretest score as a covariate, there was a statistically significant difference between groups on the high-order thinking posttest. Further, the study indicated that nine weeks later students who utilized the Vee map retained more low- and high-order knowledge than those who utilized the standard laboratory report. This study recommends the use of the Vee map as an effective formative assessment tool that should be utilized in agriscience education.

Keywords: Inquiry-Based Instruction; Vee Maps; Science Achievement; Laboratory Instruction; Assessment

According to *The Nation's Report Card* (NCES, 2011), 68% of eleventh grade students scored below the proficient level when administered the National Assessment of Education Progress science assessment. The National Research Council (NRC) (2000) posited that hands-on laboratory activities should be incorporated in the science curriculum to increase student skill and content knowledge in science. Because agriculture is considered a science (Thoron & Myers, 2010a), and because an essential component of science education is the inclusion of laboratory exercises (NRC, 2000; NRC, 2006; Roth, 1990), then laboratory instruction is necessary for a quality agricultural education program (Baker, Thoron, Myers, & Cody, 2008). Therefore, it could be purported that agricultural education could help to increase science achievement through the integration of laboratory instruction and assessment.

Currently, most science laboratories are isolated from classroom instruction (NRC, 2006). In *America's Lab Report* (2006), the NRC argued that laboratory experiences and assessment of those experiences increase students' critical thinking, argumentation skills, technical skills, reasoning ability, and engagement. Each of these abilities can be increased by integrating laboratory activities with other science teaching methods. Further, laboratory experiences must emphasize the student–learning outcomes rather than the procedures (NRC, 2006). The science skills that are developed can be enhanced and transferred to new content areas.

Teachers struggle to assess student–learning outcomes during laboratory exercises (Roth, 1990). Teachers indicated that assessments of student learning in laboratory exercises take an excessive amount of time to complete (Lebowitz, 1998; Thoron, Swindle, & Myers,

2008). Moreover, agriscience teachers struggle with assessing student learning during laboratory investigations. Consequently teachers “end up reducing or even omitting lab performance when they determine students’ grades” (Phipps, Osborne, Dyer, & Ball, 2008, p 346).

Teachers should consider using proven assessments when evaluating laboratory experiences. A variety of assessments can be used: concept maps, Vee maps, portfolios, written lab reports, or science fair projects (Phipps et al., 2008; Warner & Myers, 2006). Further, formative assessments could be developed to increase student performance and scientific knowledge. The NRC (2000) described a change in not only assessing in the laboratory, but also a need for greater frequency in the utilization of the laboratory. The teaching method that brings laboratory investigations and formative assessment together is inquiry-based instruction (Thoron, 2010).

Thoron and Myers (2011) reported that students taught through inquiry-based instruction achieved higher content knowledge scores when compared to students taught through the subject matter approach. In addition to greater content knowledge scores, students have also been reported to increase argumentation and scientific reasoning skills when taught through inquiry-based instruction (Thoron, 2010). Further, inquiry-based instruction has been found to be an effective teaching strategy for special needs students (Easterly & Myers, 2011; Scruggs, Mastropieri, Bakken, & Brigham, 1993). However, inquiry-based instruction requires teacher preparation when being utilized as a teaching strategy (Easterly & Myers, 2011; Grady, Dolan, & Glasson, 2010; Shoulders & Myers, 2011; Thoron & Myers, 2011; Thoron & Myers, 2012; Thoron, Myers, & Abrams, 2011; Washburn & Myers, 2010).

Parr and Edwards (2004) stated that the use of inquiry-based learning opportunities that incorporate hands-on, active, and concrete experiences increased student achievement in agricultural education. Therefore, laboratory exercises should incorporate activities that promote active student interaction with real-life situations that allow students to gather data and develop skills (NRC, 2006; Phipps et. al, 2008). Furthermore, laboratory exercises should be utilized for stu-

dents to comprehend adequately the science within the agriculture curriculum (Phipps et. al, 2008). Laboratory settings should be integrated in instructional units that are learner-centered, knowledge-centered, assessed through the promotion of learning, and community-centered (NRC, 2006).

