THE EFFECTS OF SMALL GROUP COOPERATION METHODS AND QUESTION STRATEGIES ON PROBLEM SOLVING SKILLS, ACHIEVEMENT, AND ATTITUDE DURING PROBLEM-BASED LEARNING

A dissertation submitted to the
Kent State University College of Graduate School
of Education, Health, and Human Services
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

by

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May 2011
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THE EFFECTS OF SMALL GROUP COOPERATION METHODS AND QUESTION STRATEGIES ON PROBLEM SOLVING SKILLS, ACHIEVEMENT, AND ATTITUDE DURING PROBLEM-BASED LEARNING (283 pp.)

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The purpose of this study was to examine the effects of integrating instructional strategies during problem-based learning (PBL) on student learning. A quasi-experimental 2 by 2 factorial design with an appended control was used to examine the effects of traditional teacher-led instruction compared to problem-based learning instruction with the interactions of cooperative learning methods—Jigsaw and traditional small group—and teacher question strategies—Socratic and didactic—on grade 5 student problem-solving skills, achievement, and attitude toward science.

The sample consisted of grade 5 rural middle school students in an Ohio public school district. Six teachers were randomly assigned to the appended control group consisting of a teacher-led lecture-based environment or an experimental group consisting of a PBL environment with modified instructional strategies. Each experimental PBL group consisted of one of the following: traditional small group with didactic teacher questioning, traditional small group with Socratic teacher questioning, Jigsaw cooperative learning with didactic teacher questioning, and Jigsaw cooperative learning with Socratic teacher questioning.

Results of the study support the use of PBL to improve student achievement. Students achieve at higher levels in science when compared to traditional teacher-led
lecture instruction. The Socratic questioning groups had significantly higher achievement scores compared to the didactic questioning groups. The 2 PBL groups that used Jigsaw had a significantly more positive attitude towards science than the traditional small groups. There were no significant differences in problem solving between the groups. To assist in higher achievement and more positive attitudes when implementing PBL, the results of this study support the integration of Jigsaw cooperative learning method and Socratic questioning.
ACKNOWLEDGMENTS

There are many people who I would like to extend my sincere appreciation for the support and contribution to this dissertation. I would first like to humbly thank an exemplary mentor and dissertation director, Dr. Dave Dalton, who I admire. I appreciate his wisdom, guidance, scholarship, leadership, and professionalism through the dissertation process. Thank you to each of my committee members, Dr. Christopher Was and Dr. Averil McClelland, for your knowledge, expertise, and expansive amount of time.

I would like to thank Fairless School District. Thank you to the administrators, Dr. Susan Stewart, and 5th grade teachers and students who were willing to engage in innovative and challenging teaching methodologies. It was an amazing experience to work and learn with each of you during this dissertation process.

To my parents I give gratitude. James Griffiths, thank you for teaching me to think critically, never be afraid to analyze and question, and always strive for perfection. Catherine Benton, thank you for always listening and being patient through the miles. Thank you to my family, friends, and each person with whom I have come into contact with during this process who made a difference through support, love, prayer, and encouragement. I would also like to thank God for His amazing grace and wisdom.

Finally, but not least, I would like to respectfully thank my husband, Tadd Maxfield, for his never ending love, strength, humor, patience, prayers, and support through the dissertation journey.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Purpose</td>
<td>2</td>
</tr>
<tr>
<td>Significance</td>
<td>2</td>
</tr>
<tr>
<td>Research Questions</td>
<td>6</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>7</td>
</tr>
<tr>
<td>Traditional Teacher-Led Instruction</td>
<td>7</td>
</tr>
<tr>
<td>Problem-Based Learning</td>
<td>8</td>
</tr>
<tr>
<td>Traditional Small Group Method</td>
<td>10</td>
</tr>
<tr>
<td>Jigsaw Method</td>
<td>11</td>
</tr>
<tr>
<td>Socratic Questions</td>
<td>12</td>
</tr>
<tr>
<td>Didactic Questions</td>
<td>13</td>
</tr>
<tr>
<td>Problem-Solving Skill</td>
<td>13</td>
</tr>
<tr>
<td>Achievement</td>
<td>14</td>
</tr>
<tr>
<td>Attitude Towards Science</td>
<td>14</td>
</tr>
<tr>
<td>Limitations</td>
<td>14</td>
</tr>
<tr>
<td>Delimitations</td>
<td>17</td>
</tr>
<tr>
<td>Chapter Summary</td>
<td>18</td>
</tr>
<tr>
<td>II. LITERATURE REVIEW</td>
<td>19</td>
</tr>
<tr>
<td>Introduction</td>
<td>19</td>
</tr>
<tr>
<td>Theoretical Foundation of Problem Based Learning</td>
<td>19</td>
</tr>
<tr>
<td>Cognitive Psychology</td>
<td>19</td>
</tr>
<tr>
<td>Inquiry Based Learning</td>
<td>20</td>
</tr>
<tr>
<td>Social Learning</td>
<td>22</td>
</tr>
<tr>
<td>Teacher as Facilitator</td>
<td>25</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>27</td>
</tr>
<tr>
<td>Problem Based Learning</td>
<td>32</td>
</tr>
<tr>
<td>Problem Based Learning Components</td>
<td>33</td>
</tr>
<tr>
<td>PBL and Traditional Pedagogy on Student Learning</td>
<td>35</td>
</tr>
<tr>
<td>Cooperative Learning</td>
<td>50</td>
</tr>
</tbody>
</table>
APPENDIX T. PERMISSIONS FOR THE PURDUE ELEMENTARY PROBLEM SOLVING INVENTORY (PEPSI) ................................. 257

REFERENCES .............................................................................................................................................................. 259
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interaction Effect for Achievement</td>
<td>111</td>
</tr>
<tr>
<td>2. Interaction Effect for Attitude</td>
<td>114</td>
</tr>
<tr>
<td>3. Interaction Effect for Problem Solving</td>
<td>117</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PBL Instructional Treatments by Group</td>
<td>90</td>
</tr>
<tr>
<td>2. Correlation Coefficient for Dependent Variables</td>
<td>107</td>
</tr>
<tr>
<td>3. Covariate Means and Standard Deviations for OAT Scores</td>
<td>108</td>
</tr>
<tr>
<td>4. Means and Standard Deviations of Achievement by Factorial Cell</td>
<td>110</td>
</tr>
<tr>
<td>5. Main Effects and Interactions of Cooperative Learning and Questioning on Achievement</td>
<td>110</td>
</tr>
<tr>
<td>6. Means and Standard Deviations of Attitude by Factorial Cell</td>
<td>112</td>
</tr>
<tr>
<td>7. Main Effects and Interactions of Cooperative Learning and Questioning on Attitude</td>
<td>113</td>
</tr>
<tr>
<td>8. Means and Standard Deviations of Problem Solving by Factorial Cell</td>
<td>115</td>
</tr>
<tr>
<td>9. Main Effects and Interactions of Cooperative Learning and Questioning on Problem Solving</td>
<td>116</td>
</tr>
<tr>
<td>10. Frequencies of Teacher Questions by Group</td>
<td>118</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

Introduction

With the transition from the industrial age to the information age, education has encountered a shift from traditional direct teacher-centered methods (lectures, tutorials, demonstrations, and drill and practice) to a student-centered approach of inquiry learning (discovery learning, discussion, role-play and problem-solving). This transition has led to changes from the student as isolated individual to cooperative learner and the teacher from a lecturer to a facilitator. Problem based learning (PBL), originally founded as an inquiry method in the field of medicine for adult learners, is increasingly utilized across K-12 curricula. PBL research has been effective in teaching problem-solving skills (Arts, Gijselaers, & Segers, 2006; Gallagher, Stepiean, & Rosenthal, 1992; Sendag & Odabasi, 2009), improving achievement (Gordon, Rogers, Comfort, Gavula, & McGee, 2001; Hmelo, Gotterer, & Bransford, 1997; Liu, Hsieh, Cho, & Schallert, 2006; McParland, Noble, & Livingston, 2004), and attitude toward learning (Goodnough & Cashion, 2006; Gordon et al., 2001; Kaufman & Mann, 1996). Research has been more limited on the effectiveness of incorporating instructional strategies such as cooperative learning methods and teacher questioning techniques into PBL. The focus of this study is the impacts of cooperative learning and teacher questioning strategies on the effectiveness of PBL on problem solving skills, achievement, and attitude toward science at the elementary level.
Purpose

The purpose of this study is to examine the effects of integrating cooperative learning methods and teacher questioning strategies on student problem-solving skills, achievement, and attitude toward science. Cooperative methods utilized during the learning process have a positive influence on achievement, problem-solving, and attitude (Johnson, Johnson, Johnson, & Anderson, 1976; Qin, Johnson, & Johnson, 1995; Slavin, 1980). Effective questioning, as a natural part of teaching and learning, has positive effects on achievement, attitude, and problem solving (Chang, Lin, & Chen, 1998; Chin, 2007; Parkinson & Ekachai, 2002; She & Fisher, 2002; Wilen, Bosse, Hutchison, & Kindsvatter, 2004). Although both cooperative learning and questioning techniques have positive outcomes on student learning, little research has been conducted on these strategies used within PBL. This study compares the effects of cooperative learning methods—traditional small group and Jigsaw—and teacher question types—Socratic and didactic—implemented into PBL with a control group of traditional teacher-led instruction. The specific outcomes studied included problem-solving skills, achievement, and attitude toward science.

Significance

There is increasing pressure on schools to ensure that students obtain the ability to solve real-world, complex, ill-structured problems in personal and professional settings (Association of American Colleges and Universities, 2010; Hart Research Associates, 2010). Industry and government leaders are requiring future employees to have information literacy, technology literacy, cooperation, communication skills, and the
ability to resolve complex and ill-structured problems (Savery, 2006). Most occupations require employees to work together, communicate, and solve ill-structured problems. Yet, results on internal comparisons since the 1970s show that American students’ achievement scores, higher-level thinking, and problem solving skills are low when compared to students from other industrialized nations (Sorenson, Buckmaster, Francis, & Knauf, 1996). PBL is a student-centered approach of inquiry learning that encourages students to solve real-world, ill-structured problems in a group environment. PBL is often applied in higher educational contexts such as medicine, business, and sociology. The outcomes of this research may not be directly applicable to K-12 school settings. Whereas elementary education has traditionally focused on teacher-centered methods as a primary means of teaching, research supports the use of student-centered methodologies. Holdzkon and Lutz (1984) reviewed research on inquiry-based curriculum materials used in secondary and elementary science classes that promote student-centeredness and found that it has positive effects on student achievement, analytical skills, processing skills, and attitude. Despite positive results students often have few opportunities to learn to solve everyday ill-structured problems and obtain problem solving skills. The use of PBL and corresponding research is limited in elementary settings. Therefore limiting the knowledge base of the effects on student outcomes and learning is equally sparse.

Research has investigated the differences between traditional instruction and PBL methodologies with mixed results. PBL has a positive impact on problem-solving skill (Gallagher et al., 1992; Hmelo et al., 1997), self-directed learning (Lohman & Finkelstein, 2000), collaboration skills (Savery & Duffy, 1995), self-efficacy (Cerezo,
2004), life-long learning, long-term retention (Strobel & van Barneveld, 2009), basic subject knowledge (Bowe & Cowan, 2004), intrinsic motivation (Pedersen, 2003; Sungur & Tekkaya, 2006), engagement in the learning, and thinking processes and metacognition, and meaningful learning (Newble & Clarke, 1986). While PBL research has shown positive outcomes for student learning in K-12 (Gordon et al., 2001; Liu et al., 2006), some authors have documented no difference in achievement when comparing PBL to other forms of teaching methods (Beers, 2005; Herzig, Linke, Marxen, Börner, & Atepohl, 2003; Sendag & Odabasi, 2009; White et al., 2004). Research also indicates that students who participate in traditional lecture scored above students in PBL in general concept knowledge (Albanese & Mitchell, 1993; Mergendoller, Maxwell, & Bellisimo, 2000; Strobel & van Barneveld, 2009).

There are multiple explanations to account for these relatively lack luster results. One possible explanation is the overall lack of research investigating different teaching strategies that can be applied to enhance the teaching and learning during PBL. Instructional strategies focusing on cooperative learning and effective questions techniques are often forwarded as means to enhance PBL. Unfortunately, minimal research to support the use of these strategies has been conducted.

Questions are a natural and essential component of the teaching and learning process (Levin & Long, 1981; Stevens, 1912). The didactic questioning technique is most often used by teachers to elicit a correct response in order to assess the ability of students to recite and recall information (Wilen, 1991). To assist students in higher-level thinking, reasoning, and problem solving, the Socratic questioning technique has been
suggested (Elder & Paul, 1998). Socratic questioning is designed to engage the teacher and students in a dialogue with the use of open-ended questions that encourages a higher-level of cognition. The Socratic questioning technique and PBL are both designed to develop problem solving skills and higher-level thinking. Socratic questioning seldom manifests itself in the elementary classroom (Guszak, 1967). Little research has focused on the effectiveness of the Socratic and didactic questioning techniques on student learning during PBL with elementary students.

Cooperation is a natural social act that involves the interaction of groups of individuals who work together to solve problems, complete tasks, and creates products for individual and group benefit. Cooperative learning methods (STAD, Jigsaw II, TGT, Small-Group Teaching and Group Investigation) have been researched extensively in educational settings. Research illustrates multiple benefits of cooperative learning such as increased achievement (Johnson et al., 1976; Slavin, 1980), self-esteem (Slavin & Karweit, 1981), problem-solving (Qin et al., 1995), attitude (Johnson et al., 1976), and reduction in ethnic and race conflicts (Slavin, 1980). However, minimal research has been conducted to demonstrate the effects on problem-solving skill acquisition and achievement when applied with PBL.

Cooperative learning often results in the “slacker effect,” in which one or two students typically complete the work for the entire group. The lack of structured individual accountability often leads to a lack of positive interdependence and the full participation of all group members. During PBL, students are generally expected to divide the authority and tasks. This expectation assumes a high degree of student
autonomy. Elementary students generally do not possess the ability to be fully autonomous, threatening the effectiveness of the PBL experience. Providing focus and cooperative groups with a structure that divides the PBL learning task may enhance student learning. Initiating a task structure during PBL through the division of a problem into sub-problems through cooperative learning methods such as Jigsaw has been suggested (Lambros, 2004). PBL and cooperative learning develop positive attitudes toward learning and higher levels of achievement. However, little empirical research has been conducted to examine the effects on student learning when combining PBL and cooperative learning methods.

The data obtained from this study will contribute to the research on problem-based learning, cooperative learning, and questioning strategies that teachers use during the learning process and the outcomes it has on student learning. The results of the study will assist researchers and educators in designing PBL curriculum to have positive effects on student learning.

**Research Questions**

There are many important questions remaining about cooperative learning and questioning techniques that teachers use during PBL and the effects they have on student learning. In this study the overall research question is, “How do traditional small group and Jigsaw cooperation methods interact with Socratic and didactic teacher questioning techniques on fifth grade student problem-solving skill acquisition, achievement, and attitude toward science during problem based learning in a rural school setting?” Specific research questions included:
1. Is there a significant difference between PBL and traditional teacher-led instruction on student learning?

2. Does the interaction of cooperative learning methods and teacher questioning techniques during PBL result in higher achievement scores?

3. Does PBL improve the attitudes of learners toward science when augmented by the use of Jigsaw with teacher Socratic questioning, Jigsaw with didactic teacher questioning, traditional small group with didactic teacher questioning, and traditional small group with Socratic teacher questioning?

4. Does the interaction of cooperative learning methods and teacher questioning techniques during PBL have an effect on improving problem solving skills?

**Definition of Terms**

The study examined the effects of traditional teacher-led instruction compared to problem-based learning instruction on student problem-solving skill acquisition, achievement, and attitude toward science. The following terms are used throughout this report.

**Traditional Teacher-Led Instruction**

For the purpose of this study, traditional teacher-led instruction is a method of teaching with an emphasis on teacher centeredness and embedded in the behaviorist principles that (a) centers around well-developed, defined, and systematic curriculum design; (b) clearly defines and prescribes tasks; (c) teaches part to whole; and (d) regularly assigns students to individual tasks to practice and test knowledge (Eggen & Kauchak, 2001; Ormond, 2009; Santrock, 2009).
**Operational definition.** In this study traditional teacher led instruction consisted of a traditionally delivered life science unit. The teacher lectured on the lesson topic—the Emerald Ash Borer—with the use of PowerPoint presentations. The students read the associated online or printed text. Students completed a worksheet related to lesson topic and lesson vocabulary. The students worked individually to complete worksheets. The teacher led a class discussion about the worksheets and then collected them at the end of class. The following day the teacher reviewed the previous day’s lecture and returned the worksheets. The teacher lectured on the next lesson topic and the cycle continued.

The students researched and prepared a one-page paper assignment using the class resources (two book sets, EAB packet, Internet, and a pathfinder). The teacher provided assistance to students individually when requested. The students turn in the one page paper.

The students were then given a test review worksheet. At the conclusion of the lesson each student completed the Abstract Storybook form of the Purdue Elementary Problem Solving Inventory (PEPSI) as a problem-solving skills assessment, a criterion referenced multiple-choice test related to the unit objectives to demonstrate achievement, and the Attitude Toward Science in School Assessment Questionnaire (ATSSA).

**Problem-Based Learning**

Problem-Based Learning is an inquiry-based and student-centered instructional method that employs constructivist principles (Savery & Duffy, 1995) including (a) engaging students in real world, complex, and ill-structured problems used as a stimulus
for learning (Barrows & Tamblyn, 1980; Hmelo-Silver & Barrows, 2006) to locate viable solution(s); (b) providing student autonomy by placing responsibility for learning on the student; (c) encouraging social interaction and collaboration; (d) empowering students to obtain problem-solving skills (Bridges & Hallinger, 1997); and (e) shifting the role of the teacher to facilitator of student learning (Torp & Sage, 2002).

**Operational definition.** In this study, PBL was operationalized as follows: students were presented with a scenario and problem. Students were randomly assigned to groups and roles (chairperson or leader, recorder, reporter, and monitor). Each student was provided with a cooperation guide that included the definition of each role. The cooperation guide was discussed and reviewed by each teacher. Folders (color coded for each group) containing an evaluation sheet and thinking log assignments were provided to each student in each group. Each group was provided an additional matching color coded folder to organize group notes and other information. The teacher provided “KWL” worksheets for each student. The K sheet was designed to be used in the beginning of the unit to help students activate prior knowledge or experiences about a topic or problem. The W sheet was designed to assist students in deciding what they want or need to know to solve a problem or complete a task. The L sheet was designed to be used at the end of the unit to assist student review of the knowledge learned during the learning process. Groups completed the “K” and “W” portion before researching. In this study, the teacher acted as a facilitator for each group with the use of an assigned teacher questioning guide to assist and scaffold student learning.
The teacher provided the learning issues or goals to the groups during the unit. Each group member in the Jigsaw experimental groups were provided with a learning issue to research as part of the final project. Jigsaw is a structured cooperative learning method that provides the role and task structures for each member of a group. Students utilized resources to locate information needed to complete the assignment. The teacher facilitated student learning through 5 minute question and answer sessions using the assigned teacher questioning guide. The teacher questioned students with Socratic questions: open-ended divergent questions used to promote higher-level thinking or didactic questions: closed-ended convergent questions used to elicit a specific answer.

After completing individual research, students reunited in groups to analyze and synthesize the information and to generate possible solutions. After sharing information and arriving at conclusions, each group created and developed a final product and presented the final project to the whole class. Products were graded using a rubric. At the end of the study, each student completed the Abstract Storybook form of PEPSI as a problem-solving skills assessment, a criterion referenced multiple-choice test related to the unit objectives to demonstrate achievement, and an attitude toward science survey.

**Traditional Small Group Method**

The traditional small group is a cooperative learning method consisting of four to five students with a role-structure and undefined task structure (Davidson, 1985; Johnson, Johnson, & Holubec, 1994; Kagan & Kagan, 1994).

**Operational definition.** In this study, students were randomly assigned a role—chairperson (leader), recorder, reporter, and monitor for the duration of the unit.
The chairperson was responsible for making sure the group stayed focused on the task(s) and that all group members had the chance to participate in the discussion. The recorder was responsible for retrieving and maintaining the group folder and kept a record of notes on the ideas of each member and the possible solutions presented. The reporter presented oral responses to the facilitator about the activities or conclusions of the group. The monitor was responsible for ensuring that the group stayed within the time limit, examined the group folder to monitor its organization, and to make certain the work area was clean for the next class meeting. In this study, the specific task structure was not provided to allow for student autonomy. Each group was responsible for dividing the research task(s) and responsibilities related to solving the problem.

**Jigsaw Method**

Jigsaw is a structured cooperative learning method that provides the role and task structures for each member of a group of four to five students. Once students are in their original groups they are given a specific task to research. Each member assigned to a specific task meets in their perspective “expert” groups to teach and learn. The “expert” groups consist of students with the identical learning task. Students share and learn information from researching their specific task. Then students return to their original groups to teach their assigned task. In Jigsaw the task structure is designed to (a) incorporate individual accountability by having each member become an expert in one learning issue of the problem (Aronson, Blaney, Stephan, Sikes, & Snapp, 1978; Johnson et al., 1994) and (b) creating positive interdependence (Johnson et al., 1994) through the sharing of learned knowledge within the group.
Operational definition. In this study, each group member was randomly assigned a learning issue or sub-problem related to the main problem. Each student with similar learning issues met in a second, “expert group” to share and discuss their research. Each student was provided 3 to 5 minutes to share ideas and research. Notes were taken during the discussion. Students returned to their original groups. Each learning issue expert took 3 to 5 minutes to teach the original group the new information gleaned from the expert group. Members of the group were responsible for the knowledge taught by their returning expert.

Socratic Questions

Socratic questions are open-ended divergent questions used to promote expanded explanations, multiple answers, and further dialogue (Elder & Paul, 1998).

Operational definition. In this study, Socratic questioning was implemented as follows: teachers were provided with Socratic teacher questioning guides with examples of questions to encourage students to respond with multiple answers and expand on the dialogue. Examples of these questions include, “Please explain why or how?” or “What information are you basing that comment?” Teachers utilized the questioning guides when students worked in groups and when students were completing individual research. The teacher spent 5 minutes with each group engaging in guided questioning and answering.
**Didactic Questions**

Didactic questions are closed-ended convergent questions used by the facilitator to focus with the intent on eliciting a specific or right answer (Costa, 1990; Sanders, 1966).

**Operational definition.** In this study, teachers were provided didactic questioning guides that included examples of questions that require a correct unitary answer. Teachers utilized the questioning guides when students were in groups working and when students completed their individual research. The teacher spent 5 minutes with each group in structured questioning and answering.

**Problem-Solving Skill**

Problem Solving is a cognitive process the employs a pattern of thinking to resolve the dissonance between a current situation and the goal (Dewey, 1938; Gagne, 1959). Problem solving skills often used include problem identification, problem definition, generation of plans and solutions, decision-making, and solution and reflection. **Problem identification** consists of locating the main problem. **Problem definition** is defining the problem and learning issues to be solved. **Generation of plans and solutions** involves reviewing past knowledge, planning for the acquisition of new knowledge, and researching additional information to generate possible solutions. **Decision-making** is the process of deciding what information is relevant and supportive and determining if additional information is required. **Solution and reflection** is choosing the best-fit solution and reflecting on the material learned.
**Operational definition.** In this study, problem solving skills were quantitatively measured at the end of the PBL unit, via the Purdue Elementary Problem Solving Inventory (PEPSI) Abstract Storybook Form as a posttest which took students approximately 45 minutes to complete.

**Achievement**

Achievement is the ability to meet the criteria based on subject specific learning objectives (Mager, 1962) at a level that demonstrates adequate knowledge and understanding of the unit material.

**Operational definition.** In this study, achievement was measured with a criterion-referenced posttest constructed by the research consisting of 15 multiple-choice questions based from the unit content objectives. The objectives are based on the Ohio Department of Education standards for fifth grade science.

**Attitude Towards Science**

Attitude is a complex cognitive process that reflects values or feelings toward learning subject(s) including science (Germann, 1988).

**Operational definition.** In this study, attitude was measured with the Attitude Toward Science in School Assessment Questionnaire (ATSSA; Germann, 1988). The instrument assesses students’ general attitudes or feelings toward science. Administration of the ATSSA required approximately 20 minutes to complete.

**Limitations**

This study had threats to internal validity due to the quasi-experimental research design used. Mortality is often a threat to internal validity and there are few appropriate
methods of controlling this threat. In this study, subject attitude was a threat due to the use of the assent form. Legitimate reasons for this loss of data included absenteeism and unsigned consent forms. Two students were absent on the last day. There were 42 students who did not return parental consent forms. These students were not included in the overall results due to lack of data collection. Participants were made aware that they are involved in a study and it may affect their participation or responses. To control for this threat, the students did not know the difference between the groups and who was receiving each treatment.

Students were located in different classrooms with diverse resources causing a location threat. This threat was controlled by allowing students to utilize web and text print and wireless laptop computers within the classrooms and having access to the same resources (computers, textbooks, websites, print materials, and newspapers). The school was newly constructed for fall of 2007. The resources in the classrooms were identical and included three desktop computers for student use. The teacher had his or her own personal desktop computer with overhead data projector. Each classroom was also equipped with a SmartBoard to view and manipulate information. The teacher’s computer and the VCR/DVD player were connected to overhead projection. Teachers also had access to microphones and speakers for presentations.

The fourth possible threat is history. Several unanticipated events occurred during the study. History threats could not be directly controlled in this study. During the second day, the health department came into one of the traditional lecture classrooms for 5 minutes to ensure that Jerod’s law requirements were being met. The teachers
prepared the room a week prior to the inspection. There was little or no disruption since
the inspectors only looked around the classroom and in cabinets. The students were
initially distracted by the entrance of the inspector. The teacher regained the attention of
the students by reminding them of their task while the inspection took place.

An information presentation on the transition to middle school caused a slight
disruption on day 4. The students were required to attend the presentation and visit to the
middle school. Three classes (traditional small group didactic, the traditional teacher-led,
and Jigsaw didactic group) were impacted by this event. The other three classes
proceeded with the lesson for the day. Class resumed when the three classes returned.
Four students in the PBL traditional didactic class left 5 minutes early on days 3, 4, and 8
for gifted education meetings. There were one to two students missing from three
groups.

There was a substitute for the Jigsaw and didactic class on day 5. The substitute
was thoroughly briefed before school began. She was a full time tutor in the school with
a teaching license and previous teaching experience. The students were familiar with her.
This class session proceeded with no noticeable disruptions.

The fifth possible threat was teacher effect. Although the teachers were randomly
assigned to a group, there is a potential for a teacher effect to occur since each teacher has
a different teaching style, personality, and rules for the classroom. To control for this
threat, teachers were provided with standardized packets including detailed lesson plans,
instructional materials, questioning scripts, and student cooperation guides. Prior to the
study, teachers were individually trained. However, no instructional treatment can be
made “teacher proof.” During the study the teacher using Socratic questioning and Jigsaw struggled at the beginning of the study. He thought that he had been using Socratic questions with his students prior to implementation.

The last possible threat was teacher as a confounding variable due to having only one teacher assigned to each of the experimental groups within PBL. This is common because carefully controlled experiments on humans are often impractical (McDonald, 2009). To control for a portion of this effect, two teachers were assigned to the control group. There were no significant differences between the control groups on each of the dependent variables\(^1\). This analysis assists in eliminating a portion of confounding variable effect. Teachers were also randomly assigned to each group to assist in controlling for this variable (Johnson & Christensen, 2007). However, further research should be conducted by having at least two teachers for each dependent variable within the cell of the factorial design to further control for teacher as a confounding variable and eliminate a possible type I error.

**Delimitations**

Extraneous variables can affect the external validity, necessitating cautious analysis of the results. The experiment took place in a rural school setting, which may limit the generalizability to other settings including urban and suburban school settings. Similarly, the study was conducted with elementary classrooms, which limited the direct-applicability to other audiences and settings such as secondary school settings.

\(^1\)Individual ANOVAs were used to analyze the six groups on each dependent variable. Collapsing the two control groups in to 26 participants (12 participants in group one and 14 participants in group two) does not influence the results: achievement, \(F(5, 94) = 5.13, p = .000\), attitude, \(F(5, 94) = 4.09, p = .002\), and problem solving, \(F(5, 94) = 0.47, p = .80\).
Further research will need to be conducted in various settings to generalize the results of the study. The use of formal structured curriculum limits the generalizability to all PBL learning situations since PBL can vary and tends to be less structured.

**Chapter Summary**

There is an increasing demand for a renewed focus on higher-order thinking skills, including the ability to solve ill-structured problems. How do educators, particularly elementary level, establish viable cooperative methods and questioning techniques during PBL to provide students with these skills? Research focused on the comparing between PBL and traditional instructional methods has yielded mixed results. However, little research has focused on the effects of cooperative learning methods and teacher questioning techniques used during PBL to augment student learning. Effective teaching strategies integrated into PBL have the potential to positively impact student learning. The rationale for incorporating the Jigsaw method into PBL is that students will be more organized, focused, and actively participate by having each member of a group become an expert on a portion of the problem. Integrating teacher questioning techniques offers an insight into the role and process the teacher can use during cooperative learning sessions in a PBL environment.

The chapters following provide the foundational literature related to the study and describe the study methodology. Chapter 2 presents the relevant research and theoretical foundation of PBL, cooperative learning and its effects on achievement, and question types and its effects on problem solving skills. Chapter 3 describes the design, methodology, and analysis in detail.
CHAPTER II
LITERATURE REVIEW

Introduction

This chapter describes the relevant literature for each construct of the study. The sections include theoretical foundations, problem based learning, cooperative learning, questioning techniques, associations between cooperative learning, questioning techniques and problem based learning, and a chapter summary. The theoretical foundation provides the framework for the research study including PBL and traditional instruction.

Theoretical Foundation of Problem Based Learning

Cognitive Psychology

Cognitive psychology is the study of how learning occurs through human internal processes including acquisition, processing, storing, reasoning, critical thinking, problem solving, memory, language, and thinking. Cognitive psychology examines human thinking and learning processes within a learning environment where students can interact and learn from one another while the facilitator promotes problem solving, creativity, self-esteem, and positive attitudes. Problem based learning is a student-centered and inquiry-based approach that creates a learning environment for positive student learning outcomes (Duch, Groh, & Allen, 2001). The basic components of problem based learning are engaging students in real world, complex, and ill-structured problems, providing student autonomy, encouraging social interaction and collaboration, empowering students to obtain problem-solving skills, and the teacher
establishing the role of a facilitator (Barrows, 1988; Hmelo-Silver, 2004; Hmelo-Silver, Duncan, & Chinn, 2007; Torp & Sage, 2002). Problem based learning is founded on the constructivist learning approach. Students construct their own understanding through personal beliefs, current knowledge structures, and interaction with new knowledge (Richardson, 2003). Constructivist learning has several principles that relate to PBL (Savery & Duffy, 1995) including learning environments that reflect the complexity of the real world and are student-centered (Hmelo-Silver & Barrows, 2006), collaboration, cooperation, social negotiation, and the teacher acting as a facilitator (Torp & Sage, 2002).

**Inquiry Based Learning**

The foundation of American education is based on behaviorist theories that develop teacher-centered, lecture and textbook based curriculum constructed upon behavioral objectives. Teachers disseminate knowledge using lectures and assess student learning based on performance objectives. Students are provided factual knowledge through lecture and textbook and assessed accordingly. This method of teaching and learning provides students with limited opportunity to obtain and practice everyday real-world higher-level thinking and problem solving skills. Moreover, students are not provided the learning opportunities to construct knowledge through individual investigation and peer collaboration.

Dewey (1897) believed that learning should not take place through direct teaching of factual information but by experiencing and participating in real-world tasks and situations. The natural curiosity of students, particularly younger students, should be
developed by bringing the outside world into the classroom. Providing real-world and ill-structured problems establishes a connection between the classroom and the real-world. Experiential learning provides learners the opportunity to discover solutions to problems that are connected to the real world to gain understanding through experience and application of subject-based knowledge, problem solving skills, collaboration, and reasoning. Learning of skills and factual knowledge should not be inert but integrated with everyday knowledge. The development of problem-solving and critical thinking skills rather than the memorization of factual information should be the focus of the learning and teaching process. Bruner (1966) highlighted this idea by stating,

[Teaching] is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as an historian does, to take part in the process of knowledge-getting.

Knowing is a process not a product. (p. 72)

Teaching students to become independent in the learning process through self-regulation via of higher-level thinking, metacognition, and problem solving is the foundation of education. If students are to learn basic facts but also have the ability to think, reason, and problem solve, the educational system has to provide experiences and opportunities within the school setting to allow students to practice and develop (Dewey, 1910; Kauchak & Eggen, 2007; Wertheimer, 1945). Inquiry methods include problem based learning, project-based learning, cased-based instruction, discovery learning, and
anchored instruction. A review of inquiry based teaching and curriculum materials in science classes through meta-analysis studies indicate positive results including higher achievement scores, attitudes, processing skills and analytical skills (Holdzkon & Lutz, 1984). PBL provides students with an open and diverse environment to explore, discover, research, and make connections through previous experiences and discussion with peers and adults to learn new knowledge, problem solving, social, and thinking skills.

**Social Learning**

Learning is a communal process, school is a social institution, and education is a social process (Dewey, 1897). Teachers and students work cooperatively as an active community toward a common outcome through discussion and tasks. If school relates to real life, students learn social responsibility. Dewey presented the “social individual” relating that students without socialization are abstract and society is lifeless without individualism. Students have to share and discuss ideas and prior experiences to become a whole person who is able to contribute to society. Problem based learning socializes students through collaborative groups while allowing each student to research and present their individual ideas, thoughts, experiences and knowledge. Students working together to complete a common task with a single goal has been recognized as a beneficial instructional strategy (Brooks & Brooks, 1999; Dewey, 1916; Jonassen, 1991).

Student social and cognitive development is dependent on learning and working with peers to obtain knowledge through experiences, prior knowledge, skills, and information. The developmental theory of Havighurst (1972) is based on a
biopsychosocial model incorporating tasks that are required to be completed during the duration of life. Human development depends upon learning and thinking throughout the life span. The developmental tasks presented by inner and outer forces must be successfully completed to avoid possible future failures, slower learning rates, and disapproval by society. The middle childhood period from 6 to 12 years of age consists of three factors: spending less time with parents in the home and more with peers and in groups at school, experiencing games and work requiring neuromuscular skills, and the mental realization of adult concepts, logic, symbolism, and communication.

