ABSTRACT

WALKER, DAVID PATRICK. Enhancing Problem Solving Disposition, Motivation and Skills Through Cognitive Apprenticeship. (Under the direction of Dr. V. William DeLuca.)

To determine the effects of teaching problem solving through the use of a cognitive apprenticeship paradigm, the researcher used a non-equivalent control group design. The experimentally accessible population for this study was high school technology education students in Durham, North Carolina. The sample was two classes of a Fundamentals of Technology course which covered technological problem solving through engineering activities.

The control group received instruction through a traditional, prescriptive approach to teaching problem solving. The treatment group received problem solving instruction through a cognitive apprenticeship approach. Each group covered the same content. However, the treatment group received additional exercises to aid in the meta-cognitive process and was guided through the problem solving activity. Both groups received instruction for 2 weeks. A researcher designed disposition instrument, the California Measure of Mental Motivation (CM3) and an authentic assessment of the unit problem solving activity were used to measure differences between groups in disposition toward problem solving, motivation to solve problems and problem solving design effectiveness. One-way ANOVAs showed significant differences in some of the dependent variables.

Follow-up analysis revealed the following results: (a) significant differences in the disposition scale of Perseverance between groups as measured by a post-test given at the end of the unit; (b) significant differences in the motivation scales of Cognitive Integrity and

Process as measured by the CM3; (c) no significant differences in problem solving performance, as measured by the effectiveness of the technological problem introduced in the unit.

The study results provided some evidence that teaching problem solving through the use of cognitive apprenticeship is more effective than that of more traditional approaches. Significant differences were found in key areas that are stressed in the cognitive apprenticeship model such as increased importance placed on using a process, as well as motivation to solve problems. In addition, interviews with the participating teachers suggested that teaching problem solving through cognitive apprenticeship has a positive effect.

ENHANCING PROBLEM SOLVING

DISPOSITION, MOTIVATION AND SKILLS

THROUGH COGNITIVE APPRENTICESHIP

by

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BIOGRAPHY

David Patrick Walker received a B.S. in Industrial Arts Education from North Carolina State University in 1987 and received a M.Ed. in Technology Education from the same institution in 1994.

Before, during and after attending graduate school, he taught public school and has worked in industry. His teaching experience encompassed middle and high school level education. He was heavily involved in new or innovative technology education programs during his time in public education. He served as a consultant to the North Carolina Department of Public Instruction during the re-design of several Technology Education courses and frequently speaks at the North Carolina State Vocational Education Summer Conference. His industry experience ranges from designing houses and trade shows to designing curriculum, designing and developing e-learning environments, and managing a group of instructional designers and multi-media specialists. He is currently working at Cisco Systems Inc., where he leads a business strategy team that develops learning and development web tools that support the Cisco sales force.

In his "off-time", he serves as a member of the North Carolina National Guard. He began his military career in 1991 as a combat medic in the Army Reserve serving for 6 years. He has since attended Officer Candidate School and currently serves in the Field Artillery as a Battery Commander. During his career he has received numerous awards for leadership and academic excellence.

He enjoys his life with his wife, Estela, and three children, Zach, Lesley and Zane. They live in Durham, NC.

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CHAPTER ONE

INTRODUCTION

The Need for Teaching Problem Solving Skills

"We are told that our schools…are failing in the main task. They do not develop the capacity for critical discrimination and the ability to reason. The ability to think is smothered by accumulation of miscellaneous ill-digested information." Although this sounds as though it were taken from today's headlines, John Dewey wrote this almost a century ago in his classic work Democracy and Education (1916). Dewey called for a more relevant education – an education that prepared students to be thinkers and problem solvers. His theory of "learning by doing" is reflected in this statement.

For years educators have wrestled with just how to improve critical thinking and problem solving skills. Based on the amount of literature on the subject, improving problem solving and critical thinking skills is omnipresent. It crosses curricular lines. Educators at all levels consider this critical (Wager, 1997). But if that is the case then why do we not see a public education system that reflects this notion?

Of course, there are pockets of innovation but too many students still labor in schools that are little changed from Henry Ford's day. In fact the settings remind one of Ford's mass production by the assembly-line method. Students sit in rows, are presented unrelated facts, absorb information by drill and rote instructional methods, move through the curriculum at breakneck speed without regard to the individual, and then are tested on the their ability to recall this information at course/unit completion. Henry Ford once remarked, "People can have the Model T in any color--so long as it's black". It appears that public education, intentional or not, is telling students that they can have any education they like as long as it is learning-to-know.

Learning to Know

This "learning-to-know" philosophy has prevailed in education for many years. It is only recently, that a systemic change toward higher level thinking is evident (International Technology Education Association [ITEA],1996, 2000; Secretary's Commission on Achieving Necessary Skills [SCANS], 1991; Paul, Binker, Jensen, & Kreklau, 1990). From these movements a common theme emerges. Public education needs to move beyond the content-based, teacher-directed curriculum now being taught (Wager, 1997). We must prepare students to take control of their learning and apply what they know, in an effort to create a <u>manipulator</u> of information instead of a <u>regurgitator</u> of information. Preparing students to take charge means teachers will have to take a step back in the classroom to allow students to assume some control. Not widely embraced by educators. For this control to be effective, students will need some tools and guidance. Instead of filling students with information, educators should be <u>guiding</u> them to find the information. Instead of providing students with answers, educators should be <u>asking</u> students' questions. Instead of solving problems for students, educators should be <u>preparing</u> students to be problem solvers. But just what is the best method to accomplish this task? And are teachers prepared to teach problem?

