

THE INFLUENCE OF THE DEEPER SCAFFOLDING  
FRAMEWORK ON PROBLEM-SOLVING  
PERFORMANCE AND TRANSFER OF KNOWLEDGE

By

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## CHAPTER I

### INTRODUCTION

#### **Problem Statement**

People face a wide range of problems in their personal and professional lives. Therefore one major goal of education is to prepare effective and efficient problem solvers (Hong, 1998). According to Jonassen (2000),” problem is an unknown entity in some situation” (p. 65) and “finding or solving for the unknown must have some social, cultural, or intellectual value” (p. 65). There are two types of problems: well-structured and ill-structured ones. In well-structured problems, all or most elements that are important for defining and solving the problem are presented in the problem description, and a limited number of regular rules is needed to find the answer. On the other hand, in ill-structured problems, many essential elements are unknown or not known with any degree of freedom (Wood, 1983). They possess multiple solutions, solution paths, or no solution at all (Kitchner, 1983). There are multiple criteria for evaluating the solution, information resources can be relevant or irrelevant to solving the problem and in addition to providing scientific evidence ill-structured problems usually require learners to make judgments and express personal opinions. Real-world problems usually are complex and ill-structured (Jonassen, 2007).

Complex problems require complex problem solving. While there are many definitions of the problem-solving process, one of the least ambiguous definitions is as follows: problem solving is “any goal-directed sequence of cognitive operations” (Anderson, 1980, p. 257) used to solve problems. A popular model of problem solving is IDEAL (Bransford & Stein, 1984). This model consists of the five problem-solving steps (Figure 1): Identify the problem, Define the problem, Explore possible strategies, Act on those strategies, and Look back and evaluate the process.

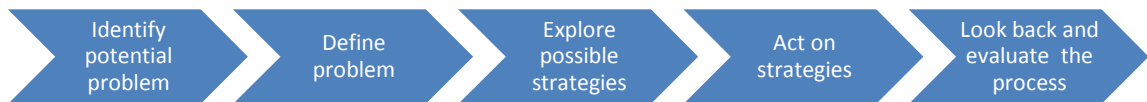


Figure 1. IDEAL framework for scaffolding problem solving.

The IDEAL model of problem solving is a good example of the instructional scaffolding that can be used in formal and informal education settings to help learners develop problem-solving skills that can potentially be applied to multiple content areas. When problem solving activities are used in the classroom, the instructional method is typically referred to as problem-based learning (PBL). PBL is very similar to (and is often confused with) inquiry-based learning and goes back to the work of John Dewey who proposed a PBL-based curriculum to solve problems with American education in the early twentieth century. Since then, PBL has been used as the primary conceptual and methodological framework to develop curriculum at many schools around the world (Putnam, 2001).



PBL was started at McMaster University in Canada more than 40 years ago (Barrows, 1986). PBL scaffolds and helps students develop specific skills such as identifying issues that are worth exploring, analyzing complex problems, critical thinking, evaluation of information resources, and collaborating in teams (Duch, Groh, & Alien, 2001).

As the process of real-life problem solving is more cognitively and metacognitively complex than the textbook, “plug-and-chug” well-structured problem solving typically used in schools, learners often experience discomfort and frustration when asked to solve an ill-structured problem in the classroom. The PBL approach uses the idea of scaffolding to help students develop problem-solving skills that they can use in real life, beyond the classroom. Scaffolding is a process through which a “more knowledgeable other” such as peers, teachers, parents, or tools offer cognitive, emotional, and social supports to foster students’ learning (Vygotsky, 1978; Wood, Bruner, Ross, 1976). The scaffolding process can be gradually reduced and finally removed when students become self-sufficient (Savery, 2006). According to Kim and Hannafin (2011), scaffolding fosters a deep understanding of content and problem solving in students and deep understanding is one of the factors that increases transfer of knowledge, a key goal of education (Barnett & Ceci, 2002). Therefore, scaffolding in PBL is critically important in order to help students develop both a deep understanding of content and problem-solving skills that can transfer to new problems in novel contexts.

Multiple scaffolding frameworks have been developed to structure PBL (e.g., the IDEAL model described above). One of such frameworks that have been proposed recently is called DEEPER (Antonenko, Hudson, Townsend, & Pritchard, 2011):

1. Define an important problem to solve.
2. Explore available information resources.
3. Explain possible solutions.
4. Present the best solution in the most appropriate format.
5. Evaluate the final solution.
6. Reflect on the problem-solving process.

The DEEPER framework of scaffolding problem solving is based on decades of problem-solving and PBL research and can be useful in encouraging and supporting real-life collaborative problem solving. It integrates most of the problem-solving steps and procedures discussed in the literature (e.g., Kim & Hannafin, 2010) but unlike most other previous models, it emphasizes potential impacts on the stakeholders of the problem-solving process and the aspect of communicating results of problem solving to the stakeholders. The present study was designed and conducted to measure the influence of the DEEPER scaffolding framework on the problem-solving performance, domain knowledge acquisition and transfer of knowledge of novice learners in an introductory undergraduate science course for non-science majors.

### **Statement of Purpose**

The purpose of this study was to determine the impact of the DEEPER framework of scaffolding problem solving on three important variables: problem-solving performance, domain knowledge acquisition, and transfer of knowledge in a problem based learning environment in higher education. In other words, this study attempted to generate evidence as to whether learners who solve problems using the DEEPER scaffolding framework demonstrate better performance in problem solving, whether they

can retain more domain knowledge, and whether they can transfer knowledge to new problem-solving contexts more successfully than learners who solve problems using a more traditional, rationale-based scaffolding approach. Specifically, this study was designed to address the following questions:

1. Research Question 1: What is the effect of the DEEPER scaffolding framework on participants' problem-solving performance?
2. Research Question 2: What is the effect of the DEEPER scaffolding framework on participants' domain knowledge acquisition?
3. Research Question 3: What is the effect of the DEEPER scaffolding framework on participants' transfer of knowledge?
4. Research Question 4: Is there a relationship between students' performance on individual DEEPER scaffolding tasks and a) problem-solving performance, b) domain knowledge acquisition, and c) transfer of knowledge

## **CHAPTER II**

### **REVIEW OF LITERATURE**

#### **Overview of the Problem-Based Learning Approach**

One of the most effective methods of learning is Problem-Based Learning (PBL), which is used to anchor learning and teaching of conceptual content in concrete problems that are relevant to students' lives (Evensen & Hmelo, 2000). According to Putnam (2001), PBL is the most popular approach for curriculum development around the world.

PBL is a learner-centered pedagogy (Savery, 2006). PBL encourages learners to conduct research, merge theory and practice, and apply content knowledge to develop a solution to a problem defined by the students. PBL develops 21<sup>st</sup> century skills such as critical thinking, analysis of real-world, complex issues, identification and evaluation of information resources, and collaborating in teams (Duch, Groh, & Alien, 2001). In PBL, the focus is on learners as they are the constructors of their body of knowledge during the problem-solving process. PBL empowers learners to think creatively and critically. The negotiation of the problem, solution strategies, and solutions developed by the team members during the problem-solving process is an essential aspect of PBL.

Implementation of PBL in formal and informal learning settings is constantly growing around the globe. A mounting body of evidence generated by PBL researchers demonstrates that applying real-world types of questions in a learner-centered approach is

more valuable for learners than the traditional teacher-centered approaches (Norman and Schmidt, 1992).

### **History of Problem Based Learning**

PBL is based on theories that go back at least one century. Such prominent educational scholars as Dewey (1910, 1916), Piaget (1954), Bruner (1954, 1961), and Ausubel (1978) have contributed to the development of PBL over the years. For example, Dewey (1910) and (1916), Piaget (1954), and Bruner (1961) explained that learning is more meaningful to learners when they are required to take responsibility for their own learning. However, PBL as it is known today was started in Canada in 1950s and 1960s for medical training purposes at McMaster University (Barrows, 1996). It evolved from the health curriculum at McMaster University more than 40 years ago (Boud and Feletti, 1998). McMaster University medical faculty introduced this method as central to their philosophy for constructing their curriculum that promotes learner-centered and lifelong learning in professional practice. During the 1980s and 1990s, PBL was accepted by other medical schools in North America and became a popular instructional approach in North America and Europe beyond the original context of medical education (Savery, 2006).

PBL is popular pedagogy in multiple disciplines and knowledge domains. For example, PBL has been applied in fields as diverse as architecture (Donaldson, 1989), engineering (Cawley, 1989), law (Kurtz, Wylie, & Gold, 1990), mathematics (Polya, 1957), chemistry (Bunce & Heikkinen, 1986), biology (Hurst and Milkent, 1996), physics (Heuvelen, 1991), medical and nursing education (Hmelo, 1998) and pre-service teacher

education (Hmelo-Silver, Derry, Bitterman, & Hatrak, 2009), social work (Heycox & Bolzan, 1991), economics (Garland, 1995), and business administration (Merchand, 1995). Furthermore, implementation of PBL has expanded from the original context of higher education to elementary schools, middle schools, and high schools (Torp & Sage, 2002). However, the adoption of PBL for different school levels and different domains has also caused misconceptions and misapplications of PBL. Designing and maintaining a problem-based learning environment, facilitating problem solving (using a tutor or technology), and teaching learners how to communicate and act in this environment is a challenging task for any instructor.

### **Characteristics of Problem Based Learning**

According to Savery (2006), PBL is an instructional learner-centered approach that encourages learners to integrate theories and practices, and apply the knowledge to develop viable solutions for problems. Several scholars have delineated specific characteristics of a successful PBL approach. For example, Duch, Groh, and Alien (2001) expanded on the methods that are used in PBL, and certain skills that are developed as a result of using PBL, such as the critical thinking, analytic reasoning, identification of reliable resources, effective team work, and developing communication skills. Torp and Sage (2002) specified that in PBL learners are engaged problem solvers who have to identify the problem and seek possible solutions. Hmelo-Silver (2004) also described PBL as an instructional approach where learners acquire knowledge and skills in a facilitated problem-solving environment, which focuses on an ill-structured and complex problem with multiple correct answers. Learners must work in collaborative teams to distinguish what they need to learn to solve the described problems, engage in self-

directed learning, apply the knowledge and skills to the problem, and reflect on what they learned and how they have employed strategies (Savery 2006). Three essential characteristics are also described in this seminal article on PBL: a) the role of tutors or facilitators of learning; b) the responsibility of learners in self-directed learning; and c) the key elements in designing problems (Savery, 2006).

The Problem-Based Learning Initiative's website (2012) describes the following essential characteristics of PBL:

- Learners must be responsible for their own learning.
- The problem that is used in PBL must be ill-structured.
- Learning should be integrated from a range of disciplines or subjects.
- Collaboration is essential in PBL.
- During the self-directed learning students learn based on their understanding, analysis, and resolution.
- The activities carried out in PBL are those valued in the real world.
- Student examinations measure student progress towards the goals of PBL.

As PBL is identified as a constructivist pedagogy (Greening, 1998), PBL shares many essential characteristics with constructivism (Savery & Duffy, 1995):

- Learning is based on learners' experiences with content, context, and their goals.
- Puzzlement is the essential factor in motivating learners.
- Social negotiation is very important

Traditional instructional approaches have been criticized for focusing almost exclusively on the retention of knowledge and the inability of learners to apply their

knowledge to real-life cases. However, Coles (1985) and Newble and Clarke (1986) claimed that PBL increases deep learning in learners and decreases the chances of shallow learning among learners. Robbs and Meredith (1994) outline a number of advantages of using PBL in the classroom:

1. Increasing the retention and application of knowledge.
2. Encouraging lifelong learning.
3. Developing an integrated knowledge environment.
4. Increasing liaison between learners and instructors.
5. Increasing learners' motivation towards learning.

Other factors that need to be addressed when discussing PBL are the cognitive and metacognitive processes involved in problem solving. Schmidt (1983, 1993) emphasizes that the cognitive process in PBL is grounded in knowledge activation and elaboration. PBL can be divided into several phases both in individual study and group work. The process starts with identifying the problem based on a description or a story. Next, learners engage in problem analysis and participate in discussions with other team members to generate definitions for the problem. In this phase, learners identify what they know and what they do not know about the problem and they make decision on what they need to know in their individual study. In the next phase, learners report what they learned to the group in order to find a solution and negotiate an appropriate solution with other team-members. Therefore, problem solving can be cognitively and metacognitively challenging for learners, especially novices.

An interesting insight into the cognitive and metacognitive aspects of problem solving is reported by Mayer (1998) who explains why some learners fail to solve



problems, especially non-routine problems. Although students who know geometry get high scores in tests, they may fail to solve a geometry problem they have never seen before. Mayer (1998) explains that motivational and metacognitive factors are sources of failure in this case. On the metacognitive side, students may not know how to plan to solve a problem. Possibly, they do not know how to explore the problem and explain the possible solutions. On the motivational side, students may have low estimation of their ability to solve the problem. Therefore, Mayer (1998) explains how the following three components can help students in the problem-solving process: skill, metaskill, and will. Skill refers to the specific knowledge that is relevant to the problem to which it will be applied. Metaskill refers to how students apply their knowledge to solve a new problem. Finally, will refers to students' interest and ability to solve problems. Therefore, learners (especially novices) need to be supported and guided through the process of problem solving to develop the skills, metaskills, and motivation necessary to solve complex problems.

### **Scaffolding of Problem-Based Learning**

Novice learners in a PBL environment need high levels of instructional scaffolding to acquire the knowledge and skills on how to engage in problem-solving, self-directed learning, and team work in effective and fulfilling ways. As they become self-sufficient (Savery, 2006), the scaffolding process can be gradually reduced and removed.

A numbers of studies have been conducted on the advantages of scaffolding techniques. Problem solving is a process that includes situated, deliberated, learner-

directed efforts to seek solutions for problems through multiple interactions between problem solvers, tools, and sources (Kim & Hannafin, 2011). Thus, scaffolding is a process that a “more knowledgeable other” such as a peer, a parent, a teacher, or a tool can use to offer cognitive and social supports to foster students’ problem solving (Vygotsky, 1978; Wood, Bruner, & Ross, 1976).

Similar to Wood and colleagues’ (1976) and Vygotsky’s (1978) scaffolding definitions, Kim and Hannafin (2011) defined scaffolding as “assistance from a more knowledgeable person that helps learners to do a learning task beyond their capacity” (p. 407). Wood and associates (1976) build their scaffolding model on Vygotsky’s model, and they emphasize the teacher’s role as a more knowledgeable person to help learners solve problems within their zones of proximal development (Vygotsky, 1978). Wood and colleagues (1976) discuss six important steps of scaffolding:

- Increasing problem solvers’ interest in the task.
- Decreasing the degrees of freedom (e.g. reducing subsequent tasks).
- Maintaining the path or direction (e.g. motivating problem solvers).
- Distinguishing critical situations or features (e.g., differences between problem solvers’ act and the correct problem-solving process path).
- Frustration control (e.g., helping problem solvers avoid excessive reliance during the process).
- Demonstration (e.g., modeling of problem solving based on performance of student problem solvers).

Studies demonstrated influences of scaffolding on problem-solving performance.