Similar to Havighurst is Erikson’s (1968) psychosocial theory that has eight distinct universal developmental stages that occur throughout the lifespan. For each stage of personal development, a person can succeed or fail at certain developmental tasks. If a person meets the “crisis” or developmental task and fails at a certain stage, it can hinder further development. Erikson’s fourth psychosocial developmental stage stated that children between the ages of six to early adolescence begin to master knowledge and intellectual skills. If students succeed, they become “industrious” but if they fail at this stage, students develop a sense of “inferiority” or incompetence. Students begin to ask, “Am I successful or worthless?” It is important for teachers to provide opportunities and structure the learning environment to allow students to be successful. During this stage of development, relationships among peers become significant. When students are provided the chance to be successful individually or within peer groups, they feel industrious through mastering intellectual skills. If students are not successful, they have issues with feeling inadequate or inferior to others.
Developmental tasks for middle childhood include learning social skills with peers and developing skills for everyday living through understanding adult concepts to achieve social development, competence, and self-esteem (Erikson, 1968; Havighurst, 1972). Students should be learning through trial and error with peers to achieve personal independence. The teacher should be the “umpire” and “committee chairman” (Havighurst, 1972, p. 33) to allow students to make mistakes and set limits so students stay focused. This guidance promotes individual responsibility for learning. Students should be provided the time to plan, discuss, and criticize. The everyday living aspect focuses on obtaining and developing skills for effective thinking to solve problems and discuss everyday issues within occupations and social matters. Engaging fifth grade students with ill-structured real-world problems provides a collaborative learning environment where adult concepts, higher-level thinking, and problem solving skills are developed at an appropriate cognitive developmental level.

Cooperative learning is a natural part of social learning. Cognitive development relies on social interaction and collaborative problem solving. The Zone of Proximal Development (ZPD) is “the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving with adult guidance or collaboration with capable peers” (Vygotsky, 1978, p. 86). During PBL students are placed in the ZPD when presented with complex and authentic problems with multiple unknown answers. When presented with an ill structured problem, children have a limited understanding about the task structure and content knowledge. Students work collaboratively in learning groups
reviewing the overall problem. Students, when placed in cooperative learning groups, continue to work to achieve a shared goal (Johnson et al., 1994). The teacher as a facilitator scaffolds the students, particularly—during the beginning of the PBL process—to guide students’ thinking, reasoning, and research processes. During PBL students gradually learn to solve problems independently and in cooperative groups with minimal scaffolding from the facilitator (Torp & Sage, 2002).

**Teacher as Facilitator**

The Zone of Proximal Development (ZPD) also refers to the “adult guidance” during the problem solving process. The adult guidance is given from the teacher during the PBL, known as scaffolding. Teachers become facilitators and scaffold student learning through questions, feedback, and discussion. The discussion between the teacher and student is an active dialogue. The active dialogue can be initiated with the use of different questioning techniques.

The facilitator provides a substantial amount of scaffolding through modeling thinking and questioning. Students transition from teacher dependence to self-regulation. The teacher is not in the school to impose certain ideas or to form certain habits in the child, but is there as a member of the community to select the influences which shall affect the child and to assist him in properly responding to these influences. (Dewey, 1897, p. 78)

The teacher does not play the role of a knowledge giver but as a part of the learning community to provide students real-world learning environments and guide students in the learning process. The teacher is not present to simply train but to formulate proper
social life for students. The teacher as a community member models and prepares students for social life through understanding how to solve everyday problems. Social learning theory (Bandura, 1977) suggests that teachers can model behaviors for students, which can assist in achievement during the learning process. An intricate and natural part of the teaching and learning process is questioning. Teachers can model the questioning processes for students. Questioning techniques can be used to assist learners in furthering their understanding of how to solve a problem. Teachers can utilize questioning techniques including didactic or Socratic during discussions to model the steps of problem solving for students. Didactic questioning can be used to model how to solve simple problems while Socratic questioning techniques are used to solve ill-structured and complex problems.

Teachers utilize questions to assist in the learning process by scaffolding students during assimilation and accommodation. During this cognitive developmental process, teachers can use different forms of questioning to assist students through the assimilation and accommodation processes. Piaget (1952) defined cognitive development through four main stages. During the third stage, Concrete Operational, fifth grade students think logically and develop schemes to organize information. The types of questions teachers use can influence how students organize and process new information and relate it to previous knowledge. Questions can be open-ended or divergent allowing for the opportunity to rationalize, connect to past experiences—peer and personal—and make connections to prior knowledge. Closed-ended or convergent questions verify understanding and confirmation of facts. Teachers often utilize closed-ended questioning
to recall and review information. During disequilibrium, a mental shock or emotional disturbance due to a new experience or problem, closed-ended questions can assist students in the recall of information that can help in recalling prior knowledge and experiences or schemas that relate to the problem. Open-ended questions, such as Socratic, can provide the support for higher-level thinking. Socratic discussions use probing and elaboration questions to encourage higher-level thinking through the explanation and support of answers to problems. During higher-level thinking, students have the ability to solve complex and ill-structured problems through the assimilation and accommodation of new and prior knowledge.

**Problem Solving**

Problem solving, decision-making, and reasoning refer to the cognitive processes of acquiring resolution to a situation or problem. Problem solving research during the early 1900s focused on creation of problem solving processes. Problem solving strategies were also researched in order to create a generalizable problem solving strategy to humans and multiple domains based on behaviorism. During the 1960s cognitive psychology shifted the focus from observable behaviors to internal and cognitive process.

Problem solving is also often viewed as an algorithmic series of steps or skills within a cognitive process. There is a lack of consensus concerning specific processes of the problem solving process. Polya (1957) developed a problem solving model that included (a) understanding the problem, (b) devising a plan, (c) carrying out the plan, and (d) looking back or reflecting. Parnes (1967) suggested a five stage creative problem solving process: (a) Fact finding to gather information about the problem, (b) problem
finding to formulate a problem definition, (c) idea finding to generate and manipulate ideas, (d) solution finding to evaluate ideas and manipulate the best into a solution strategy, and (e) acceptance finding to undertake a final consideration of the solution in order to decide how best to implement it. The problem solving process varies depending upon the situation and problem but the skills are similar within each model.

Dewey (1910, p. 72) listed the five distinct steps within problem solving: (a) a difficulty felt due to conflict between current condition and a desired result; (b) locating and defining the problem; (c) suggesting possible solutions; (d) provide the purpose, support, or explanation of the solution from investigation; and (e) testing conclusions for acceptance or rejection. The first step is often combined with the second step since the difficulty felt by the problem is often part of the process of locating and defining the problem. Students often feel a noticeable shock or emotional disturbance that creates the disequilibrium. The first and second steps require the student to acquire skills to identify and define the problem and learning issues during the PBL process. The third step is to suggest possible solution(s). Students must have the skills to generate plans, hypotheses, or multiple solutions by reviewing previous knowledge, planning for knowledge and research, and understanding roles. The fourth step requires students to obtain the skills of collecting, evaluating, organizing, and interpreting data. During this time students must also have the skills to decide what information is relevant and supportive and if additional information is required. The fifth step requires an observation of acceptance or rejection of the solution. Students must acquire the problem solving skills to observe and
rationalize the best-fit solution to the problem through reflection and discussion of learned materials.

John Dewey’s systematic and sequential process of problem solving mirrors the PBL learning process. Problems provide opportunities for students to discover and cultivate thinking and learning abilities. When a student is required to seek solutions to problems it provides an opportunity to reflect on previous knowledge, understanding, skills, and current needs necessary to solve the problem. The problem solving process spurs cognitive development through learning to use internal and external resources and reflection. The skills and abilities required to solve complex problems must be developed, practiced, learned, and acquired over time until automatic.

Through the introduction of ill-structured problems, PBL places students in disequilibrium. Students have to use adaptation through assimilation and accommodation to solve the problem and gain equilibrium. Bruner (1966) believed students should acquire problem solving skills through the process of inquiry learning environments, particularly in science classes. Students become active learners and try to reason through the process for the basis of understanding. Once students are presented with a problem they will have the desire and motivation to solve it.

Students must begin by identifying the problem and sub-problems to form a hypothesis. PBL provides students with a rich, stimulating, and student led learning environment, that Piaget believed influenced the ability of students to construct knowledge. During PBL students are at disequilibrium with the presentation of the initial ill-structured problem. KWL is an introductory teaching strategy that is used to assist
students in the learning process by giving students structure in recalling what they know, taking notes on what they need to know, and then after learning review what they have learned (Ogle, 1986). Students utilize the “KW” of the KWL to begin assimilation and accommodation. The K assists in activating prior knowledge or experiences. Students review knowledge that relates to the current problem. The W guides students in deciding what they want or need to know to begin a plan of how to solve a problem or complete a task. This process assists in the organization and pattern forming of information.

Next, the students must develop a hypothesis and review the data. Metacognition is a part of the problem solving process. Students must know and apply problem solving strategies, plan a course of action, reflect upon the plan and solutions, and monitor the progress as they move to a solution. There are two main methods of solving a problem: algorithms that are highly structured rules that guarantee a correct solution if applied correctly and heuristics, or “rules of thumb” that are broad and do not lead to one specific or right answer. During the PBL learning and problem solving processes students often use heuristic methods because they have either not faced a similar problem where positive transfer can occur or the problem is too complex for a single algorithm.

Problem solving and exercise solving are two different ideas often compared when reviewing how a problem is solved. Wertheimer (1945) disagreed that thinking can be taught as a sequential process or algorithmic formula that, when applied correctly, gave the right answer. He believed thinking occurred when the intrinsic relations between parts and wholes were learned. Woods (1994) stated that exercise solving is the use of previous routines or formulas used for similar problems. Problem solving does not
provide a script or algorithm on how to solve the problem. Problem solving employs a pattern of thinking that involves certain skills to resolve the dissonance between a current situation and a goal.

The final step consists of reflection and testing of conclusions are completed. The L of the KWL assists students in reviewing knowledge learned during the learning process. Thinking logs also assist students in reflection after learning to assist with resolving disequilibrium by making connections between previous knowledge and new knowledge.

Fifth grade students are near the end of the Concrete Operational stage (Piaget, 1952). During this stage students are beginning to think logically but still rely on concrete objects and events. Students at this age level have developed schemes to organize information and classify objects (Piaget, 1952). This stage of development can cause some barriers to generating new solutions to problems. Duncker (1945) described “functional fixedness” where an object that was used in the past for a specified task and has a specific scheme has to be rethought to be able to be used in different ways to solve problems. This adaptation can be difficult for students at this stage of cognitive development because they classify objects and do not have the ability to manipulate objects in abstract ways.

According to Piaget, students are entering the fourth and final stage of cognitive development, Formal Operations. During the Formal Operations stage, reasoning and hypothetical situations can be comprehended. Ill-structured and complex problems are usually hypothetical and demand higher-level thinking skills. There is disagreement
about the progression of the development of students in the fourth stage concerning their reasoning skills. Young adolescent students mature at a slower rate than originally proposed by Piaget when reviewing reasoning skills in math and science of elementary through college students (Adi, Karplus, & Lawson, 1980). Although young adolescent students should be entering the formal stage of development, formal operations do not automatically develop. Teachers must provide guidance to students during the problem-solving process.

**Problem Based Learning**

Problem-based learning was originally developed by Howard Barrows during the 1960s at McMaster’s University in Canada. Barrows decided to reform medical education by creating an instructional method that enabled students to role-play as physicians in an authentic environment to obtain and apply textbook knowledge, prior knowledge, higher-level thinking, and problem solving skills while becoming independent learners. PBL was designed to provide adult learners with an authentic and complex medical problem to increase their ability to problem-solve, collaborate, retain, and apply knowledge. Recently, medical education has continued to enhance learning through PBL due to the expansion of medical knowledge, rapid changes of technology, and the demands of future practice. Law, business, pharmaceutical, social work, engineering, and education fields have developed application of PBL as a viable teaching and learning methodology (Savery & Duffy, 1995). The field of K-12 education is currently experiencing an information explosion, rapid changing of technology, and the
demands of society and future workforces (Association of American Colleges and Universities, 2010).

The implementation of PBL in K-12 is in the beginning stages (Ertmer & Simons, 2006; Lam, 2004). The limited research conducted to date demonstrates that the current PBL model utilized in medical education cannot be applied directly to K-12 settings (Goodnough & Cashion, 2006). PBL research conducted in elementary settings is often studied in conjunction with multimedia programs (Liu et al., 2006) or in an online environment compared with a traditional lecture based class with students acquiring self-directedness (Zumbach, Kumpf, & Koch, 2004). The use of teaching and learning methods that compliment PBL such as cooperative learning (Lambros, 2002) and questioning techniques, has been suggested for further research.

**Problem Based Learning Components**

Recent emphasis has been placed on learning environments that provide activities that are real, relevant, and concrete. Problem based learning is a student centered and constructivist teaching method that utilizes an ill-structured and authentic problem to elicit student learning. PBL develops critical thinking, the locating, evaluation and use of resources, organization, effective communication skills, collaboration, and content knowledge (Duch et al., 2001). The first component is to provide students with an ill-structured and everyday real-life problem and scenario. “Learning from problems is a condition of human existence. In our attempts to solve the many problems we face very day, learning occurs” (Barrows & Tamblyn, 1980, p. 1). The use of the problem is to motivate, gain attention, provide an authentic environment, situation, or role, and focus
for the overall desired learning outcomes. The ill-structured problem is designed to provide limited information required to solve the problem. Everyday real life and professional problems often do not have all the information present to provide accurate solutions (Barrows, 1988). Solving a problem gives students a chance to learn to think about thinking through reflection and review. Students are forced to research, inquire, observe, examine, investigate, reflect, and deliberate.

A major component of PBL is a collaborative structure. The focus is on active exploration that allows students to work collaboratively and research independently. The collaboration between group members is beneficial through the division of the cognitive effort (Hmelo-Silver et al., 2007) through the distribution of expertise and sharing different viewpoints, students develop reasoning and higher-level thinking to assist in knowledge construction and acquisition. Another feature of collaboration is reflection. Teachers should provide students the time to reflect on group processing dynamics and commenting individually on the personal contributions made to the group (Aronson et al., 1978; Barrows, 1988). Self-assessment is a life-long skill that requires practice. Providing time at the end of the class to reflect and self-evaluate allows students to assume responsibility for learning, reason through a problem or task, and to work with peers to support group goals. When reflection is practiced at the conclusion of collaborative times, students become increasingly capable of self-evaluation.

Another major component of PBL is the role of the teacher. The teacher acts as a facilitator, “guide-on-the-side,” or meta-cognitive coach to assist, guide, facilitate, and scaffold students during the learning process. The teacher guides students through
problem solving, researching, questioning, scientific method, and discussions. The role of the facilitator in the beginning of the PBL learning process is through modeling and coaching of students in good thinking and learning strategies (Torp & Sage, 2002). The need for the facilitator to scaffold should continue to decrease during the learning process as students begin to construct their own knowledge, become self-directed by practicing problem solving, inquiry, research skills, and discussion amongst their peers (Hmelo-Silver, 2004).

Kirschner, Sweller, and Clark (2006) argued that there is discrepancy between the minimal guidance given during problem-based learning and the traditional information provided via lecture and direct instruction. When reviewing the human cognitive architecture there is a concern of cognitive overload within the working memory when the learning environment is highly complex and ill-structured. This is especially a concern for younger or novice learners who have minimal prior knowledge to integrate new knowledge. A review of empirical studies on guidance during instruction indicate that strong structured guidance by the teacher during the learning process is more effective and efficient when compared to minimal structure as demonstrated in PBL.

**PBL and Traditional Pedagogy on Student Learning**

Problem-based learning research provides evidence to support the use of PBL to improve student learning outcomes. Research on PBL has shown positive outcomes for student learning in higher education (Bowe & Cowan, 2004; Hmelo et al., 1997; McParland et al., 2004) and K-12 (Gordon et al., 2001; Liu et al., 2006). PBL has a positive impact on problem-solving skill, self-directed learning (Lohman & Finkelstein,
2000), collaboration skills (Savery & Duffy, 1995), self-efficacy (Cerezo, 2004), life-long learning, retention (Dochy, Segers, Van den Bossche, & Gijbels, 2003), basic subject knowledge (Bowe & Cowan, 2004; McParland et al., 2004), intrinsic motivation (Martin, West, & Bill, 2008; Pedersen, 2003; Sungur & Tekkaya, 2006), engagement in the learning, and metacognition.

There is also research documenting no difference in achievement (Beers, 2005; Sendag & Odabasi, 2009; Herzig et al., 2003; White et al., 2004) or lower achievement on basic knowledge and concepts (Albanese & Mitchell, 1993; Berkson, 1993; Dochy et al., 2003; Kalaian, Mullan, & Kasim, 1999; Vernon & Blake, 1993) when comparing PBL to other forms of teaching methods. These findings have been attributed to misunderstandings and misapplications of PBL (Boud & Feletti, 1997). Others have suggested poor PBL implementation or flawed research (Sanson-Fisher & Lynagh, 2005), use of research instruments that are not reliable or valid (Belland, French, & Ertmer, 2009), perceived disadvantages of PBL including the lack of knowledge before implementation (Barrows & Tamblyn, 1980), inconsistency or minimal integration into curriculum leading to inexperience (Kalaian et al., 1999), negative misconceptions about PBL such as it takes longer and students learn less (Woods, 1994), and conflict of assessment design and implementation (Goodnough & Cashion, 2006). Pedersen, Arslanyilmaz, and Williams (2009) found that teachers with PBL training used multiple types of assessments during the learning process that had the unfortunate effect of imposing structure similar to that used during a traditional lecture format, thus defeating the purpose of students learning on their own and with peers.
Some have asserted that PBL does not correlate to standards-based education and places students at a disadvantage in traditional achievement. Pedersen et al. (2009) interviewed teachers with PBL training and found that teachers voiced concerns about preparing students for standardized testing. The current educational system focuses on content and outcomes through standards-based curriculum and learning. The main focus is on outcomes and products with minimal focus on the learning process. PBL allows for a focus on both the learning product and learning process. It is the learning process that provides students with the opportunity to learn and apply higher levels of cognition while learning the desired learning objectives and outcomes. Teachers often find it difficult to teach the content and higher-level cognitive skills. PBL allows the student to learn content based standards while simultaneously learning questioning skills, cooperation, collaboration, problem-solving skills, and higher-level thinking skills to become a self-motivated and life-long learner.

**PBL and achievement.** There are mixed results for achievement when comparing traditional direct instruction and PBL methods. Early research indicated that medical students in traditional courses performed higher on standardized examinations assessing recall of basic knowledge and recognition of concepts, whereas PBL students performed better on clinical and application examinations (Albanese & Mitchell, 1993; Berkson, 1993; Dochy et al., 2003; Kalaian et al., 1999; Vernon & Blake, 1993). Albanese and Mitchell (1993) conducted a meta-analysis of PBL in the medical field, discovering that students who participated in traditional lecture scored above students in PBL on the USMLE Step 1, a measure of basic science concepts. Vernon and Blake
(1993) also conducted a meta-analysis of 22 quantitative studies from 1970 to 1992 comparing PBL and traditional methods. Students in traditional courses performed higher on tests of basic medical knowledge. Mergendoller et al. (2000) found that secondary students in the traditional lecture classes tested significantly higher in general economic knowledge than PBL classes. Gijbels, Dochy, Van den Bossche, and Segers (2005) reviewed 40 empirical studies ranging from 1976 to 2000 comparing PBL and traditional methods in medical schools. When weighted average effect size was reviewed to compare basic conceptual knowledge, PBL and traditional students performed at the same level.

Albanese and Mitchell (1993) discovered that PBL students performed higher on clinical knowledge and application of basic knowledge. Vernon and Blake (1993) also concluded that PBL students performed better in applying clinical knowledge. Colliver (2000) reviewed PBL literature from 1992 to 1998 and found PBL does not improve knowledge base and clinical performance. Sanson-Fisher and Lynagh (2005) stated that PBL research methods were flawed, and such research “offers little support for the superiority of PBL over traditional curricula” in medical education (p. 260).

Achievement is often defined as subject-specific learning that demonstrates adequate knowledge and understanding of the content. PBL implemented in higher education shows a significant difference in achievement when compared to traditional lecture classes. Bowe and Cowan (2004) developed a PBL physics science course that reflected identical learning outcomes as traditional lecture. The PBL students achieved higher scores on the traditional one-hour examination as well as having higher
achievement in physics concepts. McParland et al. (2004) also found that undergraduate psychiatry students in PBL achieved higher scores on final examinations.

Research in K-12 and PBL has shown positive outcomes for student learning. Gordon et al. (2001) researched urban minority sixth through eighth grade middle school students over a 2 year school period by implementing PBL as an enrichment activity for approximately 2% of the curriculum. Students explored health and science issues for two class periods 3 days a week. The results indicate that the overall grade point averages were higher and the science grades were higher than those of the traditional teacher lecture courses. Math scores were significantly higher for the sixth to seventh grade cohort but the seventh to eighth grade cohort had no significant achievement differences. Liu et al. (2006) found that sixth grade students who utilized a PBL computer program, Alien Rescue, had a significant increase in their science knowledge. Although there was no control group, these results suggest that students can obtain the basic knowledge through the use of PBL. Cerezo (2004) interviewed sixth through eighth grade at-risk females that were integrated into PBL for at least 2 years in math and science. Students believed that PBL was effective and had a positive impact on their learning and self-efficacy. Subject-specific content knowledge includes the vocabulary associated with the field of study. PBL students used more basic science terms than did non PBL students (Hmelo et al., 1997).

Research has generally demonstrated that there is no difference in the achievement of students when comparing PBL to other teaching methods. Beers (2005) compared objective test scores of nursing students in lecture and PBL and found no
significant differences in achievement of content knowledge. Another study compared PBL and traditional lecture medical students in the Netherlands and found no significant differences in the required basic science content knowledge (Prince et al., 2003). White et al. (2004) also documented no difference in achievement when comparing PBL to other forms of teaching methods. Sendag and Odabasi (2009) compared the effects of PBL online versus online instructor-led methods on undergraduate students’ content knowledge acquisition. After 8 weeks there were no significant differences in content knowledge. However, PBL students did score higher overall between the pre- and posttest.

**PBL and problem solving skills.** Problem solving, decision-making, higher-level thinking, and reasoning refer to the cognitive processes of acquiring resolution to a situation or problem. Problem solving is not an innate process but one that has to be taught. Williams-Boyd (2003) discussed three different methods for teaching problem solving: (a) teaching for problem solving, (b) teaching about problem solving, and (c) teaching through problem solving. Teaching for problem solving is a method where basic content skills and facts are taught without focus on application or problem solving. Here the assumption is that students cannot be good problem solvers without learning the basics of a discipline so the majority of learning is the teaching of basic knowledge. Teaching about problem solving implies that the teacher provides students with the strategies and skills necessary for problem solving. This approach also teaches students how and when to use the strategies and skills. Teaching through problem solving allows students to learn basic content knowledge and problem solving through the use of the
problem solving process. Examples include student discovery, asking open-ended questions, problem posing, use of manipulatives, and cooperative learning. This method is the most effective in assisting middle school students to become accomplished problem solvers. Problem based learning is closely correlated to the teaching through problem solving method because both provide students the opportunity to pose their own problems and sub-problems, reflect on knowledge, learn through cooperation and discussions with peers, real-life application, higher-level questioning, and use of multiple problem solving strategies and skills.

It is important that students have problem solving skills to identify and define the problem and learning issues associated with the problem. One of the most important problem solving aspects is problem identification, particularly without referring to a textbook (Barell, 1995). Identifying and understanding the problem is the first step in problem solving and PBL. Gallagher et al. (1992) researched the problem solving steps of gifted high school students in a PBL course compared to the traditional course. Problem solving process steps were researched before and after the use of PBL. The students who received the PBL course scored higher on the problem finding component of problem solving. Chin and Chia (2006) found that ninth grade students involved in an 18 week PBL unit had difficulty in the beginning of the learning process identifying a problem for investigation due to being accustomed to the teachers providing the problems and information needed. However, once students were actively involved by asking for guidance from family, teachers, and other adult assistance, students were able to easily identify and define the problem. Jonassen (2004) differentiated between multiple types
of problems. Story problems are most often researched and tend to be highly structured, resulting in the use of one specific method to solving the problem. Story problems are often used in traditional teaching, particularly in K-12 educational settings. Problem based learning was originally designed to provide medical students with case-based problems. Case-based problem structures are ill-structured and do not have a specific process to solving.

Students each have different experiences and knowledge allowing for diverse general problem solving strategies to be employed. Students must have acquired the skills to generate plans and possible solutions through heuristics with the use of prior knowledge, experiences, and research. Part of the problem solving process requires students to obtain the skills necessary to generate a plan and make decisions about information to select the best-fit solution to the problem. Berkson (1993) reviewed 10 medical based PBL studies and found there was no significant evidence to support PBL as a better teaching method for problem solving than traditional methods. Gijbels et al. (2005) reviewed 40 empirical studies comparing PBL and traditional methods. Results indicated that PBL students were able to emphasize the connection between basic concepts and apply knowledge structures at higher levels.

During the problem solving process students must know and be able to apply problem-solving strategies to assist with the plan to solve the problem. Algorithms, heuristics, means-ends analysis (Newell & Simon, 1972), chaining forwards, backwards, (Chi & Glaser, 1985) or bi-directional are problem solving strategies that can be used to solve different types of problems. Ill-structured problems are more difficult to solve and
require complex problem-solving skills, strategies, and processes. An ill-structured problem has no relevant algorithm leaving only heuristics to solve the problem through multiple acceptable solutions.

There are three components to a problem: givens, goal, and operations (Chi, Glaser, & Rees, 1982). The givens are the pieces of information provided within the problem. The goal is the desired end state or solution to the problem. Operations are the actions that can be performed to solve the problem and successfully reach the goal. Some problems, specifically well-defined structured problems, use algorithms or a set of specified operations that always lead to a correct answer to solve the problem. Ill-structured problems use heuristics or general strategies known as “rules of thumb” or best guesses based on prior knowledge and experiences to solve the problem. Well-defined problems often state the givens and goals and provide all necessary information to select an algorithm to solve the problem through one correct answer. Ill-defined problems have ambiguous goals with necessary information not included. Research generally has focused on well-defined and structured problems and not ill-structured real life problems. It was originally thought that problem solving assessed through simplistic task analysis such as the Tower of Hanoi performed in a laboratory setting would transfer to complex, ill-structured problems. The Tower of Hanoi is an example of a simple and well structured task that required minimal steps and time to solve due to a specific correct solution. The simple tasks required minimal steps and time to solve, structure was provided through the relevant information and there was a specific correct solution.
Ill-structured problems with multiple solutions take time to solve and require the background knowledge of multiple domains or experiences.

The focus of research has shifted from a process of problem solving to the distinction between novice and expert problem solving. Expert problem solvers have a more advanced organized and complete knowledge base to assist in problem solving. Expert problem solvers can easily and quickly retrieve information related to the problem due to having more specific content domain knowledge that is organized and interconnected. Experts also have domain specific problem solving strategies and procedures that are efficient and automatic (Glaser, 1987). Experts possess the skills to think about, plan, review, and examine the problem prior to having a solution. Simon and Simon (1978) compared expert and novice problem solvers in physics and found experts use a “working forward” method to solve problems. Working forward is a method of reading and understanding the givens of the problem then moving towards a physical representation. Only after analysis, research, reviewing, and retrieving domain specific information previously learned and identifying multiple solutions does an expert employ solutions. They utilize data-driven reasoning due to their extensive knowledge base about the subject. Experts often use inductive or forward reasoning to solve specific problems. Forward reasoning responses use certain input or information to solve the problem. Rarely are two problems alike and even experts with prior background knowledge face everyday problems where their prior expertise is not enough to solve the problem.
In contrast to expert problem solvers, novice problem solvers use what is seen as inefficient problem solving strategies such as trial and error due to lack of a content specific domain knowledge base. Novice problem solvers tend to jump into the problem before reading, reflecting, and reviewing the problem. Novice problem solvers work backwards by using deductive reasoning trying to determine what procedure will lead to a correct answer. Backward reasoning focuses on achieving knowledge through a search and goal-driven processes. The student begins with the problem goal and works backward using the given information within the problem and logical steps to move toward the problem state to solve. Means-ends analysis is used when the goal is clearly specified and the problem can be broken down into sub-goals. When the sub-goals are successfully completed, the problem is solved. Novices read the problem and automatically search for an answer without using proper problem solving skills. They often pursue an answer without direction and lack in problem solving skills that are necessary for the problem solving process including comprehension of the problem, planning, and organization of knowledge base and schemas.

During PBL students, when provided ill-structured and authentic problems, use backward reasoning (Patel, Groen, & Norman, 1993). A quasi-experimental study compared two different types of PBL groups in an international marketing course. The experimental group was a refined PBL group that used technology tools and problem solving templates during the learning process. The students in the refined PBL group used more inductive thinking and forward reasoning (Arts et al., 2006). Sendag and Odabasi (2009) found students in PBL acquired higher levels of critical thinking skills
between pre- and post-tests when compared to a traditional lecture group. Hmelo et al. (1997) examined the differences between problem solving skills of medical students in PBL versus traditional classes through analyzing reasoning strategies. PBL students were more likely to use a hypothesis-driven reasoning with longer reasoning chains and traditional students were more likely to use data-driven reasoning.

Due to a lack of organized domain knowledge, elementary students are usually novice problem solvers. A review of cognitive research and teaching practices suggests that when teaching elementary students, direct instruction—where explicit directions and a high degree of structure are provided—is an appropriate method based for novices (Doyle, 1983). However, through practice, modeling, coaching, and feedback, students can learn the necessary problem solving skills to begin to become expert problem solvers. Teaching problem solving skills is not as effective as having them woven into the curriculum by allowing students to experience problem solving processes through authentic and complex problems. Possessing problem solving skills is necessary since students will encounter different types of problems that are related to multiple and unfamiliar domains.

The ability to successfully use knowledge and strategies learned from one situation to another unrelated or dissimilar situation is known as transfer. Transfer occurs in everyday life and essential to human functioning.

Ideally, transfer and problem solving should be two of our educational system’s top priorities. Schools at all levels, from preschools to doctoral programs, teach knowledge and skills with assumptions that students will somehow apply what
they have learned to the ‘real world.’ Yet the things people learn in school do not always seem to transfer to new situations and new problems. (Ormrod, 1999, pp. 347-348)

Transferred knowledge and skills are acquired and applied to new situations and problems. If transfer were not used when a new problem was encountered, most of our time would be spent using trial and error methods. Norman, Brooks, Colle, & Hatala (1998) found that students using hypothesis-driven strategies led to greater accuracy on a transfer task. PBL students using hypothesis-driven reasoning are able to transfer problem solving skills to unrelated problems and generate more precise explanations than non-PBL students (Hmelo et al., 1997). Elementary students are able to transfer problem solving skills more effectively when teachers model the problem solving process during PBL. Pedersen and Liu (2003) used a problem based hypermedia instructional computer program, Alien Rescue, with sixth grade students to compare three PBL variations: (a) modeling, (b) didactic or expert explained tools and tips, and (c) help that consisted of technology tools without tips and advice. Results indicate that those who had an expert modeling the cognitive processes of problem solving performed significantly higher when asked to transfer the problem solving skills learned during PBL to an unrelated problem.

Current PBL research has focused attention on problem solving strategies. Much less has been conducted on the actual problem solving skills required to complete the problem solving processes. In this case conclusions are mixed. A review of the empirical literature concluded that there is minimal evidence to suggest that PBL
improves generic content-free problem solving skills (Norman, 1988; Norman & Schmidt, 1992). There is insufficient research concerning problem solving skills and the acquisition of skills after the implementation of PBL and more work is needed in this area.

PBL and attitude. Attitude is a complex cognitive process that reflects values or feelings toward learning and learning subject(s). There has been a steady decline in attitude towards school and learning and favorable views of schooling decrease as the grade level increases. Over the past 20 years research demonstrates a decline in attitude towards learning beginning at age 16 (Osborne, Simon, & Collins, 2003). Young adult students begin to lose interest in learning and pursuing careers in science. Greenfield (1996) assessed K-12 student attitudes toward science using multiple surveys. Third and fourth grade students expressed the most positive attitude and ninth through 12th-grade students had the least positive attitude toward science. There are multiple explanations for the decrease in positive attitudes toward science as students progress through school. One explanation is the method of teaching science. Ebenezer and Zoller (1993) surveyed and interviewed 10th-grade science students who indicated science taught in the teacher-centered traditional lecture format was boring. Students preferred to learn by having an active role in the learning process and taking responsibility for their own learning.

PBL and attitude research focuses on student attitudes towards PBL as a teaching method and learning process. Bowe and Cowan (2004) provided post secondary physics students with a questionnaire. Students reported PBL to be “fun, interesting, challenging
and motivating and wondered why problem-based learning was not used more extensively” (p. 169). Macdonald (2004) asked undergraduate students about their PBL experience to understand how to improve the learning process and found students had a positive attitude towards their learning during PBL. Students noted that it was challenging but had learned at a deeper level and enjoyed the experience. Secondary science students also have a positive attitude towards PBL. Students attribute the positive attitude toward PBL to (a) the promotion of active learning, (b) having relevant and interesting information, (c) fun lessons with variety, (d) the promotion of critical thinking, and (e) engaging in supportive group work (Goodnough & Cashion, 2006). PBL has had a positive long-term affect on attitudes. Urban middle school minority students and teachers had a positive attitude towards PBL after a 2 year implementation (Gordon et al., 2001).

PBL provides students the opportunity to learn through taking active learning roles and responsibility for individual and group learning. The attitude of students after implementing PBL has demonstrated positive effects in medical schools (Kaufman & Mann, 1996). Vernon and Blake (1993) conducted a meta-analysis comparing PBL and traditional outcomes using evaluations. They concluded that PBL students had significantly higher positive attitudes and opinions concerning their courses. Some studies have been less favorable and found no significant difference in attitudes towards a subject when implementing PBL versus traditional lecture teaching methods. For example, undergraduate psychiatry students in PBL achieved higher scores on a final examination but there were no significant differences in attitudes (McParland et al.,
2004). More research is needed to determine the conclusions under which PBL will improve attitudes toward science instruction, especially at the elementary level.