Problem Solving Strategies

There is no shortage of strategies to assist teachers in this task. Many disciplines have developed models for problem solving (Beyer, 1995; Smith, Knudsvig, & Walker, 1998). Others have developed more generic models intended to cross curricular lines. Yet the nature of problem solving is lost in many of these models. There is more to teaching problem solving than merely teaching problem solving methods. In our attempt to mechanize the problem solving process we have overlooked some of the key sub-skills associated with problem solving as well as the affective nature of problem solving. Because so few teachers are prepared to teach problem solving they rely on teaching a problem solving method as their only vehicle.

Rationale for this Study

This focus on problem solving skills is not lost on technology education. In recent years, there has been a push, within technology education, toward a problem solving emphasis. Problem solving requires critical thinking skills, something all educators are trying to address in their curriculum. With the surge in technological advancement in recent decades, it is no wonder problem solving has become so popular. The teaching of problem solving skills will enable our students to cope with new technologies, make informed decisions about them, and adapt to an ever-changing world (Christensen & Martin, 1992; ITEA, 1996, 2000). Technology is changing so fast it is no longer viable to teach the content-based curriculum of the past. We must prepare our students for a future that no one can predict. As a result, we must expose our students to a wide variety of situations. Adaptability will be an essential skill. This is the language of justification for teaching problem solving skills in our technology education curriculum (Deluca, 1992; ITEA, 1996; SCANS, 1991).

Generally, problem solving is taught through activities. In most technology education classrooms, activities come in the form of a problem statement or design brief (Deluca, 1992). "Design and construct a widget that will perform a certain function within these given limitations." Through problem solving activities, technology educators hope to provide some basic problem solving skills that can carry over to other aspects of the student's life. Students are given technical problems to solve, given a method by which to solve it (e.g. the D.E.A.L. Problem Solver)(Bransford & Stein, 1993), then asked to solve the problem. But are we truly preparing our students to be good problem solvers with this approach to teaching problem solving? Evidence would seem to suggest not (Berryman, 1991). Presenting many various problems to solve does little to enhance the general problem solving ability of our students(Campbell, 1999; Woods, 1997; Woods, 1993). Woods (1993, p.313) outlined:

> Research has shown us that many of the "usual" teaching techniques that we have depended on in the past (lecture, assigning problems, demonstrating how we solve problems, having students show other students how to solve problems, and the ever-popular, "open-ended" problems) are ineffective in developing problem solving skills.

This approach provides "opportunities," but rarely skill development. Technology educators have become too reliant on problem methods and focus too often on the product rather than the process used. By focusing on the process of problem solving the teacher has to opportunity to provide <u>explicit, prompt, personal feedback</u> on each of a host of sub-skills called on as one "solves problems" (Woods, 1993).

Disposition

Yet, teaching problem solving skills alone will not complete the puzzle. In addition to teaching students the sub-skills associated with problem solving, technology educators must keep students motivated to solve the problem. Attitude and motivation toward problem solving is typically an element that is overlooked when teaching problem solving. All too often problem solving activities go wrong simply because the students got frustrated, apathetic or embarrassed? Many students are simply afraid of their ability to solve problems (VanDemark, 1991). The student's disposition toward problem solving is key (Hollingsworth & McLoughlin, 2000; Seldon, 1997). In many ways, a student's attitude toward problem solving will be the differentiating factor in whether or not the student is successful. In addition, the experience the student has on projects early in the school year can affect that student's attitude and behavior for the remainder of the course.

A review of literature reveals many instructional strategies designed to help teachers address the concepts of problem solving and/or disposition (Berryman, 1993; Cash et al, 1996; Collins et al, 1991; Jonassen, 1997). However, there is lack of research that combines the two. In addition, some of these strategies lend themselves better toward a specific discipline. Because problem solving skills are found in all curricular areas, it is important to approach the teaching of problem solving skills more generically.

Formal, prescriptive schooling is still the primary method of instruction within our public schools. While formal schooling works for teaching conceptual and factual knowledge, it falls short when teaching complex cognitive skills.

> To teach to complex skills associated with problem solving one can look to elements of the behaviorist and constructivist learning theories. Constructivist learning theory focuses on the student rather than the subject. Learning is accomplished through experience and is individualized. (Wager, 1997, para. 5)

One method that is based in constructivist theory is that of cognitive apprenticeship. Where prescriptive methods are geared toward rote application of method, the goal of cognitive apprenticeship is to make thinking processes visible to the learner while supporting the learner's growth through scaffolding.

A review of literature reveals that learners need more than methods for solving problems, they need guidance as well (Woods, 1998; Woos et al, 1997). Cognitive apprenticeship shows promise as a model for enhancing both problem solving skills, as well as, disposition toward problem solving. The modeling, coaching, and fading paradigm of cognitive apprenticeship has proven successful in various domain areas (Berryman, 1993; Cash, 1996; Collins, Brown, and Holum, 1991; Duncan, 1996; Snyder, Farrell, & Baker, 2000).