A review of literature revealed little research that examines the use of laboratory activities in agricultural education. However, previous research stated that the use of Vee maps in agricultural education classes as a substitute for traditional laboratory reports increased science content knowledge (Thoron & Myers, 2010b; Thoron, Swindle, & Myers, 2008). Thoron and Myers (2011) found that the success of a Vee map is not influenced by a student’s gender, ethnicity, or grade level. Moreover, the time committed to grading a Vee map is between 10 and 15 minutes, reducing the overall time teachers must commit to evaluating laboratory assessments (Thoron & Myers, 2010b; Thoron, Swindle, & Myers, 2008). Thoron, Swindle, and Myers (2008) presented anecdotal findings that students participating in the study favored being assessed by a Vee map over a traditional laboratory report. Thoron and Myers (2010b) found Vee maps to be a successful assessment tool in laboratory settings. However, further investigation is needed of the Vee map as a formal assessment of laboratory exercises (Thoron & Myers, 2010b; Thoron & Myers, 2011; Thoron, Swindle, & Myers, 2008).

The NRC (2006) argued that an assessment during laboratory instruction must increase the quality of a student’s thinking and provide documentation for the teacher to view student progress. The NRC (2000) reported that when assessing inquiry-based instruction, assessment techniques should incorporate a broader perspective and gather higher ordered evidence that is embedded within inquiry-based lessons. Inquiry-based instruction enhances high-order thinking skills, because students are required to utilize the top three levels of Bloom’s (1956) taxonomy (synthesize, analyze, and evaluate) (Lebowitz, 1998). Further, students have been found to develop higher order thinking when their assessment incorporated graphic organizers (Ivie, 1998; Thoron & Myers, 2010b). Therefore, Vee maps should be examined as a form of

assessment for inquiry-based instruction in the laboratory setting. Vee maps could aid in developing high-order thinking skills when enhanced through the use of inquiry-based instruction.

Studies have found that both inquiry-based instruction (Thoron, 2010) and the Vee map have significantly increased student science content knowledge when compared to subject matter and a standard laboratory report respectively (Thoron & Myers, 2010b). Ivie (1998) argued that high-order thinking skills assist in constructing schemas that are retained longer. The National Research Agenda (Doerfert, 2011) called for research that evaluated the assessment of learning environments to prepare students to become productive citizens. Therefore, this study aimed to utilize the Vee map and a standard laboratory report as a formative assessment tool in coordination with inquiry-based instruction to determine the effects on student low- and high-order thinking.

Theoretical Framework

Ausubel's (1963a) assimilation theory of meaningful learning acted as a guide for this study. First, Ausubel (1960) believed that the learner has prior knowledge and utilizes this knowledge to influence meaningful learning. Ausubel emphasized that learners must build a new cognitive structure in the acquisition of new information. Ausubel (1963b) argued that learners need to reflect three distinct criteria to create meaningful learning and exhibit high-order thinking: 1) utilize abstract structures; 2) organize information into an integrated system; and 3) apply sound rules and logic.

Further, Ausubel (1963a) advocated for the use of advance organizers to develop meaningful learning and extend high-order thinking to other contexts. Ausubel stated that organizers are not simple introductory remarks or overviews of the learning in context. Finally, Ausubel (1960) contended this organizational structure will facilitate "relevant subsuming concepts" (p. 267). Ivie (1998) stated that using advance organizers that encourage students to operate at higher levels of abstraction will strengthen cognitive structures and learners will retain information longer.

This study incorporated Ausubel's (1963a) work through the use of the Gowin's (1979) Vee map. The Vee map is a tool specially designed to develop the scientific thinking skills of the learners (Gowin, 1979). Furthermore, the Vee map quantifies student experience through the use of graphic organizers and forces organization of information into an integrated system to better incorporate empirical data to form sound conclusions and recommendations. A full description of the Vee map is beyond the scope of this paper, for further understanding of the Vee map in detail please refer to Thoron and Myers (2010b).