For example, the most common implication of most PBL research to date is that students should break problems into smaller, more manageable steps and then work on each step of the problem. This methodology has been applied in domains like mathematics (Polya, 1957), chemistry (Bunce & Heikkinen, 1986), and biology (Hurst & Milkent, 1996). For example, Reif and associates (1979) developed an instructional method for problem-solving in physics. Their model consisted of four steps: Description, Planning, Implementation, and Checking. Problem-solving performance improved when students received guided practice while performing each problem-solving step (Halloun & Hestenes, 1987). Another example is Active Learning Problem Sheets (Heuvelen, 1991) that contain separate sections that students have to complete including representing the problem graphically and conducting a qualitative analysis before discussing the mathematics behind the problem. This method helped students categorize problems more effectively, and improve students' problem-solving performance (Dufresne, Gerace, Hardiman, & Mestre, 1992). A similar environment was designed by Jonassen (2004) – Story Problem-Solving Environment (SPSE). First, SPSE presents a story and then students have to follow a series of tasks (identifying the problem, qualitatively analyzing the problem, building a quantitative representation of the problem) in order to find a solution for the problem.

The most recent meta-analysis of problem-solving scaffolding was provided by Kim and Hannafin (2011). These scholars synthesized conceptual and empirical research on the scaffolding of problem solving and proposed five activities of problem solving to conceptualize scaffolding:

1. Problem identification and engagement.

2. Evidence exploration.
3. Explanation reconstruction.
4. Communication and justification of explanation.
5. Revision and reflection of explanation.

In the first step, problem identification and engagement, tutors and peers guide learners to identify problem(s) and help them to generate their goals by asking questions and sharing their experiences about the problems in order to increase their interest to solve the problem. Technology-enhanced scaffolding may provide vivid descriptions, visualizations, and resources for learners. Such scaffolding assists learners to seek related information in order to identify problem(s) and find conflicts and challenges related to learners' interests. For example, Science Controversies On-line: Partnership in Education (SCOPE, Linn, Davis, & Bell, 2003) uses scaffolding to guide learners to explore and solve problems as scientists.

Next, in the problem exploration step, tutors provide resources for learners and guide them to investigate the problem, test their hypotheses, and pursue solutions. Technology-enhanced scaffolding may provide lower-order tasks such as simple calculations to higher-order tasks such as generating hypotheses. For instance, the Virtual Solar System (Barab, Hay, Barnett, & Keating, 2000) is a computer-based modeling tool that supports problem solving by providing 3D models.

In the problem reconstruction step, tutors and peers guide learners to identify related resources to find solutions. Therefore, scaffolding helps learners to link their existing knowledge to a novel situation or experience. For example, narratives and stories help learners to link their experiences to the problem (Jonassen, 2003).

In the communication step, tutors guide learners to visualize or verbalize their solutions and share them with other learners. Scaffolding helps learners to challenge their thinking and solutions with others, consider other possible solutions, and evaluate them. Technology increases learners' access to different societal groups and cultures, thereby supporting collaborative knowledge construction.

In the last step, reflection and negotiation, tutors and peers guide learners to reflect on their process of problem solving and assess their progress. Scaffolding helps learners to identify their mistakes and errors and evaluate themselves. Studies have yielded specific findings regarding peer interactions in science classes (Kim & Hannafin, 2010). For example, student dyads are able to apply problem-solving strategies better than individual students (Schwartz, 1995). Additionally, engaging and collaborating have positive effects on short-term problem-solving performance of students (Barron, 2000). Web-based knowledge communities such as SCOPE (Linn, Davis, & Bell, 2003) or CSILE (Scardamalia, Bereiter, Mclean, Swallow, & Woodruff, 1989) provide a forum for learners to communicate within and among peers, tutors and experts.

Kim and Hannafin (2011) explain that scaffolding in a problem-solving activity improves many skills in novices, such as the ability to think critically, find reliable resources, learn team work, and communicate with team members. These skills involve different processes and so each scaffolding phase should focus on a specific skill of problem solving (Kim & Hannafin, 2011).

In the identification phase, scaffolding should be focused on appropriate engagement and authenticity of problem. Scaffolding of this phase guides students to find the problem and the variables that affect it. In the exploration phase, scaffolding focuses

on questioning, problematizing, and maintaining of learning goals. Scaffolding should help students learn how to find relevant resources, and how to fill the gap of knowledge that they have. In the reconstruction phase, scaffolding guides students in diagnosing their misconceptions about the problem. Also, scaffolding can help students to organize their learning process and resources and learn how to build a structured body of knowledge. In the communication phase, scaffolding can provide a tool for students to communicate with each other in order to correct each other and control the frustration. Students learn how much positive collaboration between team members is important during the problem-solving process. In the reflection/negotiation phase, scaffolding can help students to assess their process from the beginning to the end. Students learn that in any problem-solving activity, they have to assess their solution, rationale, and process to prevent them from future mistakes.

To summarize, there are many tools and guidelines that have been developed to facilitate teaching in technology-rich classrooms (Lindh & Holgersson, 2007). However, Hannafin and Kim (2004) report that sometimes they fail to reflect how students learn, and how students can be assessed and evaluated based on their use of those tools and guidelines.

### **Effects of Problem-Solving Scaffolding on Problem-Solving Skills**

Scaffolding can be developed to focus on students' practice to produce a correct answer (i.e., Product), or to help students learn and understand the process of problem solving (i.e., Process) (Mayer, 2008). Research suggests that problem-solving scaffolding should focus on the steps of problem-solving *process* rather than problem-solving *product* (Bloom & Broder, 1950, Mayer, 2008). "We should be teaching students how to

think; instead we are primarily teaching them what to think.” (Lochhead & Clement, 1979, p .1).

Bloom and Broder (1950) developed a program to improve problem-solving performance of college students at the University of Chicago by scaffolding the Process in order to enhance the Product. Students were required to pass a series of comprehensive exams in subject matter areas. Model Students were the students who passed the exams well, and Remedial Students were the students who did not pass the exams. Both the model and the remedial students were motivated, studied hard, and had high scores on a scholastic aptitude test. Although the model and the remedial students seemed to be equal in “ability, knowledge, and motivation”, apparently the remedial students lacked the cognitive and metacognitive skills to answer the questions correctly. Bloom and Broder (1950) asked the remedial students to describe their thinking process for a problem. Then the model students were asked to describe the thinking process to solve the same problem. Then the remedial students were asked to find the differences between their problem-solving process and the model students’ problem-solving process. Bloom and Broder (1950) reported that they were able to influence the process of problem-solving and helped students to understand the process of successful problem solving. Therefore, scaffolding that is based on explicating the problem-solving process to students can help them develop their problem-solving skills.

Relative to the role of scaffolding in improving problem-solving skills, Belland, Glazewski, and Richardson (2011) explored the effects of problem-solving scaffolding on the skills of argument evaluation in the context of multi-step scaffolding included in a tool called Connection Log. Their study involved four classes, and two classes were

randomly selected to use the Connection Log. Groups selected a stakeholder and approached the problem from their perspective, and they performed a persuasive presentation at the end of the unit. Individuals completed pre/post-unit multiple-choice tests designed to measure argument evaluation ability. The results of this study demonstrate that while the scaffolding did not significantly increase the overall quality of group arguments in persuasive presentations, it did increase argument evaluation ability for low-achieving students.

### **Effects of Problem-Solving Scaffolding on Transfer of Knowledge**

The history of discussing the role of transfer of knowledge in education begins with Charles Judd (1908). He reported about fifth and sixth grade students who were instructed to throw darts at a target under 12 inch water. Some of the students were taught theoretical explanations about optical refraction that made the target under water appear skewed. He found no difference in the rate of hitting darts to the target. However, when he placed the target closer from 12 inches to 4 inches, there was a big difference between the two groups of students. The students who received the theoretical explanation of refraction did much better hitting darts at the target than the other students who did not. Therefore, Judd (1908) suggested that teachers should focus on teaching general ideas and principles rather than specific skills, because learners can apply the broad principles to specific situations. Some types of learning have widespread effects on the learners' mind, and it nurtures thinking skills and it "goes beyond the specific training provided" (Barnett & Ceci, 2002).

However, Thorndike's findings (1906) do not reconcile with Judd's results (1908). They reported the result of several experiments where learners could not apply



the general principles to certain situations. Therefore, Thorndike (1906) theorized that for transfer to occur, the elements have to be presented in the transfer context. This claim was the beginning of the transfer of learning debate during the previous century (e.g., Perkins & Grotzer 1997; Halpern, 1998). Much research has been conducted to find out how transfer occurs, and what conditions are needed (Barnett & Ceci, 2002).

Bransford, Brown, and Cocking (1999) defined transfer of knowledge (hereafter transfer) as “the ability to extend what has been learned in one context to new contexts” (p.39). However, in its broadest sense transfer is the effect of previous learning on new learning or problem solving (Mayer, 2008).

Transfer can be positive, negative, or neutral (Mayer, 2008). Positive transfer occurs successfully when previous knowledge fosters new learning or problem solving; negative transfer occurs when previous learning destructively affects new learning or problem solving. Neutral transfer occurs when previous learning and knowledge has no effect (neither positive nor negative) on new learning or problem solving (Mayer, 2008).

Depending on its relation to the original context of learning, transfer is also divided into two categories: near transfer and far transfer (Cree & Macaulay, 2000). Near transfer refers to the transfer of knowledge between similar contexts (Perkins & Salomon, 1992). In other words, near transfer successfully occurs when the context of the previous learning/knowledge setting is similar to the context of a new learning or problem solving. Hence, learners can transfer the previous setting to a new setting (Mestre, 2002). Far transfer refers to transfer of knowledge between contexts which are alien to one another (Perkins & Salomon, 1992). Simply put, far transfer occurs, when the previous

learning/knowledge setting is dissimilar to the new setting. However, learners can still transfer the previous context to the new one (Barnett & Ceci, 2002).

Research suggests that scaffolding in PBL may foster deep understanding in students and that they may have successful transfer of knowledge (Kim & Hannafin, 2011). Kim and Hannafin (2011) reported that during the problem exploration step students search for information about the problem, and find the relevant resources to fill the gap between what they already know and what they need to learn. In explaining the solution, students link the knowledge domains that they went through in the problem exploration step to explain the rationale of their solution. Therefore, students are likely to have a successful transfer of knowledge to solve a new problem.

Studies indicate PBL curricula have positive effects in “promoting learning and transfer”, especially in medical education (Dochy, Segers, van den Bossche, & Gijbels, 2003; Hmelo, 1998). Hmelo-Silver, Derry, Bitterman, and Hatrak (2009) report the results of a recent study that tested the effects of problem-solving scaffolding on transfer of knowledge within a problem-based learning environment called STELLAR. The STELLAR system was developed to support online and hybrid PBL courses for preservice teachers. Scaffolding was provided through a navigation tool called the STELLAR Sidewalk, which consisted of the following steps: Tackle the Problem, Initial Proposal, View Others’ Proposals, In-Depth Exploration, Group Design, Final Group Product, Individual Explanation, Reflection, and Feedback. This quasi-experimental study determined that students who participated in a hybrid PBL course using STELLAR learned more about targeted course concepts and performed better on a test of knowledge transfer than students in a traditional comparison course. Thus, effective scaffolding of

problem solving using multi-step procedures like the ones contained in STELLAR can positively influence students' transfer of knowledge.

### **Effects of Problem-Solving Scaffolding on Domain Knowledge Acquisition**

According to Mayer (2008), research on PBL is focused either on products (students' responses on the tests) or processes (problem identification, resource discrimination and others). As mentioned earlier, Mayer (2008) reviewed a number of studies conducted on PBL beginning as early as the 1940's and 1950's (e.g., Bloom & Broder, 1950; Polya, 1945) and concluded that problem-solving activities in the classrooms influence students' problem-solving skills and, thus, such activities should focus on modeling and scaffolding of the problem-solving process rather than development of the product (e.g., domain knowledge). Also, scaffolding has been shown to produce positive effects on the transfer of knowledge and problem-solving skills, rather than mere knowledge retention (e.g., Mayer, 1983, Mayer, 2008).

PBL studies that used domain knowledge acquisition as one of their dependent measures have found that students who study in a PBL environment remember more content over a long period of time than students who study in a conventional (lecture and discussion) environment (Gallagher, 1997; Hmelo & Ferrari, 1997). Another study demonstrates that PBL students outperformed conventional students on the National Board of Medical Examiners (NBME) exam part II (Albanese & Mitchell, 1993) that is a multiple choice test of clinical knowledge taken at the end of the third year of medical school. However, conventional students had a better performance than PBL students in NBME exam part I (Albanese & Mitchell, 1993) that is a multiple choice test of clinical knowledge taken at the end of the second year. PBL students also outperformed

conventional students on authentic knowledge application tasks such as open-ended questions about a problem (Dochy, Segers, van den Bossche, & Gijbels, 2003), and on the task of understanding principles that link concepts (Gijbels, Dochy, Van den Bossche, & Segers, 2005). However, PBL students' performance did not significantly differ from conventional students' performance on either concept or application level (Gijbels et al., 2005).

PBL scholars also report that problems exist when measuring PBL effects on domain knowledge acquisition. For example, according to Belland, Glazewski, and Richardson (2011), a number of studies that determine the effects of PBL on academic performance (e.g., Finch, 1999; Dods, 1997) are lacking in terms of operationalizing and measuring the intended outcomes. For example, Dods (1997) and Finch (1999) conducted a study that employed multiple choice and essay questions to assess the effects of PBL on deep content learning. However, Finch's (1997) study lacks any information about how the questions were scored. Neither of the studies (Dods, 1997; Finch, 1999) explained the validity and reliability of data collection instruments. This is problematic because "any numerical score without this information is just a number" (Belland et al., 2011, p. 66). Therefore, readers do not know if the scoring method of questions was appropriate. Additionally, readers are not able to assess the accuracy of scores or statistical calculations, because there is no information on the reliability of scores.

### **The DEEPER Scaffolding Framework**

The scaffolding framework that is used in this study is DEEPER (Antonenko, Hudson, Townsend, & Pritchard, 2011). DEEPER scaffolding framework includes six

steps: Define, Explore, Explain, Present, Evaluate, and Reflect. In this scaffolding framework, students collaborate in teams of three or four to find a solution for a problem. In the first step (Define), students identify the specific problem, causes of the problem, effects of the problem, stakeholders, and what is known and what needs to be learned. In the second step (Explore), students identify the relevant resources and extract useful information about the problem and a potential solution and its rationales. In the third step (Explain), students propose the solution, the rationales, and the effect of the solution on stakeholders. In the fourth step (Present), students choose the effective presentation format to explain their solution to the stakeholders, and share aspects of their solution with them. In the fifth step (Evaluate), students evaluate the solution, the scientific evidence behind it, impacts on stakeholders, its viability on real life, and the process of problem solving. Finally in the sixth step (Reflect), they reflect on what was learned during the problem-solving process, the solution, and the process. Figure 1 demonstrates the DEEPER scaffolding framework steps.