Through <u>modeling</u> learners see expert problem solving technique in a realistic context. During the <u>coaching</u> phase, learners receive guidance through the problem solving process while they attempt to solve open-ended problems. These two phases create the necessary scaffolding to support the <u>fading</u> phase, where learners independently solve problems. By facilitating proper technique and supporting new learning, learners not only gain skill, their disposition toward the new learning is enhanced.

Purpose of the Study

This study was in reaction to the lack of substantial research that would provide practical guidance to the classroom teacher in the area of teaching problem solving skills (Foster, 2001; Oliver, 1999). The intent is to validate assumptions about the direct teaching of problem solving skills while finding an instructional strategy that would not only enhance problem solving performance, but would also improve a students disposition toward problem solving. This instructional strategy needed to be easy to implement and for the teacher to adapt to if the findings were to have the hope of being the practical guidance it was meant to provide.

The purpose of "Enhancing Problem Solving Disposition, Motivation and Skills through Cognitive Apprenticeship" is to test the theory that through the cognitive apprenticeship paradigm of modeling, coaching, and fading, students' problem solving disposition, motivation and performance will improve significantly over traditional methods of teaching problem solving.

Research Questions

This study addressed three major questions:

1- What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on disposition toward problem solving?

2- What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on problem solving motivation?

3- What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on technological problem solving performance?

Assumptions

The following assumptions were made about this study and the circumstances around it.

1. The teachers participating in the study followed the guidance and lesson plan provided.
2. The guidance and lesson plan materials were understood by the participating teachers and they had the skills to carry out the procedures therein.
3. The participating teachers did not collaborate with one another regarding the study content during the study.
4. The treatment and control group teachers were at a similar proficiency level with regard to disposition and ability to teach problem solving.
5. The instruments used to collect the data were understood by the students and honestly completed.
6. The measures of the pre test and post test were reliable and valid.

Limitations

The study was conducted under the following limitations:

1. The treatment and control teachers were both from the same school. Therefore they had access to each others classroom.
2. The students involved in the study were both from a Fundamentals of Technology class, but could have had previous experience in technological problem solving.

Delimitations

1. The treatment and control group sessions were staggered by one-week and occurred at different times of day.
2. The treatment and control samples were from the same district; therefore, had similar educational, environmental experiences.
3. The length of time for the study was limited to 10 class session, 55 minutes in length.
4. The curriculum materials used were designed specifically for each group and provided at the beginning on the study.
5. The project materials used to solve the technological problem were provided.

Definition of Terms

CM3 – California Measure of Mental Motivation – Measures the degree to which an individual is cognitively engaged and mentally motivated.

Cognitive Apprenticeship - Cognitive apprenticeship is a pedagogical model developed within the situated learning paradigm. The model is inspired by the apprentice-master model of traditional crafts but it is adapted to "cognitive" or intellectual domains.

Control Group – Those students whose technology education teacher uses traditional teaching methods for teaching problem solving

Disposition – Attitudes, values and inclinations

D.E.A.L. Problem Solver – An adaptation of the IDEAL Problem Solver - Identify problems and opportunities, Define goals, Explore all possible strategies, Anticipate outcomes and Act, and Look back and Learn.

Problem Solving – "An adaptive process in which knowledge and skill are applied to move toward a goal"(Cote, 1984, p.18).

Scaffolding - providing learners with support at the appropriate levels and time.

Technological Problem Solving – A systematic technological method of seeking solutions to technological problems that requires the application of technology.

Treatment Group - Those students whose technology education teacher uses cognitive apprenticeship model to teach problem solving.

Summary

Making education real and relevant is not a new phenomenon. Trying to improve student's problem solving and critical thinking skills has long been a goal of education. Francis Parker (1894) and John Dewey (1916) spoke of guiding students through "real" problems at the turn of the century. Yet the teaching of problem solving skills is illusive and complex. Teaching these complex skills requires a new approach (Wager, 1997). Traditional, teacher-directed learning does not adequately address the issue. We must move aware from the notion of "learning-to know" and embrace the notion of "learning by doing".

Learning by doing is the cornerstone of technology education. The ultimate goal of technology education is to prepare students to make informed decisions about technology. By facilitating the problem solving and critical thinking process, technology educators can create technology manipulators. As cited in Technology for All Americans (1996, p.1), technology education "is about invigorating the entire educational system with high-interest, student focused content and methods…where learners become engaged in critical thinking as they design and develop products, systems, and environments to solve practical problems".

Finding an instructional method that will foster the development of problem solving skills while improving motivation and attitude toward problem solving was the goal of this research. Providing classroom teachers with practical information that they can use is imperative if we are to improve how we teach. The researcher sought to examine whether student problem solving performance and disposition toward problem solving would improve when the cognitive apprenticeship method was used.

CHAPTER TWO

LITERATURE REVIEW

The Nature of Teaching Problem Solving

What exactly is problem solving? What is involved in the process of problem solving? How do people naturally solve problems? What are we teaching when we say we are teaching problem solving? How can we develop better problem solvers? It is these and many other questions that we, as technology educators, need to ask ourselves. Cote (1984, p.19), when referring to industrial education, asked the question, "Is industrial education developing and deepening its understanding of human problem solving, and helping to generate answers to relevant questions about this type of learning in industrial education?" He asked this because, at the time, very little useful information on problem solving had been offered in the professional journals. He expressed concern because of what he defined as "prescriptive" methods of teaching problem solving.