Purpose and Objectives

The purpose of this study was to determine the effect of two formative assessment tools on student low- and high-order thinking (Bloom, 1956) through a researcher-developed assessment. Low- and high-order thinking is defined as students' performance on the researcher-developed assessment. All null hypotheses were tested at the .05 level of significance. The specific objectives guiding the study were to:

1. Ascertain the effects of the Vee map on low-order content knowledge thinking skills of high school agriscience students following (posttest) laboratory investigation on an assessment.

The null hypothesis, H_0 : There is no significant difference in student low-order thinking on a posttest based on the formative assessment tool used (laboratory reports or Vee Map lab assessments) during laboratory instruction, when taught through inquiry-based instruction.

2. Ascertain the effects of the Vee map on low-order content knowledge thinking skills of high school agriscience students nine weeks following (post-posttest) laboratory investigation on an assessment.

The null hypothesis, H_1 : There is no significant difference in student low-order thinking on a post-posttest based on the formative assessment tool used (laboratory reports or Vee Map lab assessments) during laboratory instruction, when taught through inquiry-based instruction.

3. Ascertain the effects of the Vee map on high-order content knowledge thinking skills of high school agriscience students

following (posttest) laboratory investigation on an assessment.

The null hypothesis, H₂: There is no significant difference in student high-order thinking on a posttest based on the formative assessment tool used (laboratory reports or Vee Map lab assessments) during laboratory instruction, when taught through inquiry-based instruction.

4. Ascertain the effects of the Vee map on high-order content knowledge thinking skills of high school agriscience students nine weeks following (post-posttest) laboratory investigation on an assessment.

The null hypothesis, H₃: There is no significant difference in student high-order thinking on a post-posttest based on the formative assessment tool used (laboratory reports or Vee Map lab assessments) during laboratory instruction, when taught through inquiry-based instruction.

Methods

Population and Sample

The population of this quasi-experimental, pre, post, post-post design study was composed of learners at six Illinois high schools offering agriscience education ($N = 154$). Each participating high school agriscience program was required to have received professional development in the curriculum materials, teaching methodology (Inquiry-based instruction), web-based assessment tracker, and the formative assessment tool utilized during the investigation. Upon meeting these criteria, schools were purposefully selected on the ability to deliver content and facilities to enable online assessments. Learners were randomly selected to receive the formative treatment (Vee map or laboratory report). Researchers determined (Thoron & Myers, 2010) *a priori* that the intervention was not fully administered if a student missed 25% or more of instructional time.

Research Design

The independent variable in this study was the formative assessment used during laboratory instruction of the agricultural education classes. Treatment groups utilized a laboratory report outlined by Osborne (1994) in his text *Biologi-*

cal Applications in Agricultural Education or the Vee map created by Gowin (1979). Both groups were taught the same material in an inquiry-based instructional approach. The dependent variable in this study was high- and low-order thinking skills (Bloom, 1956) through student content knowledge assessments. Covariates were used to adjust group means in order to compensate for previous knowledge in the subject matter. These covariate measures included a pretest for the unit of instruction. This study utilized a quasi-experimental design because of the purposefully selected instructors to deliver content. Students within intact groups were randomly assigned a Vee map or a standard laboratory report (Campbell & Stanley, 1963).

Campbell and Stanley (1963) noted regression as a concern but explained that the risk of regression during a pretest-posttest procedure can be minimized if learners are not selected on extreme scores. To address this concern the formative assessment was randomly assigned to the learner. The greatest threat of interaction in this design type is that the differences found in the posttest and post-posttest are due to preexisting group differences, rather than due to the treatment (Gall, Borg, & Gall, 1996). The use of multiple sites in this study reduced the risk of interaction of subjects, and the use of covariates of content-knowledge achievement pretest scores were used to statistically adjust the means on the posttest and post-posttest. Further, questions on the pre, post, and post-post tests were randomized to address the interaction concern.