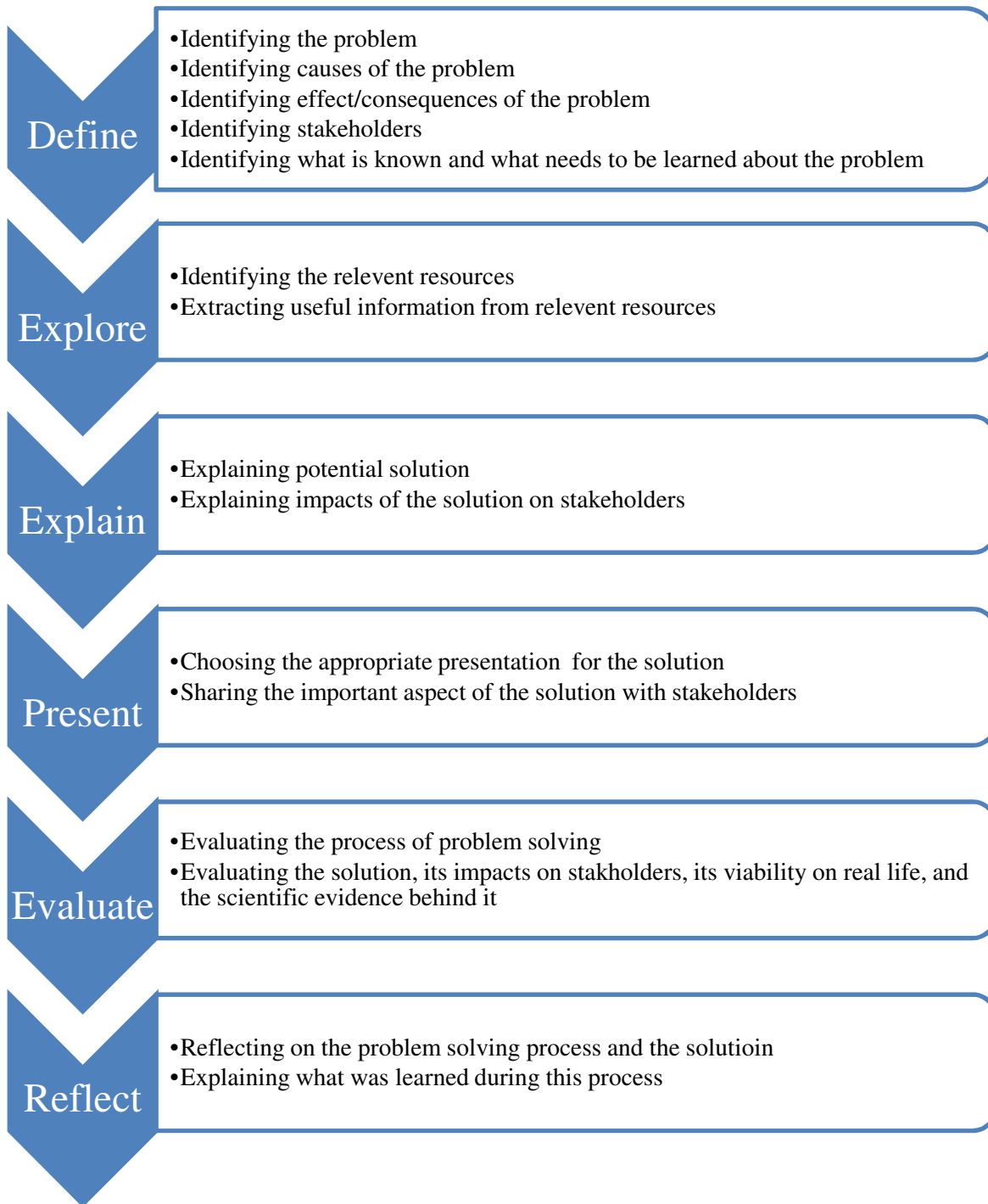


Figure 2. DEEPER framework for scaffolding problem solving.

The DEEPER scaffolding framework builds on the decades of conceptual and empirical PBL research and extends this research by providing a multi-step procedure for scaffolding problem solving that can be applied in very different settings – in higher education and K-12 education, in formal and informal learning, in various knowledge domains and using technology-enhanced (including web-based) and traditional paper-based formats.

In accordance with prior research reviewed in this chapter, the purpose of this study was to determine the effects of DEEPER scaffolding on three dependent variables: problem-solving performance, transfer of knowledge and domain knowledge acquisition. Specifically, this study was designed to address the following questions:

5. Research Question 1: What is the effect of the DEEPER scaffolding framework on participants' problem-solving performance?
6. Research Question 2: What is the effect of the DEEPER scaffolding framework on participants' domain knowledge acquisition?
7. Research Question 3: What is the effect of the DEEPER scaffolding framework on participants' transfer of knowledge?
8. Research Question 4: Is there a relationship between students' performance on individual DEEPER scaffolding tasks and a) problem-solving performance, b) domain knowledge acquisition, and c) transfer of knowledge

## **CHAPTER III**

### **METHODOLOGY**

#### **Introduction**

In this quasi-experimental study, the pretest-posttest control group design was used to collect data. The participants were randomly assigned into two groups – the treatment group and the control group. Each group consisted of teams of three to four students that engaged in collaborative problem solving during regular class times in an Introductory Entomology course. The two groups were asked to solve an ill-structured problem on the role of aquatic insects in the biological assessment of river water. The control and treatment groups differed in the nature of instructional scaffolding that they received during problem solving. The treatment group used the DEEPER scaffolding process (Antonenko, Hudson, Townsend, & Pritchard, 2011) and the control group was asked to solve the problem without the DEEPER scaffolding. The data was gathered to test if there were any differences between the groups on three dependent variables: domain knowledge, transfer of knowledge, and problem-solving performance.

#### **Participants**

The participant pool for this study consisted of 245 students who were enrolled in an



Introductory Entomology course in the Plant Pathology and Entomology Department at Oklahoma State University. Purposive sampling was the subject selection methodology in this study. In other words, only students enrolled in this class were invited to participate in this study. Students were given extra credit for their participation in the study. Based on the physical arrangement of the students in the lecture hall, the class was divided into two groups: the control group (sitting on the right side) and the treatment group (sitting on the left side) of the instructor. The instructor then assigned individual students into teams of three or four students who were sitting next to the each other.

One hundred and ninety-nine students chose to participate in this study. Ninety-three participants were male, 66 were female, and 40 participants did not answer this question in the demographic questionnaire. All participants were fluent in English and consisted of freshmen, sophomores, juniors, and seniors in non-science majors such as accounting, history, education, business, and political science.

## **Materials**

The problem that was used in this study was designed by the course instructor. It focused on the use of aquatic insects for biological assessment of river water. In this problem, people living close to a river noticed that the river water and shoreline habitat downstream of a sewage treatment plant appeared to be different than the habitat and water upstream of the sewage treatment plant (See Appendix G). The sewage treatment plant was located next to the river, discharging treated water directly into the river. Solutions to the problem would require the citizenry to provide evidence that the river was being polluted. The evidence they could provide included a water chemistry test, an

aquatic insect survey (i.e., biological assessment) with or without quantitative values, and potentially other solutions.

The information resources included five relevant resources (e.g., the Environmental Protection Agency's bioassessment protocols, a PowerPoint™ presentation on aquatic entomology) and three irrelevant resources (e.g., a webpage on the Arkansas River aquatic insects or a page on the insects used in fly fishing). Students had to review them and identify the relevant evidence that could help them solve the problem (See Appendix G) – part of the Explore step of the DEEPER scaffolding process.

DEEPER Problem-Solving Sheets were used to provide instructional scaffolding for the participants in the treatment group and contained six steps: Define Explore, Explain, Present, Evaluate, and Reflect (See Appendix H). This instrument was scored by the course instructor and two subject experts using a grading rubric (See Appendix K). The scores ranged from zero to four. In addition to the overall problem-solving performance score, each question in the DEEPER steps was scored on a scale from one to three. The best answer yielded three points, an acceptable answer yielded two points, and an unacceptable answer yielded one point.

Problem-Solving Rationale Sheet was used to scaffold the problem-solving process for the control group. The participants were to provide their solution to the problem as well as explain their rationale (See Appendix I).

## **Instrumentation**

For each participant, the paper-and-pencil materials consisted of two packets typed on 8.5 by 11 inch sheets of paper. The pre-test (the first packet) was distributed to students before solving the problem. It included an information sheet (See Appendix B), a demographic questionnaire (See Appendix C), a test of cognitive flexibility (See Appendix D, Martin & Rubin, 1995), motivated strategies learning test (See Appendix E, Pintrich, Smith, Garcia, & Mckeachie, 1993), and a test of domain knowledge (See Appendix F). The 10-item domain knowledge pre-test measured participants' domain-specific knowledge prior to engaging in the problem-solving process in this study. The test of prior knowledge was developed by the course instructor based on the relevant entomology concepts. The cognitive flexibility questionnaire was used to indicate "students' ability to switch cognitive sets to adapt to changing environmental stimuli" (Dennis & Vander, 2010, p. 242). The motivated learning strategies questionnaire was used to assess participants' motivational orientations and how they use different learning strategies. These tests together with the domain knowledge test were used to measure participants' cognitive and metacognitive skills as well as prior knowledge in the domain to determine if the groups were homogeneous relative to these important learner variables. Students had 30 minutes to answer the questions.

The second packet that was handed out in the following session, included a problem sheet (See Appendix G), DEEPER problem-solving sheets for the treatment group (See Appendix H) and a two-question problem-solving rationale sheet for the control group (See Appendix I), the domain knowledge post-test (See Appendix F), and test of knowledge transfer. The DEEPER problem-solving sheets included six steps (each

step on a separate page). Participants in the treatment group were to go through all steps to define the problem, analyze information resources, propose their solution, evaluate it and reflect on it. The domain knowledge post-test was the same instrument as the domain knowledge pre-test. It was used to reveal differences in domain knowledge acquisition between the control and treatment groups. The transfer of knowledge test (See Appendix J) was distributed to the participants to measure their ability to apply the content knowledge they learned as part of the problem solving to problems in novel contexts. This test was developed by the course instructor and the teaching assistants and approved by the Oklahoma State University Institutional Review Board (See Appendix A). Participants had 75 minutes to solve the problem and complete the post-test instruments.

**Pre-test.** Information Sheet was used to inform students about the purpose of this research study. The students who chose to participate in the study received 10 extra credits (See Appendix B). The rest of the students could complete an alternative learning activity to receive the extra credit.

Demographic Questionnaire was developed by the investigator to collect information about the demographic makeup of the study's sample. It included questions about participants' gender, age, year in college, and grade point average (See Appendix C).

Cognitive Flexibility Questionnaire contained 12 questions to indicate students' cognitive ability to adapt to changing environmental stimuli. The instrument included such questions as "I am willing to listen and consider alternatives for handling a problem". The questionnaire used a 5-point Likert scale: very true, mostly true,

moderately true, slightly true, or not true (See Appendix D). This instrument was scored by the investigator using the following grading scheme: 1 – not true, 2 – slightly true, 3 – moderately true, 4 – mostly true, and 5 – very true. Cronbach’s alpha for the Cognitive Flexibility Questionnaire with a population of college students was estimated at .81, indicating adequate internal consistency (Martin & Anderson, 1998).

Motivated Strategies Learning Questionnaire (MSLQ) contained 82 questions for assessing participants’ motivational orientations and how they use different learning strategies in their courses. The instrument contained such questions as “When I study, I practice saying the material to myself over and over”. Students had to choose their responses from a 7-point scale where 1 was “not at all true of me” to 7 – “very true of me” (See Appendix E). Cronbach’s alpha was used to estimate the internal consistency for all MSLQ subscales. Alphas ranged from .52 for the help seeking scale to .93 for the self-efficacy scale. The developers of the MSLQ claim that the alpha coefficients for this instrument scales are robust and demonstrate good internal consistency (Pintrich, Smith, Garcia, & Mckeachie, 1993).

Domain Knowledge Test consisted of 10 multiple-choice questions to assess participants’ prior knowledge about aquatic insects and bioassessment. The instrument was scored using a guide provided by the course instructor. Each correct answer yielded one point for a total of 10 points (See Appendix F).

**Post-test.** Problem-Solving Performance Rubric (See Appendix K) was the measure of problem-solving performance in this study (Research Question 1). This rubric was used to score the treatment group’s responses recorded in the DEEPER Problem-

Solving Sheets and the control group's responses recorded in the Problem-Solving Rationale Sheet. The rubric consisted of two performance categories: proposed solution and rationale; and four levels of performance for a minimum score of one and a maximum score of four per category. The rubric was adapted from the Association of American Colleges and Universities Problem Solving Value Rubric (Association of American Colleges and Universities, 2012).

Domain Knowledge Test served as the measure of domain knowledge acquisition (Research Question 2). It included the same questions as the domain knowledge pre-test. The instrument was scored using a guide provided by the course instructor. Each correct answer yielded one point for a total of 10 points (See Appendix F).

Transfer of Knowledge Test was the measure of participants' ability to transfer knowledge upon completing the problem-solving activity (Research Question 3). This instrument included 10 multiple-choice questions to measure participants' ability to apply the content knowledge they learned as part of the problem solving to problems in novel contexts. This test was developed by the course instructor and the teaching assistants (See Appendix J).

## **Procedure**

The pre-test packet was distributed to all students enrolled in the course during a regular class period. The students who chose to participate in the study had 30 minutes to answer the pre-test questions. The pre-test packets were collected by the instructor who then aligned names with the corresponding identification numbers in a spreadsheet and shared the data with the primary investigator.

In the following session, participants in both the treatment and the control group engaged in the problem-solving process. Participants in the control group were asked to propose their solution and explain the rationale using the Problem-Solving Rationale Sheet (See Appendix I). Participants in the treatment group were asked to solve the problem using the DEEPER Problem-Solving Sheets (See Appendix H). Each step of DEEPER procedure was presented on a separate page and the sheets were distributed to the students by the instructor. Students had 75 minutes to solve the problem.

All participants completed the post-test measures in the session following the problem-solving session. The process for collecting student responses and sharing the data with the primary investigator was similar to that described in the pre-test section. All data was recorded in a spreadsheet that included participant identification numbers, group assignment (i.e., treatment or control), team assignment within the group, and results of the demographic questionnaire, cognitive flexibility test, motivated strategies learning questionnaire, domain knowledge pre-test, problem-solving performance scores, transfer of knowledge test, and domain knowledge post-test.

### **Data Analysis**

All numerical data were entered from spreadsheets into a PASW™ statistical software data file. Because parametric statistical tests can only be conducted if the data meets the required assumptions, assumptions tests were conducted to examine the data's normality, homogeneity of variance and other relevant aspects. Since the normality assumption was not met for most of the data sets (Kolmogorov-Smirnov test, Smirnov, 1948), nonparametric methods such as the Mann-Whitney test (Mann & Whitney, 1947),

Wilcoxon Signed Rank test (Wilcoxon, 1945), and Kendall's *tau-b* test (Kendall, 1938) were used to analyze data. According to Rosenthal (1991), the effect size was calculated by  $r = \frac{z}{\sqrt{N}}$  for the Mann-Whitney and Wilcoxon Signed Rank tests. Specifically, Mann-Whitney test was used for determining differences in cognitive flexibility, problem solving, domain knowledge pre-test, domain knowledge post-test, and transfer performance between the treatment and control groups because the normality assumption was not met for the data. An independent samples T-test was used to determine differences in motivated strategies learning performance between the treatment and control groups because the data was normally distributed. Wilcoxon Signed Rank test was used to determine differences in domain knowledge acquisition between the treatment and control groups because the assumptions for a paired sample t-test were not met. An analysis of covariance was used to analyze the differences on domain knowledge posttest performance with the domain knowledge pretest as a covariate (because the control group scored significantly higher on the domain knowledge pre-test than the treatment group). Finally, a battery of Kendall's *tau-b* correlation analyses was run to examine the relationships between the individual tasks within the DEEPER steps and knowledge transfer, domain knowledge post-test, and problem solving performance. Kendall's *tau-b* was selected over Spearman's *rho* because it is described as a better estimate of the correlation in the population (Howell, 1997).