Prescriptive instructional strategies aligned with the traditional, teacher-directed methods found in other disciplines. Teachers teach students how to solve problems by providing them with a method (e.g. the scientific method). "Follow these steps and all will be good." This prescriptive approach aims at <u>telling</u> people how to solve the problem and tends to assume that there is a method for all problems. The issue lies in that the method taught might have little to do with the mental processes a learner must perform to solve a particular problem. The method becomes the solution. Such a prescriptive view does not embrace the way people actually solve problems. (Cote, 1984; Hollingsworth & McLoughlin, 2000)

Cote's question is viable for technology education, as well. Recent movements in technology education would indicate that this prescriptive instructional strategy is quite prevalent. In researching recent articles on problem solving in technology education journals one finds a similar prescriptive emphasis. Likewise, included in the typical Technology textbook is invariably some publisher's "method" for problem solving. Cote was concerned that the "teaching" of problem solving is mere rhetoric, because technology educators rely so heavily on problem solving methods. Indeed, problem solving and problem solving methods have become part of the content of technology education. It might be that problem-solving methods are comfortable, they give structure to this enigmatic task; therefore, it is understandable that we use these frameworks. Perhaps it is an issue of assessment. If problem solving is treated like content we need only test students' knowledge and comprehension of the subject. Yet, is it the use of problem solving methods that is our shortcoming or is it that we are stopping at the method and not adequately addressing the mental processes used to solve problems? The problem solving process differs from method in that the process is the natural evolution of a solved problem. A problem solving method is a procedure used to map the steps to solve a problem. Although there is merit in the teaching of problem solving methods, this seems to have become an end unto itself.

Problem Solving Method

Jonassen (2000, p.67) defines problem solving as "finding the unknown entity in some situation where there is a difference between the goal state and the current state, and discovering the unknown must have value for someone". Cote (1984, p. 18) defines problem solving as "an adaptive process in which knowledge and skill are applied to move toward a goal". In technology education, this "adaptive process" is typically delivered to the students in the form of a method. Deluca (1992) outlines five historically used in technology education. They include:

1. Troubleshooting / Debugging - isolating the problem, identifying possible causes, testing, implementing a solution, and evaluating the solution.
2. Scientific Process - observation, develop a hypothesis, experiment, draw conclusions.
3. Design process - ideation/ brainstorming, identify possible solution, prototype, and final design.
4. Research and Development - conceptualize a project, determine a research procedure, finalize your research design, develop a proposal, conduct research, analyze the results, report the results, evaluate.
5. Project Management - identify the project goals, identify the tasks to reach the goal, develop a plan to accomplish the tasks, implement the plan, and evaluate.

In today's curriculum, one finds these methods taking the form of various packaged problem solving methods, like the D.E.A.L Problem Solver. The D.E.A.L. Problem Solver is an adaptation of the widely known IDEAL Problem solver which was designed to provide a framework for solving problems (Bransford & Stein, 1993). The components of the IDEAL Problem solver include:

1. Identify – Actively seek problems that require solutions (rarely taught)
2. Define - Represent the problem in order to obtain a clear picture of the problem prior to any solution attempts.

3. Explore - Generate and analyze alternative strategies that might deal with the problem.
4. Act - Select the best strategy and use it to attempt to solve the problem.
5. Look - Evaluate the value of the strategy in meeting the demands of the problem

These methods are viable approaches to solving specific problems. Though, by themselves, they fall short of preparing students to become problem solvers. The sole use of problem solving methods without addressing problem solving processes like “analysis, reasoning and other skills, students will continue to use superficial and formulaic approaches to solving problems” (Leonard, Gerace, & Dufresne, 1999, p. 14). In order to fully prepare students to be problem solvers and to adapt knowledge learned to a problem, it is necessary for technology educators to understand how students process and apply information and how best to facilitate this process.

Expert versus Novice Problem Solvers.

A comparison between expert and novice problem solvers helps to illustrate the gaps many students face. Wankat and Oreovicz (1993) offer a breakdown of expert and novice problem solvers.

Characteristic	Novices	Experts
Memory	Small pieces Few Items	“Chunks” or pattern ~50,000 items
Attitude	Try once and then give up Anxious	Can-do if persist Confident
Categorize	Superficial details	Fundamentals
Problem Statement	Difficulty redescribing Slow and inaccurate Jump to conclusion	Many techniques to redescribe Fast and accurate Take time defining tentative problem May redefine several times
Simple well-defined	Slow	~ 4 times faster