Learners in the agriscience classrooms were all taught through inquiry-based instruction. Thoron and Myers (2011) found that students taught through inquiry-based instruction outperformed their counterparts when taught through this method. Learners completed the pretest assessment for the content that followed over the next fifteen days of classroom and laboratory instruction. Each learner completed a posttest immediately following the instruction, followed by a post-posttest nine weeks later.

Unit of Instruction Plans

Content selection was based on the units of instruction and the curriculum maps of the pro-

grams participating in the study. The content and context of the lessons were deemed appropriate for an earlier study conducted by Thoron (2010) and were utilized unaltered for the purposes of this study. The study utilized National Agriscience Content Standards and lessons adapted to inquiry-based instruction from the Center for Agricultural and Environmental Research and Training, Inc. (CAERT).

Instrumentation

This study utilized pre and posttest for the unit of instruction based on work by Thoron (2010). Thoron (2010) reported a reliability coefficient for the content-knowledge achievement instrument using Kuder-Richardson 20 (KR20) for dichotomous data at the coefficient alpha of .91. The questions on the pretest, posttest, and post-posttest were given in a randomized order. The posttest followed the pretest 15 instructional days (21 calendar days) after instruction began. The post-posttest followed the posttest 9 weeks (63 calendar days) after completion of instruction.

Fidelity of treatment

Audio recordings of class sessions were analyzed to ensure delivery of the content, per the recommendations of Boone (1988). Professional development was also delivered to the instructors through a one-day professional development workshop. Teachers were provided lesson plans, handouts, assessment instruments, worksheets, and supplemental items so they could effectively deliver the treatment.

Findings

The results addressed the objectives and hypotheses of the study in determining the influence of inquiry-based instruction and the Vee map, as an assessment tool, on students' high- and low-order thinking. The sample included 154 students from six Illinois high schools. A total of 23 students were removed from the study due to absences above the 25% threshold previously set by the researchers. This reduced the sample to 131 students. The Vee-Map treatment group had slightly more students ($n = 70$) due to the number of students in the selected classes (See Table 1).

Table 1

Treatment Group Participant Totals, Six Illinois High School Agriscience Programs (n=131)

Treatment Groups	<i>n</i> (students)
Vee-Map	70
Laboratory Report	61
Total	131

The majority of the participants in the study were male (61.8%), not eligible for free and reduced lunch (75.7%), and were not identified with an Individual Education Plan (IEP)

(71.4%). A majority of participants were in the tenth grade of high school (88.5%), followed by eleventh grade (24.3%) (See Table 2).

Table 2

Demographics of the Treatment Groups & Total Study of Six Illinois High School Agriscience Programs (n = 131)

	Vee-Map (n = 70)		Laboratory Re- port (n = 61)		Total (n = 131)	
	n	%	n	%	n	%
<i>Gender</i>						
Male	47	67.1	34	55.7	81	61.8
Female	23	32.9	27	44.3	50	38.2
<i>SES Eligibility</i>						
Eligible	17	24.3	20	32.8	37	28.2
Not Eligible	53	75.7	41	67.2	94	71.8
<i>IEP</i>						
Identified IEP	20	28.6	13	21.3	33	25.2
No IEP	50	71.4	48	78.7	98	74.8
<i>Grade Level</i>						
10 th Grade	63	90.0	53	86.9	116	88.5
11 th Grade	7	10.0	8	13.1	15	11.5

Note. Each student self-identified gender and grade level.

A pretest that included high- and low-order questions was administered to each participant prior to the onset of instruction. Pretest data were collected from 131 participants to ensure

that each treatment group was balanced and to measure students' prior knowledge of the subject material. Based on the results of the pretest, the groups were deemed similar (See Table 3).

Table 3

Participant Mean Pretest Scores of Six Illinois High School Agriscience Programs (n = 131)

Instrument	Vee-Map (n = 70)		Laboratory Report (n = 61)		Total (n = 131)	
	M	SD	M	SD	M	SD
High-Order Questions	29.73	8.75	30.95	10.41	30.30	9.54
Low-Order Questions	36.09	9.00	37.43	10.93	36.71	9.93

High- and low-order questions were included on a posttest and post-posttest administered to participants. The post-posttest was administered nine weeks after the completion of the study. A covariate analysis technique was utilized to analyze the data. The pretest score was used as the covariate to control for knowledge gained prior to the treatment. Correlational statistics were conducted but are not reported in the manuscript.