**Cooperative Learning**

Small group instruction dates to the late 1890s with positive effects. However, the transition from individual competitiveness fostered by the industrial age to group cooperation needed in the Information Age has been slow in American society and schools. During the 1970s and early 1980s there was a strong focus on how to assist students in the process of collaboration and structured cooperative learning methodologies were developed and implemented. Since then cooperative learning has become part of the 21st century learning outcomes. Some popular cooperative learning methodologies include Jigsaw, Jigsaw II, Teams-Games-Tournaments (TGT), Student Teams Achievement Divisions (STAD), Cooperative Integrated Reading and Composition (CIRC), Small Group Learning, Learning Together, and Group Investigation. Each varies on task, role, and incentive structures.

Cooperative learning methods build student achievement, create positive relationships, and assist in cognitive and social development. Each of these popular cooperative learning methods has been researched in educational settings across multiple subjects and age levels. There is a large body of cooperative learning research. Several classroom-based studies have confirmed positive cognitive and social benefits of cooperative learning including increased achievement (Johnson et al., 1976; Slavin, 1980), self-esteem (Slavin & Karweit, 1981), problem-solving (Qin et al., 1995), attitude (Johnson et al., 1976), and reduction in ethnic/race conflicts (Slavin, 1980).
Cooperation is a natural social act integrated into the learning process that involves the interaction of groups of individuals working together on a shared goal to solve a problem, complete a task, and create a product for individual and group benefit. Students work in groups to benefit themselves and the group to achieve a shared goal (Johnson et al., 1994). The terms “cooperative learning” and “collaborative learning” have been interchangeable within the research. Cooperation and collaboration are closely related. However, collaborative learning now refers to a broad term used to describe a variety of approaches where learning takes place in a natural unstructured social environment among students of two or more that converse about a joint intellectual effort (Johnson, Johnson, & Smith, 1998; Paz Dennen, 2000; Smith & MacGregor, 1992). On the other hand, cooperative learning is generally defined as learning that focuses more on small groups of four to six students with different levels of ability that share knowledge and have the responsibility of assisting teammates in achieving the overall goal.

**Cooperative Learning and Achievement**

When cooperative learning is compared to other teaching methods, students generally achieve at higher levels and enjoy the subject and content they are learning. Research demonstrates that when students work together in groups they generally achieve at higher levels than students who are participating in individualistic and competitive learning environments or with teacher-led instruction (Bossert, 1988; Slavin, 1983b; Slavin, 1995). Sharan (1980) reviewed experimental studies analyzing five cooperative learning methods and student achievement. Students in cooperative learning situations performed higher compared to traditional lecture classes. A meta-analysis of 122 studies
reviewing cooperative, competitive, and individualist structures concluded that cooperative learning promoted higher achievement (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981).

Elementary science and mathematic students participating in cooperative learning perform at higher levels than teacher-led instruction (Souvignier & Kronenberger, 2007). The same results were reported for college level chemistry (Doymus, 2008). Skon, Johnson, and Johnson (1981) compared the use of cooperative learning and teacher-led competitive or individualistic methods with first grade students in a suburban setting and concluded that cooperative peer discussion supported higher achievement and reasoning strategies including categorization and retrieval and metaphor interpretation. However, some have suggested that cooperative learning may not be uniformly successful. For example, Li and Adamson (1992) did not find that cooperative learning was effective in improving achievement of secondary gifted students. These students seemed to prefer the use of individualistic and competitive learning methods.

**Role Structure and Achievement**

Students work more efficiently and effectively when roles are assigned. Assigning group roles can assist in positive interdependence and maximize learning. Assigning individuals to interconnected roles delineates the responsibility for each individual group member (Johnson et al., 1994), increases the overall group accountability (Lyman, Foyle, & Azwell, 1993), and fosters self-esteem through the completion of the task (Williams-Boyd, 2003). Elementary students often require more structure for proper group functioning (Foyle, Lyman & Thies, 1991). Role assignment
provides structure and clarity for elementary students and allows them to focus on the task. The types and functions of roles depend upon time allocated, needs of group members, and the task requirements (Lyman et al., 1993). Roles can be assigned by having students role-play a real world position such as Mayor of a city or scientist. Roles can also be assigned by specific functions for each individual within the group such as reader, recorder, encourager, leader, secretary, or time keeper. The type of role structure can influence student ability to organize and connect old information with new information. Interconnected roles assist in basic functioning and application of knowledge within the group. Even though roles provide a basic structure for the group, Emmer and Gerwels (2002) observed and interviewed 18 elementary teachers and found that they usually do not follow a specific cooperative learning method and roles are often not assigned. Arts et al. (2006) compared two PBL groups with different role assignments. One group was assigned roles by a tutor and the other group assigned roles to themselves. Students who were permitted to choose their own roles used forward reasoning during problem solving and demonstrated higher quality diagnoses and solutions to the problem.

**Task Structure and Achievement**

An issue with previous cooperative learning research is determining how to measure achievement (Slavin, 1983b). Students are often assessed based on group performance and not individual performance. With individually-based task structures students are not motivated to teach each other what they have learned, resulting in lower achievement and lack of positive interdependence. Individually-based task structures
also allow students to depend upon and receive information from the more conscientious students. However, these conscientious students also feel slighted and discouraged and can frequently develop a negative attitude toward the subject and cooperative learning. The lack of individual accountability and student autonomy leads to minimal positive interdependence and achievement. Paz Dennen (2000) increased task structure for three problems given in a semester-long online course and found student performance improved for both the process and product. Students also indicated that the task structure provided extrinsic motivation and clarity, even though the facilitator was less involved as the task structures increased. In cooperative learning with group task structures, each student is assigned a task to complete to ensure individual accountability. When group members have an assigned task to complete, students are more likely to achieve in their subject areas.

When the focus of cooperative learning research shifts to group accountability, the task structures within groups also change. Traditional individualist task structures can lead to competition, negative conflict, unequal learning, less sharing and communication among group members, and lower achievement. While some learners experience positive achievement and motivational outcomes, these approaches create an environment of competitiveness. This type of learning environment distracts from the overall group goal and leads to lack on interdependence. Group tasks provide interdependence within the group. Each person has a responsibility to fulfill and without each piece, the group will not succeed. When task structure is applied during cooperative learning, student achievement increases.
**Jigsaw.** Jigsaw is one method of cooperative learning that provides a task structure to increase student learning. Students in each group are assigned to small portions of the overall unit. The student becomes an expert in the assigned portion. Students assigned a specific portion come together to share knowledge, prior experiences, and ideas to become more familiar with the material. Students return to original groups to teach and instruct the other members of the group about their individually assigned portion.

Jigsaw was designed over a 6 year period by a team of teachers, administrators, and researchers with a vision of restructuring the teaching and learning process to ensure equity outcomes and participation for each student. Aronson et al. (1978) originally created Jigsaw as a cooperative learning method to assist in elevating racial tensions amongst students and increase achievement. The focus was to eliminate competitiveness within the group environment and create a positive interdependence. Interdependence or reliance on each group member is created by assigning each member of the group a sub-task or part of the initial problem. Each student is to research and become an “expert.” Students form an “expert” group to share ideas, knowledge, and facts about the specific assigned part through peer tutoring. Students return to original groups to teach the other members of their group about his or her assigned part. Positive interdependence is created through the reliance on each group member becoming an expert in the specified assigned topic and contributing to the success of the overall group.
Jigsaw and Traditional Small Group and Achievement

Jigsaw assigns students the responsibility of becoming peer teachers or tutors to create interdependence and ensure minimized dependence on the teacher as a source of information. The students rely on each other to succeed as a team. Consensus must be reached about the learning tasks and sub-tasks. If there is disagreement about the task, a decision has to be made before the learning continues.

When Jigsaw and traditional teacher-led classes were compared with ethnically diverse fifth and sixth graders significant achievement gains for minority students in interdependent Jigsaw classes were found (Lucker, Rosenfield, Sikes, and Aronson, 1976). Anglo students, however, performed equally between traditional and interdependent classes. However, despite many reported successes, some results have been mixed. For example, Box and Little (2003) found no difference between Jigsaw, Jigsaw with advanced organizers, and traditional teacher-led classes on social studies achievement.

Cooperative Learning and Attitude

Cooperative learning research has focused on student attitudes towards others, school, subject, and self-esteem (Slavin, 1983a). Sharan (1980) reviewed empirical studies and found a positive effect on attitude when cooperative learning methods were used. Johnson and Ahlgren (1976) studied the relationships between cooperative learning, competitive learning, and attitude toward schooling at a suburban school district for grades 2 through 12. Cooperative learning was positively correlated to student attitude toward school personnel, intrinsic motivation, relationships with peers,
self-worth, and openness to share ideas and thoughts during group learning activities.

Rutgers University developed a program, SCIENCE TEAMS, a method of incorporating cooperative learning with a focus of environmental science. Thirty-two elementary schools participated over 2 years. Attitudes of students toward science were significantly more positive than those of the control group (Mastny, Kahn, & Sherman, 1992).

**Cooperative Learning and Problem-Solving**

Problem solving skills can be learned in a group setting allowing for each student to learn from the past experiences, knowledge, and understanding of peers. Cooperative learning can lead to an increase in and focus on higher-level tasks (Stodolsky, 1984). Cooperative learning has a positive effect on the cognitive strategies used to solve problems and achievement of first grade students when compared to competitive groups and individual learning (Johnson, Skon, & Johnson, 1980). Students in cooperative learning groups use multiple problem solving skills in a non-linear process (Hill & Hill, 1990). For example, after each member in the group has completed individual research and discussed the material learned, the group may decide to review the sub-problems to redefine the problem. Qin et al. (1995) conducted a meta-analysis of 46 studies from 1929 to 1993 involving cooperative and competitive learning of individuals in groups of all age ranges and the effects on problem solving. Problem solving was divided into four types: linguistic (written or oral), non-linguistic (mathematical equations), well-defined (clear definitions, operations and solutions), and ill-defined (unclear definitions operations and solutions). Overall, cooperation had a greater positive effect on problem
solving. Individuals solving ill-structured problems in cooperative learning groups outperformed individuals in competitive learning groups (ES = .60).

**PBL and Cooperative Learning**

In the past decade, collaborative inquiry—the combination of inquiry learning and cooperative learning—has gradually increased as an effective method of learning. There is a gap in the research examining the effects of integrating cooperative learning methods into the PBL process. PBL and cooperative learning as separate teaching methods have shown to increase student achievement. The use of cognitive elaboration perspective such as rephrasing, summarizing, elaborating, examples, and integrating prior knowledge and experience(s) are mediators of learning when using cooperative learning groups (Slavin, 1995). The learning process during PBL forces students to engage in cognitive elaboration perspective. The ill-structured problem causes disequilibrium, and encourages students to examine prior knowledge and experiences. During the research and collaboration phases of the PBL learning process students summarize, elaborate, and rephrase. Groups of three to six students promotes problem solving skills and self-directedness (Lohman & Finkelstein, 2000; Qin et al., 1995). When students are confronted with a complex and complicated problem and placed into groups to share knowledge, they practice and expand on problem solving skills. The collaboration that occurs during the PBL process also provides students with the opportunity to share knowledge, experiences, identify knowledge deficits, reconcile multiple perspectives, develop social skills, and distribute the cognitive load (Hmelo-Silver et al., 2007).

Although minimal research has been conducted to gain knowledge of how cooperative
learning methodologies can be employed during PBL to increase student learning, the large body of cooperative learning research demonstrates positive outcomes related to PBL.

**Questioning**

Questioning is the root of learning. The use of questions is a natural component of the teaching and learning process. Teachers use questions during the learning process as one of the main tools for learning. Typically teachers ask 300 to 400 questions a day (Levin & Long, 1981; Stevens, 1912). The use of teacher questions within the classroom has a venerable history beginning with Socrates. During the early 1900s research began on the questioning techniques and practices used by teachers. Questions are still an essential component of the learning process across all grade levels and content areas. Questioning is a fundamental way to stimulate thinking, the “catalyst of learning” (Aschner, 1961, p. 46). Questions are a required component of the learning process.

Without the question there is no processing of information. The absence of the question indicates an absence of learning, for it is the question that centers the person’s attention upon some topic; it is the question that enables the data processing; and it is the question that determines whether a conclusion is justified or not. (Hunkins, 1976, p. 2)

Secondary to lecture, questioning is one of the most common teaching techniques. The main focus of the research over the past 40 years has demonstrated positive effects of teachers questioning as a means to influence learning, thinking, interactions of students (Wilens et al., 2004). Specifically, questions can promote higher level cognitive processes
to assist with retention of information. Questions are used to evaluate prior knowledge, ensure understanding, clarify, assess, and assist students in problem-solving, achievement, and attitude towards subjects and school. The teacher has the ability to use and manipulate questions as an instructional tool during the learning process to produce specific learning outcomes. The consensus among most teachers is that students should learn and develop critical thinking and higher-level thinking skills rather than just rote and recalling of facts. However, the majority of questioning behaviors used by teachers often focus on fact and recall of knowledge (Gall, 1970; Guszak, 1967; Pate & Bremer, 1967; Stevens, 1912).

**Teacher Questioning Practices**

Research has suggested that question frequency has remained unchanged in the past century within the educational system. Teachers frequently use questions during the learning process with an average of 300 to 400 questions a day (Levin & Long, 1981; Stevens, 1912). Corey (1940) observed an eleventh grade history teacher asking students an average rate of more than one question a minute. Most questions are used to aid recall of factual information at high school (Stevens, 1912) and elementary level (Guszak, 1967). Questioning is used to check the effectiveness of instruction and the level of student knowledge through convergent questions requiring recall of factual knowledge (Gall, 1970; Pate & Bremer, 1967). Over the past century teachers utilized factual recall questions about 60% of the time with only 20% of questions requiring thinking. The remaining other 20% were procedural questions (Gall, 1970). Corey (1940) and three judges classified questions used by secondary teachers during a 1 week period. Factual
questions ranged from 40% to 67%; only 19% to 26% of the questions required higher-level thinking. Seventh grade science classes only used 4% to 8% of thoughtful or higher level questioning. Factual recall questionings ranged from 55% to 81% of the class time.

Teachers ask questions to students for multiple reasons and purposes. Questions are used to evaluate prior knowledge before the lesson begins, during the learning process to ensure understanding, and clarify and assist students in problem-solving and achievement and at the end of the learning process for assessment. Pate and Bremer (1967) asked 190 teachers grade first through sixth: “What are three important purposes of teachers’ questions of pupils?” (p. 417). Forty-seven percent of teachers thought the purpose of questioning was to ensure students could recall facts. Ten percent of teachers thought that it was important to require students to apply factual knowledge through generalizing and making inferences. Corey (1940) conducted a 1 week observation of high school teachers. Despite a high frequency of questions asked by teachers, responses by students were 12 words or less per answer, teachers answered their own questions 38% of the time, and students were not being provided time to reflect or volunteer information (Corey, 1940). Pedagogical purposes of teachers’ questions were to require students to reflect and generalize, the six classes observed were “not satisfactory” (p. 152). Stevens (1912) also concluded that a discrepancy existed between the developing good citizens through the use of teacher questioning techniques that require reflection, thought related to pupil experiences and adequate expression of thought, and the
questioning methods used by secondary teachers that focus on fact-based textbook
questions that require only recall of knowledge.

Questioning continues to be a vital teaching and learning tool within the
classroom setting. However, if learning is to go beyond the rote memorization of facts
and focus on application, teacher questioning practices need to be refocused. Types of
questions and questioning strategies used by teachers have the potential to positively
affect the teaching and learning process. The facilitator can utilize questions to solicit
knowledge, probe for cognitive levels, and to begin the process of knowledge acquisition.
Questions can also be utilized to create inquisitiveness within the learning environment
and stimulate mental activity including thinking and reasoning.

Effective Questioning

The artful technique of questioning is essential to good teaching and learning.
Dimensions of effective questioning include frequency, equitable distribution, prompting,
and wait time (Eggen & Kauchak, 2001). A comprehensive review of effective teacher
questioning by Wilen and Clegg found that effective teachers clearly phrase questions,
focus on academics, use wait-time of 3 to 5 seconds, balance between volunteers and
non-volunteers, encourage and praise correct responses, and probe for support and
clarification (1986). Teacher questioning during instruction positively affects student
abilities to (a) focus attention on relevant information, (b) deeply process information, (c)
generate higher-level reasoning skills, (d) metacognition, (e) attitude toward subject (She
& Fisher, 2002), (f) problem solving (Parkinson & Ekachai, 2002), and (g) improving
achievement (Wilen & Clegg, 1986; Wilen et al., 2004). Effective questions also promote more favorable attitudes towards instruction (Dillon, 1990).

Teachers model the questioning process for students to assist with the process of asking and answering questions. Teachers can model the questioning during dialogue, discussions, and verbal interactions with students. Questioning techniques can be used to assist learners in furthering their understanding of how to solve a problem through modeling the behavior of the facilitator. Modeling questioning during dialogue increases motivation, peer to peer communication, problem solving skills, critical thinking, and metacognition. The teacher as a facilitator is to guide and support collaboration through the use of questions as a form of scaffolding for discussion, problem solving process, and knowledge acquisition.

During the modeling of effective questioning techniques, students begin to practice and internalize how to inquire. When students are presented with an ill-structured or difficult problem, they begin a process by asking, “What is going on here?” “Do I have the entire picture?” “What data do I need to consider such possibilities?” (Schon, 1983). After individually internalizing the identification of the problem and the possible solutions through a questioning process, students must be able to continue the questioning process through the explanations, elaborations, negotiations, analyzing, synthesizing, and deciding on a final solution through discussion with the group. Students who utilize questioning techniques are more effective learners.
**Question Types and Strategies**

Questions are used in the real world every day in surveys, investigations, courtrooms, counseling, journalism, interview, sales conversations, political and religion discussions, and simple personal home repair issues. The type of question used depends upon its function.

There are two main types of questions. Convergent or low-level cognitive questions are closed-ended and channel a student’s responses along a single direction. The questions are of narrow scope and require a single answer. A correct one word or sentence answer is required to demonstrate knowledge and understanding. Divergent or high-level cognitive questions are open-ended and seek a variety of possible answers or solutions to a problem. Here, creative and unusual answers are good. The question is asked to elicit alternative ways to complete a task or solve a problem and to allow for independent thinking and higher cognitive processes. Students use inferences, interpretations, and generalizations during questioning. Divergent questions generate new, unique, and imaginative ideas that are sometimes unpredictable. Students should formulate generalizations and diverse, original, or novel responses. Students are able to break ideas or thoughts into small components to make sense of the information. Divergent questioning encourages reasoning, critical thinking, and higher-level thinking. These questions are used as probes to extend thinking by supporting assertions. Students provide evidence to support reasons, behaviors, outcomes, and conclusions. During the questioning students learn to search for motives, assumptions, cause and effect, and relationships of elements for organizational purposes.
There are intrinsic rewards in the exploration of a topic for its own sake. Students enjoy divergent questions more than convergent and learn something about themselves or their thinking (Ciardiello, 2003). The environment should provide the freedom of the expression and acceptance of new ideas as long as the student can provide evidence or support for the new idea. An environment must be created where students can explore new ideas without the pressure of the correct answer.

Questions can be used to probe, inspire, inquire, justify, reason, expand, elicit a predetermined response, provide feedback, scaffold, reciprocate, reflect, extend, and elaborate. These types of questions are referred to as cognitive domain questions. Over the past decade, questions have been categorized in many forms including Bloom’s taxonomy (1956), Aschner (1961), Guszak’s Reading-Comprehension Question-Response Inventory (1967), and Paul and Elder’s (2006) Taxonomy of Socratic Questions. Although these taxonomies are often used to classify questions, often they are either too specific or do not address questions that create and stimulate a sense of inquiry or guide problem solving processes (Gall, 1970).

Open-ended questions require students to become actively engaged in the questioning process. Elaboration on a previous comment or question is used to encourage students to expand on their thinking, allowing them to practice asking each other “teacher-like” questions to assist in peer-to-peer learning. King (1990) researched college students in small cooperative learning groups using either guided reciprocal peer-questioning or an unguided questioning method. Students in the guided peer-questioning group using questioning stems asked more critical thinking questions
and provided deeper explanations through elaboration. Students who possess the ability to generate their own questions are more effective learners.

Reciprocal teaching and questions is a strategy that is used in reading comprehension to generate questions, clarify, summarize, and predict. Research on reciprocal teaching and questioning has focused primarily on reading comprehension. The most effective method for teaching question generation to improve comprehension is through the use of generic question stems (Rosenshine, Meister, & Chapman, 1996). Question stems provide a generic base for students to apply in multiple situations such as different reading texts or different problem scenarios. The type of response required depends upon the syntactical arrangement of the question, specifically the question stem. Verbs used within the question will indicate the type of response a student is to provide. Verbs denote the action needed to answer the question. Open-ended questions tend to have verbs such as “describe,” “explain,” and “elaborate” as part of the stem. These types of questions provide a syntactical arrangement that elicits a higher-level thinking response. Closed-ended questions have verbs within the stems such as “list” and “recite” that require a one word answer. The syntax of the question stem will influence not only the answer but the means by which it is processed cognitively. Lower level questions tend to only require minimal retrieval of information such as a fact or definition. Higher level questions require students to retrieve multiple pieces of information and experiences from discussions, text, and media to piece them together forming a logical and supportive answer.
Didactic Questioning

According to Sanders (1966), didactic questions are referred to as “memory” or “input” questions that confirm or produce an answer from memory or sensory observation that is predictable or correct, closed-ended, convergent, and at a low cognitive level (Costa, 1990). Didactic questions force students to recognize and recall information. Didactic questioning is most often used by teachers to elicit a correct response in order to assess student ability to recite and recall information (Wilen, 1991). In general, 60% of questions asked in most classrooms have been fact and recall based (Gall, 1970). Pate and Bremer (1967) asked elementary teachers about the purpose of questions they used and 47% stated that the primary purpose of questions is to assess students on the recall of factual information. Didactic questioning is an effective method of transmitting and assessing information quickly and clearly. Teachers often use closed-ended and convergent questions to elicit a specific answer prior to lecture to assess students prior learning. The types of questions can further knowledge acquisition through review, recall, and repetition of the material being taught. Didactic questions, like those presented in a textbook at the end of a chapter, can also assist students in reviewing previously learned material. Teachers often use didactic questions as a way of quizzing students on specific knowledge that has a predetermined answer. Pate and Bremer (1967) divided recall questions into two categories. Simple recall questions have the greatest convergence. These questions require only a one word answer, “yes,” “no,” or a vocabulary word, for example, “What color is the Emerald Ash Borer?” Recall can
also be in the form of multiple choice or lists and requires minimal organization of previously taught information, such as “What products are made from Ash trees?”

The question is framed in a specified way to elicit a specific, usually short, answer that is definition or fact-based. The teacher provides the focus of what is important and needs to be memorized. Written and oral didactic questions serve as a tool to cue students to what the teacher believes is important to learn. Often, there is an emphasis on less significant information, particularly in the basic subject areas of math, social studies, and reading where fact-based information is memorized to be recalled. Perhaps it is not surprising that these questions when measured by traditional achievement tests dominate questioning practices in elementary classrooms, since many standardized tests assess relatively low-level cognitive skills and knowledge. In fact, achievement gains are greater at the elementary level when lower cognitive questions are used (Rosenshine, 1979; Soar & Soar, 1979). Didactic questions allow teachers the opportunity to ask students about facts to ensure they are building a foundation of knowledge. This foundational knowledge will be used in the future for higher levels of thinking. Expert problem solvers often have a large foundational base knowledge of their specific field or topic. Facts can provide a base knowledge to work from when building further knowledge of understanding and application. When using didactic questioning, students are asked to designate meanings of words. For example, science education often focuses on the memorization of definitions to begin and build upon the storage of vocabulary. The vocabulary is used to build a knowledge base for future use when involving higher levels of thinking, reasoning, and problem solving.
Using didactic questions for recall of facts and definitions can lead to learning through rote processes of memorization and the resulting retention rate of information can be low. When didactic questions are asked, overemphasizing of sequential information over more substantial information can result. This phenomena is often viewed as “surface” rather than deeper meaning. Students are not provided the opportunity to use cognitive strategies to connect new information with old. Didactic questions generally are not used to assess student understanding, application, synthesis, intricate relationships, implications, and meanings of knowledge. Didactic questioning does not allow for inductive reasoning or the time for conclusions to be reached from evidence. Didactic questioning encourages only minimal interpretation, not allowing for controversy or discussion about the topic. Communication is driven by the teacher asking questions and students answering. Communication between peers and teachers through a discussion generally does not occur.

**Socratic Questioning**

Student-centered teaching methods describe the role of the teacher as a facilitator or cognitive coach to guide the student through discussion. Socrates used open-ended or divergent questions and the response of the student to develop inferences and deductions. Elenchus was the original name for the Socratic form of inquiry. It is a dialogue between the teacher and student. The dialogue consists of repetitive questioning that motivated and encouraged learning through logic and higher cognitive processes. This method was used throughout the Middle Ages in universities and survives today in settings like law school to assist students in the process of deduction and to think through applications and
principles. Socratic questioning has been suggested as a means to assist students in constructing the processes of higher-level thinking, critical thinking, reasoning, and problem solving (Paul & Elder, 2007). Parkinson and Ekachai (2002) studied undergraduate public relations students and found a significant difference in the reported opportunities for critical thinking and problem solving for students that were taught using the Socratic method compared to students taught with lecture.

During Socratic questioning, facilitators can model questioning dialogue that promotes active listening for inquisitiveness, curiosity, and moral development. Students have the opportunity to learn active listening skills as a part of the higher-level thinking process. Students have to actively listen to the facilitator-to-student conversation or student-to-student dialogue to process the information exchanged. The facilitator uses open-ended, divergent, and Socratic questions to encourage conversation and guide student thinking, reasoning, and problem-solving.

During Socratic questioning the facilitator uses a direct line of reasoning to elicit information as a means to formatively assess the progression and direction of the discussion. The facilitator can guide the discussion in the students’ direction by assisting students to view the world, how they think about it, and apply the past and present knowledge. Socratic questioning can be used for multiple purposes simultaneously. The facilitator can further guide the students to think about their assumptions, experiences, knowledge, and beliefs about the world and to reaffirm through accuracy and completeness. It is designed to encourage students to explore, discover, apply, elaborate, and challenge their knowledge and thinking. Socratic questioning is designed for
students to discuss and argue past experiences, opinions, and knowledge in order to solve the problem.

During Socratic questioning, students are provided the opportunity to retrieve information from schemas and to connect new and prior knowledge through probing, elaboration, organization, and clarification. Barell (2003) informally interviewed fifth grade teachers and students and found agreement that good questions are higher level and open-ended questions that evoke curiosity and confusion, making a student think and retrieve prior knowledge. Socratic questioning allows the facilitator to probe. Probing involves a series of questions or comments that require a more complete and detailed explanation as an answer that is used to support prior statements. Probing can be used to address an individual student or group. Socratic questions are used to clarify. If a student response either in the form of a statement or question is not clear or needs further detail, the facilitator can ask an open-ended question to elicit further clarity. Clarification is also used when the student does not seem to comprehend the question originally posed. Socratic questioning also uses elaboration to promote extended thinking through building upon new and prior knowledge. Students utilize factual knowledge, prior experiences, and new knowledge to analyze and apply it to structure a response. Chin (2007) studied seventh grade science teachers to investigate how questioning is used in discourse during the learning process. One of the four types of questioning techniques used by teachers was Socratic questioning. These questions tended to allow reflection on incorrect answers, support answers through additional information by expanding or elaborating on an answer, or encouraging students to generate ideas from previous knowledge and
reasoning. Socratic questioning was used to coach and scaffold students when working on experimental lab problems collaboratively in groups or in whole class discussions. The teacher served as a coach and resource to assist students in productive and higher-level thinking.

Socratic questioning is seldom apparent in elementary settings. Elementary students are often curious about their world and enjoy asking questions. The Socratic questioning technique provides students the opportunity to answer and ask questions among peers and with the teacher. Some argue that elementary students do not have the cognitive skills to be able to understand and utilize Socratic questioning and discussion technique. A fifth grade student may not be able to think and question in logically deductive ways like a ninth grade student. Younger students may not have the necessary schema to be able to relate to the open-ended questions and dialogue during the discussion. However, schema can be reconstructed during discussion with peers and the facilitator to begin building and connecting knowledge. Socratic questioning was used to teach the problem solving process with 9-year-old Taiwanese students (Chang et al., 1998). Students were interviewed to identify misunderstandings in subtraction skills. Students were questioned using Socratic questioning techniques to resolve misconceptions. Factual knowledge was not taught. Student scores significantly increased indicating that Socratic dialogue increased student conceptions and reasoning during subtraction (Chang et al., 1998). The facilitator can utilize questions and responses to begin to understand existing schema, and through guiding and scaffolding, students can assist one another in the rebuilding and reordering process.
Socratic questioning during teacher-centered instruction has shown to be more effective in student achievement than didactic questioning. To date research on Socratic questioning during student-centered instruction is limited. Empirical support is needed to evaluate the benefits of the Socratic questioning method when used in conjunction with an inquiry based method. However, it seems clear that Socratic questioning promotes critical thinking and fosters cooperative learning through the use of discussion.

**Question Types and Discussion**

Discussion is viewed as an important alternative instructional method to teacher lecture and student recitation because of its potential to promote student understanding of societal issues and problems (in sciences and social studies classes, for example) and how this might lead to reflective decision making and problem solving. (Wilen et al., 2004, p. 182)

The use of different question types determines the type of discussion. “If a teacher uses the same questions for all students and all circumstances, productive interaction is unlikely” (Cunningham, 1986, p. 68). The nature of the question has a direct impact on how the discussion proceeds. The types of questions teachers ask can expand or limit the operation of the cognitive process of the student. It has been widely assumed that the cognitive level of teacher questions has a direct impact on student thought processes and levels. However, there are mixed conclusions in the literature.

While a discussion can occur where the teacher asks a closed-ended question and the student responds with the correct answer, a one-way response discussion ends the conversation without further thinking, elaboration, or further conversation. The pattern
between the teacher and student during a closed-ended discussion is often (a) the teacher initiating the question, (b) the student responding with a brief answer, and (c) the teacher evaluating the response. Cazden (1988) termed this common three-part sequence of initiation, response, evaluation as IRE questioning. IRE questioning is utilized primarily at all grade levels in a lecture based classroom. The teacher has control by being the only one to inquire. Rosenshine (1976) reviewed correlation studies concerning teacher questioning. In general student achievement was higher when questions were direct, academically focused, and fact-based, and students were reinforced with immediate feedback of correctness. However, this pattern of discussion does not occur readily in elementary settings because the teacher is “a manager of students, materials and tasks [rather] than a discussion leader” (Rosenshine, 1979, p. 43). The students are expected to actively listen and provide a short and correct answer to the question. There is expected brevity to the answers of closed-ended questions. Teachers often require a one word or one sentence response. Once the response is given the teacher rarely allows student follow up with an explanation or evidence to support thinking and learning. Students are not permitted to discuss among peers or engage the teacher.

A discussion with the use of open-ended questioning by the facilitator allows for multiple responses and a cyclical movement of communication and learning between facilitator, student, and peers. Through the cyclical conversation, questioning techniques are utilized to move the student on a cognitive trajectory leading to new knowledge and skills. Most students have minimal training and opportunities to experience an open-ended discussion. Research indicates that students lack this expertise because they
have not had the opportunity or encouragement to develop these skills (Brookfield & Preskill, 1999; Dillon, 1988). Cooperative learning during inquiry based learning provides the chance for students to learn through student-to-student discussion. When students grapple with the content by asking their own questions, they are learning and applying higher-level thinking and problem solving skills. Open-ended questions used during group discussion allows for more than one student to answer, eliminating the IRE sequence of questioning. Students often remember what they answer and by allowing multiple students to participate in the discussion, achievement of students will increase.

Open-ended questions allow for elaboration. Elaboration is a cognitive process where students continue thinking by making new connections to past information and experiences. Students engaging in elaboration through connections between past and present information begin the process of becoming life-long learners as intrinsic motivation becomes the focus. Elaboration opens the discussion and sustains student thinking throughout the learning process. Students have to take factual knowledge, prior experiences, and new knowledge, and analyze and apply them to structure a response. Students are brought into a meaningful and in-depth conversation. The facilitator engages students in a meaningful conversation by utilizing the initial student response as a launch pad for deeper thinking. During this process students are actively involved in divergent thinking.

**Questions and Achievement**

Questioning increases student achievement and positively affects student thinking. Student achievement is positively affected by higher level written and spoken
questions used by the teacher (Andre, 1979; Hand, Prian, & Wallace, 2002; Redfield & Rousseau, 1981; Ryan, 1973). Higher cognitive level questions posed by the teacher have a greater influence on student achievement than lower cognitive questions. Redfield and Rousseau (1981) conducted a meta-analysis of experimental research on higher and lower cognitive teacher questioning on student achievement. The research found higher achievement gains when higher cognitive questioning was used. Specifically, higher level questionings have a positive influence on fifth and sixth grade students (Dunkin, 1978; Ryan, 1973). Kleinman (1965) compared the use of higher-level critical thinking questions to recall questioning in seventh and eighth grade science classes and found students who had experienced higher-level questioning scored higher on an achievement test. Similarly, higher-level analogy questions had a positive impact on the science achievement of secondary students (Hand et al., 2002).

Wilen and Clegg (1986) concluded that effective teachers engaged in asking higher level questions and probed students to clarify, support, and extend their thinking. Research on student guided questioning has shown positive results on student achievement. King (1994) conducted a study using Guided Peer Questioning to support elaboration on the content during cooperative learning by providing question stems. King had students use experience-based higher level questions requiring elaboration on prior experiences and allowing for connecting questions that required students to bridge previous learned information with new knowledge.

However, the literature provides conflicting support for the use of higher-level questioning for improving achievement. A review of correlational studies concerning
teacher questioning revealed that students achieve more when questions are fact-based and have an academic focus compared to higher-level questions or the combination of higher and lower level questions (Rosenshine, 1976). The frequency of oral questions used by teachers can influence student achievement. The higher frequency of teacher oral questions used the higher student achievement (Wilen et al., 2004). In a reviewing of previous research Rosenshine (1971) found a positive correlation between frequency of fact-based teacher questions and student achievement. However, there was a negative correlation between frequency of higher-level questioning and student achievement. Achievement gains are greater at the elementary level when lower cognitive questions are used more frequently than higher level questions (Rosenshine, 1979; Soar & Soar, 1979) in science classes (Wright & Nuthall, 1970) and for low socioeconomic status (SES) students (Berliner, 1984; Brophy & Evertson, 1976).