problems	Work backward	Work forwards with known procedures
Strategy	Trial and error	Use a strategy
Information	Don't know what is relevant Cannot draw inferences from incomplete data	Recognize relevant information Can draw inferences
Parts (harder problems)	Do NOT analyze into parts	Analyze parts Proceed in steps Look for patterns
First step done (harder problems)	Try to calculate (Do It step)	Define and draw Sketch Explore
Sketching	Often not done	Considerable time Abstract principles Show motion
Limits	Do not calculate	May calculate to get quick fix on solution
Equations	Memorize or look up detailed equations for each circumstance	Use fundamental relations to derive needed result
Solution procedures	"Uncompiled" Decide how to solve after writing equation	"Compiled" procedures Equation and solution methods are single procedure
Monitoring solution progress	Do not do	Keep track Check off versus strategy
If stuck	Guess Quit	Use Heuristics Persevere Brainstorm
Accuracy	Not concerned DO NOT check	Very accurate Check and recheck
Evaluation of result	Do not do	Do from broad experience
Mistakes or failure to solve problems	Ignore it	Learn what should have done Develop new problem solving methods
Actions	Sit and think Inactive Quiet	Use paper and pencil Very active Sketch, write questions, flow paths, Subvocalize (talk to selves)
Decisions	Do NOT understand process No clear criterion	Understand decision process Clear criterion

Johnson (1994) offers additional insight into the problem solving process used by expert and novice problem solvers. His conclusion was that expert problem solvers and novices differ mostly in the way they approached a problem. Because of their vast knowledge of the subject matter, experts quickly identified possible problems. Novices tend to be guided be their senses. Novices also tend to "jump into a problem without thinking, rely on weak strategies, and lean toward one favorite problem-solving strategy." Teaching students the vast knowledge equal to that of an expert is not a realistic approach (Johnson & Thomas, 1994). However, knowing where students are and where we want to build their skills is powerful information that a teacher can use to guide the through problems. Doing this would help build a strong foundation in the process of problem solving (Berryman, 1991; Cash, 1993; Duncan, 1996; Fiscbach, 1993).

Donald Woods suggests that problem solving should be taught as a skill if we are to enhance the overall problem solving ability of our students, "think of problem solving as a discipline that has its own tacit knowledge" (Woods, 1987). Students need to become aware of the processes necessary to solve problems (meta-cognition and reflection). When students become aware of these processes, problem solving behavior slowly becomes automated to the point where they no longer need to consciously think about them (Johnson, 1988).

Natural Process over Product

Historically, technology educators have emphasized the product of problem solving over the process used to arrive at the solution. By becoming aware of the natural process of solving problems, we can guide our students to better understanding of how they solve problems. Providing a solid base knowledge is not enough, the tools to retrieve that knowledge and apply it to a given situation have to be provided. The methods we are presently using to teach problem solving skills have limited effect on the ability to adapt these methods to other areas than those posed in a given problem (Wood, 1993). Problem solving should be taught in a general context so that it can be applied to a variety of situations. In order to accomplish this we must guide them through the use of problem solving strategies like organizing knowledge, building on prior knowledge, facilitating problem finding skills, facilitating "deep thinking", and hindsight analysis. (Johnson and Thomas, 1994).

Organizing Knowledge

Johnson and Thomas (1994) state that the "key to competent performance lies in the organization of a person's knowledge." The mind can only store a finite amount of information; therefore, it becomes necessary for us to organize the vast amount of knowledge we have. To adequately solve a problem, one must have a strong base knowledge in the particular subject (Woods, 1987) and must be able to retrieve that base knowledge and apply it to a given situation (Deluca, 1992). This process of base knowledge and retrieval are essential in identifying the problems to be solved. Research indicates that expert problem solvers tend to store knowledge in bundles of information. Johnson and Thomas (1994) cite a study done comparing expert and novice electronic technicians.

In this study, expert and novice subjects were briefly shown drawings of electrical circuits and were asked to reconstruct the drawings from memory. When presented with circuit drawings of actual devices, the experts, as expected, were able to recall significantly more than the novices were. However, when shown drawings of random illogical placement of electrical components in a circuit, the experts performed no better than the novices did. This study suggests that the memory of expert electronic technicians is based on conceptual patterns that enable them to recall portions of a drawing as a group of information (i.e. amplifier circuit, tuner circuit, etc.) rather than as individual components.

This grouping of knowledge is a process that can be taught to students through the use of concept mapping and outlining information. In addition, having the students create concept maps of problems they must solve will, in turn, foster organization of knowledge. If the breakdown of the subject area can be put into a conceptual framework, students will have a better chance for understanding the subject matter. Johnson and Thomas (1994, p.38) cite the advantage of using conceptual diagrams over schematic diagrams. They concluded that:

> ... students often lack the ability to fully comprehend the abstract diagrams and have difficulty understanding the systems. When instructors provide simple conceptual diagrams of the systems being taught, students can gain a conceptual understanding of the system more quickly and accurately.... Students who learn from conceptual diagrams possess fewer misconceptions about the relationship between components within the system.

Thinking skills

After conceptualizing the subject, students can be guided through organization of specific areas of the subject. In order for educators to provide this guidance, they must become familiar with how the mind naturally stores information. Taking raw information and organizing it for later retrieval is the process of thinking. Deluca (1992, p. 26) outlines Presseisen's work on thinking processes as follows:

1. Qualification - finding unique characteristics, definitions, facts, problem recognition
2. Causation - establishing cause and effect, predictions, judgments, evaluations

3. Transformation - relating known and unknown characteristics, creating meanings
4. Relationships - detecting regular operations: parts and wholes, patterns, sequence and order, logical deduction
5. Classification - determining common qualities: similarities and differences, grouping and sorting

With knowledge of the subject area and guidance of how to store information, students will be better prepared to apply this gained knowledge.