## CHAPTER IV

### FINDINGS

#### **Participant Demographics**

One hundred and nine students enrolled in the Introductory Entomology course completed the pre-test measures, engaged in the problem-solving activity, and completed the post-test measures. Sixty-three participants were male (58%), and 46 participants were female (42%). There were 29 freshmen (27%), 35 sophomores (32%), 25 juniors (23%), and 20 seniors (18%). Sixty-five participants were between 18 and 20 years old (60%), 40 participants were 21 to 23 years old (36%), and 4 participants were between 24 and 26 years old (4%). Thirty-three participants had a grade point average of 3.5 to 4.0 (30%), 48 participants – 3.0 to 3.49 (44%), 23 participants – 2.5 to 2.99 (21%), and five participants – 2.0 to 2.49 (4%). There were 61 students in the treatment group and 48 students in the control group. Table 1 provides an overview and comparison of demographic variables for the treatment and control group.

Table 1

*Participant Demographics*

Demographic Information		Number of Participants		
		Treatment Group	Control Group	Total
Gender	Male	29	34	63
	Female	32	14	46
Age	18-20	35	30	65
	21-23	24	16	40
	24-26	2	2	4
Classification	Freshman	18	11	29
	Sophomore	15	20	35
	Junior	13	12	25
	Senior	15	5	20
GPA	3.5-4.0	21	12	33
	3.0-3.49	28	20	48
	2.5-2.99	10	13	23
	2.0-2.49	2	3	5
Total Number of participants		61	48	109

**Statistical Test Assumptions**

**Normality.** Before conducting any statistical analyses, each data set was checked for the normality of distribution of dependent variable means using Kolmogorov-Smirnov tests, Q-Q plots, and histograms. As Table 2 demonstrates, the normality assumption was not met for any data set except Motivated Strategies Learning.

Table 2

*Normality Test Results (Kolmogorov-Smirnov)*

Data Set	Control Group			Treatment Group		
	Mean	Std. Deviation	Kolmogorov Test	Mean	Std. Deviation	Kolmogorov Test
	Statistic	Statistic	Sig.	Statistic	Statistic	Sig.
Cognitive Flexibility	46.6	7.914	.001	46.11	7.38	.0001
Motivated Strategies Learning	353.54	60.107	.2	361.9	53.653	.2
Domain Knowledge Pre-test	6.69	1.703	.002	6.2	1.399	.005
Problem Solving	1.96	.874	.0001	2.62	.553	.0001
Domain Knowledge Post-test	7.42	1.796	.0001	6.79	1.582	.0001
Transfer Test	5.5	1.891	.0001	5.43	1.97	.002

**Homogeneity of variance.** Homogeneity of variance is another assumption that has to be met to conduct most parametric statistical tests. This assumption was checked using Levene's test for all data sets. This test checks if the spread of scores is roughly equal in the groups. Table 3 demonstrates the Levene's test results for all data sets. Homogeneity of variance could be assumed for all data sets, except the domain knowledge post-test.

Table 3

*Homogeneity of Variance Test Results (Levene's)*

Data Set	Levene's Statistics Result
Cognitive Flexibility	F(1,107)=.029, <i>ns</i>
Motivated Strategies Learning	F(1,107)=.199, <i>ns</i>
Domain Knowledge Pre-Test	F(1,105)=2.429, <i>ns</i>
Problem Solving	F(1,107)=.007, <i>ns</i>
Domain Knowledge Post-Test	F(1,107)=16.512, <i>sig</i>
Transfer	F(1,106)=.067, <i>ns</i>

### **Similarities and Differences Between the Treatment and Control Groups on Pre-Test Measures**

**Cognitive flexibility performance.** Because the normality assumption for T-test was not met, differences in cognitive flexibility performance between treatment and control groups were determined using the non-parametric equivalent of the independent samples t-test – the Mann-Whitney test. Cognitive flexibility performance of the treatment group ( $\bar{X}_T = 46.6$ ,  $SD_T = 7.91$ ,  $MDN_T = 48$ ) was not significantly different from that of the control group ( $\bar{X}_C = 46.11$ ,  $SD_C = 7.38$ ,  $MDN_C = 47$ ) with  $U = 1370.5$ ,  $z = -.57$ ,  $p = .57$ . This provides evidence that the two groups were homogenous relative to their ability to exercise cognitive flexibility and that this variable could not affect further data analysis.

**Motivated learning strategies performance.** Differences in motivated learning strategies performance between the treatment and control groups were determined using an independent samples T-test, because the statistical assumptions for the t-test were met. Motivated learning strategies performance of the treatment group ( $\bar{X}_T = 353.54$ ,  $SD_T = 60.11$ ,  $MDN_T = 347.5$ ) was not significantly different from the control group ( $\bar{X}_C = 361.9$ ,  $SD_C = 53.653$ ,  $MDN_C = 385$ ) with  $F_{107} = .2$ ,  $p = .66$ . This provides evidence that the two groups were homogenous relative to their use of motivated learning strategies and that this variable could not affect further data analysis.

**Domain knowledge pre-test.** Differences in the domain knowledge between the treatment and control groups were determined using the Mann-Whitney test, because the normality assumption for the t-test was not met. Domain knowledge pre-test performance of the treatment group ( $\bar{X}_T = 6.2$ ,  $SD_T = 1.7$ ,  $MDN_T = 7.0$ ) was significantly lower than that of the control group ( $\bar{X}_C = 6.7$ ,  $SD_C = 1.7$ ,  $MDN_C = 7.0$ ) with  $U = 1.134E3$ ,  $z = -1.81$ ,  $p = .04$ . The effect size was low at  $r = -.17$ . This finding demonstrates that despite the low effect size, participants in the control group had a significantly higher level of prior knowledge in the domain than the treatment group, which necessitates the use of prior knowledge as a covariate in the subsequent analyses of domain knowledge acquisition.

## Research Questions

**Research question 1: what is the effect of the DEEPER scaffolding framework on participants' problem-solving performance?** Differences in problem-solving performance between the treatment and control groups were determined using the

Mann-Whitney test, because the normality assumption for the t-test was not met. Problem-solving performance of the treatment group ( $\bar{X}_T = 2.62$ ,  $SD_T = .55$ ,  $MDN_T = 3.0$ ) was significantly higher than that of the control group ( $\bar{X}_C = 1.96$ ,  $SD_C = .88$ ,  $MDN_C = 2.0$ ) with  $U = 864$ ,  $z = -3.97$ ,  $p < .0001$ . The effect size was medium at  $r = -.38$ .

**Research question 2: what is the effect of the DEEPER scaffolding framework on participants' domain knowledge acquisition?** Differences in domain knowledge acquisition for treatment and control groups were determined using the Wilcoxon Signed Rank test (the non-parametric equivalent of the paired samples t-test), because the normality assumption for the paired sample t-test was not met. Domain knowledge of the participants in the treatment group increased from  $\bar{X}_T = 6.2$  (pretest) to  $\bar{X}_T = 6.76$  (posttest). This increase was statistically significant ( $z = -2.61$ ,  $p < .009$ ). The effect size was medium at  $r = -.34$ . For the control group domain knowledge increased from  $\bar{X}_C = 6.69$  (pretest) to  $\bar{X}_C = 7.42$  (posttest). This increase was statistically significant ( $z = -2.99$ ,  $p < .003$ ). The effect size was medium at  $r = -.43$ . This finding indicates that both groups acquired statistically significant levels of domain knowledge as a result of the problem-solving activity.

Because the treatment and the control group differed on the domain knowledge variable during the pre-test ( $\bar{X}_T = 6.2$  and  $\bar{X}_C = 6.69$ ), an ANCOVA test was conducted to determine the differences in domain knowledge acquisition between the two groups after the variance associated with the domain knowledge pre-test variable was removed. This resulted in two important findings. First, the covariate (i.e., domain knowledge pre-test) significantly predicted the dependent variable (i.e., posttest,  $p < .0001$ ). Second,

when the variance associated with the covariate was removed, the differences on the domain knowledge post-test between treatment and control groups were not significant ( $p=.2$ ). These findings indicate that the DEEPER scaffolding framework had no effect on domain knowledge acquisition compared to the scaffolding materials used with the control group.

**Research question 3: what is the effect of the DEEPER scaffolding framework on participants' transfer of knowledge?** Differences in the transfer of knowledge between the treatment and control groups were determined using the Mann-Whitney test, because the normality assumption for the independent samples t-test was not met. Transfer performance of the treatment group ( $\bar{X}_T = 5.50$ ,  $SD_T = 1.89$ ,  $MDN_T = 5.0$ ) was not significantly different from that of the control group ( $\bar{X}_C = 5.43$ ,  $SD_C = 1.97$ ,  $MDN_C = 6.0$ ) with  $U = 1420$ ,  $z = -.269$ ,  $p = .788$ .

**Research question 4: is there a relationship between students' performance on individual DEEPER scaffolding tasks and a) problem-solving performance, b) domain knowledge acquisition, and c) transfer of knowledge?**

Analysis of student scores on individual DEEPER tasks demonstrated that the DEEPER framework consists of tasks with a high degree of internal consistency (Chronbach's  $\alpha = .72$ ). However, because the normality assumption for most of the dependent variable data sets was not met, Kendall's *tau-b* (Kendall, 1938) correlation coefficients were computed to determine relationships between individual DEEPER tasks (See Appendix H) and problem-solving performance, domain knowledge acquisition, and transfer of knowledge. The magnitude of relationship is generally described as weak

when the correlation coefficient is between 0 and .3), moderate with the correlation coefficient of .3 to .7, and strong for values of .7 and above. The following section describes the significant relationships that were found.

*Problem-solving performance and the Define step.* Within the Define step, problem-solving performance had a significant positive relationship with a) the task of identifying the main issue ( $\tau = .61, p < .0001$ ), b) the task of identifying the stakeholders ( $\tau = .28, p = .019$ ), and c) with the sum of all Define tasks ( $\tau = .33, p = .003$ ).

*Problem-solving performance and the Explore step.* Within the Explore step, problem-solving performance had a significant positive relationship with a) the task of identifying relevant resources ( $\tau = .36, p = .004$ ), b) the two tasks related to extracting useful information from relevant resources ( $\tau = .57, p < .0001$ ), and c) with the sum of all Explore tasks ( $\tau = .51, p < .0001$ ).

*Problem-solving performance and the Explain step.* Within the Explain step, problem-solving performance had a significant positive relationship with a) the task of explaining the solution ( $\tau = .67, p < .0001$ ), b) the task of explaining the impacts of the proposed solution on stakeholders ( $\tau = .66, p < .0001$ ), and c) with the sum of all Explain tasks ( $\tau = .72, p < .0001$ ).

*Problem-solving performance and the Present step.* Problem-solving performance had a significant positive relationship with the task of choosing appropriate information and format for the presentation of the solution to stakeholders ( $\tau = .54, p < .0001$ ).

*Problem-solving performance and the Evaluate step.* Problem-solving performance had a significant positive relationship with the task of evaluating the



proposed solution, its impacts on the stakeholders, its viability in real life, and the scientific evidence behind it ( $\tau = .76, p < .0001$ ).

*Problem-solving performance and the Reflect step.* Problem-solving performance had a significant positive relationship with the task of reflecting on the experience of solving the problem, the most challenging aspects of this activity, and what was learned ( $\tau = .47, p < .0001$ ).

*Problem-solving performance and the sum of all the DEEPER tasks.* Problem-solving performance had a significant positive relationship with the sum of all DEEPER tasks that the participants had to complete as part of the problem-solving activity ( $\tau = .67, p < .0001$ ).

*Transfer performance and the Define step.* Unlike problem-solving performance, transfer of knowledge had a significant positive relationship with only one task within the Define step of the DEEPER framework: identifying what needs to be learned ( $\tau = .34, p = .002$ ).

*Transfer performance and the Explain step.* Transfer of knowledge also had a significant positive relationship with only one task within the Explain step of the DEEPER framework: explaining the solution ( $\tau = .24, p = .03$ ).

As evident from the results reported above, the dependent variable of problem-solving performance had the highest number and magnitude of positive relationships with individual DEEPER scaffolding tasks. Weaker positive relationships were also found with the transfer of knowledge variable and the tasks of identifying knowledge gaps and explaining the solution. Table 4 provides a summary of these findings.

Tabel 4

*Correlational Test Results (Kendall's tau-b) for DEEPER Tasks and the Three**Dependent Variables*

DEEPER Steps and Tasks	Problem-Solving Performance	Domain Knowledge Acquisition	Transfer of Knowledge
<b>Step 1: Define</b>			
Identifying the main issue	$\tau = .61, p < .0001$		
Identifying the stakeholders	$\tau = .28, p = .019$		
Identifying what was known and what needs to be learned			$\tau = .34, p = .002$
<b>Step 2: Explore</b>			
Identifying relevant resources	$\tau = .36, p = .004$		
Extracting useful information from relevant resources	$\tau = .57, p < .0001$		
<b>Step 3: Explain</b>			
Explaining the solution	$\tau = .67, p < .0001$		$\tau = .24, p = .03$
Explaining the proposed solution's impacts on stakeholders	$\tau = .66, p < .0001$		
<b>Step 4: Present</b>			
Choosing appropriate information and format for the presentation	$\tau = .54, p < .0001$		
<b>Step 5: Evaluate</b>			
Evaluating the proposed solution, its impacts on the stakeholders, its viability in real life, and the scientific evidence behind it	$\tau = .76, p < .0001$		
<b>Step 6: Reflect</b>			
Reflecting on the experience of solving the problem, the most challenging aspects of this activity, and what was learned	$\tau = .47, p < .0001$		

## **Other Findings**

Correlation analyses were also conducted to determine potential relationships between the three dependent variables in this study (i.e., problem-solving performance, domain knowledge acquisition, and transfer of knowledge) and participant demographics. A weak positive relationship was found between transfer of knowledge and age ( $\tau = .29$ ,  $p < .0001$ ) as well as transfer of knowledge and year in college ( $\tau = .24$ ,  $p < .001$ ).

## **CHAPTER V**

### **CONCLUSION**

#### **Discussion**

The data and the findings generated as part of this study provide a rich body of evidence to describe explain and predict the instructional usefulness of problem-based learning (PBL) activities in the classroom. The DEEPER scaffolding framework was shown to produce positive effects on students' problem-solving performance and their transfer of knowledge. Furthermore, most of the individual scaffolding tasks within the DEEPER framework had a strong positive relationship with problem-solving performance and several of these tasks had a moderate positive relationship with transfer of knowledge.

#### **DEEPER Scaffolding and Problem-Solving Performance**

Analysis of the differences between the treatment and the control group on the problem-solving performance rubric revealed that the group that used the DEEPER scaffolding framework to solve the problem had a problem-solving performance that was significantly higher than that of the group exposed to non-DEEPER scaffolding. Examination of the means for the two groups demonstrates that the problem-solving activity was challenging to both groups: the treatment group had a mean of 2.62 and the control group – 1.96 on a four-point scale. This result is consistent with the findings of

most empirical studies on PBL. Students generally find problem-solving activities more difficult and feel less prepared to engage in PBL compared to more well-defined and well-structured learning activities. Results of multiple prior studies demonstrate that students experience challenges in meeting the demands of PBL (Evensen, 2000; Evensen, Salisbury-Glennon, & Glenn, 2001). For example, Henry and colleagues report that the main complaint of their participants was little structure and they repeatedly requested additional support. These authors chose to augment their project with several lectures that were designed to provide the additional scaffolding that the students needed (Hmelo-Silver, 2012).