Moreover, some studies and reviews of prior research suggest that there are no relationship differences between questioning levels and student achievement (Armento, 1977; Samson, Strykowski, Weinstein, & Walberg, 1987; Winne, 1979). Gall (1984) suggested that findings supporting lower level questioning are due to the student characteristics. When the population is heterogeneous and all grade levels are considered, the results indicate that higher level questioning promotes higher achievement. According to Rosenshine (1979), higher level questions are often those that require opinions and personal responses that are not academically focused. Also, many achievement tests are not designed with higher level questions that require interpretation and critical thinking.
Questions and Attitude

Questions can affect attitude toward school and subject matter. During open-ended questioning and discussions, students begin to share opinions, feelings and attitudes toward the topic, enlightening each other with new perspectives (Dillon, 1990). Teachers assist students in gaining content knowledge which in turn develops more positive attitudes toward the information and subject matter. She and Fisher (2002) found a correlation between teacher use of higher level questioning and seventh through ninth grade Taiwanese student attitudes toward science.

PBL and Questioning

Questioning is a critical activity during PBL. The facilitator is an expert learner present to guide the learning process with the use of questioning. Hmelo-Silver and Barrows (2006) found experienced facilitators in PBL scaffolded through modeling open-ended and meta-cognitive questions and assisted students in the internalizing and using question strategies. Hmelo-Silver and Barrows (2008) also concluded that higher level questions used by experienced facilitators assisted in collaborative knowledge building. The use of a variety of questions including open-ended, divergent, thought-provoking, clear, and focusing questions to promote problem solving is critical in PBL (Ronis, 2008). Barrows (1988) noted that the facilitator should refrain from giving opinions or information about the subject matter that could lead to a “correct” answer. Instead, the facilitator should use questioning to scaffold students in deeper thinking and elaboration. Orig (2004) has suggested the use of Socratic questioning and PBL as complimentary contemporary methods to teach literature.
Chapter Summary

The demands of society and the information explosion have contributed to the need to shift from instructivist to constructivism instructional models. PBL, as a constructivist methodology, has elements that provide students the opportunity to engage in learning and applying problem-solving skills and basic science knowledge. There is limited empirical research on the role that teacher questioning plays in cooperative learning during PBL in improving problem solving skills, achievement, and attitude towards science.

The model originally designed and used in medical school has been refined and implemented into K-12 settings (Gallagher & Stepien, 1995). “Research on how to best make use of PBL in nonmedical education programs is not fully developed, and the studies of theory and practice integration through PBL have yet to be developed” (Lam, 2004, p. 384). Non-empirical research detailing the implementation of PBL into the K-12 context suggests using cooperative learning methods such as Jigsaw (Lambros, 2004) and Socratic questioning.

Limited research has been conducted to provide evidence of the effects of instructional strategies that are logical supplements to PBL. Cooperative learning and PBL both assist students in building problem solving skills, communication, research, positive attitudes, and higher-level achievements. Questioning is a fundamental way to stimulate thinking and learning of students (Aschner, 1961; Hunkins, 1976). Effective questioning strategies in PBL provide students the opportunity to practice speaking, listening, questioning, discussion, communicating, collaboration, thinking at different
levels, and learning information. Questions can be used to evaluate prior knowledge, ensure understanding, and assist students in problem-solving, achievement, and attitude. Primary research has established an effective, high-level, and positive relationship between teacher questioning and achievement. Didactic questioning instructs and assesses students on the basic factual and definitions of the core subjects. Socratic questioning in PBL is designed to develop problem solving skills and higher-level thinking. Teachers believe that students should learn and develop critical thinking and higher-level thinking skills rather than just rote and recalling of facts. However, teachers questioning behaviors focus on fact and recall of knowledge. Research on questioning has focused on the use of teacher questioning during the traditional lecture based classroom where questions are fact-based and used after exposure of new material through textbook or lecture. Minimal research has focused on teacher questioning strategies during the PBL learning process.

The purpose of this study was to examine the effects of integrating cooperative learning methods and teacher questioning strategies on student problem-solving skills, achievement, and attitude toward science. The chapters following provide the study methodology, analysis, and discussion of results. Chapter 3 describes the design, research questions, dependent measures, procedures, methodology, and analysis in detail. Chapter 4 presents the results of the data analysis. Chapter 5 discusses the results of the analysis based on the literature review, implications of the study, and suggestions for future research.
CHAPTER III

METHODS

Introduction

This chapter describes the research design, methodology, and procedures used for this study. The methodology includes a description of the subjects, materials used for preparation and during the study, instruments used to gather data, and procedures for collecting and analyzing data.

Research Questions

Despite a relatively long history of research, many important questions remain concerning cooperative learning methods, and the nature of questions teachers pose during PBL and their effects on student learning. In this study the overall research question is, “How do traditional small group and Jigsaw cooperative methods interact with Socratic and didactic teacher questioning techniques on fifth grade student problem-solving skill acquisition, achievement, and attitude toward science during problem-based learning?” Specific research questions included:

1. Is there a significant difference between PBL and traditional teacher-led instruction on student learning?

2. Does the interaction of cooperative learning methods and teacher questioning techniques during PBL result in higher achievement scores?

3. Does PBL improve the attitudes of learners toward science when augmented by the use of Jigsaw with teacher Socratic questioning, Jigsaw with didactic
teacher questioning, traditional small group with didactic teacher questioning, and traditional small group with Socratic teacher questioning?

4. Does the interaction of cooperative learning methods and teacher questioning techniques during PBL have an effect on improving problem solving skills?

**Subjects**

The sample consisted of fifth grade middle school students in a rural Northeast Ohio public school district. Student ages ranged from 10 to 11 years. The gender of the students was representative of schools of this type. There were 42 males and 58 females in the study. There was a total of 1 male and 5 female teachers. Each of the six teachers had teaching experience ranging from 2 years to 38 years.

**Materials**

The instructional materials used during the implementation of the study were designed by the researcher and included (a) teacher packets with the unit outline and unit materials and (b) teacher workshop instructional materials. Each packet contained an introduction letter (Appendix A) to explain the contents of the packet and a request that the teachers not share information with other teachers involved in the study in an attempt to control for possible diffusion effects. The traditional teacher-led group packets contained the unit daily outline (Appendix B) and the unit materials (Appendix C). Specifically the packet included (a) unit objectives, (b) unit daily procedures including outlines of lecture points, (c) worksheets, and (d) *Emerald Ash Borer Report Guidelines* sheet to explain the structure and questions for students to complete a one-page research paper. Students were given paper guidelines including paragraph structure and questions
about the Emerald Ash Borer. An example question was, “What is the life cycle of the Emerald Ash Borer?”

The problem based learning group packets contained the unit daily outline (Appendix D) and unit materials (Appendix E), including (a) unit objectives; (b) unit daily procedures; (c) problem scenario letter and map; (d) KWL worksheets; (e) group evaluation sheets 1, 2 and 3; (f) seven thinking log assignments; (g) final project presentation rubric; and (h) Student Cooperation Guide sheets (Appendix F) to randomize students into groups and remind students about the rules and role structure.

The problem scenario letter was used to introduce the students to the overall problem and learning issues to begin the learning process. The KWL sheets were used to assist students in the learning process. The K sheet was designed to be used in the beginning of the unit to help students activate prior knowledge or experiences about the topic. The W sheet was designed to assist students in deciding what they want or need to know to solve the problem and complete the task. The L sheet was designed to be used at the end of the unit to assist student review of the knowledge learned during the learning process. Group evaluation sheets allowed each student to reflect on and evaluate the cooperative learning experience for each day and at the end of the unit. The thinking logs engaged students in the process of individual reflection on their learning process, thus providing the opportunity to organize, analyze, and synthesize information and skills used. A final product and presentation rubric was used to evaluate each group on content knowledge learned and presentation of knowledge. The student cooperation guides were used to assign students to roles and provide the rules for participating in the group. The teacher
questioning guides were used to assist the teacher in asking either Socratic or didactic questioning during the unit.

The teacher workshop was taught face-to-face by the researcher in two, 40 minute sessions. The overall design and accompanying materials for each group was designed by the researcher before the implementation of the study. The first day of the workshop the researcher provided *Day 1 Workshop* sheet (Appendix G) to present information on PBL including the definitions, elements and procedures, unit design, and the roles of the facilitator and student. The unit instructional materials within the packets: (a) unit objectives; (b) unit daily procedures; (c) problem scenario letter and map; (d) KWL worksheets; (e) group evaluation sheets 1, 2, and 3; (f) seven thinking log assignments; (g) final project presentation rubric; and (h) *Student Cooperation Guide* sheets (Appendix F) were explained.

During day two of the workshop, the teachers were randomly assigned to treatment groups and provided with the corresponding *Day 2 Workshop* sheet (Appendix H). The researcher provided individual instruction using the unit outline, unit materials, teacher questioning guides, and *Day 2 Workshop* sheet.

The Traditional Small Group with Didactic Questioning *Day 2 Workshop* sheet (Appendix H) included the definition of cooperative learning, introduction to the traditional small group cooperative learning method, assigned student roles, introduction on questions and questioning, and an introduction to the didactic questioning technique. The teacher was given and instructed on the use of the *Teacher Didactic Questioning Guide* (Appendix J).
The Traditional Small Group with Socratic Questioning *Day 2 Workshop* sheet (Appendix H) included the definition of cooperative learning, introduction to the traditional small group cooperative learning method, assigned student roles, introduction on questions and questioning, and an introduction to the Socratic questioning technique. The teacher was given and instructed on the use of the *Teacher Socratic Questioning Guide* (Appendix J).

The Jigsaw with Didactic Questioning *Day 2 Workshop* sheet (Appendix H) included the definition of cooperative learning, introduction and overview of the Jigsaw cooperative learning method, assigned student roles, Jigsaw task assignment, the *Jigsaw Group Student Learning Issue Role* sheet, introduction on questions and questioning, and an introduction to the didactic questioning technique. The teacher was given and instructed on the use of the *Teacher Didactic Questioning Guide* (Appendix J). The teacher was given the *Jigsaw Group Student Learning Issue Role* sheet (Appendix I). The sheet listed the learning issue role for each student in each group. The researcher instructed on the use of the *Jigsaw Group Student Learning Issue Role* sheet.

The Jigsaw with Socratic Questioning *Day 2 Workshop* sheet (Appendix H) included the definition of cooperative learning, introduction and overview of the Jigsaw cooperative learning method, assigned student roles, Jigsaw task assignment, the *Jigsaw Group Student Learning Issue Role* sheet, introduction on questions and questioning, and an introduction to the Socratic questioning technique. The teacher was instructed on the use of the *Teacher Socratic Questioning Guide* (Appendix J). The teacher was provided with the *Jigsaw Group Student Learning Issue Role* sheet (Appendix I). The sheet lists
the learning issue role for each student in each group. The researcher instructed on the use of the *Jigsaw Group Student Learning Issue Role* sheet to assist the expert groups.

At the end of the data collection, all six teachers were given the opportunity to review past material learned in their group and to learn the additional material from an online workshop course website.

**Dependent Measures**

This section includes the description and rationale of the following instruments used in this study. The instrument used during instruction was a tally sheet to record teacher questioning. The materials used at the end of the unit include a criterion referenced multiple-choice posttest to assess learning from the unit. One posttest was developed by the researcher to correlate with the science unit objectives. The Abstract Storybook Form of the PEPSI was used to assess problem solving skills and the Attitude Toward Science in School Assessment Questionnaire (ATSSA) to assess attitude toward science.

**Ohio Achievement Test**

The Ohio Achievement Test (OAT) was used as a covariate. The reliability of the test has been high during the many years it has been implemented. The Cronbach’s alpha of .87 indicates high internal consistency reliability reported for 2007 OAT test (Ohio Department of Education, 2007).

**The Achievement Posttest**

The achievement posttest was a criterion-referenced test developed by the researcher to assess student attainment of the unit science objectives (Appendix K). The
reliability of the data collected during this study indicated a Cronbach’s alpha of .70 and a Spearman-Brown Coefficient split-half reliability of .77. Validity of the Achievement posttest was evaluated by two experts in the field. The test was reviewed for proper alignment of content, clarity, and format. A 15 question multiple-choice test was based on the science unit objectives that correlate with Ohio Department of Education fifth grade science standards. The test was designed to test the achievement of basic science content. A sample question was, “Butterflies, Emerald Ash Borer, Ash trees, and other plants are a(n) ________ in an ecosystem. a. Abiotic Factor, b. Biotic Factor, c. Ecology.” Students took approximately 20 minutes to complete the assessment.

**Purdue Elementary Problem Solving Inventory**

The Purdue Elementary Problem Solving Inventory (PEPSI; Feldhusen, 1972) was originally designed to assess everyday problem solving skills of culturally disadvantaged students between second and sixth grade. The inventory internal consistency reliability $r = 0.79$ established by the experts was high when reviewed (Feldhusen, Houtz, & Ringenbach, 1972; Houtz & Feldhusen, 1975). Data collected during this study indicated a reliability of Cronbach’s $\alpha = .70$. The Abstract Storybook form of the PEPSI test was utilized (Appendix L). This assessment measures the following categories of problem solving: (a) sensing that a problem exists, (b) identifying and defining the problem, (c) asking questions, (d) guessing causes, (e) clarifying the goal of the problem situation, (f) judging if more information is needed, (g) analyzing details of the problem and identifying critical elements, (h) redefining familiar objects for unusual uses, (i) seeing implications, (j) sensing what should follow a problem solution,
(k) selecting one possible solution from many, and (l) selecting the best solution. The PEPSI Abstract Storybook Form was utilized as a posttest. Students were provided a booklet that consisted of written scenarios of everyday problem situations. The test consisted of 25 items. Item response format is either “yes,” “no,” or “I don’t know,” or “A,” “B,” or “C.” Students chose what they believed to be the best answer to each question pertaining to a scenario or problem. The test took approximately 40 to 45 minutes to complete. A sample question includes,

A young boy is standing in front of a tent. He looks scared. A large beast is coming toward the tent through the bushes. The boy has been fishing and his fishing pole is leaning against the side of the tent. A coffee pot is on a grill and two fish are lying beside it. A cloud hides the sun. What is the main problem here?

**Attitude Toward Science in School Assessment Questionnaire**

The Attitude Toward Science in School Assessment (ATSSA, Germann, 1988) questionnaire was used to measure student attitudes toward science (Appendix M). The instrument was designed to measure student attitudes towards school science. The published internal consistency reliability was high with a Cronbach’s $\alpha = .93$. In this study the data collected indicated a high reliability with a Cronbach’s $\alpha = .95$. The questionnaire consists of 14 Likert scale items that range from *strongly agree* to *strongly disagree.* The test required approximately 20 minutes to complete. Sample questions included, (a) “I do not like science and it bothers me to have to study it,” and (b) “Science is interesting to me and I enjoy it.”
**Teacher Question Tally Sheet**

The observation sheet was developed to assess the quantity of the different types of questions posed by teachers during their instruction. A fixed interval of 10 minutes was used to observe each of the six classes each day and tally each question the teacher posed. Socratic or didactic questioning frequency was recorded as well as other types of questions related to management and engagement (Appendix R).

**Instructional Treatments**

The appended control groups consisted of teacher-led instruction with lectures, individual reading, worksheets, and class discussions. The four experimental groups consisted of a problem based learning environment, modified with cooperative learning groups and structured teaching questioning techniques. Each group consisted of one of the following: traditional small group with didactic teacher questioning, traditional small group with Socratic teacher questioning, Jigsaw cooperative learning with didactic teacher questioning, and Jigsaw cooperative learning with Socratic teacher questioning. Table 1 provides detail for each instructional treatment group. The six teachers were randomly assigned to one of four experimental groups or one of two appended control groups. Teachers in the experimental groups were randomly assigned one of the two teacher question types and associated questioning guides. Each of the four experimental classes was randomly assigned to one of the two cooperative learning methods.
Table 1

PBL Instructional Treatments by Group

<table>
<thead>
<tr>
<th>Cooperative Learning</th>
<th>Questioning Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Socratic</td>
</tr>
<tr>
<td>Jigsaw</td>
<td>• Randomly assigned to original groups of four to five students</td>
</tr>
<tr>
<td></td>
<td>• Role Structure Defined (Chairperson, recorder, reporter and monitor)</td>
</tr>
<tr>
<td></td>
<td>• Task Structure Defined (Each student in the group was given a specific task to research)</td>
</tr>
<tr>
<td></td>
<td>• Randomly assigned to “Expert” groups to share information researched (consisted of students with the identical learning tasks)</td>
</tr>
<tr>
<td></td>
<td>• Students return to their original groups to teach their assigned task.</td>
</tr>
<tr>
<td></td>
<td>• Teacher facilitated each group by using open-ended and divergent questions on the questioning guide in 5 minute increments.</td>
</tr>
<tr>
<td>Traditional</td>
<td>• Randomly assigned to groups of four to five students</td>
</tr>
<tr>
<td></td>
<td>• Role Structure Defined (Chairperson, recorder, reporter and monitor)</td>
</tr>
<tr>
<td></td>
<td>• Task Structure Undefined (Students decide)</td>
</tr>
<tr>
<td></td>
<td>• Teacher facilitated each group by using open-ended and divergent questions on the questioning guide in 5 minute increments.</td>
</tr>
</tbody>
</table>

Procedures

Preparation

The materials used prior to implementation of the study were designed by the researcher and included: (a) permission letter to obtain Ohio Achievement Test scores
from the previous year, (b) student assent forms, and (c) parent consent forms. A Permission Letter to obtain previous Ohio Achievement Test scores (Appendix N) was given to the principal and school administrator to sign for approval to obtain the scores. The student assent form (Appendix O) was read aloud to the students to explain the study and obtain permission to use the data collected. The teacher in each class was a witness. Parental consent forms (Appendix P) were used to explain the study and obtain permission from the parents or guardians to allow the students to participate in the study.

**Teacher Workshop**

Teachers attended a workshop designed and conducted by the researcher prior to implementation of the unit. Prior to the workshop, the researcher and teachers agreed upon a science unit to teach over the 2 week duration of the study. The teachers were randomly assigned to the control groups or one of the four treatment groups detailed above: (a) traditional small group with didactic questioning, (b) traditional small group with Socratic questioning, (c) Jigsaw with didactic questioning, or (d) Jigsaw with Socratic questioning. Packets were given to the teachers prior to meeting.

Each packet contained an introduction letter (Appendix A) to explain the contents of the packet and requesting teachers not to share information with other teachers. The traditional teacher-led group packets contained the following instructional materials: (a) unit objectives, (b) unit daily procedures including outline of lecture points, (c) worksheets, and (d) *Emerald Ash Borer Report Guidelines* sheet to explain the structure and questions to complete a one page report paper (Appendices A & B). The *Emerald Ash Borer Report Guidelines* sheet provides structure for completing the task of
researching and writing a one page report paper about the Emerald Ash Borer. Students were given paper guidelines including paragraph structure and questions about the Emerald Ash Borer. A sample includes, “What is the life cycle of the Emerald Ash Borer?” The problem based learning group packets contained the unit materials and workshop instructional materials (Appendices C & D). The instructional information included (a) unit objectives, (b) unit daily procedures, (c) problem scenario letter and map, (d) KWL worksheets, (e) group evaluation sheets, (f) seven thinking log assignments, (g) final project presentation rubric, and (h) Student Cooperation Guide sheet (Appendix F) to remind students about the rules and role structure.

The workshop was divided into two days. During the first 40 minute meeting teachers were divided into two groups: (a) teacher-led instruction and (b) PBL instruction. The Workshop Day 1 section of the packet as described above was briefly reviewed with teachers in the teacher-led group. The Emerald Ash Borer Report Guidelines sheet was presented as a guide for the structure for completing the task of researching and writing a one page report paper about the Emerald Ash Borer. Teachers worked together to discuss and align the objectives, worksheets, readings, and lectures accordingly to ensure consistency. Teachers assigned to the four PBL experimental treatments reviewed the Workshop Day 1 section of the packet including instructions, basic definition of PBL, procedures, unit design, the role of the facilitator, and student roles.

During the second workshop session the researcher met briefly with the control group to ensure alignment of standards, lecture outlines, and instructional materials. The
four PBL teachers were individually instructed using the *Day 2 Workshop* sheet (Appendix H). Cooperative learning and questioning strategies specific to each group were reviewed. Each teacher was coached on the procedures specific to his or her treatments. The *Teacher Questioning Guides* (Appendix J), unit outline (Appendix D), unit materials (Appendix E), *Student Cooperation Guide* (Appendix F) were reviewed with each teacher. The Jigsaw groups were also instructed on the *Jigsaw Group Student Learning Issue Role* sheet (Appendix I).

**Control Group**

The first day consisted of the researcher entering and explaining the study and collecting assent forms. Parental consent forms were distributed. The teacher introduced the life science unit and lectured for 30 minutes on the basics of life cycles, the life cycle of insects, and the Emerald Ash Borer life cycle with the use of a PowerPoint slide show. Students individually read text related to the lesson for 25 minutes. Students completed a worksheet related to the lesson topic and vocabulary. The teacher led a class discussion about the worksheets and then collected them at the end of class.

Teacher questioning frequency was recorded during a structured 10 minute cycle during days two through nine. During days two and three, the teacher reviewed the lecture from the previous day and returned the worksheets. The teacher lectured for 30 minutes each day with the use of PowerPoint slides. One lecture focused on ecosystems and the other lecture on the forest habitat. Both lectures related to the Emerald Ash Borer. The students read the associated online or print text for 15 to 20 minutes. Students completed a worksheet related to the lesson topic and vocabulary (Appendix C).
The students worked individually for 15 to 20 minutes to complete the worksheets. The teacher led a 20 minute class discussion about the worksheets and then collected them at the end of class.

The teacher proceeded on the fourth day to review the lecture from the previous day and returned the worksheets. The teacher lectured for 30 minutes on the topic of the Emerald Ash Borer. The teacher used a PowerPoint presentation during the lecture to explain the details, description, origin, economic and ecological effects, life cycle, and the signs and symptoms of and current prevention of the Emerald Ash Borer. The teacher provided the *Emerald Ash Borer Report Guidelines* (Appendix C). The teacher allowed students approximately 5 minutes to review the guidelines and directions. The teacher continued utilizing 10 to 15 minutes to explain the one page report due at the end of the unit. The one page report covered the topic of the Emerald Ash Borer and the science unit objectives. Students were provided 20 minutes to research and prepare for the one page paper assignment. The teacher was available if students indicated the need for assistance.

During days 5 and 6 the teacher continued to review the lecture from the previous day and check for completed worksheets. The teacher lectured for 30 minutes with the use of the PowerPoint presentation. One lecture focused on food chains and food webs and the other lecture on survival in ecosystems. Both lectures related to the Emerald Ash Borer. The students read the associated online or print text for 15 to 20 minutes. Students completed a worksheet related to the lesson topic and vocabulary (Appendix C).
The students worked individually for 15 to 20 minutes to complete the worksheets. The teacher led a 20 minute class discussion to review the worksheets.

During days 7 and 8 the teacher reviewed the lecture from the previous day and the Emerald Ash Borer Report Guidelines sheet for 15 minutes. Students were provided 1 hour to research using computers, classroom resources, and library resources. Students individually used the Emerald Ash Borer Report Guidelines to begin outlining and writing the one page paper.

The students completed and proofread the draft of the one page paper on the ninth day. The students were given 30 minutes to finalize the paper. The teacher led a class discussion about the papers and information about the Emerald Ash Borer for 15 minutes. The students were given a test review worksheet (Appendix C). The students used 15 minutes to complete the test review worksheet assignment. The teacher led a 25 minute class discussion to prepare students for the test by reviewing each question on the worksheet.

On the final day the teacher collected the final Emerald Ash Borer one page report. Students required approximately 1 hour and 25 minutes to complete the science achievement posttest (Appendix K), Purdue Elementary Problem Solving Inventory (Appendix L), and the Attitude Toward Science in School Assessment Questionnaire (Appendix M) posttests.

Experimental Groups

Jigsaw method and Socratic questioning. The first day consisted of explaining the study and collecting assent forms. The parental consent forms were given to students.
The topic and unit were briefly introduced by the teacher. The teacher provided the scenario and problem to students through a letter and map (Appendix E). The students were provided 10 minutes to underline learning issues within the scenario letter that related to the overall main problem. The class had a 10 minute discussion to identify the main problem. Students individually worked on the “K” worksheet (Appendix E) from the KWL sheets for 10 minutes. KWL is designed to assist students in the learning process (Ogle, 1986). The K sheet is designed to be used in the beginning of the unit to help students activate prior knowledge or experiences about a topic or problem. The W sheet is designed to assist students in deciding what they want or need to know to solve a problem or complete a task. The L sheet is designed to be used at the end of the unit to help students review the knowledge learned during the learning process.

Students were randomly assigned to small groups with a role assignment (chairperson, recorder, reporter, and monitor). (If there was an additional fifth student in a group, the role of recorder was shared.) Each group was provided with a Student Cooperation Guide (Appendix F). The basic concepts and roles of cooperative learning presented in the cooperation guide were discussed for 10 minutes.

Each group member was provided with a group color-coded folder to organize daily notes, cooperation guides, and other information gathered during the PBL unit. The teacher introduced the thinking logs (Appendix E). Students individually completed thinking log one assignment during the allotted 5 minutes. If a thinking log was not completed during class, it was considered a homework assignment. The thinking log was assessed by the teacher the following day for completeness.
The following day, students returned to their assigned groups and role and the problem was reviewed. The teacher provided a W worksheet (Appendix E) of the KWL. Groups discussed and completed the K and W portions of the three KWL worksheets. The teacher facilitated each group by spending 5 minutes with each group utilizing the *Socratic Teacher Questioning Guide* (Appendix J). The main learning issues that needed to be researched were summarized in a 15 minute class discussion. Each student was provided a group evaluation sheet 1 and the teacher explained the function. Each student was given 10 minutes to complete the group evaluation sheet 1 and the second thinking log (Appendix E). The frequency of teacher questioning was recorded during a structured 10 minute cycle during days 2 through 9.

On the third day, students returned to their original assigned groups. Students were provided the *Jigsaw Group Student Learning Issue Role* sheet (Appendix I). The teacher explained each learning issue. Students utilized resources to locate information needed to complete the assignment while the teacher asked Socratic questions to each group for 5 minutes. Students were provided 30 minutes to individually research. Students were reminded of the requirement to complete a final project with information pertaining to their assigned learning issue. Students individually completed the group evaluation sheet 1 and thinking log three for 10 minutes.

During days four and five, students continued to utilize the resources to individually research. Students worked in their assigned groups to analyze and synthesize the information to generalize possible solutions. The teacher facilitated each group by using the *Socratic Teacher Questioning Guide* to ask questions for 5 minutes.
Students worked individually for 10 minutes to complete the group evaluation sheet 1 and the fourth thinking log (Appendix E) on the fifth day.

Students reunited in groups on day six. The teacher explained the expert groups. Each group member in the original group was divided into a new “expert” group according to the learning issue researched. Each person in the expert group was allotted 3 minutes to discuss and take notes on what they researched. The expert group debriefed for 5 minutes to organize the information and to begin preparations to teach the members of their original group. During this time, the teacher facilitated by asking students Socratic questions for the allotted 5 minutes per group. Students from the expert group reunited with the original group and each student was given 3 minutes to teach the group about his or her learning issue. The teacher proceeded asking questions to each group. The teacher checked the previous thinking log while the students completed the group evaluation sheet 1 and the fifth thinking log assignment (Appendix E).

During day 7 the students discussed and agreed on a “best fit” solution for 30 minutes. The teacher proceeded to spend 5 minutes with each group using the Socratic Teacher Questioning Guide. The teacher informed the students about the final project and provided the rubric (Appendix E). Students worked on the final project for 20 minutes. Students individually worked on the group evaluation sheet 1 and the sixth thinking log assignment during the last 10 minutes.

Each group created and worked on a final product during the eighth day. To continue to assist and facilitate students, the teacher worked 5 minutes with each group
asking Socratic questions. Each student required 10 minutes to complete the group evaluation sheet 1 and the seventh thinking log assignment (Appendix E).

The groups reviewed and presented the final product on the ninth day. Students were given 5 minutes to finalize the product for presentation. Groups presented a product to the entire class to provide evidence of learning. Each group was given a maximum of 5 minutes to present. The teacher graded the final products using a rubric (Appendix E). Students were provided 10 minutes to work individually on the L Worksheet (Appendix E) of the KWL. A 20 minute class discussion was used to debrief the problem. Group evaluation sheets 1, 2, and 3 were completed (Appendix E).

The teacher collected the individual thinking logs during the tenth day. The students completed the science achievement posttest (Appendix K), Purdue Elementary Problem Solving Inventory (Appendix L), and the Attitude Toward Science in School Assessment Questionnaire (Appendix M) posttests in approximately 1 hour and 25 minutes.

**Jigsaw method and didactic questioning.** The procedures for the Jigsaw cooperative learning methodology and curriculum materials were identical to the treatment group above. This treatment group differed by the teacher using the *Didactic Teacher Questioning Guide* when questioning students.

**Traditional small group and Socratic questioning.** The procedures from the previous treatment groups listed above were identical for this treatment group except for days 3 and 6. On the third day, students discussed and planned how to divide responsibilities among themselves. Students began the research process by utilizing
resources needed to complete the assignment. During this time the teacher spent 5 minutes with each group asking students Socratic questions using the Socratic Teacher Questioning Guide. Students were given 30 minutes to complete the research. Students were reminded of the requirement to complete a final project with the information located during research. Each student took 10 minutes to complete the group evaluation sheet 1 and thinking log three assignment.

Students reunited in groups on day 6 and each group discussed the research and information gathered during researching. The teacher spent 5 minutes with each group asking Socratic questions using the Socratic Teacher Questioning Guide. Students were given 10 minutes to complete the group evaluation sheet 1 and the fifth thinking log assignment (Appendix E).

**Traditional small group and didactic questioning.** The procedures and curriculum materials for this treatment group were identical to the traditional small group cooperative learning treatment group explained above. The only difference is the Didactic Teacher Questioning Guide was used when questioning students in this treatment group. Detailed treatment group lesson outlines and objectives are listed in Appendix D.

**Research Design and Data Analysis**

A quasi-experimental 2 by 2 factorial design with an appended control was used in this study. The Internal Review Board form was submitted and approval granted prior to the study (Appendix Q). The proficiency state standardized test scores, Ohio Achievement Test (OAT), from the previous year were analyzed to ensure the groups
were equal. The fourth grade OAT is a multiple choice and essay test that assesses basic knowledge at the end of the school year. An analysis of variance (ANOVA) using the previous year proficiency state standardized test scores for the control and experimental groups were analyzed for significant differences. There were no significant differences between the groups. The state standardized proficiency test scores from the previous year were utilized as a covariate. The two traditional lecture classes were combined into one control group for the data analysis\(^2\). The classes were consistent during the study. There were no differences when the data were reviewed.

Correlations between the three dependent variables were analyzed for inter-correlations using a Pearson Product Moment. The correlations were low and two correlations were significant. Usually a multivariate analysis of variance (MANOVA) is used when correlations between multiple dependent variables are significant. The MANOVA\(^3\) was not necessary for this study for a couple of reasons. First was due to the low inter-correlations between outcome variables (Bray & Maxwell, 1985; Huberty & Morris, 1989). The second reason an ANOVA was more appropriate for this study was the research questions were each analyzing individual outcome variables (Huberty & Morris, 1989). Due to these reasons, factorial ANOVAs were used to analyze each dependent variable.

\(^2\)Individual ANOVAs were used to analyze the six groups on each dependent variable. Collapsing the two control groups in to 26 participants (12 participants in one group and 14 participants in group two) does not influence the results: achievement, \(F(5, 94) = 5.13, p = .000\), attitude, \(F(5, 94) = 4.09, p = .002\), and problem solving, \(F(5, 94) = 0.47, p = .80\).

\(^3\)A MANOVA with Bonferroni post-hoc tests were used to analyze the data to compare and control for Type I errors (Toothaker, 1993). The results for the MANOVA with Bonferroni post hoc tests were identical to the multiple ANOVA results.
The coding of the negative stated items on the attitude scale were reversed by recoding to ensure high scores related to positive attitudes towards science after the PBL experience. The data from the three dependent variables were analyzed with descriptive statistics consisting of the means, standard deviation, and number of subjects in each group. The assumptions for each of the dependent variables were analyzed and met.

To analyze the differences between PBL and traditional teacher-led instruction, each group was analyzed with the scores from the achievement test. A t-test was utilized to assess whether the means of the two groups statistically differed on the achievement. Factorial ANOVAs were used to analyze the groups on each dependent variable of achievement, problem-solving skill, and attitude toward science. The means were analyzed for differences. The differences within the main effects and interaction effects of the independent variables on each dependent variable were analyzed with an alpha level of 0.05. A post-hoc test was not necessary due to having only two factors.

Teachers were each observed in 10 minute increments once each day. The researcher observed and tallied each type of question. Teachers asked the proper types of questions according to the teacher questioning guide. Data on the frequency of the types of questions teachers asked were recorded.

**Chapter Summary**

The study was designed to examine the effects of different instructional strategies used during PBL on student learning in a rural setting. This chapter provided the research questions, dependent measures, procedures, methodologies, and data analysis. The overall question for the research was, “What effect does cooperative learning
methods—traditional small group and Jigsaw—and teacher questioning techniques—
Socratic and didactic—have on fifth grade student problem-solving skill acquisition,
achievement, and attitude towards science during problem based learning in a rural
school setting?” A quasi-experimental 2 by 2 factorial with an appended control design
was chosen as a means to best answer the research questions. Fifth grade students in a
rural Northeast Ohio school were selected as subjects.

The classes were randomly assigned to either one of two traditional teacher-led
instruction (control) groups or one of four PBL experimental groups (Jigsaw with
Socratic questioning, Jigsaw with didactic questioning, traditional small group with
Socratic questioning, or traditional small group with didactic questioning). Teachers
attended a workshop prior to data collection to give details and other study related
information.