Building on Prior Knowledge

When presenting a problem to be solved there is undoubtedly new information that the students must possess. The conceptual organization of this information provides a structure. This structure, in turn, will put the problem into context. It is easier to understand new information if it is put in a familiar context. For example, learning about how a computer works with the use of the on / off devices of binary code would be a complex issue. Comparing binary code to something that is familiar would help to make the complex issue easier to understand. Binary code works much like a switch, the 1's mean the switch is "on" -- the 0's mean the switch is "off". If a comparison was made the complex would be simplified and the student would be able to recognize the relationship between the two. Once the relationship was made all the information concerning binary code would be grouped in the mind under a simple identifier for easy retrieval.

Facilitating Problem Finding Skills

Before true problem solving can occur, identification of the problem must occur. Woods (1993) alluded to this need for identifying problems. With the speed at which new knowledge is being generated and the rate at which our society is changing, problem finding and problem solving are essential skills if we are to expect our students to be successful.

According to writers within the field of technology education, problem finding skills are not adequately being addressed in technology education (Petrina, 1994). For problem finding to occur, students must have a strong foundation of knowledge about the subject and must be able to view the problem from a Gestalt perspective (Johnson, 1988). A method for creating this perspective might be reciprocal teaching. In reciprocal teaching the instructor models the appropriate problem finding behavior by asking questions, conceptualizing the scope of the problem, identifying possible key areas of concern, verbalizing methods for addressing those concerns, and beginning to make a plan of action. This represents the first phase of cognitive apprenticeship – modeling. Through this method, students become more aware of those processes and slowly begin to use them independent of the teacher (Johnson & Thomas, 1994).

Facilitating "Deep Thinking"

The process of problem solving is a complex entity. Research shows that the use of a group or team approach helps to simplify its complexity. In groups or teams students are less likely to become overwhelmed and can learn from each other. "Cooperative learning techniques such as peer tutoring or paired problem solving (in which one students thinks aloud during the process of solving a problem) makes students aware of their own thinking processes" (Kerka, 1992, p.7). Through this " thinking aloud" technique, students can generate questions, offer explanations, and build on each other's knowledge. The result is a more informed and aware student. Johnson and Thomas (1994) cite Brown who stated that "the ability to monitor ones own understanding ... is an essential pre-requisite for all problem solving ability."

Hindsight Analysis

After the completion of a particular problem it is important that the students realize their experience was not an isolated one. What they learned from the present experience will aid them in future problems to solve. Research supports the use of "hindsight" analysis to facilitate this retrieval. By using hindsight to examine past performance, they can recognize their own mistakes and pinpoint the misconceptions that caused the errors. In this way, hindsight improves future performance (Johnson & Thomas, 1994). Since we are only able to recall information that is in our short-term memory, the use of hindsight for the express purpose of plotting the problem solving process has limited use (Johnson, 1988). The intent is that students can reflect upon the whole process outlining successes and failures that will serve as their repertoire for future experiences (Johnson & Thomas, 1994).

Getting to the root of the sub-skills associated with problem solving is essential not only for the teacher but for the student as well. Better understanding problem solving processes with allow teachers to pinpoint areas that need attention. Becoming aware of these elements will help facilitate meta-cognition for the students. Knowing and honing the problem solving sub-skills is the first step. Perhaps an even more importance influencer of successful problem solving is that of one's motivation to solve the problem.

The Importance of Affect

Attitudes and disposition have historically not been considered in problem solving research (Pugalee, Douville, Lock, & Wallace, 2003). However, successful problem solving depends of three components – skill, meta-skill, and will (Mayer, 1998). Gourgey (1998) asserts the effective support of meta-cognitive skills requires an interaction between cognitive, meta-cognitive, and affective components of learning. Teachers must recognize this and design instruction that acknowledges this interplay.

By addressing problem solving skills, teachers expose students to the processes used during a problem solving activity, but teaching skills alone is not enough. To fully prepare a student for the unstructured, sometimes very frustrating nature of problem solving one must address the affective side to the process. This affective side can be summed-up as one's disposition and motivation toward problem solving. Dewey (1933, p.34) recognized the importance of disposition by noting, "If we were compelled to make a choice between these personal attributes and knowledge about the principles of logical reasoning together with some degree of technical skill in manipulating special logical processes, we should decide for the former." Problem solving competency involves knowledge, skills and attributes working in concert with one another. Of these elements one's disposition and motivation toward problem solving are intangible factors that carry great weight in the total process of a problem solved.

This leads one to consider - What factors affect disposition? Can we isolate and address these factors to enhance a positive disposition toward problem solving? What can be done to create an environment that promotes a positive disposition toward problem solving?

Before we can answer these questions, it is necessary to identify the components of disposition as they relate to problem solving and critical thinking. Peter Facione's research in the area of disposition produced seven habits indicative of disposition toward critical thinking: Inquisitiveness, Open-mindedness, Systematicity, Analyticity, Truth-seeking, CT Self-confidence, and Maturity (Facione, Giancarlo, Facione,& Gainen, 1995). Facione's seven habits are based on a two-year Delphi study completed by the American Philosophical Association (1990, p.3) that resulted in defining "the ideal critical thinker".