Additionally, analysis of the standard deviations for the problem-solving performance scores shows that there was more consistency among the problem-solving performance scores within the treatment group ( $SD_T = .55$ ) than the control group ( $SD_C = .88$ ). Coupled with the main result of significantly higher problem-solving scores for the treatment group, this finding indicates that the DEEPER scaffolding framework was more effective than the rationale-based scaffolding used with the control group.

Another important finding relative to the students' problem-solving performance is that many of the individual tasks within each step of the DEEPER framework (See Appendix H) had a positive relationship with problem-solving performance. Each problem-solving step within the DEEPER scaffolding framework consists of several subtasks. For example, the Define step consists of the following tasks: recalling situations similar to the ones described in the description of the main issue, stating the problem, identifying causes and effects of the problem, describing the parties affected by the problem (i.e., stakeholders), and reflecting on what is known about the problem and what

needs to be learned. The results of this study show that at least one task within each step of the DEEPER scaffolding framework was correlated with students' ability to solve problems, as measured by the problem-solving performance rubric.

During the Define step, the task of identifying the main issue, the task of identifying the stakeholders, and the sum of all Define tasks had a positive relationship with problem-solving performance. The importance of engaging in problem identification and articulation cannot be overstated. According to a recent review of PBL scaffolding studies (Kim & Hannafin, 2011), problem identification requires participants to observe and analyze phenomena (Linn, Clark, & Slotta, 2003), estimate the possible causes, relate the main issue to their life experiences, prepare to engage students in the problem-solving activity, and share relevant experiences with others in order to first articulate and then solve the problem. In real life and in workplace problem solving, people employ inductive, deductive, and causal reasoning skills to identify problems that warrant exploration, while taking into account a host of variables such as the causes of the problem and its potential effects on the stakeholders (Dunbar, 2007). And while skilled problem solvers have most of these skills automated, novices must be provided with explicit scaffolds to engage in the important cognitive and metacognitive processes to identify problems that require further investigation.

The tasks that had a significant positive relationship with problem-solving performance in the Explore step include the task of identifying relevant relationships, the two tasks related to extracting useful evidence from relevant resources, and the sum of all Explore tasks. During this step of problem solving, learners must analyze the available information resources while also maintaining their learning goals in order to pursue their

solutions (Antonenko et al., 2011). Exploration is a critical problem-solving process because it allows learners to analyze the existing perspectives on the problem, locate evidence that is helpful in terms of developing arguments for an appropriate solution, detect anomalies, and discard irrelevant information, claims, and evidence. The DEEPER scaffolding framework assists students in exploratory activities by requiring students to mark each information resource as relevant or irrelevant, locate potentially useful evidence in each of the resources, reflect on the claims and evidence gathered during resource exploration, and discuss the relevance of these claims and evidence relative to the context of the problem that was defined by the team.

During the Explain step, participants internalize the knowledge with linking the claims and evidence that they identified during the Explore step. The Explain tasks that were found to have a positive relationship with problem-solving performance are explaining the proposed solution(s), explaining the impacts of the proposed solution on the stakeholders, and the sum of all Explain steps. It is important to note that the magnitude of the relationship between students' problem-solving performance and each of these tasks was rather strong (between  $\tau = .66$  and  $\tau = .72$ ). Much research has been done on the importance of problem reconstruction (Kim & Hannafin, 2011) and self-explanations in PBL and scholars agree that the scaffolding that allows students to connect existing knowledge to novel experience via analysis of existing evidence and reconstruction of their schemata is fundamental to meaningful learning (Mayer, 1984). The DEEPER framework scaffolds these important problem-solving processes by providing students with a template to develop evidence-based arguments (e.g., One possible solution is to ..... (your claim goes here) ..... because ..... (list relevant

evidence here)), requiring students to analyze the impact of each potential solution on the stakeholders. The fact that a strong positive relationship was found between these tasks and students' problem-solving performance indicates that the DEEPER framework provides useful problem reconstruction and explanation scaffolds for developing stronger problem-solving skills.

The Present tasks in the DEEPER scaffolding framework asked student participants to discuss with team members and select an appropriate presentation format and useful, most pertinent information to be included in the final presentation of the solution to the stakeholders. Presentation and communication of findings requires the students to visualize and verbalize their solutions and explanations, develop strategies and employ the tools that best meet the needs of the parties most interested in the solution – the stakeholders. Analysis of stakeholder perspectives scaffolded through the DEEPER framework allows students to practice once again justifying their ideas relative to the diverse views of and impacts on the stakeholders. Koschmann, Myers, Feltovich, and Barrows (1994) described the instructional benefits of such activities through the principle of multiplicity – the idea that instruction should reflect knowledge as “complex, dynamic, context-sensitive, and interactively related.”

After completing the Present step, participants had to evaluate their proposed solution, its impact on stakeholders, its viability in real life, and the scientific evidence behind it. The tasks involved in this problem-solving step of the DEEPER framework resulted in the strongest positive relationship between problem-solving activities and problem-solving performance ( $\tau = .76, p < .0001$ ). This finding underscores the importance of the metacognitive activity of solution evaluation in the development of



problem-solving skills. Along with planning and monitoring, evaluation is one of the three core metacognitive processes (Flavell, 1987) and this study contributes to the existing body of literature on the importance of scaffolding evaluative activities for students because they have a strong relationship with overall problem-solving performance.

The Reflect step of DEEPER problem solving asked students to reflect on their experience of solving this problem, describe the most challenging aspects of this activity, and reflect on what was learned (compared to the information the students provided about what is known and what needs to be learned in the Define step). The tasks within this final step of the problem-solving process resulted in a positive relationship with problem-solving performance as well. These tasks encouraged students to “connect all of the dots” and analyze their experiences and the value (or lack thereof) of this problem-solving activity relative to their learning in the course. Reflection activities are described as important in PBL literature because they require students to actively engage in the analysis of the entire problem-solving experience, which allows them to solidify their schemata of the problem and its solution for future use. Reflection activities can also potentially help improve transfer of knowledge and problem-solving skills. For example, Land and Zembal-Saul (2003) found that reflection and articulation scaffolds in the context of learning physics helped participants to frame their questions and explanations.

Finally, problem-solving performance was also significantly correlated with the sum of all DEEPER problem-solving tasks. This strong positive relationship indicates that as a whole the DEEPER scaffolding framework is a useful tool for supporting development of students’ problem-solving skills. Less directly, this result also serves to

validate the construct validity of the rubric that was used to measure problem-solving performance in this study.

### **DEEPER Scaffolding and Domain Knowledge Acquisition**

Analysis of the pre-test measures collected in this study indicates that the prior domain knowledge of the control group was higher than that of the treatment group. Comparison of the domain knowledge scores for the pre-test and the post-test indicated that both groups exhibited statistically significant learning gains a progress during the problem-solving activity. This demonstrates that in terms of domain knowledge acquisition both groups benefited from engaging in the problem-solving activity. Once the variance associated with prior domain knowledge was accounted for, the results on the domain knowledge test were not statistically different. This finding signifies that although the problem-solving activity was useful for the groups, use of the DEEPER scaffolding framework did not improve acquisition of the domain knowledge.

This result is not surprising when one considers the instructional design of the DEEPER scaffolding framework (See Appendix H). The DEEPER steps and individual tasks are designed to assist students in the development of process skills rather than acquisition of knowledge in any specific domain. As a process scaffold, the DEEPER framework turned out to be effective because, as described earlier, the treatment group demonstrated higher scores on the measure problem-solving performance and most of the individual tasks had a positive relationship with students' problem-solving performance scores.

Another explanation for this finding can be provided by reviewing prior research on PBL relative to the products (students' responses on the tests) versus processes (problem identification, resource discrimination and others). For example, Mayer (2008) reviewed a number of studies conducted on PBL beginning as early as the 1940's and 1950's (e.g., Bloom & Broder, 1950; Polya, 1945) and concluded that problem-solving activities in the classrooms influence students' problem-solving *skills* and, thus, such activities should focus on modeling and scaffolding of the problem-solving *process* rather than development of the *product* (e.g., domain knowledge). Also, scaffolds like the ones used in this study have been shown to produce an effect on the transfer of knowledge and skills, rather than knowledge retention (e.g., Mayer, 1983, Mayer, 2008).

### **DEEPER Scaffolding and Transfer of Knowledge**

Transfer has been described as the ultimate goal of education. Researchers also note that transfer is notoriously difficult to achieve (Barnett & Ceci, 2002; Bransford, Brown, & Cocking, 2000). In this study, a test of the differences between group means on the transfer of knowledge revealed no significant differences between the treatment and control group relative to knowledge. This finding may be explained by the limitations of this study. First, participants engaged only in one scaffolded problem-solving activity. Second, participants spent only two class periods on the problem-solving activity and the tests associated with it. Thus, it appears that the magnitude of the potential influence on the transfer of knowledge could have potentially been larger if a) the participants had engaged in more scaffolded problem-solving activities, and b) the participants had been engaged in scaffolded problem solving over a longer period of time.

While no significant differences were found between group means on the test of knowledge transfer, results of correlational analyses on the potential relationships between individual DEEPER scaffolding tasks and transfer of knowledge demonstrated a positive relationship between transfer test results and one of the Define tasks: identifying what is known and what needs to be learned. Evidently, engaging in the evaluative-reflective activities on the current understanding of the problem and on the existing knowledge gaps enabled students to perform better on the test of knowledge transfer. This reflection scaffolded through the DEEPER framework's Define step seems to have assisted students in encoding stronger connections and between what they already knew and what they had to learn to be successful in this learning activity, which, in its turn, allowed them to develop a deeper understanding of the problem (Barnett & Ceci, 2002) and resulted in a positive relationship with the results of the knowledge transfer test.

The other task that had a positive relationship with transfer of knowledge was explanation of the solution. Instructions for this task asked students to use the evidence they collected during the Explore step and develop solution proposals using a proposal template that explicitly linked students' claim(s) with scientific evidence located in information resources. This finding indicates that in the context of near transfer (the problems in the transfer test were designed to be relatively close to the context of the original problem and the test was administered four days after the problem-solving activity), students may have adopted the approach to developing evidence-based arguments used in the DEEPER scaffolding and possibly applied the argument construction template provided in the scaffold.

Finally, a positive relationship was also found between transfer of knowledge and participant age and year in college. This finding points to what is considered by many common knowledge: as people gain more experience, they develop the ability to apply their knowledge and skills in more diverse contexts (Barnett & Ceci, 2002).

### **Implications for Further Research**

The results of this study suggest several implications for future research. It appears that the DEEPER framework for scaffolding problem-based learning was beneficial relative to influencing the problem-solving performance of novice learners in an introductory entomology course for undergraduate non-science majors. Because the present study used DEEPER scaffolding only in one problem-solving activity that lasted only 75 minutes, it may be useful to replicate this study using a time-series control-group research design with three or more problem-solving activities in a semester or implementing the DEEPER framework to help students solve a more complex problem that spans several days or weeks. These designs would result in a more prolonged exposure to the DEEPER method of problem solving and an enhanced magnitude of effect, which may influence transfer of knowledge and problem-solving skills.

As far as transfer of knowledge and skills is concerned, many educational researchers note that developing valid measures of “deep learning” and transfer is a daunting task. Thus, one of the reasons why no significant differences in the transfer of knowledge were observed in the present study was the items (i.e., problems) that were used in the knowledge transfer test did not necessarily align with the knowledge and skills that were practiced by students as part of solving the original problem. The

challenge of understanding transfer of knowledge and skills and the challenge of designing valid transfer instruments should be addressed by conducting more conceptual research on the transfer of learning and applying this research in a variety of content areas.

Another implication stemming from this study has to do with implementing the DEEPER scaffolding framework in technology-enhanced learning environments (e.g., Kim & Hannafin, 2010). The integration of DEEPER problem-solving steps and the tasks involved in each step will likely increase not only the practical aspects of research (e.g., collection of digital “trace” data and ability to analyze of web server log data, Antonenko, Toy, and Niederhauser, 2012) but will also make student research and student problem-solving more seamless. For example, the students would not have to switch back and forth between paper-based DEEPER scaffolding materials and web-based or multimedia information resources provided by the instructor.

Correlational analyses conducted as part of this study also demonstrated that a number of tasks within each step of the DEEPER framework had moderate to strong positive relationships with problem-solving performance and two of such tasks had moderate positive relationships with transfer of knowledge. While overall these results are encouraging, they provide limited information and insight on what exactly the participants were doing, for example, during the task of identifying what is known and what needs to be learned and why this process resulted in a positive relationship with transfer of knowledge. Therefore, another implication of this study is the importance of collecting qualitative data (e.g., observations, video stimulated recall interviews). A more balanced mixed-method approach typically requires more time and effort and was beyond

the scope of the present study but it would greatly increase the amount and nature of useful data that could help explain and predict problem-solving processes with and without the DEEPER scaffolding framework.

Finally, the main implication for practice produced by the findings of this study is that the DEEPER framework for scaffolding problem solving can enhance the problem-solving performance of novice science learners and can thus be used to enhance the current instructional practices in science teaching and learning.

## **Conclusions**

Overall, the results of this study complement other findings in the literature on problem-based learning. Earlier studies supported the positive effects of multi-step problem-solving scaffolding procedures on learning in mathematics (Polya, 1957), chemistry (Bunce & Heikkinen, 1986), biology (Hurst and Milkent, 1996), physics (Heuvelen, 1991), medical education (Hmelo, 1998) and pre-service teacher education (Hmelo-Silver, Derry, Bitterman, & Hatrak, 2009). The problem-solving scaffolds like the ones used in this study typically affect development of problem-solving skills and transfer of knowledge skills rather than acquisition of domain knowledge and performance on knowledge retention tests (Mayer, 2008). Similar to these previous results, the findings of this study demonstrate that while the implementation of the DEEPER scaffolding of problem-solving resulted in improved problem-solving performance in the treatment group, differences were not observed on the measures of domain knowledge acquisition. Transfer of knowledge was not significantly impacted according to a test of the differences in group means, however correlational analyses

revealed a moderate to strong positive relationship between two of the DEEPER tasks and performance on the measure of knowledge transfer. Finally, most of the tasks embedded within each of the DEEPER scaffolding steps were positively correlated with students' problem-solving performance and the magnitude of these relationships was moderate to strong. Thus, it appears that the DEEPER framework for scaffolding problem solving provides a useful method for designing and structuring problem-solving activities for novice science learners at the higher education levels. Future studies are needed to determine the effects of DEEPER on transfer and problem-solving performance in other formal and informal education contexts.