The first objective sought to determine the effect that the treatment had on the students' high-order thinking skills on a posttest assessment. The analysis of the data for this objective was guided by the null hypothesis that there is no significant difference in students' high-order content knowledge skills following laboratory instruction. When examining high-order questions on the posttest, Vee map students reported a mean score of 83.03 (SD = 10.01) and tradi-

tional lab report students reported a posttest score of 78.28 ($SD = 12.06$). The difference in posttest scores of high-order questions was statistically significant, $F_{(1, 127)} = 6.10, p = .015, r^2 = .04$ (See Table 4). A statistically significant difference was found due to the treatment effect, thus the null hypothesis was rejected.

students were 76.56 ($SD = 10.17$) and the control group reported a mean score of 56.84 ($SD = 13.27$). The difference in post-posttest scores of high-order questions was statistically significant, $F_{(1, 127)} = 90.72, p = <.001, r^2 = .42$ (See Table 5). A statistically significant difference was found due to the treatment effect, thus the null hypothesis was rejected.

Table 4

Participant High-Order Mean Posttest Scores of Six Illinois High School Agriscience Programs ($n = 131$)

Instrument	Vee-Map ($n = 70$)		Laboratory Re- port ($n = 61$)		Total ($n = 131$)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Posttest	83.03	10.01	78.28	12.06	80.82	11.22

Note: $F_{(1, 127)} = 6.10, p = .015, r^2 = .04$.

The second objective sought to determine the effect that the treatment had on the students high-order thinking skills on a post-posttest assessment. The analysis of the data for this objective was guided by the null hypothesis that there is no significant difference in students' high-order content knowledge skills nine weeks following laboratory instruction. The post-posttest high-order question scores of Vee Map

test mean score of 78.36 ($SD = 12.74$). The difference in posttest scores of low-order questions was not statistically significant, $F_{(1, 127)} = 2.62, p = .11, r^2 = .04$ (See Table 6). No statistically significant differences were found in the posttest assessment scores, thus the null hypothesis failed to be rejected.

Table 5

Participant High-Order Mean Post-posttest Scores of Six Illinois High School Agriscience Programs ($n = 131$)

Instrument	Vee-Map ($n = 70$)		Laboratory Report ($n = 61$)		Total ($n = 131$)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Post-posttest	76.56	10.17	56.84	13.27	67.37	15.29

Note: $F_{(1, 127)} = 90.72, p = <.001, r^2 = .42$.

The third objective sought to determine the effect that the treatment had on the students' low-order thinking skills on a posttest assessment. The analysis of the data for this objective was guided by the null hypothesis that there is no significant difference in students' low-order content knowledge skills following laboratory instruction. When examining low-order questions on the posttest, Vee map students reported a mean score of 82.07 ($SD = 12.11$) and traditional laboratory report students reported a post-

test mean score of 78.36 ($SD = 12.74$). The difference in posttest scores of low-order questions was not statistically significant, $F_{(1, 127)} = 2.62, p = .11, r^2 = .04$ (See Table 6). No statistically significant differences were found in the posttest assessment scores, thus the null hypothesis failed to be rejected.

Table 6

Participant Low-Order Mean Posttest and Post-posttest Scores of Six Illinois High School Agriscience Programs (n = 131)

Instrument	Vee-Map (n = 70)		Laboratory Report (n = 61)		Total (n = 131)	
	M	SD	M	SD	M	SD
Posttest	82.07	12.11	78.36	12.74	80.34	12.50

Note: $F_{(1, 127)} = 2.62, p = .11, r^2 = .04$.