The instructional materials were created by the researcher or co-created by the
researcher and teachers. The instructional materials included the teacher question guides,
student cooperation guide, Jigsaw group student learning role sheet, group evaluation
sheets 1, 2 and 3, one page paper guidelines, and thinking logs. The instructional
materials included the 2 week traditional teacher-led instruction unit, traditional
teacher-led instruction materials, PBL unit, and PBL unit materials. The instruments
used to collect data included a criterion reference multiple-choice achievement posttest to
assess achievement correlated with the science unit objectives, the Abstract Storybook
Form of the PEPSI to assess problem solving skills and the ATSSA to assess attitude
toward science.
The data analysis consisted of using the state standardized proficiency test scores from the previous year to ensure the groups were equal. Correlations of the dependent variable scores were analyzed and the inter-correlational relationships were low. Descriptive statistics were reported. To analyze the differences between PBL and traditional teacher-led instruction on achievement, a t-test of the two groups was utilized. Coding of the negatively stated items on the attitude scale were reversed by recoding to ensure high scores related to positive attitudes towards science after the PBL experience. The non-statistical and statistical assumptions were met and 2 by 2 factorial ANOVA’s were utilized to examine the main and interaction effects of each independent variable at an alpha level of 0.05.
CHAPTER IV

RESULTS

Preliminary Analysis

Pearson Product-Moment correlations were calculated to analyze inter-correlations between dependent variables. When the outcome variables are independent of each other and not highly correlated, individual ANOVAs are appropriate to use to analyze the data (Bray & Maxwell, 1985; Huberty & Morris, 1989). Factorial analysis of covariance was used due to the three dependent variables displaying very low correlation. The second reason a factorial ANOVA was more appropriate for this study was the research questions were each focused on an individual single outcome variable (Huberty & Morris, 1989). Due to these factors a MANOVA was not deemed necessary. A factorial ANOVA was completed for each dependent variable to compare each of the groups. Descriptive statistics for the covariate and each of the three dependent variables were calculated.

The Ohio Achievement Test (OAT) scores from the previous year were used as a covariate. The covariate data assumptions were met and analyzed using an ANOVA to ensure the groups were equal. The three dependent scores for each student were composited. The two traditional lecture-based control classes were combined into one

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4A MANOVA with Bonferroni post-hoc tests were used to analyze the data to compare and control for Type I errors (Toothaker, 1993). The results for the MANOVA with Bonferroni post hoc tests were identical to the multiple ANOVA results.
group for the data analysis. There were no mean differences between the two control groups when the data were reviewed. The data from the three dependent variables were analyzed with descriptive statistics consisting of the means, standard deviation, and number of subjects in each group (see Tables 4, 6, and 8).

The differences between PBL and traditional teacher-led instruction were analyzed. The statistical and non-statistical assumptions were met. A t-test of the two groups was utilized to assess whether the means of the two groups statistically differ on science achievement posttest scores.

The assumptions for each of the dependent variables were analyzed. The non-statistical and statistical assumptions were met and individual factorial ANOVAs were used to analyze the groups on each dependent variable of achievement, problem-solving skill, and attitude toward science. ANOVA was utilized due to the three dependent variables being uncorrelated. The data were analyzed reviewing the separate control groups with significant results being identical to the combination control group.

Correlations of Dependent Variables

A Pearson-product moment correlation coefficient was used to review inter-correlations between the three variables. The Pearson Product Moment results in Table 2 indicate there were low correlational relationships between the three variables.

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5 Individual ANOVAs were used to analyze the six groups on each dependent variable. Collapsing the two control groups into 26 participants (12 participants in group one and 14 participants in group two) does not influence the results: achievement, $F(5, 94) = 5.13, p = .000$, attitude, $F(5, 94) = 4.09, p = .002$, and problem solving, $F(5, 94) = 0.47, p = .80$.

6 Individual ANOVAs were used to analyze the six groups on each dependent variable. Collapsing the two control groups into 26 participants (12 participants in group one and 14 participants in group two) does not influence the results: achievement, $F(5, 94) = 5.13, p = .000$, attitude, $F(5, 94) = 4.09, p = .002$, and problem solving, $F(5, 94) = 0.47, p = .80$. 
Two of the correlations were significant between the three variables. These results support the use of ANOVA for each of the dependent variables\textsuperscript{7}.

Table 2

\textit{Correlation Coefficient for Dependent Variables}

<table>
<thead>
<tr>
<th></th>
<th>Problem Solving</th>
<th>Achievement</th>
<th>Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement</td>
<td>0.20*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>0.09</td>
<td>0.23*</td>
<td>1</td>
</tr>
</tbody>
</table>

*\(p < .05\)

\textbf{Covariate}

The non-statistical assumptions required to perform an ANOVA were met. Specifically, the covariate was continuous and measured on an interval scale and the independent variables were categorical. There were a total of five groups in the study. The three statistical measurement assumptions for an ANOVA were analyzed and tenable. A One-sample Kolmogorov-Smirnov Test demonstrated normality, \(Z = 1.11, p = .17\). The Levene Statistic Test, \(F(4, 95) = 0.39, p = .82\), demonstrated homogeneity of variance. Subject independence was met by having each student complete all the independent variables individually.

\textsuperscript{7}A MANOVA with Bonferroni post-hoc tests were used to analyze the data to compare and control for Type I errors (Toothaker, 1993). The results for the MANOVA with Bonferroni post hoc tests were identical to the multiple ANOVA.
The state proficiency standardized test scores from the previous year were used as a covariate. The scores were analyzed to ensure the groups were statistically equal and free from systematic bias due to non-random sampling procedures. An ANOVA using the previous year proficiency scores for the control and experimental groups were analyzed for significant differences. Table 3 presents the descriptive data for the covariate means for each group. There were no significant differences between the groups, $F(4, 95) = 0.37, p = .83$, indicating the groups were statistically equivalent.

Table 3

_Covariate Means and Standard Deviations for OAT Scores_

<table>
<thead>
<tr>
<th></th>
<th>$M$</th>
<th>$SD$</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>423.77</td>
<td>29.85</td>
<td>26</td>
</tr>
<tr>
<td>PBL Traditional Didactic</td>
<td>427.94</td>
<td>34.32</td>
<td>16</td>
</tr>
<tr>
<td>PBL Traditional Socratic</td>
<td>418.02</td>
<td>28.46</td>
<td>20</td>
</tr>
<tr>
<td>PBL Jigsaw Didactic</td>
<td>427.32</td>
<td>27.64</td>
<td>20</td>
</tr>
<tr>
<td>PBL Jigsaw Socratic</td>
<td>425.37</td>
<td>24.62</td>
<td>18</td>
</tr>
</tbody>
</table>

**Hypothesis 1**

Hypothesis 1 stated there would be a significant difference between PBL and traditional teacher-led instruction on student learning. The assumptions required to perform a t-test for independent samples were met. A test of homogeneity of variances was calculated using the Levene Statistic $F(2, 98) = 0.15, p = .70$. A t-test for independent samples was used to compare the means of the two groups. The 26
participants in the traditional lecture group had a mean score of 10.38 (SD = 2.13) and the 74 participants in the PBL group had a mean score of 12.04 (SD = 1.97). These means were significantly different, \( t(2, 98) = -3.60, p = .001 \). These results support the hypothesis that PBL students would achieve higher levels when compared to traditional teacher-led lecture instruction.

**Hypothesis 2**

A factorial ANOVA was used to examine achievement scores. The effects of questioning techniques and cooperative learning methods used during PBL on science achievement were analyzed. Assumptions for a factorial ANOVA were analyzed and met. A One-sample Kolmogorov-Smirnov Test was used to determine normality, \( Z = 1.12, p = .16 \). A test of homogeneity of variances was calculated using the Levene Statistic and was tenable \( F(3, 70) = 0.59, p = .62 \). Table 4 presents the achievement means and standard deviations for each group.

Table 5 presents the results of the main and interaction effects of cooperative learning methodologies and questioning strategies on achievement. There was a significant main effect for questioning strategies, \( F(1, 70) = 9.53, p = .003 \). These results support the hypothesis that the use of questioning techniques used by the teacher during PBL result in higher achievement scores. Results show Socratic questioning (\( M = 12.66, SD = 1.66 \)) scored higher than students in didactic questioning (\( M = 11.39, SD = 2.09 \)). There was no significant main effect for cooperative learning methods, \( F(1, 70) = 1.84, p = .180 \). Jigsaw (\( M = 12.26, SD = 1.91 \)) did not score significantly higher than the traditional cooperative learning groups (\( M = 11.80, SD = 2.04 \)). Figure 1 demonstrates a
Table 4

**Means and Standard Deviations of Achievement by Factorial Cell**

<table>
<thead>
<tr>
<th>Cooperative Learning</th>
<th>Questioning</th>
<th>Socratic</th>
<th>Didactic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jigsaw</td>
<td></td>
<td>$M = 12.61$</td>
<td>$M = 11.95$</td>
<td>$M = 12.26$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$SD = 1.81$</td>
<td>$SD = 1.99$</td>
<td>$SD = 1.91$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$n = 18$</td>
<td>$n = 20$</td>
<td>$n = 38$</td>
</tr>
<tr>
<td>Traditional</td>
<td></td>
<td>$M = 12.70$</td>
<td>$M = 10.69$</td>
<td>$M = 11.80$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$SD = 1.56$</td>
<td>$SD = 2.06$</td>
<td>$SD = 2.04$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$n = 20$</td>
<td>$n = 16$</td>
<td>$n = 36$</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$M = 12.66$</td>
<td>$M = 11.39$</td>
<td>$M = 12.04$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$SD = 1.66$</td>
<td>$SD = 2.09$</td>
<td>$SD = 1.98$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$n = 38$</td>
<td>$n = 36$</td>
<td>$n = 74$</td>
</tr>
</tbody>
</table>

Table 5

**Main Effects and Interactions of Cooperative Learning and Questioning on Achievement**

<table>
<thead>
<tr>
<th>Factor</th>
<th>SS</th>
<th>MS</th>
<th>df</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questioning</td>
<td>32.78</td>
<td>32.78</td>
<td>1</td>
<td>9.55</td>
<td>.003**</td>
</tr>
<tr>
<td>Cooperative</td>
<td>6.32</td>
<td>6.32</td>
<td>1</td>
<td>1.84</td>
<td>.184</td>
</tr>
<tr>
<td>Interaction</td>
<td>8.38</td>
<td>8.38</td>
<td>1</td>
<td>2.43</td>
<td>.123</td>
</tr>
<tr>
<td>Error</td>
<td>240.87</td>
<td>3.44</td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Questioning = Questioning Strategies; Cooperative = Cooperative Learning Methodologies; **$p < .01$
Figure 1. Interaction Effect for Achievement

possible interaction effect. However, the interaction effect was not significant, $F(1, 70) = 2.43, p = .123$.

Hypothesis 3

A factorial ANOVA was used to determine if PBL improved the attitude of learners towards science when compared to the use of Jigsaw with teacher Socratic questioning, Jigsaw with didactic teacher questioning, traditional small group with didactic teacher questioning, and traditional small group with Socratic teacher questioning. The non-statistical and statistical assumptions were met. Normality was analyzed using a One-sample Kolmogorov-Smirnov Test, $Z = 0.80, p = .537$. 
Homogeneity of variances was calculated using the Levene Statistic, $F(3, 70) = 1.30, p = .282$. Table 6 presents the means and standard deviations for attitude.

Table 6

*Means and Standard Deviations of Attitude by Factorial Cell*

<table>
<thead>
<tr>
<th>Cooperative Learning</th>
<th>Questioning</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Socratic</td>
<td>Didactic</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Jigsaw</td>
<td>$M = 57.94$</td>
<td>$M = 59.65$</td>
<td>$M = 58.84$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$SD = 7.82$</td>
<td>$SD = 9.86$</td>
<td>$SD = 8.88$</td>
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</tr>
<tr>
<td></td>
<td>$n = 18$</td>
<td>$n = 20$</td>
<td>$n = 38$</td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td>$M = 54.31$</td>
<td>$M = 53.38$</td>
<td>$M = 53.89$</td>
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</tr>
<tr>
<td></td>
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<td>$SD = 10.32$</td>
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<tr>
<td></td>
<td>$n = 20$</td>
<td>$n = 16$</td>
<td>$n = 36$</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$M = 56.03$</td>
<td>$M = 56.86$</td>
<td>$M = 56.44$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$SD = 8.53$</td>
<td>$SD = 11.02$</td>
<td>$SD = 9.85$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$n = 38$</td>
<td>$n = 36$</td>
<td>$n = 74$</td>
<td></td>
</tr>
</tbody>
</table>

The main and interaction effects are presented in Table 7. The main effect on attitude with the use of questioning strategies during PBL was non-significant, $F(1, 70) = 0.03, p = .86$. Cooperative learning methodologies had a significant main effect on attitude during PBL, $F(1, 70) = 4.77, p = .03$. The results in Table 6 indicate Jigsaw cooperative learning groups ($M = 12.11, SD = 1.93$) scored higher than students participating in the traditional cooperative learning groups ($M = 11.80, SD = 2.04$). Individual Jigsaw group means (Jigsaw with didactic $M = 59.65, SD = 9.86$; Jigsaw with
Table 7

*Main Effects and Interactions of Cooperative Learning and Questioning on Attitude*

<table>
<thead>
<tr>
<th>Factor</th>
<th>SS</th>
<th>MS</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questioning</td>
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<td>2.74</td>
<td>1</td>
<td>0.03</td>
<td>.86</td>
</tr>
<tr>
<td>Cooperative</td>
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<td>450.53</td>
<td>1</td>
<td>4.77</td>
<td>.03*</td>
</tr>
<tr>
<td>Interaction</td>
<td>31.92</td>
<td>31.92</td>
<td>1</td>
<td>0.34</td>
<td>.56</td>
</tr>
<tr>
<td>Error</td>
<td>6607.02</td>
<td>94.39</td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Questioning = Questioning Strategies; Cooperative = Cooperative Learning Methodologies; *p < .05*

Socratic *M = 57.94, SD = 7.82* were higher than the traditional cooperative learning groups (Traditional with Socratic *M = 54.31, SD = 8.96; Traditional with didactic *M = 53.38, SD = 12.09*). The results indicate that students have a more positive attitude toward science when Jigsaw is used during PBL. There is a possible interaction effect as demonstrated in Figure 2. There was no significant interaction effect between cooperative learning methods and questioning strategies during PBL on attitude, *F*(1, 70) = 0.34, *p = .56.*
Hypothesis 4

The interaction of cooperative learning methods and teacher questioning techniques during PBL in improving everyday problem solving skill acquisition was examined. Assumptions for a factorial ANOVA were met. Normality was verified with a One-sample Kolmogorov-Smirnov Test, $Z = 0.801, p = .542$. The Levene Statistic was used to test homogeneity of variances, $F(3, 70) = 0.99, p = .39$. The means and standard deviations for each group on problems solving are presented in Table 8.
The main and interaction effects for problem solving are presented in Table 9. There was a non-significant main effect on problem solving with the use of questioning strategies during PBL, $F(1, 70) = 0.042, p = .839$. As demonstrated in Table 8, Socratic questioning ($M = 18.88, SD = 2.82$) did not score significantly higher than didactic questioning ($M = 19.05, SD = 3.37$). Cooperative learning methodologies, Jigsaw ($M = 19.12, SD = 3.03$) and Traditional ($M = 18.80, SD = 3.17$), had a non-significant main effect on problem solving during PBL, $F(1, 70) = 0.168, p = .683$.

There was no interaction effect between cooperative learning methods and questioning strategies during PBL on problem solving, $F(1, 70) = 0.001, p = .973$. The
Table 9

*Main Effects and Interactions of Cooperative Learning and Questioning on Problem Solving*

<table>
<thead>
<tr>
<th>Factor</th>
<th>SS</th>
<th>MS</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questioning</td>
<td>0.41</td>
<td>0.41</td>
<td>1</td>
<td>0.042</td>
<td>.839</td>
</tr>
<tr>
<td>Cooperative</td>
<td>1.65</td>
<td>1.65</td>
<td>1</td>
<td>0.168</td>
<td>.683</td>
</tr>
<tr>
<td>Interaction</td>
<td>0.01</td>
<td>0.01</td>
<td>1</td>
<td>0.001</td>
<td>.973</td>
</tr>
<tr>
<td>Error</td>
<td>689.85</td>
<td>9.86</td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Questioning = Questioning Strategies; Cooperative = Cooperative Learning

Methodologies

The graph of the means in Figure 3 demonstrates there was no interaction. Despite the lack of statistical significance between the groups on problem solving, the Jigsaw groups (Jigsaw with didactic $M = 19.20, SD = 2.95$; Jigsaw with Socratic $M = 19.03, SD = 3.19$) scored higher than the traditional cooperative learning groups (Traditional with didactic $M = 18.88, SD = 3.93$; Traditional with Socratic $M = 18.75, SD = 2.51$).
Figure 3. Interaction Effect for Problem Solving

Teacher Questioning

Part of the purpose of the study was to investigate the effects of different questioning techniques within PBL. It was necessary to evaluate the questioning techniques of each instructor throughout the duration of the study to ensure consistency. Data on the frequency of the types of questions teachers asked during the research study were recorded. Table 10 represents the frequency data for the observations of teacher questioning techniques.
Table 10

*Frequencies of Teacher Questions by Group*

<table>
<thead>
<tr>
<th></th>
<th>Management</th>
<th>Engagement</th>
<th>Socratic</th>
<th>Didactic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td>28</td>
<td>5</td>
<td>5</td>
<td>86</td>
<td>124</td>
</tr>
<tr>
<td>PBL TD</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>93</td>
<td>102</td>
</tr>
<tr>
<td>PBL TS</td>
<td>4</td>
<td>3</td>
<td>49</td>
<td>15</td>
<td>71</td>
</tr>
<tr>
<td>PBL JD</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>64</td>
<td>71</td>
</tr>
<tr>
<td>PBL JS</td>
<td>10</td>
<td>4</td>
<td>48</td>
<td>23</td>
<td>85</td>
</tr>
<tr>
<td>Total</td>
<td>52</td>
<td>13</td>
<td>107</td>
<td>281</td>
<td>453</td>
</tr>
</tbody>
</table>

*Note.* TD = Traditional Didactic; TS = Traditional Socratic; JD = Jigsaw Didactic; JS = Jigsaw Socratic.

**Chapter Summary**

The Ohio Achievement Test scores from the previous year were used as a covariate. There were no significant differences between the groups. The results support the hypothesis that students in PBL achieve at higher levels in science when compared to traditional teacher-led lecture instruction.

When comparing the PBL groups on achievement there was a main interaction effect for questioning strategies. This supports the hypothesis that the use of questioning strategies increases student achievement during PBL. The Socratic questioning scored significantly higher than the didactic questioning strategy. There was no main effect for cooperative learning methods and achievement. There was no interaction effect for
questioning strategies and cooperative learning methodologies on achievement during PBL. These results support the hypothesis that the use of questioning during PBL, specifically the use of Socratic questioning with traditional cooperative learning or Jigsaw increases student achievement.

Cooperative learning had a main effect on the attitude of students toward science. The Jigsaw means were higher than the traditional cooperative learning groups. This supports the hypothesis of using cooperative learning methods—specifically Jigsaw—during PBL to positively effect students attitudes towards science. There was no main effect for questioning strategies and no interaction effect. The hypothesis that questioning strategies affect students’ attitudes toward science was not supported.

There were no significant differences in problem solving between the groups. The hypothesis of cooperative learning methods and questioning strategies improving problem solving during PBL was not supported. Even though there was no statistical significance between groups on problem solving, the means indicate that the Jigsaw groups scored higher than the traditional cooperative learning groups.
CHAPTER V
DISCUSSION

This chapter reviews the results and considers future implications of the study. The chapter discusses (a) the research questions and findings, (b) implications of the study, (c) limitations, and (d) recommendations for future research.

Research Questions and Findings

The purpose of this study was to examine the effects of integrating instructional strategies during PBL on student learning. The overall study focused on how the effects of traditional small group and Jigsaw cooperation methods interact with Socratic and didactic teacher questioning techniques on fifth grade student problem-solving skill acquisition, achievement, and attitude toward science during problem based learning.

PBL and Achievement

Results of the study support the emerging body of research that suggests that PBL is an effective means of improving student achievement (Albanese & Mitchell, 1993; Berkson, 1993; Dochy et al., 2003; Gordon et al., 2001; Kalaian et al., 1999; Liu et al., 2006; McParland et al., 2004). Students in the PBL groups overall scored higher than the lecture group on basic science knowledge. Current research for adult learners suggests that students in traditional lecture courses gain more (Mergendoller et al., 2000; Vernon & Blake, 1993) or equal (Gijbels et al., 2005) basic science concept knowledge when compared to PBL students. However, the outcomes of this study suggest that elementary students in PBL learn more basic science concepts and declarative knowledge than students in traditional lecture. One explanation for these discrepancies in research results
is that medical students struggle at the beginning of PBL due to the transition from traditional teacher-centered lecture-based curriculum to PBL as a student-centered curriculum (Albanese, 2000). Students in elementary are continuing to develop cognitively and are able to adapt to a new learning environment easier than an adult learner who has become accustomed to the teacher-centered learning environment. Sanson-Fisher and Lynagh (2005) also offered another possible explanation that past PBL research methods were flawed, indicating a difference in overall results.

Didactic questioning was not as effective as Socratic questioning during PBL. Didactic questioning is generally used to elicit short convergent answers and does not allow for students to expand on knowledge and make connections. Both didactic groups performed lower than the Socratic groups. One possible explanation of why learning was suppressed by the didactic questions is that students were focused on obtaining the correct answers that they were not able to focus on the initial problem, problem solving and research processes. Another explanation is that retention of knowledge was minimal for the didactic groups due to the rote process of memorization of facts and limited use of cognitive strategies such as elaboration to make connections for meaningful learning.

The Socratic questioning groups achieved significantly higher when compared to the didactic questioning groups. Socratic questioning has been posited as a means to assist students in meaningful learning through connections of previous experiences and learned information (Elder & Paul, 1998). Student achievement is positively affected by higher level spoken questions used by teachers during the learning process (Redfield & Rousseau, 1981; Ryan, 1973). Science students who experience higher-level versus
lower-level questioning by the teacher tend to score higher on achievement tests (Kleinman, 1965). One explanation is that Socratic questions when used by teachers tended to allow reflection on incorrect answers, support answers through additional information by expanding or elaborating on an answer, and encourage students to generate ideas from previous knowledge and reasoning (Chin, 2007). Socratic questioning provides students the opportunity to solve problems through discussion with the use of past experiences and researched knowledge.

During the course of this study students in the traditional Socratic group reviewed multiple pages of notes. Students were writing and discussing what solutions they wanted to use to eliminate the Emerald Ash Borer. Higher-level thinking processes include creating meaning (Bruner, 1966; Dewey, 1916; Lewis & Smith, 1993; Piaget, 1952). Students engage in inquiry by posing questions that are challenging and grounded in “real world” situations. They take advantage of uncertainties and ambiguities such as those presented in the initial problem. Students evaluate gaps in their understanding and learning. They have to be active and persistent in making meaning through support in order to close these gaps (Bruner, 1966; Dewey, 1910; Hmelo-Silver & Barrows, 2006). Observations made during this study indicated that students used Socratic questions during their discussion without the presence of the teacher. Students asked questions such as, “Why do you think that would work?” and “How would this affect other animals, plants, and things in the environment around us?” These observations support Bandura’s (1977) assertion that teachers who become an active member in the learning process as part of the learning community have an influence on the social behaviors of
students. Teachers become facilitators through modeling higher level-thinking skills with the use of Socratic questioning.

An example of how students use Socratic questioning to support their learning, occurred on the ninth day during presentations in the traditional Socratic PBL class. After the teacher modeled the research process, students presented their final products demonstrating how to solve the Emerald Ash Borer problem. The first group was completing their presentation and students in the class began asking questions. One student asked, “Why do you think that would work better than the boxes used now?” One member from the presenting group responded, “This is a trap that is good for the ecosystem and is similar to the fly trap used to catch flies.” Another student from the audience asked, “Won’t they get out of the trap?” Another group member responded, “No. The bug goes into the trap down the tunnel and there is a door that only opens one way. Once on the honey they can’t get away.” Another student inquired about why the group thought the insects would be attracted to the honey. The group provided information from their research explaining that the Emerald Ash Borer likes sweet tasting foods since the sap in the tree is sweet. Another student pressed the group about the effectiveness of the solution across the seasons; “The honey would freeze during the winter so that can’t work! What are you going to do?” One member of the presenting group stated, “My dad is a farmer and raises bees. I know that honey does not freeze during the winter but gets thick.” The students in the audience and the group presenting continued for approximately 4 minutes with this dialogue until the teacher reminded them to raise their hands, effectively ending the Socratic questions and discussion process.
Observations suggested three major trends related to student discussions during the presentation in the traditional and Socratic questioning PBL group. First, the discussion was student-centered with minimal structure and interference from the facilitator (Hmelo-Silver, 2002; Hmelo-Silver & Barrows, 2006). The students were not raising their hands to discuss or question the issue but respecting each other and taking turns responding. Second, the students were using and applying Socratic questioning to question their peers about how their problem solutions worked. Also, the teacher modeled and scaffolded students through higher-level thinking and problem solving during the PBL learning process with the use of Socratic questioning. The students were applying higher-level thinking and questioning allowing the teacher to fade the initial support (Hmelo-Silver and Barrows, 2008). Third, while students used higher-level thinking through Socratic questioning, they often applied their own personal experiences. According to Dewey,

The initial stage of that developing experience which is called thinking is experience. This remark may sound like a silly truism. It ought to be one; but unfortunately it is not. On the contrary, thinking is often regarded both in philosophic theory and in educational practice as something cut off from experience, and capable of being cultivated in isolation. (1916, p. 180)

During the discussion, a student presenting a solution mentioned how she had personal experience with using and collecting honey during the winter months. The student was connecting past experiences to discuss the overall problem and support the possible solution.
Didactic questions were used more frequently by teachers than Socratic. This result was demonstrated by the number of didactic questions used during lecture by the control group. Didactic questions that focus student thinking into convergent directions, often simple recall of a right or wrong answers, are more frequently used in the classroom (Gall, 1970; Guszk, 1967; Pate & Bremer, 1967, Stevens, 1912). Teachers find open-ended divergent questioning techniques to be difficult since they are more familiar with providing immediate corrective feedback. The teacher in the Jigsaw Socratic group began to question each group when students were researching their problem. The teacher had a difficult time asking questions and relied on the questioning guide for assistance while conversing with student groups. During the workshop training the teacher asserted he already used Socratic questions on a regular basis in his classroom. During the training program, he began to realize that he was using didactic questions during instruction. He began to use didactic question and referred to his teacher questioning sheet to rephrase his questions in a Socratic form. Over time, his frustration in shifting from didactic to Socratic decreased and he became more relaxed with Socratic questions. According to Cazden (1988), most teachers want to follow the questioning sequence of initiation, response, evaluation during discussion. This structure provides teachers with the ability to provide structured and positive reinforcement to shape students responses directly. However, feedback can be provided in many different forms and alternatives to the traditional right and wrong feedback. For example, feedback can be in the form of the teacher asking a question in response to a question to allow the student to continue the thinking process.
Students also initially struggled with Socratic questions. After questioning a group of students, the teacher gave a full 10 seconds to allow for a response. If an answer was not given, the teacher repeated the question. Students struggled at first to provide answers. After a few minutes students began to think about the learning and research materials they were reading and began to apply it to answering questions. Even though there were initial struggles with Socratic questioning, after some practice, teachers and students seemed to enjoy the freedom and flexibility provided by the Socratic questioning technique.

Although the Socratic questioning groups were significant, the cooperative learning groups were not significant. One possible explanation is that the novelty of Jigsaw was a new method of learning cooperatively and more time might be required for students to become comfortable with this type of cooperative learning. Results for achievement occur over a period of time when implementing task structures that are unfamiliar (Paz Dennen, 2000). Students may have needed additional time to be acclimated to the new role and task structures provided during the cooperative learning groups.

**Attitudes**

Attitudes toward science become less favorable as students progress K-12 (Greenfield, 1996). Some suggest that the overuse of teacher-centered methodologies may contribute to this decline (Ebenezer & Zoller, 1993). In this study, students in PBL demonstrated a more positive attitude toward science than traditional teacher-centered lecture. Research suggests students in PBL have higher positive attitude towards learning
and school in general (Gordon et al., 2001; Kaufman & Mann, 1996; Macdonald, 2004; Mastny et al., 1992).

Observations indicated that students working cooperatively took an active role in learning and were motivated to do additional research to achieve at higher levels. For example, a group of students in the Jigsaw Socratic class made a shoebox collage and brought it to class. The shoebox, which was not a required assignment, contained a model replica of a forest, house, grass, and other real-life attributes of his backyard. The student was interested in the topic and had taken a walk with his family in their backyard looking for Ash trees and any signs of the Emerald Ash Borer. The student built a model of his backyard using real ash tree leaves, bark, and grass to share with the group. The house was made of cardboard with marker-drawn windows and a door. The teacher asked the student who created it why he did extra work. The student explained that he was enjoying science class again because it was fun. The student began showing the other students and continued by explaining the differences between the ash tree leaves and oak leaves to his peers. This observation supports the research that suggests that students have more positive attitudes toward learning, science, and PBL as a learning method (Bowe & Cowan, 2004; Goodnough & Cashion, 2006; Gordon et al., 2001).

Cooperative learning as a component of PBL has the overall effect of increasing positive attitudes of students toward school subjects (Sharan, 1980). The results of the study support the use of Jigsaw during PBL to improve attitudes towards science. Assigning task and group roles within cooperative learning groups allows students to work more efficiently and effectively, thus having a more positive attitude towards
learning. Allocating individual interconnected roles creates a sense of responsibility and individual accountability for group members (Johnson et al., 1994) and increases the overall group accountability (Lyman et al., 1993). This study suggests that role and task assignments provide structure and clarity for elementary students allowing them to focus on the task and increase students’ attitudes towards science. The Jigsaw groups had significantly more positive attitudes toward science. The results of this study strongly support the work of Mastny et al. (1992) who reported that incorporating cooperative learning in elementary science over a 2 year period significantly improved attitudes toward science.

**Problem Solving Skills**

There were no significant differences between the groups in acquisition of problem solving skills. Higher level cognitive processes including problem solving skills are acquired and developed over a long time period due to previous experiences and knowledge (Gagne, 1966). Since the study was limited to a 2 week duration, there was likely an inadequate amount of time to affect problem solving skills. Moreover, elementary students seldom have the opportunity to practice and experience true problem solving in traditional classrooms. Ill-structured problems are complex and require higher-level cognitive skills due to reasoning skills and processing. Since there is no one right answer, the problem solving process can be complex with the use multiple heuristics to arrive at a best fit solution. Elementary curriculum often focuses on recall and algorithmic problem-solving skills. A 2 week problem solving intervention is unlikely to have a dramatic impact in fostering these skills.
PBL is an effective method for problem solving skill acquisition (Williams-Boyd, 2003). The initial problem provided the student with “something to do, not something to learn; and the doing is of such a nature as to demand thinking, or the intentional noting of connections; learning naturally results” (Dewey, 1916, p. 181). However, while not significant statistically, $F(1, 70) = 0.001, p = .973$, there appeared to be a consistent trend indicating that problem solving skills were higher for those in the Jigsaw groups (Jigsaw with didactic $M = 19.20, SD = 2.95$; Jigsaw with Socratic $M = 19.03, SD = 3.19$) than the traditional groups (Traditional with didactic $M = 18.88, SD = 3.93$; Traditional with Socratic $M = 18.75, SD = 2.51$). Problem solving is not innate but has to be experienced and practiced. Students can increase their problem solving abilities when immersed into inquiry based learning environments and provided adequate time to practice and apply new skills (Bruner, 1966). Students need ample amount of time to process information and develop cognitive abilities including well-organized knowledge structures and automatic information processing. When elementary students are faced with an ill-structured problem for the first time the problem solving process is a slow and laborious and demands close attention and retrieval of relevant information and experiences from long-term memory.

Recent problem solving research has focused on the specific mental processes used to reach problem solutions. Information processing theories focus on the role of working memory capacity, meaningful learning, organization of long-term memory, and information retrieval (Atkinson & Shiffrin, 1968; Siegler & Alibali, 2005). Human information processing theories are used to research problem solving. Working memory
capacity is limited. If the domain specific information needed to solve the problem exceeds working memory capacity, learning becomes difficult and the problem cannot be easily solved due to cognitive overload (Sweller, 1988). Kirschner et al. (2006) suggested the minimal structure provided by the teacher during student centered methods such as PBL has an influence on cognitive overload. One method of reducing overload is to teach and allow students to practice problem solving skills until they become automatic. Automaticity then allows students to focus on the main task, rather than the problem solving skills themselves. Over time and with practice, students become able to embrace the problem independently with confidence. The process of reviewing requisite understanding and the skills needed to seek information from various sources become routine and transparent. While the results of this study are promising, further research is needed to examine automaticity in the underlying skills needed for PBL.

Considerable amount of scaffolding and modeling is required by the facilitator to support the development of problem-solving and cooperative learning skills, especially when elementary students encounter PBL for the first time (Pedersen & Liu, 2003). Once these skills begin to evolve, scaffolding can decrease (Savery, 2006). It is evident in elementary that problem solving skill levels are minimal since higher cognitive questioning techniques are seldom utilized. The more experience students have with PBL the greater and more positive are the effects (Kalaian et al., 1999). This study may represent the first encounter with these types of questioning techniques for many students. Teachers need to teach and model the process of actively questioning during
the learning process to obtain information in a meaningful way and to go beyond rote memorization of facts and definitions.

**Conclusion**

The findings support the use of PBL to increase student learning when compared to traditional lecture based classes. Students in the PBL groups scored significantly higher on basic science knowledge. When comparing the PBL groups, the Socratic questioning groups scored higher than the didactic questioning groups on achievement. It seems that Socratic questioning has a positive influence on student achievement during PBL. Cooperative learning methodologies did not have a significant effect on student achievement. Although the graph demonstrated that cooperative learning methods and questioning strategies when combined during PBL could have an interaction effect on student achievement, the results demonstrated it was not significant.

Research demonstrates that cooperative learning has a positive effect on attitude. The Jigsaw groups demonstrated significantly more positive attitudes towards science than the traditional cooperative learning groups. Questioning strategies did not have a significant effect on attitude. There was no significant interaction effect between question strategies and cooperative learning methods on attitude. There were no significant differences between treatment groups in problem solving. However, the Jigsaw groups had the highest means on the problem solving assessment of all the groups. Higher-level cognitive processes such as problem solving develop over time through practice and application. The results of this study suggest that integrating Jigsaw
and Socratic questioning into PBL may promote higher achievement and more positive attitudes in elementary science.

**Implications of Study**

Students in the 21st century are confronted with the demands of the information age and globalization that often, within a worldwide setting, require developing and applying higher-level thinking, problem-solving, basic content knowledge, research skills, and teamwork. The results of the study support the use of PBL to improve student learning in basic science.