> The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking information, reasonable in selection of criteria, focused in inquiry, and persistent in seeking results which are precise as the subject and circumstances of inquiry permit.

Facione's seven habits are discipline neutral and can be interpreted across all subject areas. Facione describes the seven habits as follows:

1. Inquisitiveness - one's intellectual curiosity and one's desire for learning even when the application of knowledge is not readily apparent.
2. Open-mindedness - being tolerant of divergent views and sensitive to the possibility of one's own bias
3. Systematicity - being organized, orderly, focused and diligent in inquiry

4. Analyticity - prizing the application of reasoning and the use of evidence to resolve problems, anticipating potential conceptual or practical difficulties, and consistently being alert to the need to intervene
5. Truth-seeking - being eager to seek the best knowledge in a given context, courageous about asking question, and honest and objective about pursuing inquiry even if the findings do not support one's self-interests or one's preconceived opinions
6. CT Self-confidence - trusting the soundness of one's own reasoned judgments and to lead others in the rational resolution of problems
7. Maturity - one who approaches problems, inquiry, and decision making with a sense that some problems are necessarily ill-structured, some situations admit of more than one plausible option, and many times judgments must be made based on standards, contexts and evidence which preclude certainty.

Knowing the students' dispositional makeup would help inform teachers of the students strengths and weaknesses; thereby, offer further insight to use when creating an appropriate learning environment that will foster a positive disposition toward problem solving.

Atkinson (1999) addressed the issue of disposition and motivation in her study "Key factors influencing pupil motivation in Design and Technology". By addressing perhaps the more illusive issue of motivation, Atkinson rounds-out the affective factors associated with problem solving. In fact, additional considerations affecting disposition are introduced when considering motivation. To accurately assess a student's motivation one must also consider the teacher's motivation as well as the learning environment. Atkinson's study centers on the use of a prescriptive approach to teaching Design and Technology (D&T) in England, where

D&T is a part of the compulsory education and is assessed yearly by the state. Atkinson examined the relationship between internal and external factors: pupil performance and skills in D&T project work, goal orientation, cognitive style, and creativity, as well as, teacher strategy and motivation.

Atkinson found a significant relationship between teacher motivation and student's motivation. Not surprisingly, poor teacher motivation resulted in poor student motivation. Atkinson attempted to analyze the origin of the poor teacher motivation and concluded that it was the result of the pressures of the national assessment and the deadlines associated with it. She felt that teacher perceived that control of their classrooms was being taken away due to the prescribed approach mandated. This lack of control created not only poor teacher motivation, but also prompted teachers to seek control elsewhere. In most cases, teachers regained control by taking control of student projects. This, in turn, stripped ownership of the project away from the students and induced student frustration and apathy. Her suggestions include taking a holistic approach to assessment "that will encourage the use of more appropriate, flexible, design process models" and for teachers to "develop strategies that will enable them to guide pupils through the process in a partnership where ownership is a joint affair." To achieve this, Atkinson goes on to say "teachers need to develop a far deeper understanding of the activity involved." This argument further supports the argument outlined in the previous chapter calling for teachers needing to fully understand the processes involved in problem solving and how to facilitate those processes.

Attitudes (dispositions) toward success and failure have a significant bearing upon motivation for both teacher and learner (Atkinson, 1999), creating an environment that supports the growth of learners is an essential ingredient in the recipe for successfully enhancing problem solving ability.

Facione, Facione and Giancarlo (1997) summarize their suggestions for a nurturing learning environment by recommending:

1- Cultivate a culture of reasoned thinking and evidence-based inquiry. Teachers should avoid "recipe-bound" approaches.

2- Replace rote training with thoughtful mentoring. This involves guiding learners through the process "asking probing questions, demanding understandable explanations, questioning untested assumptions and, at times, letting people make mistakes which they can fix themselves." Understanding your mistakes and how to avoid them in the future is essential. It is a form of meta-cognition. Learners rarely forget such mistakes. But it is important, however, that these mistakes are fixable. A good guide will not let the learner proceed down a path that is futile. If mistakes are made in this case, frustration and apathy are the result.

3- Present information from the bottom-up. Most people learn on the job or in school through the specific, not by the general. Teachers should take advantage of this, by not beginning with the basic, but with examples that are engaging and that address the target skills. This approach will then motivate the learners to seek information and the underlying principles on their own. Using case studies would help accommodate this strategy. In such cases, one could show best-case and worst-case scenarios. These scenarios will later serve as needed schema for future knowledge and experience.

4- Evaluate processes, not results only. In order for learners to fully understand the processes involved, they must be made aware of the processes used. In order to do this they must reflect on strategies that they used. This data should then be discussed to analyze what worked and where gaps are present. If you do not analyze the data, learners are merely performing an exercise and are doomed to repeat mistakes made.

5- Expect and reward virtue. Often overlooked when discussing teaching critical thinking, "internal motivation to be inquisitive, organized, analytical, judicious, tolerant, and intellectually honest is an intellectual virtue." Express to the learners your expectation of these skills being life-long skills. However, although being virtuous brings with its own intrinsic rewards, teachers should take this opportunity to make it known to the learners that the ability and willingness to think will bring other rewards as well.