## REFERENCES

- Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: a review of literature on its outcomes and implementation issues. *Academic medicine : journal of the Association of American Medical Colleges*, 68(1), 52-81.
- Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978). Educational psychology: a cognitive view. New York: Holt, Rinehart and Winston.
- Anderson, J. R., (1980). *Cognitive psychology and its implications*. New York: Freeman.
- Antonenko, P. D., Ogilvie, C. A., Niederhauser, D. S., Jackman, J., Kumsaikaew, P., Marathe, R. R., & Ryan, S. M. (2011). Understanding student pathways in context-rich problems. *Education and Information Technologies*, 16(4), 323-342. doi:10.1007/s10639-010-9132-x
- Antonenko, P.D., Hudson, G., Townsend, R., & Pritchard, J. (2011). DEEPER e-learning with environment for collaborative learning integrating problem solving experience (ECLIPSE).
- Antonenko, P., Toy, S., & Niederhauser, D. (2012). Using cluster analysis for data mining in educational technology research. *Educational Technology Research and Development*, 60(3), 383-398. doi: 10.1007/s11423-012-9235-8
- Association of American Colleges and Universities (2012). Problem solving VALUE

rubric. Retrieved from :

[Http://www.aacu.org/value/rubrics/index\\_p.cfm?CFID=39913777&CFTOKEN=23901582](http://www.aacu.org/value/rubrics/index_p.cfm?CFID=39913777&CFTOKEN=23901582)

Barab, S. A., Hay, K. E., Barnett, M., & Keating, T. (2000). Virtual solar system project: building understanding through model building. *Journal of Research in Science Teaching*, 37(7), 719-756.

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups, *Journal of the Learning Science*, 9(4), 403-436.

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn?: A taxonomy for far transfer. *Psychological Bulletin*. 128(4), 612-637. doi: 10.1037/0033-2909.128.4.612

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education*, 20(6), 481-486. doi: 10.1111/j.1365-2923.1986.tb01386.x

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning*, (68), 3-12. doi: 10.1002/tl.37219966804

Barrows, H. S., & Tamblyn, R. M. (1979). *Problem-based learning in health sciences education*. New York:Springer.

Belland, B. R., French, B. F., & Ertmer, P. A. (2009). Validity and Problem-Based Learning Research: A Review of Instruments Used to Assess Intended Learning

Outcomes. *Interdisciplinary Journal of Problem-based Learning*: 3( 1), Retrieved from : <http://docs.lib.purdue.edu/ijpbl/vol3/iss1/5>

Belland, B., Glazewski, K., & Richardson, J. (2011). Problem-based learning and argumentation: testing a scaffolding framework to support middle school students' creation of evidence-based arguments. *Instructional Science*, 39(5), 667-694. doi: 10.1007/s11251-010-9148-z

Bloom, B. S., & Broder, L. J. (1950). *Problem-solving process of college students*. Chicago: University of Chicago Press

Boud, D. (1987). Problem-based learning in education for the professions. 58.

Boud, D., & Feletti, G. (1998). *The challenge of problem-based learning (2<sup>nd</sup> ed.)*. London: Kogan Page.

Bowerman, B.L., & O'Connell, R. T. (1990). *Linear statistical models: An applied approach (2<sup>nd</sup> ed.)*. Belmont, CA: Duxbury

Bransford, J. D., & Stein, B.S. (1984). *The IDEAL problem solver: A guide for improving thinking, learning, and creativity*. New York: Freeman.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (1999). *How people learn: brain, mind, experience and school*. Washington : National Academy Press.

Bransford, J., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. Washington, D.C.: National Academy Press.

- Brown, A. L., Kane, M. J., & Long, C. (1989). Analogical transfer in young-children – analogies as tools for communication and exposition. *Applied Cognitive Psychology*, 3(4), 275-293.
- Bruner, J. S. (1954). *Learning and thinking*. Harvard Educational Review.
- Bruner, J. S. (1961). *The act of discovery*. Harvard Educational Review.
- Bunce, D. M., & Heikkinen, H. (1986). The effects of an explicit problem-solving approach on mathematical chemistry achievement. *Journal of Research in Science Teaching*, 23(1), 11-20. doi: 10.1002/tea.3660230102
- Cree, V., & Macaulay, C. (2000). *Transfer of learning in professional and vocational education*. Routledge.
- Cawley, P. (1989). The introduction of a problem-based option into a conventional engineering degree course. *Studies in Higher Education*, 14(1), 83-95. doi: 10.1080/03075078912331377632
- Coles, C. R. (1985). Differences between conventional and problem-based curricula in their students' approaches to studying. *Medical Education* 1985;19:308-309
- Dennis, J., & Vander W, J. (2010). The cognitive flexibility inventory: Instrument development and estimates of reliability and validity. *Cognitive Therapy and Research*, 34(3), 241-253. doi: 10.1007/s10608-009-9276-4
- Detterman, D. K. (1993). The case for the prosecution: Transfer as an epiphenomenon.
- Dewey, J. (1910). *How we think*. Boston: D.C. Heath & Co.
- Dewey, J. (1916). *Democracy and education*. New York: The Macmillan Company.

- Donaldson, R. (1989). *A good start in architecture*. University of Newcastle.
- Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction*, 13, 533-568.
- Dods, R. F. (1997). An action research study of the effectiveness of problem-based learning in promoting the acquisition and retention of knowledge. *Journal for the Education of the Gifted*, 20, 423-437.
- Duch, B. J., & Groh, S.E., & Alien, D. E. (2001). *The power of problem-based learning: a practical" how to" for teaching undergraduate courses in any discipline*. Virginia:Stylus
- Dufresne, R. J., Gerace, W. J., Hardiman, P. T., & Mestre, J., ( 1992). Constraining novices to perform expertlike problem analyses: effects on schema acquisition.  
doi: 10.1207/s15327809jls0203\_3
- Dunbar, K. (2007). How scientist think in the real world:implications for science education. *Journal of Applied Developmental Psychology*, 21(1), 49-58.
- Evensen, D. (2000). *Observing self-directed learners in a problem-based learning context: Two case studies*. Mahwah NJ: Erlbaum.
- Evensen, D. H., & Hmelo, C. E. (2000). *Problem-based learning: a research perspective on learning interactions*. Mahwah, N.J: L. Erlbaum Associates.
- Evensen, D. H., Salisbury-Glennon, J. D., & Glenn, J. (2001). A qualitative study of

- six medical students in a problem-based curriculum: Toward a situated model of self regulation. *Educational Psychology*, 2001, 93(4), 659– 676
- Field, A. P. (2009). *Discovering statistics using SPSS*: Los Angeles: SAGE Publications.
- Finch, P. M. (1999). The effect of problem-based learning on the academic performance of students studying podiatric medicine in Ontario. *Medical Education*, 33, 411-417.
- Flavell, J. H. (1987) *Speculation about the nature and development of metacognition*. Hillsdale, NJ: Lawrence Erlbaum.
- Gallagher, S. A. (1997). Problem-based learning: Where did it come from, what does it do, and where is it going? *Journal for the Education of the Gifted*, 20, 332-362.
- Garland, N. J. (1995). *Peer group support in economics: Innovations in problem-based learning*. Boston: Kluwer Academic Publishers.
- Gijbels, D., Dochy, F., Van den Bossche, & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research*, 75(1), 27-61.
- Greening, T. (1998). Scaffolding for Success in Problem-Based Learning. *Medical Education Online*, 3. doi:10.3402/meo.v3i.4297
- Hadwin, A. F., & Winne, P. H. (2001). CoNoteS2: A software tool for promoting self-

regulation. *Educational Research and Evaluation*, 7(2-3), 313-334.

doi:10.1076/edre.7.2.313.3868

Halloun, I., & Hestenes, D. (1987). Modeling instruction in mechanics. *American Journal of Physics*, 55(5), 455-462.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains. *The American Psychologist*, 53(4), 449.

Heuvelen, A. V. (1991). Overview, case study physics. *American Journal of Physics*, 59(10), 898. doi:10.1119/1.16668

Heycox, K., & Bolzan, N. (1991). *Applying problem-based learning in first-year social work*. In D. Boud & G. Feletti (Eds.), *The challenge of problem-based learning in work*. 186-193. New York: St. Martin's Press.

Higgins, L. (1994). Integrating background nursing experience and study at the postgraduate level: An application of problem based learning. *Higher Education Research & Development*, 13(1), 23-34. doi: 10.1080/0729436940130103

Hill, J. R., & Hannafin, M. J. (2001). Teaching and learning in digital environments: The resurgence of resource-based learning. *Educational Technology Research and Development*, 49(3), 37-52. doi:10.1007/BF02504914

Hong, N. S. (1998). *The relationship between well-structured and ill-structured problem solving in multimedia simulation*, The Pennsylvania State University, University Park, PA.

- Hmelo, C. E., & Ferrari, M. (1997). The problem-based learning tutorial: Cultivating higher-order thinking skills. *Journal for the Education of the Gifted*, 20, 401-422.
- Hmelo-Silver, C. E. (1998). Cognitive consequences of problem-based learning for the early development of medical expertise. *Teaching and Learning in Medicine*, 10, 92 – 100.
- Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review*, 16(3), 235-266. doi: 10.1023/B:EDPR.0000034022.16470.f3
- Hmelo-Silver, C. E., Derry, S. J., Bitterman, A., & Hatrak, N. (2009). Targeting transfer in a STELLAR PBL course for pre-service teachers. *Interdisciplinary Journal of Problem-based Learning*: 3(2). Retrieved from : <http://docs.lib.purdue.edu/ijpbl/vol3/iss2/4/>
- Hmelo-Silver, C. E. (2012). International Perspectives on Problem-based Learning: Contexts, Cultures, Challenges, and Adaptations, *Interdisciplinary Journal of Problem-based Learning*: 6(1). Retrieved from : <http://docs.lib.purdue.edu/ijpbl/vol6/iss1/3>
- Howell, D. C. (1997). *Statistical methods for psychology*. Belmont, CA: Thompson.
- Hurst, R. W., & Milkent, M. M. (1996). Facilitating successful prediction problem solving in biology through application of skill theory. *Journal of Research in Science Teaching*, 33(5), 541-552. doi: 10.1002/(sici)1098-2736(199605)33:5<541::aid-tea5>3.0.co;2-r



- Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development*, 48(4), 63-85. doi: 10.1007/bf02300500
- Jonassen, D. H. (2003). Designing research-based instruction for story problems. *Educational Psychology Review*, 15(3), 267-296. doi:10.1023/A:1024648217919
- Jonassen, D. H. (2004). *Learning to solve problems: An instructional design guide*. San Francisco: Pfeiffer
- Jonassen, D. H. (2007). *Learning to solve complex scientific problems*. New York: Lawrence Erlbaum Associates.
- Judd, C. H. (1908). The relation of special training to general intelligence. *Educational Review*, 36, 28-42.
- Kendall, M. (1938). A new measure of rank correlation. *Biometrika*, 30(1-2), 81-89.
- Kitchner, K.S. (1983). Cognition, metacognition, and epistemic cognition: A three-level model of cognitive processing. *Human Development*, 26, 222-232.
- Kim, M. C., & Hannafin, M. J. (2004). Designing online learning environment to support scientific inquiry. *Quarterly Review of Distance Education*, 5(1), 1.
- Kim, M. C., & Hannafin, M. J. (2010). Scaffolding 6<sup>th</sup> graders' problem solving in technology-enhanced science classrooms: A qualitative case study. *Instructional Science*.
- Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-

enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers & Education*, 56(2), 403-417.

doi:10.1016/j.compedu.2010.08.024

Koschmann, T. D., Myers, A. C., Feltovich, P. J., & Barrows, H. S. (1994). Using technology to assist in realizing effective learning and instruction :A principal approach to the use of computers in collaborative learning. *Journal of the Learning Science*, 3(3), 227-264.

Kurtz, S., Wylie, M., & Gold, N. (1990). Problem-based learning: An alternative approach to legal education. *Dalhousie Law*.

Land, S. M., & Zembal-Saul, C. (2003). Scaffolding reflection and articulation of scientific explanations in a data-rich, project-based learning environments: An investigation of progress portfolio. *Educational Technology Research and Development*, 51(4), 65-84.

Lindh, J., & Holgersson, T. (2007). Does lego training stimulate pupils' ability to solve logical problems? *Computers & Education*, 49(4), 1097-1111. doi: 10.1016/j.compedu.2005.12.008

Linn, M. C., Clark, D., & Slotta, J. D. (2003). Wise design for knowledge interaction. *Science Education*, 87(4), 517-538.

Linn, M. C., Davis, E. A., Bell, P. (2003). *Internet environments for science education*. Mahwah: Lawrence Erlbaum Associates.

- Lochhead, J. & Clement, J., (1979). *Cognitive process instruction. Research on teaching thinking skills*. Philadelphia:Franklin Institute Press.
- Luchins, A. S. (1942). Mechanization in problem solving. *Psychological Monographs*, 54.
- Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *Annals of Mathematical Statistics*, 18(1), 50-60.
- Martin, M. M., & Rubin, R. B. (1995). A new measure of cognitive flexibility. *Psychological Reports*. 76. 623-626. doi: 10.2466/pr0.1995.76.2.623
- Martin, M. M., & Anderson, C. M. (1998). The cognitive flexibility scale: Three validity studies. *Communication Reports*, 11(1), 1-9. doi: 10.1080/08934219809367680
- Mayer, R. E. (1984). Aids to text comprehension. *Educational Psychologist*, 19, 30-42
- Mayer, R. E. (2008). *Learning and instruction*. N.J: Pearson Merrill Prentice Hall.
- Mayer, R. E., & Wittrock, M. C. (1996). Problem-solving transfer. *Handbook of Educational Psychology*.
- Mestre, J. (2002). *Transfer of learning: Issues and research Agenda*. Arlington:NSF
- Merchand, J. E. (1995). *Problem-based learning in the business curriculum: An alternative to traditional approaches*. Boston : Kluwer Academic Publishers.

- Newble, D. I., & Clarke, R. M. (1986). The approaches to learning of students in a traditional and in an innovative problem-based medical school. *Medical Education*, 20(4), 267-273. doi: 10.1111/j.1365-2923.1986.tb01365.x
- Norman, G. R., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine*, 67, 557-565.
- Perkins, D. N. (1991). What constructivism demands of the learner. *Educational Technology*.
- The Problem-Based Learning Initiative's Website. Retrieved from [http://www.pbli.org/pbl/generic\\_pbl.htm](http://www.pbli.org/pbl/generic_pbl.htm)
- Perkins, D. N., & Salamon, G. (1992). Transfere of learning. Retrieved from <http://learnweb.harvard.edu/alps/thinking/docs/traencyn.htm>
- Perkins, D. N., & Grotzer, T. A. (1997). Teaching intelligence. *American Psychologist*, 52(10), 1125-1133. doi: 10.1037/0003-066x.52.10.1125
- Perkins, D. N., & Salomon, G. (1992). Transfer of learning. Retrieved from: <http://learnweb.harvard.edu/alps/thinking/docs/traencyn.htm>
- Piaget, J. (1954). *The construction of reality in the child*. Routledge and Kegan Paul Ltd.
- Polya, G. (1945). *How to solve it*. Princeton: Princeton University Press.
- Polya, G. (1957). *How to Solve it*. (2<sup>nd</sup> ed). Princeton: Princeton University Press.
- Putnam, A. R. (2001). Problem-based teaching and learning in technology education.
- Reif, F., Jill, H., & Larkin. (1979). Understanding and teaching problem-solving in

physics. doi: 10.1080/0140528790010208

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences*, 13(3), 273-304. doi:10.1207/s15327809jls1303\_2

Robbs J, Meredith S. (1994).The problem-based learning curriculum at southern illinois university school of medicine. Retrieved from:  
<http://www.suimed.edu/pblc/pblcur.html>

Savery, J.R, & Duffy. T.M.,(1995). Problem based learning: an instructional model and its constructivist framework. *Educational Technology* 1995;35(5):31-38

Savery, John R. (2006). Overview of problem-based Learning: Definitions and distinctions, *Interdisciplinary Journal of Problem-based Learning*. 1(1). Retrieved from <http://docs.lib.purdue.edu/ijpbl/vol1/iss1/3>.