The fourth objective sought to determine the effect that the treatment had on the students low-order thinking skills on a post-posttest assessment. The analysis of the data for this objective was guided by the null hypothesis that there is no significant difference in students' low-order content knowledge skills nine weeks following laboratory instruction. When examining low-order questions on the post-posttest, Vee Map

students reported a mean score of 76.16 ($SD = 10.01$) while traditional laboratory report students reported a post-posttest score of 64.93 ($SD = 11.77$). A statistically significant difference was found between post-posttest scores on low-order question, $F_{(1, 127)} = 29.28, p = <.001, r^2 = .19$ (See Table 7). A statistically significant difference was found due to the treatment effect, thus the null hypothesis was rejected.

Table 7

Participant Low-Order Mean Post-posttest Scores of Six Illinois High School Agriscience Programs (n = 131)

Instrument	Vee-Map (n = 70)		Laboratory Report (n = 61)		Total (n = 131)	
	M	SD	M	SD	M	SD
Post-posttest	76.16	11.62	64.93	11.77	70.93	12.93

Note: $F_{(1, 127)} = 29.28, p = <.001, r^2 = .19$.

Conclusions

Based on the findings of this study the following conclusions can be made:

1. When coupled with inquiry-based instruction, the Vee map is a more effective formative assessment tool when compared to the standard laboratory report based on Bloom's (1956) high-order thinking;
2. When coupled with inquiry-based instruction, the Vee map is a more effective formative assessment tool when compared to the standard laboratory report based on student retention of knowledge.

Discussion and Implications

This study presented findings which indicated that the Vee map is a more effective assessment tool that leads to higher student achievement in the agriscience classroom. These results are consistent with the findings of Thoron and Myers (2010b). Ivie (1998) stated that high-order thinking skills are enhanced through the use of graphic organizers as a formative assessment tool. The graphic component of the Vee map aids in the development of student thinking skills.

The findings suggest that the utilization of formative assessment enhances student content knowledge through agriscience laboratories.

This study supports the argument made by the NRC (2006) that laboratory experiences and assessment increases students' critical thinking and technical skills. Warner and Myers (2006) presented the Vee map as an assessment tool that could be utilized in the laboratory setting. This study provides empirical data that support the use of Vee maps as a formative assessment tool in laboratory settings.

The findings of this study support Ausubel's (1963a) belief that meaningful learning is individually constructed by the learner and enhanced through the use of graphic organizers. The utilization of the Vee map as a formative assessment tool allows the learner to receive feedback (formative) from their instructor to create meaningful learning. The feedback provided by the instructor incorporated Ausubel's three distinct criteria of 1) utilizing an abstract structure (laboratories incorporating inquiry-based instruction); 2) organize information into an integrated system (Vee map); and 3) apply sound rules and logic (assessment).

Recommendations

Based on the findings of this study, four recommendations were made for teacher educators and curriculum developers in secondary school agriscience education: (a) based on the

finding that the Vee map was more effective in developing high-order thinking skills the Vee map should be considered as an effective formative assessment in preparation of student development of such skills; (b) teacher educators should provide professional development on the effective use of Vee maps and other graphic organizers to be used during laboratory instruction to help students attain high-order thinking; (c) further investigations of the Vee map as a formative and summative assessment tool in various settings and contexts in the agricultural education profession should be examined to determine the effectiveness across learning styles, grade levels, and ability levels; and (d) continue to investigate, through quasi-experimental research, teaching methodologies and assessment tools that develop empirical evidence for use in the agriscience classroom and laboratory.

Based on the findings of this study, two recommendations were made for practitioners of agriscience education: (a) laboratory investigations that incorporate the Vee map enhances student high-order thinking skills on a standardized assessment; and (b) inquiry-based instruction and Vee maps when utilized together can lead to meaningful learning for students as they create their own graphic organizer to help them conceptualize information.

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ANDREW C. THORON is an Assistant Professor of Agricultural Education in the Department of Agricultural Education and Communication at the University of Florida, 307C Rolfs Hall, Gainesville, FL 32611, athoron@ufl.edu

ERIC D. RUBENSTEIN is a Graduate Student of Agricultural Education in the Department of Agricultural Education and Communication at the University of Florida, 310 Rolfs Hall, Gainesville, FL 32611, erubenstein@ufl.edu