Additionally, the results of this study suggest that augmenting PBL with structured cooperative learning and systematic, open-ended questions can enhance learning and attitudes towards science. Specifically, the results indicate that Socratic questioning increased student learning and the Jigsaw method also had a positive effect on student attitude towards science during PBL. This study can serve as a model for the integration of instructional strategies during PBL for the purpose of increasing student learning. Based on these results, Jigsaw learning tasks should come from the learning issues related to the main problem when beginning to design the PBL unit. The learning tasks can be created before the unit is introduced to ensure alignment with standards and learning objectives. The issues should be open-ended enough to allow students freedom in researching and devising a solution to the overall problem. It is also possible, after students have experience with PBL, to allow them more democracy in the learning process by having them present learning issues after a K and W of the KWL process. The class then chooses the top four to five learning issues from the K and W process.
related to the overall problem that become the tasks for the expert groups. Once the main learning issues are established and discussed, the Jigsaw process should be implemented by dividing students into groups and providing the learning task(s). The research process during PBL is pivotal to the learning process. During this time, students should be placed in their expert groups to share and exchange knowledge. When students are placed in the role of an “expert,” they are provided an opportunity to be a leader and equal partner within a cooperative learning group, which creates positive interdependence. Although students are provided with a specific task, they are responsible for becoming an expert through researching, sharing, and teaching.

Socratic questioning should be implemented from the time the problem is presented in the introduction of the unit. During the PBL process, Socratic questioning during the learning and teaching process can assist the teacher in the new role of facilitator and begin to guide students in higher order thinking skills. In the beginning of PBL the teacher should spend adequate time with each group modeling higher level questioning to assist students in learning how and when to use open-ended questions during the problem solving process. Once the teacher has begun the modeling process for students, the teacher should decrease the quantity of questions allowing students to begin asking each other questions and ensuring there is adequate time for responses. As the PBL process proceeds, students should be able to support and explain their solutions, which would lead the teacher to inquiring less. As demonstrated in this study, students begin to acquire and apply the use of higher level questioning with their peers during the research process and presentation of final learning products. The amount of scaffolding
and modeling by the teacher can decrease as students apply Socratic questioning during the progression of the PBL unit.

Teachers in the PBL groups expressed a strong interest in integrating PBL into the curriculum the following year. The lead teacher of the fifth grade team obtained positive feedback from the team. Teachers indicated that students benefited academically from the structure of the Jigsaw method, including responsibility for an individually assigned task following a structured research process and organizing their learning materials. Teachers enjoyed the combination of students being able to learn within groups while having to research and study on their own. Teachers expressed that assigning roles within groups allowed students to stay focused on the task and continue to learn. They also noted that using a real-world current event was a helpful context for student learning of the basic concepts and students were able to focus and enjoy science class.

**Limitations**

Extraneous variables affected the external validity, necessitating cautious analysis of the results. Generalizability is limited due to the study taking place in a rural setting. It is difficult to generalize to other settings including urban and suburban school settings. The study was conducted with elementary classrooms. This limits the application to other audiences and settings such as secondary school and higher educational settings. Further research will need to be conducted in various settings to generalize the results of the study. The formal rigorous structure of the study with the use of the training, teacher packets, and specific curriculum of PBL makes it difficult to generalize to all types of PBL.
Recommendations for Future Research

This was the first study of its kind to examine the combinations of cooperative and teacher questioning strategies during PBL. Findings should serve as a baseline for future research analyzing cooperative learning and structured questioning strategies during PBL. Research in different cooperative learning methodologies and questioning techniques used to augment PBL should be conducted to increase the body of research in this area. Although Jigsaw and other methodologies are often recommended during PBL (Chin & Chia, 2006; Lambros, 2004), additional research is required to examine the overall effects on student learning. Questioning techniques used by teachers have been well studied over the past century. However, student learning outcomes and cognitive processes that occur during PBL with the use of questioning techniques designed to promote higher order thinking skills need to be further researched. Additional research should be conducted to include two or more teachers for each group within the factorial design or have one teacher teach all four methods to control for the possibility of teacher as a confounding variable.

Future studies should use an expanded time frame to investigate the long-term effects on problem solving. Classroom research is often conducted within a short time period of 2 to 3 weeks with resultant small. Problem solving is a cognitive process that develops over a long period of time. Automaticity of problem solving strategies requires consistent practice and application and the development can depend upon past experiences. Elementary students are beginning to develop higher-level thinking and problem solving skills and further research is required to understand how these cognitive
processes develop and specifically how the PBL learning process can promote this development.

Further research needs to focus on the different problem solving processes and skills students use individually and within the group settings during the learning process. Past research has focused on individual novice and expert problem solving with specific domains. PBL provides the opportunity for students to use both individual and group problem solving skills that can be used in ill-structured and non-domain specific settings (Gall & Gall, 1990). Additional focus should be placed on the problem solving skills used when solving ill-structured problems in the group settings and when the student is researching individually.

One interesting result concerning achievement is the Socratic traditional PBL group had the lowest mean on the OAT but had the highest mean scores for the science achievement test. Administrators and teachers have often voiced a concern that the use of PBL is time consuming and students may not be adequately prepared for a state or national standardized test (Pedersen et al., 2009). The results of this study provide evidence to address this concern. A longitudinal study should be conducted to investigate the effects of PBL on standardized test scores.

PBL research is limited in the elementary setting. This study should be replicated in other elementary settings to further develop applications of PBL for the classroom environment. PBL research in elementary settings has begun to emerge but the focus has been mainly on online or computer settings. The research lacks the comparison between PBL and the traditional lecture groups within the elementary classrooms. Additional
research should be conducted in elementary face-to-face settings with comparisons to traditional teacher-centered classrooms. Research in elementary settings is limited in examining the basic science concept knowledge of PBL compared to traditional lecture courses. Since student interest in science tends to decline as they progress through the grade levels (Greenfield, 1996), providing students the opportunity to learn basic concepts and apply them during the learning process has the potential to increase retention and application of knowledge.

Additional studies should be conducted replicating similar methodologies. This study focused primarily on student final outcomes with limited focus on the learning processes that occur during the different phases of PBL. While these results should have an impact on theoretical perspectives and practical applications within the classroom, a larger body of research is required to understand the influence of questioning techniques and cooperative learning methodologies on student overall learning processes and products during PBL.
Dear 5th grade teacher,

Greetings. Thank you for your time and cooperation. I have included in this packet an outline of the unit and the instructional materials required for the unit. Please take a few moments to read and review. If you have any questions, concerns, or comments about the unit, please let me know during our meetings on April 29th and May 1st. Please do not share or discuss the unit with the other members of your fifth grade teaching team.

Thank you again. I look forward to meeting with you.

Marian Maxfield
APPENDIX B

TRADITIONAL TEACHER-LED INSTRUCTION UNIT
Appendix B

Traditional Teacher-Led Instruction Unit

The Emerald Ash Borer and Ash Tree Problem
A Traditional Teacher-Led Instruction Unit
5th grade Science / Interdisciplinary
By: Marian Maxfield

This interdisciplinary (science, social studies, writing, and technology) unit about the Emerald Ash Borer will focus on science and introduce students to the concepts of life science, life cycles, ecosystems, habitats, economics, and research. Students will be taught the basic science and concepts through lecture, class discussion, text reading, worksheets, and a one-page report.

Objectives:
The objectives correlate with the Ohio Department of Education Standards.
1. Students will describe life cycles, ecosystems, food chains and food webs, and survival in ecosystems including and the effects on resources, humans, and other animals.
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Reading) Reading Process: Comprehension Strategies 7
2. Students will read and describe basic economics.
   a. (Social Studies) Geography (B) 6, (C) 9
   b. (Social Studies) Economics (C) 4, 5
   c. (Reading) Reading Process: Comprehension Strategies 7
3. Students will define terms and vocabulary for each topic.
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Reading) Vocabulary: Tools and Resources 8
4. Students will participate in a class discussion each topic.
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Reading) Vocabulary: Tools and Resources 8
5. Students will complete vocabulary concept map worksheets at the end of each topic.
   a. (Reading) Vocabulary: Tools and Resources 8
   b. (Science) Life Science (B) 3, (C) 4-6
6. Students will individually research and locate information from multiple sources on the Emerald Ash Borer.
   a. (Social Studies) Social Studies Skills and Methods (A) 1
   b. (Reading) Reading Process: Self-Monitoring Strategies 8, 9
   c. (Writing) Writing Process 2
   d. (Writing) Research 2
   e. (Technology) Technology for Productivity Applications (B) 2, 3
   f. (Technology) Technology and Information Literacy (B) 3 (C) 2, 3, (D) 1
7. Students will summarize, analyze, and synthesize collected information and data.
   a. (Social Studies) Social Studies Skills and Methods (A) 2, (B) 5, 6, 7
   b. (Reading) Reading Application: Informational, Textual and Persuasive Text 1, 3, 5
   c. (Writing) Research 3, 4
   d. (Technology) Technology and Information Literacy (A) 1, 4
8. Students will be able to identify the Emerald Ash Borer life cycle, habitat, effect on ecosystems (local), interactions to other living things, and areas of habitat (original and current in the US).
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9
   c. (Social Studies) Economics (C) 4, 5
9. Students will type a one page paper describing the Emerald Ash Borer.
   a. (Writing) Writing Applications 10
   b. (Writing) Writing Processes 6
   c. (Technology) Technology and Information Literacy (A) 2
   d. (Technology) Technology for Productivity Applications (C) 1

Materials:
- Computers with Internet accessibility
- Science text readings
- Additional resources (books, internet, newspapers, etc.)
- Worksheets
- Microsoft Word
- Printer

Lesson Procedures:
- **Day one**
  1. Students will be introduced to the Life Science Unit.
     a. Life cycle introduction and metamorphosis
     b. Life cycles of the butterfly, moth, Ladybug and frog
     c. Introduction to and life cycle of the Emerald Ash Borer
  3. Students read individually about life cycle and insect life cycle.
  4. Students work individually to complete a compare and contrast the Emerald Ash Borer, frog, and butterfly lifecycles using the Life Cycles worksheet to review vocabulary.
  5. Students will also complete the Life Cycle of the Emerald Ash Borer worksheet.
  6. Teacher and students have a class discussion to review worksheets.
  7. Teacher will collect worksheets at the end of class.
- **Day two**
  8. Teacher reviews lecture from previous day and passes back worksheets.
  9. Teacher provides instruction on ecosystems using PowerPoint and lecturing.
     a. An introduction to Ecosystems
     b. Explain vocabulary of abiotic, biotic, population, community, habitat, niche
  10. Students read about living things and their environment using online text.
  11. Students will individually complete the Ecosystems – Living and Nonliving Things and Their Environment worksheet. (Students will be going outside during this activity.)
  12. Teacher and students will have a class discussion about the worksheet to discuss the correct answers for the four vocabulary terms and to compare and contrast answers for the examples.
  13. Teacher will collect worksheets at the end of class.
- **Day three**
  14. Teacher reviews the lecture from previous day and returns worksheet.
  15. Teacher provides instruction on North American Habitats, Forest Habitats, and Ash trees.
     a. Habitat introduction
     b. North American Habitats – Arctic Tundra, wetlands, deserts, grasslands, and forests.
     c. Coniferous and deciduous trees
     d. North American Ash tree description, types, locations and uses
     e. Emerald Ash Borer and the effect on the Ash tree in North America
  16. Students will read about the different types of North American habitats and Forest habitats using online and printed text.
  17. Students work individually to complete the Forest Habitat and Ash Tree concept map worksheet.
  18. Teacher and students have a class discussion to review.
19. Teacher will collect worksheets at the end of class.

- Day four

20. Teacher reviews the lecture from previous day and return worksheet.

   a. Detailed Emerald Ash Borer Description
   b. Where it came from originally and current locations in the Northeastern US
   c. Economic and ecological effects
   d. Life cycle of Emerald Ash Borer
   e. The signs and symptoms caused by the Emerald Ash Borer
   f. What is currently being done to prevent the spread of the Emerald Ash Borer

22. Students are provided the *Emerald Ash Borer report guidelines* to introduce the one page paper about the Emerald Ash Borer.

23. Teacher explains and reviews the guidelines.

24. Students are provided time to begin researching the Emerald Ash Borer.

- Day five

25. Teacher provides instruction on food chains and food webs.
   a. Review of ecosystems
   b. Vocabulary of carnivores, herbivores, omnivores, consumers, producers, predator, prey, food chain, food web, endangered, and extinct

26. Students will read individually about food chain and food webs using online and printed text.

27. Students work individually to complete the *Food Chain and Food Web Vocabulary Map Worksheets*

28. Students work to complete the *Food Chain Worksheet*.

29. Teacher and students have a class discussion to review the vocabulary map worksheets and then compare and contrast the Food Chain Worksheets.

30. Teacher will collect worksheets at the end of class.

- Day six

31. Teacher reviews the lecture from previous day.

32. Teacher provides instruction on the survival in ecosystems.
   a. Vocabulary including limiting factor, mutualism, parasitism, commensalisms and invasive species
   b. The Emerald Ash Borer and the changes in the ecosystem

33. Students will read individually about different organisms and their survival in different ecosystems using online text.

34. Students work in assigned groups complete the *Survival in Ecosystems Vocabulary Maps* and the *Survival in Ecosystems – Cause and Effects*.

35. Teacher and students have a class discussion to review.

36. Teacher will collect worksheets at the end of class.

- Day seven

37. Teacher reviews the lecture from previous day and return worksheets.

38. Teacher reviews the one-page Emerald Ash Borer report guidelines.

39. Students continue to research and write on the Emerald Ash Borer.

- Day eight

40. Teacher will remind students about the paper and that they should be preparing for a test on the tenth day.

41. The students continue to research and write paper for remainder of class.

- Day nine

42. Students will proof read draft and make final corrections.

43. Student will complete of the one page Emerald Ash Borer report.

44. Teacher and students will have a class discussion about the Emerald Ash Borer.

45. Students are presented with a *Test Review Worksheet* to review the life-cycle unit.
46. Teacher and students will have a class discussion about the test review worksheet in preparation for the test.

- **Day ten**

47. Students will turn in completed Emerald Ash Borer Papers.

48. Students will complete assessments: a problem solving test, science achievement test, and attitude survey.

**Assessments:**

- Worksheets
- One-page Emerald Ash Borer report
- A problem solving test: Purdue Elementary Problem Solving Inventory.
- Students will be given a test to demonstrate competency of basic science objectives stated at the end of the unit.
- A science attitude survey: Attitude Toward Science in School Achievement
APPENDIX C

TRADITIONAL TEACHER-LED INSTRUCTION UNIT

INSTRUCTIONAL MATERIALS
Life Cycles

Name: 
Date: 

Using the tables below compare and contrast the life cycles of the butterfly, frog and Emerald Ash Borer.

<table>
<thead>
<tr>
<th>Similarities</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the similarities in the life cycles of butterflies, frogs and the Emerald Ash Borer?</td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
<tr>
<td>6.</td>
</tr>
<tr>
<td>7.</td>
</tr>
<tr>
<td>8.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the differences in the life cycles of butterflies, frogs, and the Emerald Ash Borer?</td>
</tr>
<tr>
<td>Emerald Ash Borer</td>
</tr>
<tr>
<td>--------------------</td>
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<tr>
<td></td>
</tr>
</tbody>
</table>
Life Cycle of a Emerald Ash Borer

List each stage of the Emerald Ash Borer life cycle in order on the line. Draw each stage of the Emerald Ash Borer life cycle in the appropriate box.

1. ________________

2. ________________

3. ________________

4. ________________
ECOSYSTEMS – LIVING AND NONLIVING THINGS AND THEIR ENVIRONMENT

Use the words below to fill in the numbered boxes. You will be going outside to locate examples of living and nonliving things in the ecosystem outside of your school building. Use the examples you find to fill in the remaining blank boxes.

**Ecosystems**

- A living part of an ecosystem
- A nonliving part of an ecosystem

1. Examples from outside

2. Examples from outside

3. A group of species living in the same place is a

4. Populations that live in the same area

Use these vocabulary words to complete the diagram.
- Abiotic
- Biotic
- Community
- Populations
Emerald Ash Borer Report Guidelines

Name

Date

You will be researching and writing on the Emerald Ash Borer. You have been asked to write a one page paper about the current issue that the Emerald Ash Borer is causing in the United States and your local area. You may use multiple resources including your textbooks, web sites, newspapers, and other resources.

Use the following questions below and write a one-page paper.

1. Paragraph 1 – Answer the following questions.
   1. What does the adult Emerald Ash Borer look like? (Describe it)
   2. How did the Emerald Ash Borer get to the United States?

2. Paragraph 2 – Answer the following questions.
   1. What tree is the habitat for the Emerald Ash Borer?
   2. What is the life cycle of the Emerald Ash Borer?
   3. Who are the predators of the Emerald Ash Borer in the food chain?

3. Paragraph 3 – Answer the following questions.
   1. How does the Emerald Ash Borer affect the ecosystem in our local area? (List two.)
   2. List two products that are made in Ohio from the tree that the Emerald Ash Borer lives in and eats?

4. Paragraph 4 – Answer the following question.
   1. Describe one thing that is being done to stop or prevent the Emerald Ash Borer?
Food Chain and Food Web Vocabulary Map

Name:
Date:

Use the boxes below to write in your definition, text definition, and examples of the word “Carnivore.”

Carnivore

Your definition

Text definition

Example 1
Example 2
Example 3
Food Chain and Food Web Vocabulary Map

Name: 
Date: 

Use the boxes below to write in your definition, text definition, and examples of the word “Herbivore.”

<table>
<thead>
<tr>
<th>Your definition</th>
<th>Text definition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Herbivore

<table>
<thead>
<tr>
<th>Example 1</th>
<th>Example 2</th>
<th>Example 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Food Chain and Food Web Vocabulary Map

Name:
Date:

Use the boxes below to write in your definition, text definition, and examples of the word “Omnivore.”

Your definition

Text definition

Omnivore

Example 1

Example 2

Example 3
Food Chain

Name:
Date:

Use the boxes below to draw a food chain. In each box draw and write the name of the plant or animal that completes the food chain. The food chain must end with you. (Remember that a food chain always starts with a plant.)

1. (Remember it has to be a plant.)

2.

3.

4. YOU!
Survival in Ecosystems Vocabulary Map

Name:  
Date:  

Commensalism  
Parasitism

How are they alike?

How are they different?
Survival in Ecosystems Vocabulary Map

Name: 
Date: 

Limiting Factor

How are they alike?

Invasive Species

How are they different?
Changes in the Ecosystem often happen due to cause and effect. Read the following story below and choose the cause and effect situations that made changes in the ecosystem.

The forests are being destroyed everyday in the United States. People are cutting down trees for paper and building supplies. This will affect the habitat of many species. Birds and squirrels will lose their place to build nests and complete their life cycles. Plants like ferns will not have the shade from the sun to continue to grow. Insects such as bees will not have as many flowers to pollinate to provide them with food. This could cause these species to become endangered or extinct. The Emerald Ash Borer is an invasive species eating and living in Ash trees only to destroy them. This will take vital habitat and food from Wood Ducks and Cardinals. If the Ash tree is lost, there will be less baseball bats and hockey sticks. Trees are also being cut down due to diseases. When a tree is diseased it will either die or be cut down. Trees provide us with oxygen (fresh air) to breath. Trees are very important to our everyday living.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>People are cutting down trees for paper and building supplies.</td>
<td>This will affect the habitat of many species. Birds and squirrels will</td>
</tr>
</tbody>
</table>
**Test Review Worksheet**

Name  

Date  

Match the vocabulary words to the correct definition by writing the vocabulary number on the line that matches the definition.

<table>
<thead>
<tr>
<th>Vocabulary</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Limiting Factor</td>
<td>___A species in danger of becoming endangered</td>
</tr>
<tr>
<td>2. Herbivore</td>
<td>___An animal that eat only plants, or algae.</td>
</tr>
<tr>
<td>3. Threatened Species</td>
<td>___A species that is in danger of becoming extinct.</td>
</tr>
<tr>
<td>4. Niche</td>
<td>___A stage during metamorphosis that is before the adult stage in the development process.</td>
</tr>
<tr>
<td>5. Endangered Species</td>
<td>___The role(s) of an organism in a community</td>
</tr>
<tr>
<td>6. Pupa</td>
<td>___Anything that controls the growth or survival of population</td>
</tr>
<tr>
<td>7. Invasive Species</td>
<td>___Non-native species that is successful in a new habitat and whose presence is harmful to other species.</td>
</tr>
</tbody>
</table>
Write a short answer (3 to 5 sentences) for the following questions

1. Describe what the Emerald Ash Borer looks like and what it eats.

2. Describe or draw the life cycle of the Emerald Ash Borer.

3. How does the Emerald Ash Borer affect the local economy?

4. List the seven states the Emerald Ash Borer has been located.
   a.
   b.
   c.
   d.
   e.
   f.
   g.
APPENDIX D

PROBLEM BASED LEARNING UNITS
Appendix D

Problem Based Learning Units

Traditional Small Group and Didactic Questioning

The Emerald Ash Borer and Ash Tree Problem
A Problem Based Learning Unit

This is a Problem Based Learning (PBL) lesson about the Emerald Ash Borer (EAB) that will provide students the opportunity to work collaboratively to solve a current real-life problem. The students will be provided an introduction to the problem through a real-life scenario. This interdisciplinary unit (science, social studies, writing, and technology) with a main focus on science will introduce students the concepts of life science, life cycles, ecosystems, geography, economics, and research. Students will be taught the basic concepts through student-centered environment, cooperative learning, individual and group research, final project, and project presentation. A devised letter will be provided from local politicians and federal agencies that will provide information relevant to the problem of the EAB. Students will work in groups to discuss, locate resources, agree on best solution to the problem and present to the class a project to demonstrate understanding of the problem and a plausible solution.

Objectives:
The objectives will correlate with the Ohio Department of Education Standards.

1. Students will define the problem and sub-problems
   a. (Technology) Technology and Information Literacy (B) 1
   b. (Social Studies) Social Studies Skills and Methods (D) 9

2. Students will work in cooperative group to solve the problem
   a. (Social Studies) Social Studies Skills and Methods (D) 9

3. Students will research and locate information on the problem and sub-problems (learning issues).
   a. (Social Studies) Social Studies Skills and Methods (A) 1
   b. (Writing) Writing Process 2
   c. (Writing) Research 2
   d. (Technology) Technology for Productivity Applications (B) 2, 3
   e. (Technology) Technology and Information Literacy (B) 3 (C) 2, 3, (D) 1

4. Students will summarize, analyze, and synthesize collected information and data
   a. (Reading) Vocabulary: Tools and Resources 8
   b. (Reading) Reading Process: Comprehension Strategies 1, 2, 5, 7
   c. (Reading) Reading Process: Self-Monitoring Strategies 8, 9
   d. (Reading) Reading Application: Informational, Textual and Persuasive Text 1, 3, 5
   e. (Social Studies) Social Studies Skills and Methods (A) 2, (B) 5, 6, 7 (D) 9
   f. (Writing) Research 3, 4
   g. (Technology) Technology and Information Literacy (A) 1, 4

5. Students will discuss and reflect on research notes
   a. (Social Studies) Social Studies Skills and Methods (B) 7
   b. (Writing) Writing Process 10
   c. (Writing) Writing Applications 5

6. Students will describe life cycles, ecosystems, food chains and food webs, and survival in ecosystems including and the effects on resources, humans, and other animals
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9

162
7. Students will be able to identify the Emerald Ash Borer life cycle, habitat, effect on ecosystems (local), interactions to other living things, and areas of habitat (original and current in the US).
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9
   c. (Social Studies) Economics(C) 4, 5
8. Students will pose and defend multiple solutions
   a. (Science) Science and Technology 2, 3
   b. (Technology) Design (C) 1
9. Students will choose a solution to problem
   a. (Science) Scientific Ways of Knowing 1, 2
   b. (Social Studies) Social Studies Skills and Methods (D) 9
10. Students will create a final product to demonstrate knowledge with multiple tools.
    a. (Writing) Writing Process 10
    b. (Technology) Nature of Technology (A) 2
    c. (Technology) Technology for Productivity Applications (B) 4
11. Students will present knowledge and solution to problem
    a. (Writing) Research 6
    b. (Writing) Communication: Oral and Visual 8
    c. (Technology) Technology and Information Literacy (A) 2
    d. (Technology) Technology and Communication Application (B) 1 – 5 (possible)
12. Students will reflect on knowledge learned through class discussion and thinking logs
    a. (Technology) Design (B) 1
    b. (Writing) Writing Applications 5

Lesson Procedures:

- **Day one**
  1. The teacher will introduce the topic.
  2. The students are presented with a real-life problem and scenario concerning the Emerald Ash Borer. A letter explaining the situation, scenario, and problem will be presented with detailed maps.
  3. **Problem:**
     
  There is an emergency concerning the Emerald Ash Borer pest that has been accidentally released in the United States and is destroying ash trees of all varieties.
  4. **Scenario:**
     
  To be given in a letter describing the problem and sub-problems for students to research.
  5. Student will read and then underline any sub-problems or learning issues within the scenario.
  6. The class will discuss the letter to identify the problem and sub-problems.
  7. Students will complete a “K” worksheet of the KWL worksheets to begin thinking about what they already know about the EAB problem.
  8. Students will be randomly assigned to groups.
  9. Each student will be randomly assigned a role within the group. The roles include chairperson, recorder, reporter, and monitor.
  10. The teacher will provide and explain a student cooperation guide that included the rules of how to participate in groups and it defines each role.
  11. Each group is provided a group folder to organize daily notes, cooperation guides, and other materials.
  12. Students return to individual seats and the teacher introduces the thinking logs.
  13. The first thinking log assignment is to be started in class and completed for homework.
- **Day two**
  14. The problem is reviewed from the previous day.
  15. Students return to groups and obtain group folders.
  16. The “W” worksheet of the KWL is provided for each student. Students will write what they still need to know to solve the problem.
17. Each group works collaboratively to complete and review the K and W worksheets.
18. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Didactic Teacher Questioning Guide.
19. A class discussion concerning the “K” and “W” worksheets will summarize the main learning issues.
20. Students will return to individual seats and be provided with a group evaluation sheet 1.
21. The teacher will explain the group evaluation sheet and students will complete it.
22. The teacher will check each thinking log for completion.
23. Students are to complete the second thinking log assignment.
   • Day three
24. Students will return to original groups.
25. Each group will decide how to divide the research responsibilities and what information is needed to solve the problem.
26. Students will work independently and in groups to research by going to the library and using the resources in the classroom that include books, textbooks, newspapers, and websites.
27. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Didactic Teacher Questioning Guide.
28. Students will be reminded to take notes about the Emerald Ash Borer.
29. Students will complete the group evaluation sheet 1.
30. The teacher will check each thinking log for completion.
31. Students are to begin the third thinking log and complete it for homework.
   • Days four and five
32. Students utilize library and classroom resources to complete research.
33. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Didactic Teacher Questioning Guide.
34. The teacher will check each thinking log for completion.
35. Students are to begin the fourth thinking log and complete it for homework.
   • Day six
36. Students will continue to work in groups to discuss the research and information about the Emerald Ash Borer.
37. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Didactic Teacher Questioning Guide.
38. Students will complete the group evaluation sheet 1.
39. The teacher will check each thinking log for completion.
40. Students are to begin the fifth thinking log and complete it for homework.
   • Day seven
41. Students return to groups.
42. Students will be reminded to review notes and begin to think of the best-fit solution.
43. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Didactic Teacher Questioning Guide.
44. Teacher introduces and provides a rubric for the final project and final project presentation.
45. Students begin to formulate the final project.
46. Students will complete the group evaluation sheet 1.
47. The teacher will check each thinking log for completion.
48. Students are to begin the sixth thinking log and complete it for homework.
   • Day eight
49. Students will be reminded about the final project and final project presentation.
50. Students return to groups and complete the final project.
51. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Didactic Teacher Questioning Guide.
52. Students will complete the group evaluation sheet 1.
53. The teacher will check each thinking log for completion.
54. Students are to begin the seventh thinking log assignment and complete it for homework.

- **Day nine**

55. Students review final project with group to prepare for presentation.

56. Each group takes 5 minutes and presents projects to demonstrate what they learned and their ideas to the class.

57. Teacher will utilize rubric to grade final projects.

58. Students will individually complete the “L” of KWL worksheet.

59. The students and teacher will debrief the assignment and review.

60. Students will complete group evaluation sheets 2 and 3.

61. The teacher will check each thinking log for completion.

62. Teacher will collect thinking logs.

- **Day ten**

63. Students will complete assessments: a problem solving test, science achievement test, and attitude survey.
Traditional Small Group and Socratic Questioning

The Emerald Ash Borer and Ash Tree Problem
A Problem Based Learning Unit

This is a Problem Based Learning (PBL) lesson about the Emerald Ash Borer (EAB) that will provide students the opportunity to work collaboratively to solve a current real-life problem. The students will be provided an introduction to the problem through a real-life scenario. This interdisciplinary unit (science, social studies, writing, and technology) with a main focus on science will introduce students the concepts of life science, life cycles, ecosystems, geography, economics, and research. Students will be taught the basic concepts through student-centered environment, cooperative learning, individual and group research, final project, and project presentation. A devised letter will be provided from local politicians and federal agencies that will provide information relevant to the problem of the EAB. Students will work in groups to discuss, locate resources, agree on best solution to the problem and present to the class a project to demonstrate understanding of the problem and a plausible solution.

Objectives:
The objectives will correlate with the Ohio Department of Education Standards.

1. Students will define the problem and sub-problems
   a. (Technology) Technology and Information Literacy (B) 1
   b. (Social Studies) Social Studies Skills and Methods (D) 9

2. Students will work in cooperative group to solve the problem
   a. (Social Studies) Social Studies Skills and Methods (D) 9

3. Students will research and locate information on the problem and sub-problems (learning issues).
   a. (Social Studies) Social Studies Skills and Methods (A) 1
   b. (Writing) Writing Process 2
   c. (Writing) Research 2
   d. (Technology) Technology for Productivity Applications (B) 2, 3
   e. (Technology) Technology and Information Literacy (B) 3 (C) 2, 3, (D) 1

4. Students will summarize, analyze, and synthesize collected information and data
   a. (Reading) Vocabulary: Tools and Resources 8
   b. (Reading) Reading Process: Comprehension Strategies 1, 2, 5, 7
   c. (Reading) Reading Process: Self-Monitoring Strategies 8, 9
   d. (Reading) Reading Application: Informational, Textual and Persuasive Text 1, 3, 5
   e. (Social Studies) Social Studies Skills and Methods (A) 2, (B) 5, 6, 7 (D) 9
   f. (Writing) Research 3, 4
   g. (Technology) Technology and Information Literacy (A) 1, 4

5. Students will discuss and reflect on research notes
   a. (Social Studies) Social Studies Skills and Methods (B) 7
   b. (Writing) Writing Process 10
   c. (Writing) Writing Applications 5

6. Students will describe life cycles, ecosystems, food chains and food webs, and survival in ecosystems including and the effects on resources, humans, and other animals
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9

7. Students will be able to identify the Emerald Ash Borer life cycle, habitat, effect on ecosystems (local), interactions to other living things, and areas of habitat (original and current in the US).
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9
   c. (Social Studies) Economics(C) 4, 5

8. Students will pose and defend multiple solutions
   a. (Science) Science and Technology 2, 3
b. (Technology) Design (C) 1

9. Students will choose a solution to problem
   a. (Science) Scientific Ways of Knowing 1, 2
   b. (Social Studies) Social Studies Skills and Methods (D) 9

10. Students will create a final product to demonstrate knowledge with multiple tools.
    a. (Writing) Writing Process 10
    b. (Technology) Nature of Technology (A) 2
    c. (Technology) Technology for Productivity Applications (B) 4

11. Students will present knowledge and solution to problem
    a. (Writing) Research 6
    b. (Writing) Communication: Oral and Visual 8
    c. (Technology) Technology and Information Literacy (A) 2
    d. (Technology) Technology and Communication Application (B) 1–5 (possible)

12. Students will reflect on knowledge learned through class discussion and thinking logs
    a. (Technology) Design (B) 1
    b. (Writing) Writing Applications 5

Lesson Procedures:

   • Day one
1. The teacher will introduce the topic.
2. The students are presented with a real-life problem and scenario concerning the Emerald Ash Borer. A letter explaining the situation, scenario, and problem will be presented with detailed maps.
3. Problem:
   There is an emergency concerning the Emerald Ash Borer pest that has been accidentally released in the United States and is destroying ash trees of all varieties.
4. Scenario:
   To be given in a letter describing the problem and sub-problems for students to research.
5. Student will read and then underline any sub-problems or learning issues within the scenario.
6. The class will discuss the letter to identify the problem and sub-problems.
7. Students will complete a “K” worksheet of the KWL worksheets to begin thinking about what they already know about the EAB problem.
8. Students will be randomly assigned to groups.
9. Each student will be randomly assigned a role within the group. The roles include chairperson, recorder, reporter, and monitor.
10. The teacher will provide and explain a student cooperation guide that included the rules of how to participate in groups and it defines each role.
11. Each group is provided a group folder to organize daily notes, cooperation guides, and other materials.
12. Students return to individual seats and the teacher introduces the thinking logs.
13. The first thinking log assignment is to be started in class and completed for homework.