Scardamalia, M., Bereiter, C., Mclean, R. S., Swallow, J., & Woodruff, E. (1989). Computer-supported intentional learning environments. Retrieved from:  
[http://www.ikit.org/fulltext/1989\\_CSILE.pdf](http://www.ikit.org/fulltext/1989_CSILE.pdf)

Schmidt, H. G. (1983). Problem-based learning: rationale and description. *Medical Education* 17:11-16.

Schmidt, H. G. (1993). Foundations of problem-based learning: some explanatory notes. *Medical Education* 27:422-432.

- Schwartz, D. L., (1995). The emergence of abstract representations in dyad problem solving. *Journal of the Learning Science*, 4, 321-354.
- Singley, M. K., & Anderson, J. R., (1989). *The transfer of cognitive skill*. Cambridge: Harvard University press.
- Smirnov, N.V. (1948). Tables for estimating the goodness of fit of empirical distributions. *Annals of Mathematical Statistics*, 19, 279.
- Thorndike, E. L. (1906). *Principle of teaching*. New York : Seiler.
- Torp, L., & Sage, S. (2002). *Problems as possibilities: Problem-based learning for K-16 education*. Baltimore: Association for Supervision and Curriculum Development
- Vernon, D. T., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine : Journal of the Association of American Medical Colleges*, 68(7), 550-563. doi: 10.1097/00001888-199307000-00015
- Vygotsky, L. S., & Cole, M. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.
- Wilcoxon, F. (1945). Individual comparisons by ranking methods. *Biometrics Bulletin*, 1(6), 80-83.
- Wood, P. K. (1983). Inquiring systems and problem structures: Implications for

cognitive development . *Human Development* , 26,249-265.

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving.

*Child Psychology and Psychiatry and Allied Disciplines*, 17 (1976), pp. 89–100

Woodworth, R. S., & Schlosberg, H. (1954). *Experimental psychology*. New York ;

Toronto: Holt.

## APPENDICES

### Appendix A: IRB Approval

#### Oklahoma State University Institutional Review Board

Date: Thursday, April 05, 2012  
IRB Application No: ED1272  
Proposal Title: Scaffolding of Collaborative Problem Solving in Introductory Science Courses

Reviewed and Processed as: Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 4/4/2013

Principal Investigator(s):

Farzaneh Jahanzad 220 Willard Hall Stillwater, OK 74078	Pasha Antonenko 209 Willard Stillwater, OK 74078
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The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, [beth.mcternan@okstate.edu](mailto:beth.mcternan@okstate.edu)).

Sincerely,



Shelia Kennison, Chair  
Institutional Review Board



## Appendix B: Information Sheet

### Recruitment Script

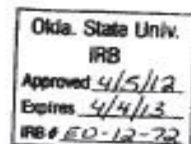
(to be read by the course instructor, Dr. Carmen Greenwood)

Faria Jahanzad is a graduate student in the Educational Technology Masters program working under the supervision of Dr. Pasha Antonenko. They are conducting a research study to understand effective scaffolding of collaborative problem solving. The title of their study is "Scaffolding of Collaborative Problem Solving in Introductory Science Courses." I invite you to participate in this study. As part of this study, you will complete several questionnaires (30 minutes) and then spend a class period solving a problem on the use of aquatic insects in bioassessment, followed by two short tests.

You will receive 10 extra credit points for participating in this study. If you choose not to participate, you can earn 10 extra credit points in this class by writing a research paper on the use of aquatic insects for the purpose of bioassessment.

Please review the Participant Information Sheet for this study and if you agree to participate, complete the attached questionnaires. Please do not forget to write your names on the blank top sheet. This will allow me to award extra credit. Your names will not be shared with this study's investigators.

Thank you!



**PARTICIPANT INFORMATION  
OKLAHOMA STATE UNIVERSITY**

**Title:** Scaffolding of Collaborative Problem Solving in Introductory Science Courses.

**Investigator(s):** Ms. Faria Jahanzad, Educational Technology Masters student, Oklahoma State University; Dr. Pasha Antonenko, Educational Technology, Oklahoma State University.

**Purpose:** The purpose of the research study is to understand effective implementation of problem solving activities in introductory science courses. You are being asked to participate in this study because you are enrolled in ENTO 2003.001.

**What to Expect:** Participation in this research will involve completion of several questionnaires (30 minutes) and a 75-minute session where you will work with 2-3 team-mates to solve a real-life problem that involves the use of aquatic insects for the purpose of bioassessment and complete two tests that will show your knowledge of this content and your ability to transfer this knowledge to novel situations. The points that you earn for this activity will only be used as extra credit for this class. This study will have no other effect on your grade in this class.

**Risks:** There are no risks associated with this project, which are expected to be greater than those ordinarily encountered in daily life. To minimize the risks associated with confidentiality, no identifiers are to be associated with your data and no signed record of your consent will be collected. You will return your responses to the Teaching Assistant.

**Benefits:** You may gain an appreciation and understanding of the use of self-regulated learning strategies in formal education and learn about processes involved in conducting survey-based research.

**Compensation:** 10 extra credit points will be provided for your participation. Students who opt out of participating will be able to complete an alternative activity – that is, a 5-page research paper on the use of aquatic insects in bioassessment.

**Your Rights:** Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time, without penalty.

**Confidentiality:** All information about you will be kept confidential and will not be released. Questionnaires will have identification numbers, rather than names, on them. The names that you provide on a separate blank sheet will be used by the course instructor to award extra credit. At no time will this study's investigators have access to your names. De-identified responses questionnaires and tests will be shared with the PIs who will enter them into PASW/SPSS data files. These files will be stored on a secure, password-protected computer with access only by the co-PIs. The computer is located in Dr. Antonenko's office in 209 Willard Hall. Both co-PIs have completed training in the protection of human subjects and conducted research that involves human subjects. Paper copies of the questionnaires and the envelopes they came in will be shredded promptly. The PASW/SPSS files will be kept for three years (2012 – 2015) to provide



## APPENDIX C: Demographic Questionnaire

### 1. Age:

{ }

### 2. Gender:

{ } Female

{ } Male

### 3. Classification:

{ } Freshman

{ } Sophomore

{ } Junior

{ } Senior

{ } Graduate student

### 4. Grade Point Average:

{ } 3.5 – 4.0

{ } 3.0 – 3.49

{ } 2.5 – 2.99

{ } 2.0 – 2.49

{ } Less than 2.0

## APPENDIX D: Cognitive Flexibility Questionnaire

**Instructions:** The following statements deal with your beliefs and feelings about your own behavior. Read each statement and check the number that best represents your agreement with each statement.

	Very true	Mostly true	Moderately true	Slightly true	Not true
1. I can communicate an idea in many different ways.	5	4	3	2	1
2. I avoid new and unusual situations.	5	4	3	2	1
3. I feel like I never get to make decisions.	5	4	3	2	1
4. In any given situation, I am able to act appropriately.	5	4	3	2	1
5. I can find workable solutions to seemingly unsolvable problems.	5	4	3	2	1
6. I seldom have choices to choose from when deciding how to behave.	5	4	3	2	1
7. I am willing to work at creative solutions to problems.	5	4	3	2	1
8. My behavior is a result of conscious decisions that I make.	5	4	3	2	1
9. I have many possible ways of behaving in any given situation.	5	4	3	2	1
10. I have difficulty using my knowledge on a given topic in real life situations.	5	4	3	2	1
11. I am willing to listen and consider alternatives for handling a problem.	5	4	3	2	1
12. I have the self-confidence necessary to try different ways of behaving.	5	4	3	2	1

## APPENDIX E: Motivated Strategies Learning Questionnaire

Directions: Below are statements that people use to describe themselves. These are opinions about yourself; there are no right or wrong answers. Please darken in the circle of the response that best describes you using the following scale:

NOT AT ALL TRUE OF ME ● ● ● ● ● ● ● VERY TRUE OF ME

1. When I study, I practice saying the material to my self over and over. ① ② ③ ④ ⑤ ⑥ ⑦
- When studying for classes, I read my class notes and the course reading over and over. ① ② ③ ④ ⑤ ⑥ ⑦
- I memorize key words to remind me of important concepts when I study. ① ② ③ ④ ⑤ ⑥ ⑦
- When I study, I make lists of important terms and memorize the lists. ① ② ③ ④ ⑤ ⑥ ⑦
  
2. When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions. ① ② ③ ④ ⑤ ⑥ ⑦
- I try to relate ideas in one subject to those in other courses whenever possible. ① ② ③ ④ ⑤ ⑥ ⑦
- When reading for classes, I try to relate the material to what I already know. ① ② ③ ④ ⑤ ⑥ ⑦
- When I study, I write brief summaries of the main ideas from the readings and the concepts from the lectures. ① ② ③ ④ ⑤ ⑥ ⑦
- I try to understand the material in classes by making connections between the readings and the concepts from the lectures ① ② ③ ④ ⑤ ⑥ ⑦

I try to apply ideas from course readings in other class activities such as lecture and discussion. ① ② ③ ④ ⑤ ⑥ ⑦

3. When I study the readings for a class, I outline the material to help me organize my thoughts. ① ② ③ ④ ⑤ ⑥ ⑦

When I study, I go through the readings and my class notes and try to find the most important ideas. ① ② ③ ④ ⑤ ⑥ ⑦

I make simple charts, diagrams, or tables to help me organize course material. ① ② ③ ④ ⑤ ⑥ ⑦

When I study, I go over my class notes and make an outline of important concepts. ① ② ③ ④ ⑤ ⑥ ⑦

4. I often find myself questioning things I hear or read in this classes to decide if I find them convincing. ① ② ③ ④ ⑤ ⑥ ⑦

When a theory, interpretation, or conclusion is presented in class or in readings, I try to decide if there is good supporting evidence. ① ② ③ ④ ⑤ ⑥ ⑦

I treat the course material as a starting point and try to develop my own ideas about it. ① ② ③ ④ ⑤ ⑥ ⑦

I try to play around with ideas of my own related to what I am learning in a class. ① ② ③ ④ ⑤ ⑥ ⑦

Whenever I read or hear an assertion or conclusion in classes, I think about possible alternatives. ① ② ③ ④ ⑤ ⑥ ⑦

5. During class time I often miss important points because I'm thinking of other things. ① ② ③ ④ ⑤ ⑥ ⑦

When reading for classes, I make up questions to help focus my reading. ① ② ③ ④ ⑤ ⑥ ⑦

When I become confused about something I'm reading, I go back and try to figure it out. ① ② ③ ④ ⑤ ⑥ ⑦

If course materials are difficult to understand, I change the way I read the material. ① ② ③ ④ ⑤ ⑥ ⑦

Before I study new material thoroughly, I often skim it to see how it is organized. ① ② ③ ④ ⑤ ⑥ ⑦

I ask myself questions to make sure I understand the material I have been studying in class. ① ② ③ ④ ⑤ ⑥ ⑦

I try to change the way I study in order to fit the course requirements and instructor's teaching style. ① ② ③ ④ ⑤ ⑥ ⑦

I often find that I have been reading for class but don't know what it was all about. ① ② ③ ④ ⑤ ⑥ ⑦

I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying. ① ② ③ ④ ⑤ ⑥ ⑦

When studying, I try to determine which concepts I don't understand well. ① ② ③ ④ ⑤ ⑥ ⑦

When I study, I set goals for myself in order to direct my activities in each ① ② ③ ④ ⑤ ⑥ ⑦

study period.

If I get confused taking notes, I make sure I sort it out afterward.

① ② ③ ④ ⑤ ⑥ ⑦

6. I prefer course material that really challenges me so I can learn new things.

① ② ③ ④ ⑤ ⑥ ⑦

I prefer course material that arouses my curiosity, even if it is difficult to learn.

① ② ③ ④ ⑤ ⑥ ⑦

The most satisfying thing for me in classes is trying to understand the content as thoroughly as possible.

① ② ③ ④ ⑤ ⑥ ⑦

When I have the opportunity, I choose course assignments that I can learn from even if they don't guarantee a good grade.

① ② ③ ④ ⑤ ⑥ ⑦

7. Getting a good grade is the most satisfying thing for me right now.

① ② ③ ④ ⑤ ⑥ ⑦

The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.

① ② ③ ④ ⑤ ⑥ ⑦

If I can, I want to get better grades in this class than most of the other students.

① ② ③ ④ ⑤ ⑥ ⑦

I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.

① ② ③ ④ ⑤ ⑥ ⑦



8. I think I will be able to use what I learn in this course in other courses. ① ② ③ ④ ⑤ ⑥ ⑦
- It is important for me to learn the material in this class. ① ② ③ ④ ⑤ ⑥ ⑦
- I am very interested in the content area of this course. ① ② ③ ④ ⑤ ⑥ ⑦
- I think the material in this class is useful for me to learn. ① ② ③ ④ ⑤ ⑥ ⑦
- I like the subject matter of this course. ① ② ③ ④ ⑤ ⑥ ⑦
- Understanding the subject matter of this course is very important to me. ① ② ③ ④ ⑤ ⑥ ⑦
9. If I study in appropriate ways, then I will be able to learn the material in this course. ① ② ③ ④ ⑤ ⑥ ⑦
- It is my own fault if I don't learn the material in this course. ① ② ③ ④ ⑤ ⑥ ⑦
- If I try hard enough, then I will understand the course material. ① ② ③ ④ ⑤ ⑥ ⑦
- If I don't understand the course material, it is because I didn't try hard enough. ① ② ③ ④ ⑤ ⑥ ⑦
10. I believe I will receive an excellent grade in this class. ① ② ③ ④ ⑤ ⑥ ⑦
- I'm certain I can understand the most difficult material presented in the readings for this course. ① ② ③ ④ ⑤ ⑥ ⑦

I'm confident I can understand the basic concepts taught in this course. ① ② ③ ④ ⑤ ⑥ ⑦

I'm confident I can understand the most complex material presented by the instructor in this course. ① ② ③ ④ ⑤ ⑥ ⑦

I'm confident I can do an excellent job on the assignments and tests in this course. ① ② ③ ④ ⑤ ⑥ ⑦

I expect to do well in this class. ① ② ③ ④ ⑤ ⑥ ⑦

I'm certain I can master the skills being taught in this class. ① ② ③ ④ ⑤ ⑥ ⑦

Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class. ① ② ③ ④ ⑤ ⑥ ⑦

11. When I take a test I think about how poorly I am doing compared with other students. ① ② ③ ④ ⑤ ⑥ ⑦

When I take a test I think about items on other parts of the test I can't answer. ① ② ③ ④ ⑤ ⑥ ⑦