   • Day two
14. The problem is reviewed from the previous day.
15. Students return to groups and obtain group folders.
16. The “W” worksheet of the KWL is provided for each student. Students will write what they still need to know to solve the problem.
17. Each group works collaboratively to complete and review the K and W worksheets.
18. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
19. A class discussion concerning the “K” and “W” worksheets will summarize the main learning issues.
20. Students will return to individual seats and be provided with a group evaluation sheet 1.
21. The teacher will explain the group evaluation sheet and students will complete it.
22. The teacher will check each thinking log for completion.
23. Students are to complete the second thinking log assignment.
   • Day three
24. Students will return to original groups.
25. Each group will decide how to divide the research responsibilities and what information is needed to solve the problem.
26. Students will work independently and in groups to research by going to the library and using the resources in the classroom that include books, textbooks, newspapers, and websites.
27. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
28. Students will be reminded to take notes about the Emerald Ash Borer.
29. Students will complete the group evaluation sheet 1.
30. The teacher will check each thinking log for completion.
31. Students are to begin the third thinking log and complete it for homework.
   • Days four and five
32. Students utilize library and classroom resources to complete research.
33. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
34. The teacher will check each thinking log for completion.
35. Students are to begin the fourth thinking log and complete it for homework.
   • Day six
36. Students will continue to work in groups to discuss the research and information about the Emerald Ash Borer.
37. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
38. Students will complete the group evaluation sheet 1.
39. The teacher will check each thinking log for completion.
40. Students are to begin the fifth thinking log and complete it for homework.
   • Day seven
41. Students return to groups.
42. Students will be reminded to review notes and begin to think of the best-fit solution.
43. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
44. Teacher introduces and provides a rubric for the final project and final project presentation.
45. Students begin to formulate the final project.
46. Students will complete the group evaluation sheet 1.
47. The teacher will check each thinking log for completion.
48. Students are to begin the sixth thinking log and complete it for homework.
   • Day eight
49. Students will be reminded about the final project and final project presentation.
50. Students return to groups and complete the final project.
51. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
52. Students will complete the group evaluation sheet 1.
53. The teacher will check each thinking log for completion.
54. Students are to begin the seventh thinking log assignment and complete it for homework.
   • Day nine
55. Students review final project with group to prepare for presentation.
56. Each group takes 5 minutes and presents projects to demonstrate what they learned and their ideas to the class.
57. Teacher will utilize rubric to grade final projects.
58. Students will individually complete the “L” of KWL worksheet.
59. The students and teacher will debrief the assignment and review.
60. Students will complete group evaluation sheets 2 and 3.
61. The teacher will check each thinking log for completion.
62. Teacher will collect thinking logs.
   •  Day ten
63. Students will complete assessments: a problem solving test, science achievement test, and attitude survey.
Jigsaw Method and Didactic Questioning

The Emerald Ash Borer and Ash Tree Problem
A Problem Based Learning Unit

This is a Problem Based Learning (PBL) lesson about the Emerald Ash Borer (EAB) that will provide students the opportunity to work collaboratively to solve a current real-life problem. The students will be provided an introduction to the problem through a real-life scenario. This interdisciplinary unit (science, social studies, writing, and technology) with a main focus on science will introduce students the concepts of life science, life cycles, ecosystems, geography, economics, and research. Students will be taught the basic concepts through student-centered environment, cooperative learning, individual and group research, final project, and project presentation. A devised letter will be provided from local politicians and federal agencies that will provide information relevant to the problem of the EAB. Students will work in groups to discuss, locate resources, agree on best solution to the problem and present to the class a project to demonstrate understanding of the problem and a plausible solution.

Objectives:
The objectives will correlate with the Ohio Department of Education Standards.

1. Students will define the problem and sub-problems
   a. (Technology) Technology and Information Literacy (B) 1
   b. (Social Studies) Social Studies Skills and Methods (D) 9
2. Students will work in cooperative group to solve the problem
   a. (Social Studies) Social Studies Skills and Methods (D) 9
3. Students will research and locate information on the problem and sub-problems (learning issues).
   a. (Social Studies) Social Studies Skills and Methods (A) 1
   b. (Writing) Writing Process 2
   c. (Writing) Research 2
   d. (Technology) Technology for Productivity Applications (B) 2, 3
   e. (Technology) Technology and Information Literacy (B) 3 (C) 2, 3, (D) 1
4. Students will summarize, analyze, and synthesize collected information and data
   a. (Reading) Vocabulary: Tools and Resources 8
   b. (Reading) Reading Process: Comprehension Strategies 1, 2, 5, 7
   c. (Reading) Reading Process: Self-Monitoring Strategies 8, 9
   d. (Reading) Reading Application: Informational, Textual and Persuasive Text 1, 3, 5
   e. (Social Studies) Social Studies Skills and Methods (A) 2, (B) 5, 6, 7 (D) 9
   f. (Writing) Research 3, 4
   g. (Technology) Technology and Information Literacy (A) 1, 4
5. Students will discuss and reflect on research notes
   a. (Social Studies) Social Studies Skills and Methods (B) 7
   b. (Writing) Writing Process 10
   c. (Writing) Writing Applications 5
6. Students will describe life cycles, ecosystems, food chains and food webs, and survival in ecosystems including and the effects on resources, humans, and other animals
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9
7. Students will be able to identify the Emerald Ash Borer life cycle, habitat, effect on ecosystems (local), interactions to other living things, and areas of habitat (original and current in the US).
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9
   c. (Social Studies) Economics (C) 4, 5
8. Students will pose and defend multiple solutions
   a. (Science) Science and Technology 2, 3
b. (Technology) Design (C) 1

9. Students will choose a solution to problem
   a. (Science) Scientific Ways of Knowing 1, 2
   b. (Social Studies) Social Studies Skills and Methods (D) 9

10. Students will create a final product to demonstrate knowledge with multiple tools.
    a. (Writing) Writing Process 10
    b. (Technology) Nature of Technology (A) 2
    c. (Technology) Technology for Productivity Applications (B) 4

11. Students will present knowledge and solution to problem
    a. (Writing) Research 6
    b. (Writing) Communication: Oral and Visual 8
    c. (Technology) Technology and Information Literacy (A) 2
    d. (Technology) Technology and Communication Application (B) 1 – 5 (possible)

12. Students will reflect on knowledge learned through class discussion and thinking logs
    a. (Technology) Design (B) 1
    b. (Writing) Writing Applications 5

Lesson Procedures:

- **Day one**
  1. The teacher will introduce the topic.
  2. The students are presented with a real-life problem and scenario concerning the Emerald Ash Borer. A letter explaining the situation, scenario, and problem will be presented with detailed maps.
  3. **Problem:**
     There is an emergency concerning the Emerald Ash Borer pest that has been accidentally released in the United States and is destroying ash trees of all varieties.
  4. **Scenario:**
     To be given in a letter describing the problem and sub-problems for students to research.
  5. Student will read and then underline any sub-problems or learning issues within the scenario.
  6. The class will discuss the letter to identify the problem and sub-problems.
  7. Students will complete a “K” worksheet of the KWL worksheets to begin thinking about what they already know about the EAB problem.
  8. Students will be randomly assigned to groups.
  9. Each student will be randomly assigned a role within the group. The roles include chairperson, recorder, reporter, and monitor.
  10. The teacher will provide and explain a student cooperation guide that included the rules of how to participate in groups and it defines each role.
  11. Each group is provided a group folder to organize daily notes, cooperation guides, and other materials.
  12. Students return to individual seats and the teacher introduces the thinking logs.
  13. The first thinking log assignment is to be started in class and completed for homework.

- **Day two**
  14. The problem is reviewed from the previous day.
  15. Students return to groups and obtain group folders.
  16. The “W” worksheet of the KWL is provided for each student. Students will write what they still need to know to solve the problem.
  17. Each group works collaboratively to complete and review the K and W worksheets.
  18. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Didactic Teacher Questioning Guide.
  19. A class discussion concerning the “K” and “W” worksheets will summarize the main learning issues.
  20. Students will return to individual seats and be provided with a group evaluation sheet 1.
  21. The teacher will explain the group evaluation sheet and students will complete it.
22. The teacher will check each thinking log for completion.
23. Students are to complete the second thinking log assignment.
   • Day three
24. Students will return to original groups.
25. Each group member is provided with an assigned learning issue.
26. Students will work independently and in groups to research by going to the library and using the
resources in the classroom that include books, textbooks, newspapers, and websites.
27. The teacher will be a facilitator by working with each group at five minute increments and asking
questions with the use of the Didactic Teacher Questioning Guide.
28. Students will be reminded to take notes about the Emerald Ash Borer.
29. Students will complete the group evaluation sheet 1.
30. The teacher will check each thinking log for completion.
31. Students are to begin the third thinking log and complete it for homework.
   • Days four and five
32. Students utilize library and classroom resources to complete research.
33. The teacher will be a facilitator by working with each group at five minute increments and asking
questions with the use of the Didactic Teacher Questioning Guide.
34. The teacher will check each thinking log for completion.
35. Students are to begin the fourth thinking log and complete it for homework.
   • Day six
36. Students will be divided into “expert” groups with the use of the “Jigsaw Group Student Learning
Issue Role” sheet. Students with similar learning issues will teach each about the research
collected.
37. Each student will be provided 3 to 5 minutes to teach. Students should take notes during this time.
38. Students will take notes and each group will have 5 minutes to debrief to organize information and
prepare to instruct their original group on their learning issue.
39. Students return to original groups and take 3 to 5 minutes each to teach the group about their
learning issue.
40. The teacher will be a facilitator by working with each group at five minute increments and asking
questions with the use of the Didactic Teacher Questioning Guide.
41. Students will complete the group evaluation sheet 1.
42. The teacher will check each thinking log for completion.
43. Students are to begin the fifth thinking log and complete it for homework.
   • Day seven
44. Students return to groups.
45. Students will be reminded to review notes and begin to think of the best-fit solution.
46. The teacher will be a facilitator by working with each group at five minute increments and asking
questions with the use of the Didactic Teacher Questioning Guide.
47. Teacher introduces and provides a rubric for the final project and final project presentation.
48. Students begin to formulate the final project.
49. Students will complete the group evaluation sheet 1.
50. The teacher will check each thinking log for completion.
51. Students are to begin the sixth thinking log and complete it for homework.
   • Day eight
52. Students will be reminded about the final project and final project presentation.
53. Students return to groups and complete the final project.
54. The teacher will be a facilitator by working with each group at five minute increments and asking
questions with the use of the Didactic Teacher Questioning Guide.
55. Students will complete the group evaluation sheet 1.
56. The teacher will check each thinking log for completion.
57. Students are to begin the seventh thinking log assignment and complete it for homework.
   • Day nine
58. Students review final project with group to prepare for presentation.
59. Each group takes 5 minutes and presents projects to demonstrate what they learned and their ideas to the class.
60. Teacher will utilize rubric to grade final projects.
61. Students will individually complete the “L” of KWL worksheet.
62. The students and teacher will debrief the assignment and review.
63. Students will complete group evaluation sheets 2 and 3.
64. The teacher will check each thinking log for completion.
65. Teacher will collect thinking logs.
66. Students will complete assessments: a problem solving test, science achievement test, and attitude survey.

Day ten
Jigsaw Method and Socratic Questioning

The Emerald Ash Borer and Ash Tree Problem
A Problem Based Learning Unit

This is a Problem Based Learning (PBL) lesson about the Emerald Ash Borer (EAB) that will provide students the opportunity to work collaboratively to solve a current real-life problem. The students will be provided an introduction to the problem through a real-life scenario. This interdisciplinary unit (science, social studies, writing, and technology) with a main focus on science will introduce students the concepts of life science, life cycles, ecosystems, geography, economics, and research. Students will be taught the basic concepts through student-centered environment, cooperative learning, individual and group research, final project, and project presentation. A devised letter will be provided from local politicians and federal agencies that will provide information relevant to the problem of the EAB. Students will work in groups to discuss, locate resources, agree on best solution to the problem and present to the class a project to demonstrate understanding of the problem and a plausible solution.

Objectives:
The objectives will correlate with the Ohio Department of Education Standards.

1. Students will define the problem and sub-problems
   a. (Technology) Technology and Information Literacy (B) 1
   b. (Social Studies) Social Studies Skills and Methods (D) 9

2. Students will work in cooperative group to solve the problem
   a. (Social Studies) Social Studies Skills and Methods (D) 9

3. Students will research and locate information on the problem and sub-problems (learning issues).
   a. (Social Studies) Social Studies Skills and Methods (A) 1
   b. (Writing) Writing Process 2
   c. (Writing) Research 2
   d. (Technology) Technology for Productivity Applications (B) 2, 3
   e. (Technology) Technology and Information Literacy (B) 3 (C) 2, 3, (D) 1

4. Students will summarize, analyze, and synthesize collected information and data
   a. (Reading) Vocabulary: Tools and Resources 8
   b. (Reading) Reading Process: Comprehension Strategies 1, 2, 5, 7
   c. (Reading) Reading Process: Self-Monitoring Strategies 8, 9
   d. (Reading) Reading Application: Informational, Textual and Persuasive Text 1, 3, 5
   e. (Social Studies) Social Studies Skills and Methods (A) 2, (B) 5, 6, 7 (D) 9
   f. (Writing) Research 3, 4
   g. (Technology) Technology and Information Literacy (A) 1, 4

5. Students will discuss and reflect on research notes
   a. (Social Studies) Social Studies Skills and Methods (B) 7
   b. (Writing) Writing Process 10
   c. (Writing) Writing Applications 5

6. Students will describe life cycles, ecosystems, food chains and food webs, and survival in ecosystems including and the effects on resources, humans, and other animals
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9

7. Students will be able to identify the Emerald Ash Borer life cycle, habitat, effect on ecosystems (local), interactions to other living things, and areas of habitat (original and current in the US).
   a. (Science) Life Science (B) 3, (C) 4-6
   b. (Social Studies) Geography (B) 6, (C) 9
   c. (Social Studies) Economics(C) 4, 5

8. Students will pose and defend multiple solutions
   a. (Science) Science and Technology 2, 3
9. Students will choose a solution to problem
   a. (Science) Scientific Ways of Knowing 1, 2
   b. (Social Studies) Social Studies Skills and Methods (D) 9

10. Students will create a final product to demonstrate knowledge with multiple tools.
    a. (Writing) Writing Process 10
    b. (Technology) Nature of Technology (A) 2
    c. (Technology) Technology for Productivity Applications (B) 4

11. Students will present knowledge and solution to problem
    a. (Writing) Research 6
    b. (Writing) Communication: Oral and Visual 8
    c. (Technology) Technology and Information Literacy (A) 2
    d. (Technology) Technology and Communication Application (B) 1 – 5 (possible)

12. Students will reflect on knowledge learned through class discussion and thinking logs
    a. (Technology) Design (B) 1
    b. (Writing) Writing Applications 5

Lesson Procedures:

• Day one
  1. The teacher will introduce the topic.
  2. The students are presented with a real-life problem and scenario concerning the Emerald Ash Borer. A letter explaining the situation, scenario, and problem will be presented with detailed maps.
  3. Problem:
     There is an emergency concerning the Emerald Ash Borer pest that has been accidentally released in the United States and is destroying ash trees of all varieties.
  4. Scenario:
     To be given in a letter describing the problem and sub-problems for students to research.
  5. Student will read and then underline any sub-problems or learning issues within the scenario.
  6. The class will discuss the letter to identify the problem and sub-problems.
  7. Students will complete a “K” worksheet of the KWL worksheets to begin thinking about what they already know about the EAB problem.
  8. Students will be randomly assigned to groups.
  9. Each student will be randomly assigned a role within the group. The roles include chairperson, recorder, reporter, and monitor.
 10. The teacher will provide and explain a student cooperation guide that included the rules of how to participate in groups and it defines each role.
 11. Each group is provided a group folder to organize daily notes, cooperation guides, and other materials.
 12. Students return to individual seats and the teacher introduces the thinking logs.
 13. The first thinking log assignment is to be started in class and completed for homework.

• Day two
  14. The problem is reviewed from the previous day.
  15. Students return to groups and obtain group folders.
  16. The “W” worksheet of the KWL is provided for each student. Students will write what they still need to know to solve the problem.
  17. Each group works collaboratively to complete and review the K and W worksheets.
  18. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
  19. A class discussion concerning the “K” and “W” worksheets will summarize the main learning issues.
  20. Students will return to individual seats and be provided with a group evaluation sheet 1.
  21. The teacher will explain the group evaluation sheet and students will complete it.
22. The teacher will check each thinking log for completion.
23. Students are to complete the second thinking log assignment.

- **Day three**
24. Students will return to original groups.
25. Each group member is provided with an assigned learning issue.
26. Students will work independently and in groups to research by going to the library and using the resources in the classroom that include books, textbooks, newspapers, and websites.
27. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
28. Students will be reminded to take notes about the Emerald Ash Borer.
29. Students will complete the group evaluation sheet 1.
30. The teacher will check each thinking log for completion.
31. Students are to begin the third thinking log and complete it for homework.

- **Days four and five**
32. Students utilize library and classroom resources to complete research.
33. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
34. The teacher will check each thinking log for completion.
35. Students are to begin the fourth thinking log and complete it for homework.

- **Day six**
36. Students will be divided into “expert” groups with the use of the “Jigsaw Group Student Learning Issue Role” sheet. Students with similar learning issues will teach each about the research collected.
37. Each student will be provided 3 to 5 minutes to teach. Students should take notes during this time.
38. Students will take notes and each group will have 5 minutes to debrief to organize information and prepare to instruct their original group on their learning issue.
39. Students return to original groups and take 3 to 5 minutes each to teach the group about their learning issue.
40. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
41. Students will complete the group evaluation sheet 1.
42. The teacher will check each thinking log for completion.
43. Students are to begin the fifth thinking log and complete it for homework.

- **Day seven**
44. Students return to groups.
45. Students will be reminded to review notes and begin to think of the best-fit solution.
46. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
47. Teacher introduces and provides a rubric for the final project and final project presentation.
48. Students begin to formulate the final project.
49. Students will complete the group evaluation sheet 1.
50. The teacher will check each thinking log for completion.
51. Students are to begin the sixth thinking log and complete it for homework.

- **Day eight**
52. Students will be reminded about the final project and final project presentation.
53. Students return to groups and complete the final project.
54. The teacher will be a facilitator by working with each group at five minute increments and asking questions with the use of the Socratic Teacher Questioning Guide.
55. Students will complete the group evaluation sheet 1.
56. The teacher will check each thinking log for completion.
57. Students are to begin the seventh thinking log assignment and complete it for homework.

- **Day nine**
58. Students review final project with group to prepare for presentation.
59. Each group takes 5 minutes and presents projects to demonstrate what they learned and their ideas to the class.
60. Teacher will utilize rubric to grade final projects.
61. Students will individually complete the “L” of KWL worksheet.
62. The students and teacher will debrief the assignment and review.
63. Students will complete group evaluation sheets 2 and 3.
64. The teacher will check each thinking log for completion.
65. Teacher will collect thinking logs.
- **Day ten**
66. Students will complete assessments: a problem solving test, science achievement test, and attitude survey.
APPENDIX E

PROBLEM BASED LEARNING UNIT INSTRUCTIONAL MATERIALS
Appendix E

Problem Based Learning Unit Instructional Materials

Problem Scenario Letter

United States Department of Agriculture (USDA)
Animal Plant Health Inspection Services (APHIS)
00 South White House Street
Washington, D.C. 00000
May 12, 2008

Dear Ohio (Stark County) Emerald Ash Borer Task Force Member,

This letter is to notify you that the USDA and APHIS requests your services in developing a solution to the current Emerald Ash Borer beetle problem destroying the Ash trees in the United States. Currently the insect has destroyed about 20% of the ash trees in 7 states, including Ohio. At the current rate of destruction, the beautiful resource of the Ash tree will be destroyed within a few years unless a solution is proposed.

The Emerald Ash Borer is a devastating and yet beautiful metallic green looking insect that destroys Ash trees. The pest was discovered in the summer of 2002 in Michigan. The pest was accidentally brought from Asia in a shipment into the United States eastern seaports and airports containing products with wood packing. The products and packing were shipped to Michigan to be sold, ultimately spreading the beetle. The beetle has also spread by campers transporting firewood from their backyards and surrounding areas to camp in neighboring states causing the beetle to spread further. Since then, over 20 million Ash trees in West Virginia, Michigan, Maryland, Pennsylvania, Illinois, Indiana and Ohio have been destroyed and the beetle continues to spread westward. Enclosed are maps of the areas that the Emerald Ash Borer has invaded. The Ohio map indicates that the Emerald Ash Borer is close to your area of Stark County. It has not been confirmed in your area at this time but there have been sightings reported in the last few weeks. What are ways the Emerald Ash Borer can be prevented or controlled from coming into your local area?

The Emerald Ash Borer is a beetle of metallic green color about ½ to 1 inch in length and as an adult can fly. Its life cycle is similar to a butterfly. The eggs hatch in the early spring and the larvae move into the tree bark. They eat the inside of the tree, which in time starves the tree and ultimately kills it within a 3 to 5 year period. When a tree is infected, the top of the tree dies first and within a year or two, the tree will die. The tree will have D-shaped holes in the bark and possibly woodpeckers on the trunk of the tree in search of food. The Emerald Ash Borer will make a home in any of the multiple varieties of Ash trees found in these 7 states.

What is at stake if the Emerald Ash Borer beetle isn’t stopped? In Ohio, the Ash tree provides businesses and people with resources and many other insects and animals...
with food and shelter. Ohio is one of the largest suppliers of wooden tool handles made from Ash wood. Ash wood is also used in making other everyday products we use in our schools, homes, and other buildings. Even tree nurseries are worried about the sale of Ash trees. There is also concern about the damage to the environment such as other wildlife including plants, animals, and other insects. Local, State, and Federal agencies are working together to make sure the Ash tree is preserved and we need your help. Emerald Ash Borer threatens over 3.8 billion Ash trees in Ohio. The only two solutions to date are to burn all Ash trees that are infected and those trees within a ½ mile of the infected tree and restrict the transportation of Ash firewood. As a member of the Ohio (Stark County) Emerald Ash Borer Task Force, I am requesting your assistance in finding a solution to this local, state, and national problem.

Thank you for your help.

President William Hall
Problem Scenario Map

U.S. Map of Emerald Ash Borer in 2008
**What do I already know about the problem?**

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td><strong>K</strong></td>
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<tr>
<td>What do I know?</td>
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<tr>
<td>1.</td>
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<td>2.</td>
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<td>3.</td>
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<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
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</table>
**What do I NEED to know about the problem to solve it?**

**Name:**

**Problem:**

**Date:**

**Directions:** After stating the problem, (above) and reviewing the “What do I know about the problem?” worksheet, think about what you need to know. Write at least 5 things you need to know about the problem to help solve the problem.

<table>
<thead>
<tr>
<th><strong>W</strong></th>
<th>What do I want to know?</th>
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<tbody>
<tr>
<td>1.</td>
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<tr>
<td>2.</td>
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<td>3.</td>
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<tr>
<td>4.</td>
<td></td>
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<tr>
<td>5.</td>
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</table>
What have I Learned?

Name: 
Date: 

Problem:

Directions: After solving the problem, think about what you have learned. Write at least 5 things you have learned when you were solving the problem.

<table>
<thead>
<tr>
<th>L</th>
<th>What have I learned?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<tr>
<td>2.</td>
<td></td>
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<td>3.</td>
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<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
</tr>
</tbody>
</table>
Group Evaluation Sheet #1

Name:

Date:

1. Is everyone in the group participating?
   Yes_____  No_____  
   If no, who is not participating?

2. Are you participating?
   Yes_____  No_____  
   If no, why are you not participating?

3. Are you asking questions?
   Yes_____  No_____  
   If no, why are you not asking questions?

4. Are you sharing your ideas?
   Yes_____  No_____  
   If no, why are you not sharing?

5. Are you listening to others?
   Yes_____  No_____  
   If no, why are you not listening to others?
Group Evaluation Sheet #2

For each group member, complete the information below by using the rating scale.

4 = Always – 5 or more times  
3 = Occasionally – 3 to 4 times  
2 = Rarely – 1 to 2 times  
1 = Never

<table>
<thead>
<tr>
<th>Name: Date:</th>
<th>Group Member Names</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CRITERIA**

- Participated in group work
- Listened while others spoke
- Answered and asked questions
- Stayed focused on tasks
- Waited to speak until the person was done speaking.
- Located, provided, and shared information with group members
- Contributed to final project
- Worked well with others
Group Evaluation Sheet #3

Name:

Date:

1. Take a moment and list or describe what you contributed to the final group project.

2. Did each member of your group contribute to the final project?
   Yes_____ No_____

   If no, who did not participate?
Thinking Log One

Name:

Date:

Take a few minutes and answer all of the questions below. You must write at least 3 to 5 sentences for each question.

1. What do you think is the problem you are trying to solve?

2. How do you know that is the problem?

3. Are there any other problems to be solved mentioned in the letter or video?

4. How do you think you can solve these problem(s) listed in #1 and #3?
Thinking Log Two

Name:

Date:

Take a few minutes and answer all of the questions below. You must write at least 3 to 5 sentences for each question.

1. What is the problem you are trying to solve?

2. What have you learned about the problem after working in your groups and the K and W worksheets?

3. Name at least 2 things you want to learn when you go to the library.

4. What are possible solutions to the problem?
Thinking Log Three

Name:

Date:

Take a few minutes and answer all of the questions below. You must write at least 3 to 5 sentences for each question.

1. What is the problem you were trying to solve today?

2. What have you learned about the problem today?

3. What were you looking for when you went to the library today?

4. What materials have you used to help solve the problem? (Books, articles, etc.)

5. What are possible solutions to the problem?
Thinking Log Four

Name:

Date:

Take a few minutes and answer all of the questions below. You must write at least 3 to 5 sentences for each question.

1. What is the problem you are trying to solve today?

2. What did you learn today about the problem through reading?

3. What did you learn today about the problem while in your group discussion?

4. What is your plan to solve the problem?
Thinking Log Five

Name:

Date:

Take a few minutes and answer all of the questions below. You must write at least 3 to 5 sentences for each question.

1. What is the problem you are trying to solve today?

2. What did you learn today through reading?

3. What did you learn today about the problem while in your group discussion?

4. Name 3 possible ways to solve the problem.
   a. 
   b. 
   c.
Thinking Log Six

Name:

Date:

Take a few minutes and answer all of the questions below. You must write at least 3 to 5 sentences for each question.

1. What is the problem you are trying to solve?

2. What did you learn today about the problem while in your group discussion?

3. What is the best way or best solution to solve the problem?

4. Why do you think that solution would work best to solve the problem?
Thinking Log Seven

Name:

Date:

Take a few minutes and answer all of the questions below. You must write at least 3 to 5 sentences for each question.

1. What did you learn today about the problem while in your group discussion?

2. What do you think is the best way to solve the problem?

3. Is your solution the same as the group’s solution? Why or why not?

4. Do you agree with your group’s solution to the problem? Why or why not?
# Problem Based Learning Project Rubric

**Names:**

**Date:**

**Project Title:**

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<th>Problem and Sub-Problems</th>
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<td>Problem(s) clearly stated and understood</td>
<td>Problem(s) Somewhat clearly stated and understood</td>
<td>Problem(s) not clearly stated and understood</td>
<td>Problem(s) not presented or stated</td>
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<tr>
<td>Solution / strategy was logical</td>
<td>Solution / strategy was somewhat logical</td>
<td>Solution / strategy was not logical</td>
<td>Solution / strategy was not provided</td>
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<th>3</th>
<th>2</th>
<th>1</th>
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<tbody>
<tr>
<td>Student had full subject knowledge and terms / student could answer and elaborate on questions. There were no factual mistakes.</td>
<td>Student had broad subject knowledge and terms / student could answer questions but cannot elaborate. There were one to two factual mistakes.</td>
<td>Student had limited subject knowledge and terms / student could answer rudimentary questions. There were three to four factual mistakes.</td>
<td>Student did not have grasp of subject knowledge and terms/ student could not answer questions. There were more than five factual mistakes.</td>
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<table>
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<tr>
<th>Presentation Length</th>
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<tr>
<td>5 + minutes</td>
<td>3-4 minutes</td>
<td>1-2 minutes</td>
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<td>Text, color, images, contrast, etc. were excellent: well organized or correlated with topic</td>
<td>Text, color, images, contrast, etc. were satisfactory: somewhat organized or correlated with topic</td>
<td>Text, color, images, contrast, etc. were unsatisfactory: were not organized or correlated with topic</td>
<td>Text, color, images, contrast, etc. were not presented</td>
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</table>

<table>
<thead>
<tr>
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<tr>
<td>Information was fully understood: it was well organized and clearly presented.</td>
<td>Information was somewhat understood: most information was complete one portion is not logically organized.</td>
<td>Information was not fully understood: some information was clear and logically sequenced.</td>
<td>Information was not understood: information was incomplete and unclear.</td>
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</table>

<table>
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<tr>
<th>Presentation speaking</th>
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<tr>
<td>Student used a clear and loud voice and pronounced words / terms correctly</td>
<td>Spoke somewhat soft and unclear and pronounced some words / terms incorrectly</td>
<td>Spoke unclearly and soft and did not pronounce any words / terms correctly</td>
<td>Did not participate</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>References</th>
<th>3</th>
<th>2</th>
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<th>0</th>
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<tbody>
<tr>
<td>All sources used were cited</td>
<td>Most sources were cited</td>
<td>Some sources were cited</td>
<td>No sources were cited</td>
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<table>
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<th>Grammar / Spelling</th>
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<td>One to two grammar / spelling mistakes</td>
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<td>Five or more grammar / spelling mistakes</td>
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<th>B = 22 – 17</th>
<th>C = 16 – 11</th>
<th>D = 10 – 5</th>
<th>F = 4 – 0</th>
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**Comments:**

**Final Grade:**
APPENDIX F

STUDENT COOPERATION GUIDE
Appendix F

Student Cooperation Guide

Rules:
1. Look at the person speaking
2. Wait until the person is completely done speaking.
3. Take notes if you think it is important to solve the problem.
4. Wait your turn to speak and take turns speaking.
5. Use your normal voice.
6. Listen to the chairperson and respect their leadership.

ROLE STRUCTURE:

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Assigned Role</th>
<th>Role Responsibilities</th>
</tr>
</thead>
</table>
| Student A    | Chairperson   | 1. Makes sure to stay on task(s)  
|              |               | 2. Makes sure everyone has a chance to speak. |
| Student B    | Recorder      | 1. Retrieve group folder  
|              |               | 2. Keeps notes during discussion of ideas shared. |
| Student C    | Reporter      | 1. Presents oral responses to the teacher.  
|              |               | 2. Assists the recorder in summarizing the notes each day. |
| Student D    | Monitor       | 1. Ensure the group stays within the time limit.  
|              |               | 2. Checks the folder before it is put away.  
|              |               | 3. Cleans work area. |
APPENDIX G

TEACHER WORKSHOP INSTRUCTIONAL MATERIALS DAY ONE
Appendix G

Teacher Workshop Instructional Materials Day One

Workshop Day 1

What is Problem Based Learning?

Problem-based learning (PBL) is a student-centered instructional method that provides students with an everyday, ill-structured, and complex problem that has to be solved with prior experiences, research and cooperative learning.

Basic Elements of PBL

1. **The problem:** It becomes the center of learning. The problem is presented to students without instruction or lecture from the teacher.
2. The problem has the following characteristics
   a. Ill-structured
   b. Changes with new information
   c. Is not solved easily or with a specific formula
   d. There is no one right answer
3. **Roles:**
   a. Students are active problem solvers and learners
   b. Teachers are cognitive coaches assisting and scaffolding students but not providing the “right answers.”
4. **Cooperative Learning:** Information is shared but the knowledge is learned and constructed by each individual student.
5. **Assessment:** It is authentic and constant throughout the process. The final project chosen by each group reflects knowledge learned.

Procedures of PBL (What does it look like in a classroom?)

1. Teacher prepares the learners and provides an ill-structured everyday problem with a scenario.
2. Students engage in the problem and take the role of a stakeholder in the problem. Students locate and identify the problem and learning issues (sub-problems)
3. Students recall what they know and identify what they need to know (KWL) about the problem and learning issues.
4. Students begin to work cooperatively in groups to identify the problem in detail before beginning to research.
5. Students research the problem to understand it further and begin to provide possible solutions.
6. Students return to groups to review researched information and possible solutions.
7. Students choose the best possible solution and explain why the solution is the best way to solve the problem.
8. Students give a presentation to demonstrate knowledge and share with the class.
9. Debriefing the problem with the entire class to review knowledge learned.

**Problem design**

When considering a problem, it is important to choose a current and real-life event or problem that students can relate to and research. Choose a relevant problem.

**Scenario design**

Once the problem is selected it is time to consider what subject(s) can be covered with this type of problem. Although PBL can focus on one specific subject, it is often interdisciplinary, meaning it overlaps with other fields of study. Develop a scenario using the objectives and real life problem that attracts student attention and interest.

**Assessments / Rubrics**

Assessment is an essential part of the learning and teacher process. The assessment(s) should be authentic and align with the objectives (and standards) to ensure students are learning the required material and knowledge. There are multiple ways of assessing students during and after the unit. During PBL, teachers facilitate student learning by asking questions, using individual thinking logs and group evaluation sheets. Thinking logs allow students time to reflect individually on their learning process and provide the opportunity to organize, analyze, and synthesize information and skills utilized. Group evaluation sheets allow each student to reflect on and evaluate the cooperative learning experience for the day and at the end of the unit.

Summative or final assessments should be open-ended to allow the students to create, imagine, and produce a learning product that is relative to their prior knowledge and connected with the new current knowledge learned during the process. Examples can include research papers, projects such as videos, website creation, poster, artwork, role playing, acting, etc. Once the products are created each group presents to an audience. A rubric is used to grade and provide feedback on the project and presentation. Rubrics are a quick and reliable method of assessing student learning.

**Role of the facilitator**

There is a role change for the teacher when transitioning from a teacher-centered instruction to a student-centered instruction such as PBL. The role of a teacher changes from directly instructing through lecture and dispense knowledge to a facilitator to guide and scaffold students in the learning process. During teacher-centered learning the teacher’s role is often one of a coach, guide on the side, or facilitator. Each of these role
names refers to the idea that the teacher is a vital part of the learning and teaching process in a way that assists or coaches students. This usually includes more facilitating, scaffolding, and guiding learning that allows students the opportunity to have some control or responsibility for their own learning.

**What does the facilitator’s role look like during PBL?**

The first phase is to present the students with a problem and problem scenario. During this time the facilitator typically does not intervene. However, the teacher can scaffold students to understanding the problem and identify the sub problems or learning issues. The teacher embeds periodic assessments and appropriate instruction such as KWL worksheets to find out what students already know and need to know about the problem. Teachers can have a class discussion (using the KW sheets from the KWL) to allow students to share what they already know about the problem and what they need to know to solve the problem. During the cooperative learning and research processes the amount of support and interaction the teacher has should begin to gradually lessen. The teacher should begin to empower the students to take control. The teacher can provide some guidance and assessment by listening to discussions, asking questions, and scaffolding. Teachers can observe and monitor students. However, the teacher should make sure not to lecture or try to guide the students to what an imposed “right” answer since there should be multiple answers to the problem.

**What facilitators should do during PBL:**

- Speak slowly and clearly when asking a question.
- Provide students time to think and process before asking an additional question.

**What facilitators should not do during PBL:**

- Do not impose information on students and take the problem away from them.
- Do not lecture students on the subject or problem.

**Role of the student**

- Students become investigators and are hooked in a real-life ill-structured everyday problem.
- Students review what they know and what they need to know to become further engaged in the learning process (KWL Worksheets).
- Students discuss the problem and reflect on past experiences in groups.
- Students become researchers and begin the research process individually, occasionally meeting in groups to discuss information and progress.
- Students learn to become self-directed learners by having the responsibility for their own learning.
• Students take knowledge learned during the research process and apply it to find possible solutions that are logical and can be supported by the research and previous knowledge and experiences.
• After meeting in groups to discuss solutions, a best-fit solution to the problem is chosen and agreed upon by the group.
• Students create a project to reflect on the content or subject knowledge and application of skills.
APPENDIX H

TEACHER WORKSHOP INSTRUCTIONAL MATERIALS DAY TWO
Traditional Small Group with Didactic Questioning

Workshop Day 2

What is cooperative learning?

Cooperative learning is a teaching strategy in which groups of three to five students utilize a variety of learning activities, discuss, listen, and negotiate learning. Each member of the group is responsible for individual learning and assisting other group members.

Traditional Small Group:

The traditional group is a methodology often used in the classroom. Students are assigned to groups consisting of four to five students with a role-structure. Role assignments include chairperson (leader), recorder, reporter, and monitor, and are assigned. Each group is responsible for dividing the research task(s), producing a learning product or project, and ensuring that each member knows and comprehends the content of the lesson.

Assigned Student Roles

Assigning student roles provides structure for the group. Each person has a responsibility. The assigned roles include:

Chairperson is responsible for making sure the group stays focused on the task(s) and that all group members have the chance to participate in the discussion.

Recorder is responsible for retrieving and maintaining the group file folder and keeps a record of notes on the ideas of each member and the possible solutions presented.

Reporter presents oral responses to the facilitator about the activities or conclusions of the group.

Monitor is responsible for ensuring that the group stays within the time limit, examines the folder to ensure organization, and to make certain the work area is clean for the next class meeting.

Questioning Introduction:

People use questions everyday in our lives since they are naturally embedded into everyday living. Questioning is an essential part of learning. Questions have been used in education for years. They are used before, during and after instruction.
**Didactic Questioning**

Didactic questions are closed-ended convergent questions used by the facilitator to focus the attention of the student with the intent on eliciting a specific or right answer. Didactic questions are used to recall and repeat information. There are times when a facilitator wants a correct answer to a problem. An example is a math problem where there is only one right or correct answer. Another important element of Didactic questioning is the role of the facilitator. The facilitator is not to impose his or her own beliefs on students but rather try to have the students answer a specific question related to the unit materials and objectives. Didactic questions are not presented to elicit creative, insightful, or opinionated answers.

Included in the packet is a Didactic Teacher Questioning Guide. You will use this guide when students are working cooperatively in groups. The guide will be attached to a clipboard with a timer. You will be spending five minutes with each group using the questions provided to guide and facilitate students during the learning process. You will have an equal amount of time to spend with each group.
Traditional Small Group with Socratic Questioning

Workshop Day 2

What is cooperative learning?

Cooperative learning is a teaching strategy in which groups of three to five students utilize a variety of learning activities, discuss, listen, and negotiate learning. Each member of the group is responsible for individual learning and assisting other group members.

Traditional Small Group:

The traditional group is a methodology often used in the classroom. Students are assigned to groups consisting of four to five students with a role-structure. Role assignments include chairperson (leader), recorder, reporter, and monitor, and are assigned. Each group is responsible for dividing the research task(s), producing a learning product or project, and ensuring that each member knows and comprehends the content of the lesson.

Assigned Student Roles

Assigning student roles provides structure for the group. Each person has a responsibility. The assigned roles include:

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People use questions everyday in our lives since they are naturally embedded into everyday living. Questioning is an essential part of learning. Questions have been used in education for years. They are used before, during and after instruction.

Socratic Questioning

Socratic questions are open-ended divergent questions used by a facilitator to probe, allowing students to expand, explain, give multiple answers and further dialogue. The
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Included is the packet is a Socratic Teacher Questioning Guide. You will use this guide when students are working cooperatively in groups. The guide will be attached to a clipboard with a timer. You will be spending five minutes with each group using the questions provided to guide and facilitate students during the learning process. You will have an equal amount of time to spend with each group.
Jigsaw with Didactic Questioning

**Workshop Day 2**

**What is cooperative learning?**

Cooperative learning is a teaching strategy in which groups of three to five students utilize a variety of learning activities, discuss, listen, and negotiate learning. Each member of the group is responsible for individual learning and assisting other group members.

**Jigsaw:**

Jigsaw is a structured cooperative learning method that provides the role and task structure for each member of a group of four to five students. Each student is assigned to a role: chairperson (leader), recorder, reporter, and monitor. Students are individually assigned a task based on the learning content. The task structure is designed to have each member become an expert in one portion of the learning content and then share learned knowledge within the group to support the learning of each other.

1. Each member is assigned to a role (as described below).
2. Each group member is randomly assigned a learning issue to research using the Jigsaw group student learning issue role sheet (as described below).
3. Each student with similar content assignments will meet in an ‘expert’ group to share and discuss information.
4. Each person in the expert group is allotted three to five minutes to discuss what they researched. Each student should be taking notes during this process.
5. The expert group will debrief for five minutes to organize the information and begin preparations to teach the members of their original group.
6. Students from the expert group reunite with the original group and each student will be given three to five minutes to teach the group about his or her learning issue.

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Assigning student roles provides structure for the group. Each person has a responsibility. The assigned roles include:

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Assigned Tasks and the Jigsaw Group Student Learning Issue Role sheet

Each student is assigned the task of researching a specific portion or a learning issue related to the overall problem. Students in each group are assigned one of the following learning issues related to the Emerald Ash Borer:

Learning Issue 1 – Why is the Ash tree important to the Emerald Ash Borer and what will happen to the ash trees in the future if it is not stopped?
Learning Issue 2 - How does the Emerald Ash Borer affect our state (Ohio) and local community (economy and the way we live)?
Learning Issue 3 - How does the Emerald Ash Borer affect the environment (plants, animals, humans, etc.)?
Learning Issue 4 - How did the Emerald Ash Borer arrive here and what solutions or changes can be made to keep it from happening again?

After assigning students to a specific learning issue, each student will begin researching. After researching, each student will meet with students from the other groups that have the identical learning issue to form an “expert” group to discuss what they have researched. Use the “Jigsaw Group Student Learning Issue Role” sheet to divide students into expert groups. Each student will be provided three to five minutes to present what has been researched. The expert group will debrief and review what has been learned. Students will then reunite with his or her original group and teach about their assigned learning issue before completing a final project.

Questioning Introduction:

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Didactic Questioning

Didactic questions are closed-ended convergent questions used by the facilitator to focus the attention of the student with intent on eliciting a specific or right answer. Didactic questions are used to recall and repeat information. There are times when a facilitator
wants a correct answer to a problem. An example is a math problem where there is only one right or correct answer. Didactic questions are not presented to elicit creative, insightful, or opinionated answers.

Included in the packet is a Didactic Teacher Questioning Guide. You will use this guide when students are working cooperatively in groups. The guide will be attached to a clipboard with a timer. You will be spending five minutes with each group using the questions provided to guide and facilitate students during the learning process. You will have an equal amount of time to spend with each group.
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APPENDIX I

JIGSAW GROUP STUDENT LEARNING ISSUE ROLE
Appendix I

Jigsaw Group Student Learning Issue Role

Listed below is an assigned learning issue role for each student in each group. Use the completed form to assist in creating the expert groups.

**Learning Issue 1** – Why is the Ash tree important to the Emerald Ash Borer? What has been done to control the Emerald Ash Borer population?

**Learning Issue 2** - How does the Emerald Ash Borer affect our state (Ohio) and local community (economy and the way we live)?

**Learning Issue 3** - How does the Emerald Ash Borer affect the environment (plants, animals, humans, etc.)?

**Learning Issue 4** - How did the Emerald Ash Borer arrive here and what solutions or changes can be made to keep it from happening again?

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APPENDIX J

TEACHER QUESTIONING GUIDES
Appendix J

Teacher Questioning Guides

Socratic Teacher Questioning Guide

Socratic questions include:

1. What are we trying to accomplish?
2. What is the problem or problems we are trying to solve?
3. I am not sure what you mean by…please explain further?
4. What do we know about …?
5. Can you give an example or more details about…?
6. Why is … important?
7. Please explain why / how?
8. What information are you basing that comment?
9. Where can I find that information?
10. Can you explain your reasoning?
11. Is there an alternative solution or conclusion?
12. What do you think would or is causing…?
13. Why do you assume that…?
14. If we do this…what do you think would be the results or implications?
15. What are other ways of looking at this…?
16. How are …and… similar or different?
17. What if you compared…and…?
18. Which of these viewpoints, solutions, or strategies makes the most sense given the problem or situation? Why?
19. How did you reach that conclusion?
20. Does everyone agree?
21. What are your concerns with this solution or strategy?
22. Than what would happen?
23. How does … affect…?
24. What are the consequences of that assumption?
25. Turn the question back to the student. Allowing time for the student to reflect.
Didactic Teacher Questioning Guide

Didactic question include:

1. What are the 2 or 3 types of …? Can you list each?
2. Are the “X” in “Y” equal?
3. Does the “X” effect “Y”? 
4. What are “X” and “Y”?
5. Is that the correct answer?
6. How many…?
7. What is “X”?
8. What is the definition of “X”…?
9. What does your research state about “X”?
10. What are the similarities and differences between “X” and “Y”? 
11. Compare and Contrast “X” and “Y”.
12. Is “X” important?
APPENDIX K

ACHIEVEMENT POSTTEST
Appendix K

Achievement Posttest

Emerald Ash Borer and Life Science Test

Name: ___________________________ Date: ___________________________

For each question listed below choose the best answer by circling the letter.

1.  Butterflies, Emerald Ash Borer, Ash trees, and other plants are a(n) _________ in a ecosystem.
   a.  Abiotic Factor
   b.  Biotic Factor
   c.  Ecology

2.  What is the life cycle of the Emerald Ash Borer?
   a.  Egg – Larva – Pupae – Adult
   b.  Egg – Pupae – Adult – Larva
   c.  Egg – Larva – Adult – Pupae
   d.  Egg – Adult – Larva – Pupae

3.  The life cycle of the Emerald Ash Borer is most similar to what other insect?
   a.  Butterfly
   b.  Grasshopper
   c.  Blue Bird
   d.  Frog

4.  The Emerald Ash Borer is what type of species, specifically in the United States?
   a.  Endangered
   b.  Invasive
   c.  Threatened
   d.  Extinct

5.  Where did the Emerald Ash Borer come from originally?
   a.  North America
   b.  Asia
   c.  Africa

6.  How did the Emerald Ash Borer arrive in the United States?
   a.  Passengers and their luggage arrived in Ohio from Europe.
   b.  A shipment of goods arrived from Asia to Michigan.
   c.  Animals from South America were shipped to an Ohio zoo.
7. What states have the Emerald Ash Borer?
   a. Kentucky, Ohio, California, New York, Michigan, Tennessee, Pennsylvania
   b. Michigan, Ohio, Indiana, Illinois, West Virginia, Pennsylvania, Maryland
   c. Utah, California, Montana, Indiana, Texas, Florida, Georgia

8. The Ash tree is where the Emerald Ash Borer lives. This is called a(n)
   a. Niche
   b. Food web
   c. Population
   d. Habitat

9. The Emerald Ash Borer eats a similar diet to many beetles. It is considered a(n)
   a. Omnivore
   b. Herbivore
   c. Carnivore

10. What will happen to the Ash tree population if the Emerald Ash Borer is not controlled?
    a. Increase
    b. Decrease
    c. Stay the same

11. Which of the following is a predator of the Emerald Ash Borer in the food chain?
    a. Dog
    b. Woodpecker
    c. Cat
    d. Fox

12. If the Ash tree becomes extinct, what Ohio industry(s) will suffer?
    a. Fire wood
    b. Wooden handles for tools
    c. Wooden cabinets
    d. All of the above

13. How are Ash trees part of the Ecosystem?
    a. Provides food
    b. Provides shelter
    c. Can be used for fires and making wood products
    d. All of the above

14. All the Emerald Ash Borers that live in an area at the same time is a(n)
    a. Ecosystem
    b. Ecology
    c. Community
    d. Population
15. A person who studies plants, animals, and their environment, including the Emerald Ash Borer, and its effect on an ecosystem is a
   a. Ecologist
   b. Chemist
   c. Sociologist
APPENDIX L

PURDUE ELEMENTARY PROBLEM SOLVING INVENTORY (PEPSI)
Appendix L

Purdue Elementary Problem Solving Inventory (PEPSI) Abstract Storybook Form

READ THE STORY ON THIS PAGE TO YOURSELF. AFTER YOU HAVE READ THE STORY, LOOK FOR THE ROW OF BOXES UNDER THE STORY. THERE ARE THREE BOXES UNDER THE STORY. READ THE STORY AND THE THREE CHOICES. THEN PUT A BIG X IN THE BOX THAT TELLS THE CORRECT ANSWER TO THE QUESTION.

Two girls both want to play with the same doll. One girl is pulling the doll's legs and the other girl is pulling the doll by the arms. What might happen if the two girls keep pulling the doll?

A
THEY WILL TAKE TURNS PLAYING WITH IT.

B
ONE OF THE GIRLS WILL WIN.

C
THE DOLL MAY RIP.

MARK THE RIGHT ANSWER TO THE QUESTION WITH AN X. MAKE YOUR X FILL THE WHOLE BOX. MAKE SURE THE LINES ARE DARK ENOUGH TO SEE. THIS TIME I'M GOING TO TELL YOU THE RIGHT ANSWER. C IS THE RIGHT ANSWER. IF THE GIRLS KEEP PULLING ON THE DOLL, THE DOLL MAY RIP.

NOW I WANT YOU TO TRY SOME ON YOUR OWN. I WILL NOT TELL YOU THE ANSWERS EACH TIME. READ EACH STORY, READ THE ANSWERS IN THE BOXES BELOW EACH STORY, AND MARK THE RIGHT ANSWER IN YOUR BOOKLET BY PUTTING A BIG X IN THE RIGHT BOX.

NOW TURN TO PAGE 2

Page 1
A young boy is standing near an empty doghouse. He looks worried. He is looking at his dog's broken rope that is attached to a stake close by. The dog is hiding behind a garbage can. The boy's dog does not see the dog. What is the problem here?

A
THE BOY'S DOG IS LOST.

B
THE BOY BROKE THE DOG'S ROPE.

C
THE BOY THINKS HIS DOG HAS RUN AWAY.

A young boy is standing in front of a tent. He looks scared. A large bear is coming toward the tent through the bushes. The boy has been fishing and his fishing pole is leaning against the side of the tent. A coffee pot is on a grill and two fish are lying beside it. A cloud hides the sun. What is the main problem here?

A
THE BOY SEES SOMETHING THAT FRIGHTENS HIM.

B
THE BOY IS AFRAID IT WILL RAIN.

C
THE BOY IS AFRAID HIS TENT WILL FALL DOWN.

NOW TURN TO PAGE 3
Two boys are sitting on a bench in a corner of their classroom. A third boy is standing near the bench. All three boys are laughing. A fourth boy is leaving the room. He is crying. The teacher looks angry. Four books are in a pile on the floor near the laughing boys. Which question would be the best one for you to ask if you wanted to find out what the problem is?

A: Were the 3 boys mean to the small boy?

B: Are the books interesting?

C: Can they get a drink?

A small boy and a barking dog are watching two big boys. The two big boys are pulling a tiny tree. A girl is running toward the boys from a house close by. Which question would be the best one for you to ask if you wanted to find out what was happening?

A: Why is the house so large?

B: Why is the girl running toward the boys?

C: Is the small boy her brother?

TURN TO PAGE 4
READ THE STORY AT THE TOP OF THIS PAGE AND ANSWER THE TWO QUESTIONS ABOUT IT.

The sun is shining, but the roads are icy. A boy sees a black car go through a stop sign and hit the side of a white car. Why did the accident happen?

A
THE BLACK CAR SLID ON ICE.

B
THE WHITE CAR WAS GOING TOO FAST.

C
THE SUN WAS TOO BRIGHT.

HERE IS ANOTHER QUESTION ABOUT THE CAR CRASH.

Why didn't the black car stop at the stop sign?

A
THE SUN BLINDED THE DRIVER OF THE BLACK CAR.

B
THE STOP SIGN WAS TOO SMALL TO SEE.

C
THE BLACK CAR WAS DRIVING TOO FAST TO STOP.

GO ON TO PAGE 5
Five children are sitting around a table. The teacher is standing in front of them. She has asked them to prepare a report about an Indian named Geronimo. Now she will answer any questions the children have. What should you ask if you had to do this report?

A
WILL WE STILL GET RECESS AFTER THE REPORT?

B
DID GERONIMO KILL GENERAL CUSTER?

C
HOW LONG SHOULD THE REPORT BE?

NOW TURN TO PAGE 6.
A party is being planned by four children. They are seated around a table in front of a blackboard. There are three words written on the blackboard: 1. money, 2. permission, and 3. date. The children must have this information before the party plans are complete. They talk about it for awhile. Then they decide that they have $17.50 to spend and are considering October 29 as the date for the party. Do the children have enough information to complete their plans?

YES  NO  DON'T KNOW

A boy wishes to build a model airplane. In order to do this, he needs a razor blade, a ruler, blue and yellow paint, and some glue. He has a razor blade, a ruler, and some glue. Does the boy have everything he needs?

YES  NO  DON'T KNOW

Page 6
Read the story at the top of the page and answer the three questions about the story.

Two boys and a barking dog are in a room. One boy is carrying a stack of books from one side of the room to put into a bookcase on the other side of the room. There are three shelves in the bookcase, but no one shelf is high enough for all the books. The bookcase is almost as high as the ceiling. There is a box on the floor in the middle of the room. The second boy is reading at a table in a corner close by. What should the boy think about before he gets to the bookcase? Pick the most important from these three.

A
HOW MANY BOOKS ARE ON THE SHELVES?

B
WHO PUT THE BOOKCASE WHERE IT IS?

C
WHERE WILL HE SET THE BOOKS WHEN HE GETS TO THE SHELF?

Here is another question about the boy and the books.

Which of the following should the boy carrying the books do while he is making room for the books in the bookcase?

A
ASK THE BOY WHO IS SITTING IN THE CORNER TO HELP.

B
PUT THE BOOKS IN THE BOX.

C
PLACE THE BOOKS ON TOP OF THE BOOKSHELF.
Here is question number three about the boy and the books.

What should the boy carrying the books do first if he had a choice of these three?

A
SET THE BOOKS ON THE TABLE.

B
PUSH THE TABLE OVER BY THE SHELF.

C
KICK THE BOX OUT OF THE WAY.

Now turn to page 9.
THE STORIES ON THIS PAGE ARE ABOUT A BOY WHO WANTS TO BUILD A PLAY TOWN IN HIS BASEMENT. READ EACH STORY AND MARK AN X ON THE RIGHT ANSWER TO THE QUESTION.

A young boy is sitting in his basement alone. He wants to build a play town which has a jail. A padlock with a key is on the floor near the boy. Behind him is an empty wire bird cage. Near the stairs is a doll house with one side missing. Which of these three objects could the boy use for his jail?

A  DOLL HOUSE
B  PADLOCK WITH KEY
C  BIRD CAGE

HERE IS ANOTHER STORY ABOUT THE BOY AND HIS PLAY TOWN.

The small boy is playing in his basement because it is raining. Raindrops can be seen through a window near the basement ceiling. The boy wants to have the sun in his play town. There is a lamp behind the boy and there is an old record player with several records near one corner of the room. What could the boy use for the sun?

A  WINDOW
B  LAMP
C  OLD RECORD
Two boys and a girl are looking at a ball which has landed on a roof. They want to play with the ball. What is the most unusual or different way for them to get it? By unusual we mean a way that most people will not think of to solve the problem.

A
THEY CAN ASK AN OLDER PERSON TO HELP THEM.

B
THEY CAN USE A LADDER TO GET THE BALL.

C
EACH CHILD CAN STAND ON THE SHOULDERS OF ANOTHER CHILD UNTIL THEY ARE TALL ENOUGH TO REACH THE BALL.

Clothes are drying on a line. There are more wet clothes in the wash basket, but there is no more line space. A girl is standing by the basket wondering what to do. What is the most unusual or different way for the girl to dry the clothes from the basket?

A
SHE CAN TIE THE CLOTHES ON A POLE LIKE A SAIL ON HER WAGON AND GO FOR A RIDE WHILE THEY DRY.

B
SHE CAN PLACE THE CLOTHES OVER A NEARBY FENCE TO DRY.

C
SHE CAN HAVE SOMEONE HELP HER PUT UP ANOTHER CLOTHES LINE.

GO ON TO PAGE 11
The chain on one side of a swing is broken into two pieces. Four children are looking at the damage. They wish to swing. What is the most unusual or different way for them to do this?

A
THEY CAN FIX THE OLD SWING BY TYING THE TWO PIECES OF THE CHAIN TOGETHER WITH A STRING.

B
THEY CAN FIX THE OLD SWING BY REPLACING THE BROKEN CHAIN WITH A NEW ONE.

C
THEY CAN MAKE A NEW SWING BY TYING ONE CHAIN TO A TIRE.

NOW TURN TO PAGE 12
A girl wants to hang a picture in her room. She has put a hook close to one corner of the picture. What will happen when the girl tries to hang her picture on a nail in the wall?

A
THE PICTURE WILL HANG CROOKED.

B
THE PICTURE WILL HANG STRAIGHT.

C
THE PICTURE WILL CRACK AND FALL.

TURN TO PAGE 13
A large jar of white paint and two paint brushes are on a table. A girl is holding a small jar of red paint. What will happen when the girl mixes the paints?

A

SHE WILL GET A PINK COLOR.

B

SHE WILL SPILL ALL OF IT.

C

THE PAINT WILL DRY UP.

There is a cabinet with three shelves. There are boxes and other things on the shelves. More boxes are to be put in the cabinet. There is very little space on either the top or bottom shelf. Several heavy paint cans are on the middle shelf. This shelf is sagging. What might happen when more boxes are put into the middle shelf of the cabinet?

A

THE CABINET MIGHT FALL OVER.

B

THE SHELF MIGHT BREAK UNDER THE LOAD.

C

THE BOXES MIGHT NOT FIT.

GO ON TO PAGE 14
A girl is looking around in her bedroom. The room is neat, but toys, books, clothes, and records fill all the shelves. She does not want to have a messy room. What is the best place for her to put new things?

A
OUT IN THE HALLWAY.

B
IN BOXES UNDER THE BED.

C
IN SOMEBODY ELSE'S ROOM.

A full chest of drawers has to be moved upstairs. Two boys stand looking at this. What is the easiest way for them to move it?

A
EMPTY OUT THE DRAWERS.

B
CARRY IT UP JUST LIKE IT IS.

C
CARRY THE DRAWERS UP FIRST.

NOW TURN TO PAGE 15
A student is sitting at a low desk. She is having difficulty writing because the desk is wobbling. What should she do?

A GET A HIGHER CHAIR.  
B PLACE A PIECE OF FOLDED PAPER UNDER ONE LEG.  
C PRESS DOWN HARDER WITH HER PENCIL.

A sofa, an armchair, a rug, and a fireplace are in a living room. There is no fire in the fireplace. One of the windows is broken. A boy in the room is very cold. What should he do?

A PUT A PIECE OF CARDBOARD OVER THE WINDOW PANE.  
B PUT THE CHAIR IN FRONT OF THE WINDOW.  
C BUILD A FIRE IN THE FIREPLACE.

TURN TO PAGE 16
A girl is sitting in a chair at a desk. She has just finished writing her answers for a test. What should the girl do now?

A
CHECK HER WORK.

B
WRITE A LETTER TO A FRIEND.

C
COPY HER ANSWERS ON ANOTHER PIECE OF PAPER.
APPENDIX M

THE ATTITUDE TOWARD SCIENCE IN SCHOOL ASSESSMENT (ATSSA)
Appendix M

The Attitude Toward Science in School Assessment (ATSSA)

**Attitude toward Science in School Assessment**

Please use this scale to answer the following questions:

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(Circle one choice.)

1. Science is fun.
2. I do not like science and it bothers me to have to study it.
3. During science class, I usually am interested.
4. I would like to learn more about science.
5. If I knew I would never go to science class again, I would feel sad.
6. Science is interesting to me and I enjoy it.
7. Science makes me feel uncomfortable, restless, irritable, and impatient.
8. Science is fascinating and fun.
9. The feeling that I have towards science is a good feeling.
10. When I hear the word science, I have a feeling of dislike.
11. Science is a topic which I enjoy studying.
12. I feel at ease with science and I like it very much.
13. I feel a definite positive reaction to science.
14. Science is boring.

APPENDIX N

PERMISSION LETTER TO OBTAIN OHIO ACHIEVEMENT TEST SCORES
Appendix N

Permission Letter to Obtain Ohio Achievement Test Scores

Dr. Susan Stewart and Fairless Local School Administrators, April 5, 2008

Greetings. I am currently a PhD Candidate at Kent State University working on a dissertation. I am inquiring about your approval for the collection and use of the Ohio Achievement Test scores from the previous year. I have included a brief outline of the study, the necessity of the collection and use of the Ohio Achievement Test scores and the means of ensuring confidentiality for Fairless Local School District and the individual students.

All fifth grade classes will be involved in a two-week study. The teachers and researchers will meet during the teacher planning period for a workshop to explain the study, align the unit with state standards and provide other study related information. A week prior to the study, the students will be provided with assent forms to sign and consent forms to be signed by their parents.

The purpose of this study examines collaborative learning methods and teacher questioning techniques on student problem-solving skills, achievement, and attitude toward science. Two classes will have a traditional lecture and worksheet curriculum and the other four classes will have a PBL curriculum with different forms of cooperative learning and teacher questioning techniques. Each of these instructional strategies used individually have positive outcomes on student learning. The researcher is interested in learning more about cooperative learning methods, traditional small group and Jigsaw, and teacher question types, Socratic and didactic, implemented into PBL on problem-solving skill acquisition, achievement, and attitude toward science of fifth grade students. At the end of the two-week unit students will be tested on their achievement, which is based on the state standards, problem-solving skills, and attitude toward science.

Collecting the Ohio Achievement Test scores of the fifth grade students from the fourth grade school year is necessary to ensure the homogeneity among the six classes. If the data is not collected, it will be impossible to know if the traditional lecture, PBL, cooperative learning, and teacher questioning techniques had an effect on student learning.

Confidentiality will be maintained. The teachers, principal and researcher will be the only persons to have access to the student information and scores. All identifiable student information, including the school’s name and the names of the individual students will be removed before analyzing the data. Random numbers will be assigned to each student to use and when entering data to be analyzed. No identifiers will be included in the final dissertation or reported in future publications and presentations.

The students and teachers will benefit from the study. The students will be learning, applying, and practicing new information and skills such as research skills, problem solving skills, cooperative learning skills, subject content, and world, national, and local information. Teachers will have the opportunity to learn and apply current teaching and learning methodologies, strategies, and techniques. At the end of the study, teachers will be provided the opportunity to attend and earn one graduate workshop credit free of charge through Kent State University.

If you have any questions, please contact me at 330.770.2912 or Dr. David Dalton at 330.672.9079.

Sincerely,
Marian Maxfield, PhD Candidate

I agree to provide Marian Maxfield approval to collect the data as described above.

Signature
Date
Appendix O

Student Assent Form

A Comparison of the Effects of Jigsaw and Traditional Small Group Cooperation Methods and Teacher Didactic and Socratic Questions on Student Problem Solving Skills, Achievement, and Attitude During Problem-Based Learning

Hi,

My name is Marian Maxfield, and I am trying to learn more about how you learn in your science and social studies classes.

I would like you to participate in your science and social studies classes as you normally would each day. You will be learning about the Emerald Ash Borer. You will be spending approximately one and a half hours a day working individually with the teacher lecturing or working in groups with the teacher spending time and asking questions. You will be going to the library and using classroom resources to research. You will write a report paper or create a group project. At the end of the two weeks you will be given tests to see what you have learned.

Do you have any questions before we start?

Do you want to do this? If you want to do this, please sign your name below.

If you want to stop at any time just tell me and I will not hold it against you.

I agree to take part in this project. I know what I will have to do and that I can stop at any time.

__________________________________________  __________
Signature                                           Date

This was witnessed by:

__________________________________________  __________
Signature                                           Date
APPENDIX P

PARENTAL CONSENT FORM
Appendix P

Parental Consent Form

A Comparison of the Effects of Jigsaw and Traditional Small Group Cooperation Methods and Teacher Didactic and Socratic Questions on Student Problem Solving Skills, Achievement, and Attitude During Problem-Based Learning

I want to do research on a teaching strategy called Problem Based Learning (PBL) and how students learn. I want to do this because it is important to understand how students learn when provided with a real life problem. Students may have to solve problems within groups and with teacher assistance. I would like you to let your child take part in this project. If you decide to do this, your child will be asked to participate in a two week unit. Students will be learning about the Emerald Ash Borer in science and social studies classes under the direction of their classroom teacher. Students will be spending approximately one and a half hours a day on this project. During each day some students will be working individually with the teacher lecturing and some will work in groups to solve an ill-structured problem with the teacher spending time and asking questions to each group to learn about the Emerald Ash Borer and how it affects our local community. Students will be going to the library and using classroom resources to research about the Emerald Ash Borer. Some students will write a report paper. Some students will create a group project. Students will be learning and applying science and social studies knowledge. At the end of the two weeks students will be given a 45 minute problem solving test, a 20 minute survey about his or her attitude toward science, and a science test about the basic science knowledge and vocabulary that the state requires students to learn.

The researcher will remove the name or other personal identifiers to ensure anonymity. All personal identifiers will be removed from the problem-solving test, attitude survey, and science achievement test given at the end of the two weeks. The Ohio Achievement Test score from the previous year will be obtained. All scores will remain confidential using the random student number during the data analysis. Your child’s name will not be associated with any information obtained during this study.

If your child takes part in this project, there are multiple benefits to be gained. The student will benefit by learning, applying, and practicing new information and skills such as research skills, problem solving skills, and cooperative learning skills in relation to the subject and current world, national, and local events. The study focuses on the application of different teaching strategies that can have a positive impact on student learning. Teachers will have the opportunity to learn and apply current teaching and learning techniques. Studying the effects of teaching strategies on student learning can assist teachers in designing lessons that help students learn. Taking part in this project is entirely up to you, and no one will hold it against you or your child if you decide not to do it. If you do or your child does take part, he or she may stop at any time.

If you want to know more about this research project, please call me at 330.770.2912 or Dr. David Dalton 330.672.9079. The project has been approved by Kent State University. If you have questions about Kent State University’s rules for research, please call Dr. John West, Vice President of Research, Division of Research and Graduate Studies (Tel. 330.672.2704).

You will get a copy of this consent form.

Sincerely,

Marian Maxfield, PhD Candidate

A. CONSENT STATEMENT(S)

I agree to let my child take part in this project. I know what he or she will have to do and that he or she can stop at any time.

Signature  Date

249
APPENDIX Q

INTERNAL REVIEW BOARD LEVEL II APPROVAL
Appendix Q

Internal Review Board Level II Approval
May 14, 2008

Marian Belle Maxfield
Educational Foundations and Special Services

Re: 08-509: “A Comparison of the Effects of Jigsaw and Traditional Small Group Cooperation Methods and Teacher Didactic and Socratic Questions on Student Problem Solving Skills, Achievement, and Attitude during Problem-Based Learning”

Dear Ms. Maxfield:

I am pleased to inform you that the Kent State University Institutional Review Board has reviewed and approved your Application for Approval to Use Human Research Participants as Level II research. This application was approved on May 12, 2008 and is effective for a twelve-month period, expiring on May 12, 2009.

Federal regulations and Kent State University IRB policy require that research be reviewed at intervals appropriate to the degree of risk, but not less than once per year. The IRB has determined that this protocol requires an annual review and progress report. The IRB will forward an annual review reminder notice to you by email as a courtesy. Please note that it is the responsibility of the principal investigator to be aware of the study expiration date and submit the required materials. Please submit review materials (annual review form and copy of current consent form) one month prior to the expiration date.

HHS regulations and Kent State University Institutional Review Board guidelines require that any changes in research methodology, protocol design, or principal investigator have the prior approval of the IRB before implementation and continuation of the protocol. The IRB must also be informed of any adverse events associated with the study. The IRB further requests a final report at the conclusion of the study.

Kent State University has a Federal Wide Assurance on file with the Office for Human Research Protections (OHRP); FWA Number 00001853.

If you have any questions or concerns, please contact me at 330-672-2704 or tfreder2@kent.edu.

Sincerely,

Tonya Frederick, R.N., B.S.N.
Research Compliance Administrator

Cc: Dr. David Dalton

Division of Research and Graduate Studies
Office of Research Safety and Compliance
(330) 672-2704 Fax: (330) 672-2655
P.O. Box 5190, Kent, Ohio 44242-0001
APPENDIX R

TEACHER QUESTIONING TALLY SHEET
Appendix R

Teacher Questioning Tally Sheet

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Additional Observations:
APPENDIX S

PERMISSIONS FOR THE ATTITUDE TOWARD SCIENCE IN SCHOOL ASSESSMENT (ATSSA)
Appendix S

Permissions for the Attitude Toward Science in School Assessment (ATSSA)

John Wiley & Sons, Inc.
Publishers Since 1807

May 5, 2008

Marian Maxfield
Kent State University
mmaxfield@kent.edu

Dear Ms Maxfield:


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Sincerely,

Brad Johnson
Permissions Assistant
201.748.6786
201.748.6008 (fax)
bjohns@wiley.com
APPENDIX T

PERMISSIONS FOR THE PURDUE ELEMENTARY PROBLEM SOLVING INVENTORY (PEPSI)
Appendix T

Permissions for the Purdue Elementary Problem Solving Inventory (PEPSI)

From: anne feldhusen
Sent: Thursday, August 19, 2010 8:42 PM
Subject: Re: Copyright permissions

Hello Marian and Cindy,

Thank you for your kind words. And for being respectful of my father's work.

Please accept this email as your permission to use his work. You simply need to ensure that when it is used, it is correctly attributed to Dr. John Feldhusen. My father would be happy that his work lives on.

Marian, best wishes for completing your PhD.

All the best,

Anne Feldhusen
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Educational Laboratory, Inc.

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