When I take tests I think of the consequences of failing. ① ② ③ ④ ⑤ ⑥ ⑦

I have an uneasy, upset feeling when I take an exam. ① ② ③ ④ ⑤ ⑥ ⑦

I feel my heart beating fast when I take an exam. ① ② ③ ④ ⑤ ⑥ ⑦

12. I usually study in a place where I can concentrate on my course work. ① ② ③ ④ ⑤ ⑥ ⑦
- I make good use of my study time. ① ② ③ ④ ⑤ ⑥ ⑦
- I find it hard to stick to a study schedule. ① ② ③ ④ ⑤ ⑥ ⑦
- I have a regular place set aside for studying. ① ② ③ ④ ⑤ ⑥ ⑦
- I make sure I keep up with the weekly readings and assignments for my courses. ① ② ③ ④ ⑤ ⑥ ⑦
- I attend class regularly. ① ② ③ ④ ⑤ ⑥ ⑦
- I often find that I don't spend very much time on school work because of other activities. ① ② ③ ④ ⑤ ⑥ ⑦
- I rarely find time to review my notes or readings before an exam. ① ② ③ ④ ⑤ ⑥ ⑦
13. I often feel so lazy or bored when I study that I quit before I finish what I planned to do. ① ② ③ ④ ⑤ ⑥ ⑦
- I work hard to do well even if I don't like what we are doing. ① ② ③ ④ ⑤ ⑥ ⑦
- When course work is difficult, I give up or only study the easy parts. ① ② ③ ④ ⑤ ⑥ ⑦
- Even when course materials are dull and uninteresting, I manage to keep working until I finish. ① ② ③ ④ ⑤ ⑥ ⑦

14. When studying for a class, I often try to explain the material to a classmate or a friend. ① ② ③ ④ ⑤ ⑥ ⑦
- I try to work with other students to complete the course assignments. ① ② ③ ④ ⑤ ⑥ ⑦
- When studying for a class, I often set aside time to discuss the course material with a group of students from the class. ① ② ③ ④ ⑤ ⑥ ⑦
15. Even if I have trouble learning the material in a class, I try to do the work on my own, without help from anyone. ① ② ③ ④ ⑤ ⑥ ⑦
- I ask the instructor to clarify concepts I don't understand well. ① ② ③ ④ ⑤ ⑥ ⑦
- When I can't understand the material in a course, I ask another student in this class for help. ① ② ③ ④ ⑤ ⑥ ⑦
- I try to identify students in my classes whom I can ask for help if necessary. ① ② ③ ④ ⑤ ⑥ ⑦

## APPENDIX F: Domain Knowledge Test

1. Which of the following would be considered an “aquatic insect?”
  - a. Dragonfly
  - b. Caddisfly
  - c. Mayfly
  - d. stonefly
  - e. All of the above
  
2. Which type of aquatic insect would be most impacted by nutrient run-off into a water supply?
  - a. An insect that lives underwater and uses gills to obtain oxygen
  - b. An insect that flies and breathes air but also swims in the water to hunt for food
  - c. An insect that lives in the water but breathes air which it obtains thru a “siphon,” a tube that extends above the water like a snorkel.
  
3. Aquatic insects exhibit different tolerance levels to different types of water pollution
  - a. True
  - b. False
  
4. What role(s) do aquatic insects fulfill in aquatic ecosystems?
  - a. Decomposition & nutrient cycling
  - b. Forage base for larger animals
  - c. Indicators of biological integrity

- d. All of the above
5. Which of the following would be considered a source of nutrient run-off into a water supply?
- a. A large pastureland, heavily populated by livestock, adjacent to riverbank
  - b. An oil spill from a tanker in the ocean
  - c. Groundwater that becomes saline after salts seep down into the water table
  - d. All of the above
6. Which of the following insect orders contain insects that are dominated by an aquatic life stage?
- a. Coleoptera
  - b. Diptera
  - c. Hemiptera
  - d. All of the above
7. Which type of aquatic habitat would have the highest diversity of insect life?
- a. Open ocean
  - b. Wetland (freshwater)
  - c. Tidal pool
  - d. In the middle (open water) of a large lake
8. Which of the following insects DOES NOT have an aquatic life stage?

- a. Mosquito
  - b. Damselfly
  - c. Giant water bug
  - d. Ladybug
9. What is biological assessment?
- a. Use of living organisms to indicate the relative health of a system
  - b. Use of aquatic insects to indicate the relative health of a system
  - c. Use of chemical and physical measurements to indicate the relative health of a system
  - d. Use of opinion surveys to indicate the relative health of a system
10. Biological assessment is a technique often employed by the Environmental Protection Agency to determine the impacts of pollution
- a. True
  - b. false

## APPENDIX G: The Problem and Resources

**Instructions:** Read the following brief scenario. Look through the list of potential references provided. Using the information you were provided in class and any of the references from the list below, come prepared on Thursday to provide a brief solution to the scenario. With your solution please indicate which, of the references listed below, were helpful to you in determining your solution. You can use as many or as few as you like. List them in the order of usefulness (the most useful at the top). You can indicate references using the letter designation for each – to make it easier.

**Scenario:** You are the water resources extension educator for the community and citizens within your community have informed you that they have observed differences in the river water and shoreline habitat downstream of a sewage treatment plant compared to the habitat and water upstream of the sewage treatment plant. The sewage treatment plant is located right next to the river and discharges "treated" water directly into the river. The citizens are concerned and would like to know if there is any reason for concern. You go to the river and do some preliminary inspections and collect some insects from both upstream and downstream of the sewage treatment plant (see table 1). What would you do next?



Table 1

<b>upstream - type of insect or other invertebrate</b>	<b>Number collected</b>	<b>downstream - type of insect or other invertebrate</b>	<b>Number collected</b>
stoneflies (family: Perlidae)	6	Mayflies (family: Heptageniidae)	3
stoneflies (family: Isoperlidae)	4	Mayflies (family: Ephemeridae)	9
stoneflies (family: Nemouridae)	8	Caddisflies (family: Hydropsychidae)	16
Mayflies (family: Caenidae)	11	Diptera (family: Tipulidae) "crane flies"	18
Mayflies (family: Baetidae)	12	Diptera (family: Chironomidae) "midges"	61
Mayflies (family: Isonychiidae)	6	Diptera (family: Simuliidae) "black flies"	33
Mayflies (family: Heptageniidae)	9	leeches	4
Caddisflies (family: Leptoceridae)	16	scuds	5
Caddisflies (family: Hydropsychidae)	21	lunged snails	6
Dragonflies (Libellulidae)	3		
Dragonflies (Gomphidae)	2		
Damselflies (Coenagrionidae)	7		
Hemiptera (Nepidae)	1		
Hemiptera (Notonectidae)	5		
Dobsonfly (Megaloptera: Corydalidae)	2		
gilled snails	8		
<b>Total</b>	<b>121</b>		<b>155</b>

Potential references:

- A. <http://www.wisflyfishing.com/bridge.html>
- B. <http://www.entomology.umn.edu/midge/VSMIVP%20Key/English/VSMIVP.htm>
- C. <http://www.cals.ncsu.edu/course/ent425/tutorial/aquatictic.html>

- D. <http://royalgorgeanglers.com/arkansas-river-aquatic-insects>
- E. <http://lakes.chebucto.org/ZOOBENTH/BENTHOS/tolerance.html>
- F. <http://www4.uwsp.edu/cnr/research/gshepard/history/History.htm>
- G. [www.iwla.org/sos](http://www.iwla.org/sos)
- H. <http://pubs.ext.vt.edu/420/420-531/420-531.html>

## APPENDIX H: DEEPER Problem-Solving Sheets

### Step 1: Define the Problem

1. Browse the problem description provided by the instructor, and think whether you have read about or heard of similar issues in the past. Does this scenario bring back any recollections?

Discuss as a team and indicate below.

2. Discuss the problem description and state the problem in one sentence or question.

3. What are the causes of this problem? Discuss and list them below.

4. What the effects/consequences of this problem? Discuss and list them below.

5. Who are the stakeholders, people or groups impacted by the problem? Discuss and list them below.

6. Using the information from the problem description, indicate what you know about the problem and what you need to know to solve this problem.

KNOW

NEED TO KNOW

## Step 2: Explore the Resources

1. Which of the information resources are relevant to solving the problem? Why? Discuss and list below. Be specific.

2. What useful information have you located in the information resources? How can this information help your team solve this problem?

3. What useful *evidence* for solving the problem were you able to find? How can this evidence help you solve the problem? Discuss and list below.

### Step 3: Explain Your Solution

1. Use the relevant information and evidence that you identified in information resources and develop your solution proposal.

*Example: One possible solution is to ..... (your claim goes here) ..... because ..... (list relevant evidence here).*

2. How will this solution impact the stakeholders (in positive and negative ways)?

## Step 4: Present Your Solution

1. How would you present your solution to the stakeholders? What would be the most effective presentation format (e.g., website, town hall meeting, brochures, posters, Facebook campaign, mobile app etc...)?

2. What is your rationale for choosing this presentation format? Think about the characteristics of your stakeholders. For example, if this is a rural area with limited Internet access, a website would not be the best format.

3. What information should be included in your final presentation? Think about the most important aspects of your solution that need to be shared with the stakeholders.

## Step 5: Evaluate Your Solution

1. Think again about your proposed solution, its impacts on the stakeholders, its viability in real life, and the scientific evidence behind it. Are you completely happy with this solution or do you feel that it could be improved? Elaborate.

## Step 6: Reflect on Your Problem Solving

1. Discuss and reflect on your experience solving this problem. What were the most challenging aspects of this activity?

2. When you were defining the problem (Step 1), you listed what you knew and what you needed to know to solve this problem. Now that you proposed a solution, what have you learned relative to your initial response in Step 1?



## **APPENDIX I: Problem-Solving Rationale Sheet**

### Problem-solving Activity

1. What solution to this problem does your team propose? Be specific.

2. What is your team's rationale for this solution? Again, be specific.

## APPENDIX J: Transfer of Knowledge Test

1. A mass emergence of adult stoneflies from a creek would indicate?
  - a. The creek is likely polluted in some way
  - b. The water quality of the creek is excellent
  - c. A lack of fish in this creek
  - d. This phenomenon is not informative in any way
  
2. An aquatic system subject to high levels of nutrient run-off would most significantly affect which of the following insects?
  - a. Water beetle
  - b. Water strider (true bug)
  - c. Mayfly
  - d. Mosquito
  
3. What information is provided by biological assessment that cannot be provided by chemical or physical assessment?
  - a. Water quality over a long period of time
  - b. Dissolved oxygen levels of water
  - c. pH of water
  - d. conductivity of water
  
4. What is a watershed?
  - a. All of the area of land that drains into a specific aquatic system

- b. A river and all of its tributaries
  - c. A creek that flows into a river
  - d. A heavy rain event
5. Which characteristic of an aquatic insect would make it most susceptible to pollution involving nutrient inputs?
- a. Having a predatory feeding strategy
  - b. Using gills to obtain oxygen
  - c. Having a flying adult stage
  - d. Having complete (versus gradual) metamorphosis
6. Polluted streams would affect conservation of which of the following animals in the vicinity of the polluted system?
- a. Fish
  - b. Spiders
  - c. Birds
  - d. Bats
  - e. All of the above
7. A government agency is most likely to address a pollution issue if provided with:
- a. Confirmed observations (by citizens) that waters appear to be polluted
  - b. Observations of insects that tend to be tolerant to pollution

- c. Quantified (numerical) data showing a difference in the insect community subject to the influence of pollution
  - d. All of the above
8. What allows aquatic insects to be useful as indicators of water quality?
- a. They vary in their sensitivity level to various pollutants
  - b. They are all equally very sensitive to pollutants in the water
  - c. Aquatic insects still breathe air so the pollutants have to reach high levels to kill them
  - d. Aquatic insects are much harder to kill than the fish that inhabit the same system
9. Which of the following has beneficial effects in the terrestrial environment, potentially preying upon pest insects, like mosquitoes?
- a. Dragonflies
  - b. Mayflies
  - c. Stoneflies
  - d. Caddisflies
10. Which of the following has fluffy gills on the larval stage?
- a. Dragonflies
  - b. Mayflies
  - c. Stoneflies
  - d. Caddisflies

## APPENDIX K: Rubric

Evaluator #:

# PROBLEM SOLVING PERFORMANCE RUBRIC

*(based on AACU's Problem Solving VALUE Rubric)*



### Definition

Problem solving is the process of designing, evaluating, and implementing a strategy to answer an open-ended question or achieve a desired goal.

*Evaluators are encouraged to assign a zero to any work sample that does not meet benchmark (cell one) level performance.*

	<b>Capstone</b> 4	<b>Milestones</b>		<b>Benchmark</b> 1	<b>Score</b>
		3	2		
<b>Proposed Solution(s)</b>	Proposes one or more solutions that indicates a deep comprehension and quantitative analysis of the problem.	Proposes one or more solutions that indicates comprehension and quantitative analysis of the problem.	Proposes one solution that is “off the shelf” rather than individually designed to address the specific contextual factors of the problem.	Proposes a solution that is difficult to evaluate because it is vague, does not include a quantitative analysis or only indirectly addresses the problem statement.	
<b>Rationale</b>	Solution(s) are based on and directly linked to the useful evidence from information resources. All useful and relevant evidence is linked to the solution proposal(s).	Solution(s) are based on and directly linked to the useful evidence from information resources but more relevant evidence could be added to strengthen the solution proposal.	Solution(s) seem to be based on the useful evidence from information resources but several important pieces of evidence are missing. The solution proposal would definitely benefit from more relevant evidence.	The solution is not linked to relevant evidence from information resources, so the solution proposal consists only of student's unsubstantiated claim(s). The solution proposal cannot realistically be used to solve the problem.	
<b>Total</b>					

VITA

Farzaneh Jahanzad

Candidate for the Degree of

Master of Science

Thesis: THE INFLUENCE OF THE DEEPER SCAFFOLDING FRAMEWORK ON  
PROBLEM-SOLVING PERFORMANCE AND TRANSFER OF  
KNOWLEDGE

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Scope and Method of Study: One of major goals of education is to prepare effective and efficient problem solvers. The purpose of this study was to determine the impact of the DEEPER framework of scaffolding problem solving on three important variables: problem-solving performance, domain knowledge acquisition, and transfer of knowledge in a problem-based learning environment in higher education. In this quasi-experimental study, the pretest-posttest control group design was used to collect data. One hundred and nine students participated in this study. They were randomly assigned to two groups: the treatment group and the control group. The two groups were asked to solve an ill-structured problem on the role of aqua insects in the biological assessment of river water. The control and treatment groups differed in the nature of instructional scaffolding that they received during problem solving. The treatment group used the DEEPER process scaffolds, and the control group was asked to solve the problem using a more traditional, rationale-based scaffold. The data was gathered to determine if there were any differences between the groups on three dependent variables: domain knowledge, transfer of knowledge, and problem-solving performance.

Findings and Conclusions: The findings of this study demonstrate that while the implementation of the DEEPER scaffolding of problem-solving resulted in improved problem-solving performance in the treatment group, differences were not observed on the measure of domain knowledge acquisition. Transfer of knowledge was not significantly impacted according to a test of the differences in group means, however correlational analyses revealed a positive relationship between two of the DEEPER tasks and performance on the measure of knowledge transfer. Most of the tasks embedded within each of the DEEPER scaffolding steps were positively correlated with students' problem-solving performance and the magnitude of these relationships was moderate to strong. Thus, it appears that the DEEPER framework for scaffolding problem solving provides a useful method for designing and structuring problem-solving activities for novice science learners at the higher education level.

ADVISER'S APPROVAL: Dr. Pasha Antonenko

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