Further support for such an environment can be found in expert versus novice problem solving research. Experts and novices exhibit similar kinds of emotional reactions during problem-solving, but experts handle them better (McLeod, Craviotto & Ortega, 1990). Recently, DeBellis and Goldin (1997) have considered the influence of values, i.e., one's psychological sense of what is right or justified, on problem solving. For example, some students may feel they "should" follow established procedures when tackling problems, whereas others may value originality and self-assertiveness. Good problem solvers exhibit productive responses to insufficient understanding, while others(novices), not wanting to admit deficiencies in their problem solving ability, may feel they "should" know how to solve a given problem and this may lead them to guess or use plausible, but inappropriate, procedures.

Pugalee et al (2002) reference DeBellis and Goldin in noting that "beliefs, attitudes, emotions, and values interplay with cognition and as such can either facilitate or hinder monitoring during problem solving. While emotions are more temporary, the others have more stability serving as self-regulating structures. Affective pathways are either positive or negative and impact problem-solving behavior". For example, if a positive pathway is invoked at the onset of problem solving, curiosity may motivate the solver to better understand the problem and lead to exploratory heuristics; frustration at a subsequent impasse can cause a revision of strategies. If a negative pathway is invoked, bewilderment can led to a search for "safe" procedures, rather than exploration; when these fail, frustration may lead to anxiety and reliance on authority or avoidance.

Learning environment plays a key role in facilitating positive disposition and motivation. Creating a learning environment that promotes exploration and support provides the non-threatening atmosphere needed to build confidence. Without the willingness and confidence to tackle problems, teaching problem solving skills and methods would be meaningless. The students must be open to the complex and sometimes frustrating nature of problem solving. Creating this type of nurturing learning environment requires teachers to balance the cognitive and affective elements of problem solving.

Instructional Design and Strategies

Orchestrating these elements of methods, skills, sub-skills and disposition is what makes up the instructional design and strategy. Finding a balance that will not only enhance skill but will also positively affect disposition is the goal. "Within business as well as schools and homes the cultivation of a culture which encourages thinking and honest inquiry is essential" (Facione, Facione & Giancarlo, 1997). These researchers argue that guiding workers and students to use their thinking skills more effectively will help motivate individuals toward critical thinking without compromising content.

Jonassen & Tessmer (1996) state that teaching problem solving requires teachers to grapple with and balance a host of complex skills that bridge multiple domains. Problem solving encompasses:

1. Domain knowledge - information, concepts, rules and principles
2. Structural knowledge - information networking, semantic mapping, conceptual networking, and mental models
3. Meta-cognitive skills - goal setting, allocating cognitive resources, assessing prior knowledge, progress/error checking
4. Motivational/Attitudinal components - exerting effort, persisting on a task, engaging intentionally
5. Knowledge about self - articulating prior knowledge, articulating socio-cultural knowledge, articulating personal strategies, and articulating cognitive prejudices and weaknesses

Sprinthall, Sprinthall, and Oja (1994) came to a similar conclusion when addressing the issue of teaching high-order thinking and understanding. They point out that there are a number of approaches to fostering students' higher-level thinking. "All include some balance of focus on the following components: (1) in-depth knowledge of a subject or topic (Glaser, 1984; Prawat, 1991), (2) critical thinking skills (Beyer, 1987; Perkins and Salomon, 1988), (3) dispositions of thoughtfulness (Sizer, 1992); Perkins, Jay, and Tishman, 1992)."

Facione suggests "the fundamental strategy … is to balance nurture with challenge while directing the learner toward the next most achievable area for development." This notion of "scaffolding" is the backbone to many strategies designed to improve critical thinking and problems solving skills. Rosenshine and Meister (1992) outlined suggestions on how to use scaffolds to teach higher-order cognitive strategies. They suggest six strategies outlining the genesis of acquiring a new skill:

1. Present the new cognitive strategy
    a) Introduce the concrete prompt
    b) Model the skill
    c) Think aloud as choices are made
2. Regulate difficulty during guiding practice
    a) Start with simplified material and gradually increase the complexity of the ask
    b) Complete part of the task for the student
    c) Provide cue cards
    d) Present the material in small steps
    e) Anticipate student errors and difficult areas
3. Provide varying contexts for student practice
    a) Provide teacher-led practice
    b) Engage in reciprocal teaching (instructor models the appropriate problem solving behavior)
    c) Have students work in small groups
4. Provide feedback

a) Offer teacher-led feedback

b) Provide checklists

c) Provide models of expert work

5. Increase student responsibility

a) Diminish prompts and models

b) Gradually increase complexity and difficulty of the material

c) Diminish student support

d) Practice putting all the steps together (consolidation)

e) Check for student mastery

6. Provide independent practice

a) Provide extensive practice

b) Facilitate application to new examples

These "scaffolds are forms of support provided by the teacher (or another student) to help students bridge the gap between their current abilities and the intended goal" (Collins, Brown, and Newman, 1989).

Donald Woods (1998) discusses a similar approach listing four basic steps in the process: Tell, Build, Bridge, and Extend. Tell the students results from research that identifies the target skills and attitudes. Use reflection and prompt feedback often and throughout the activity. Build the process skill in a subject-independent domain. Bridge the skill by applying it to a subject domain. Extend the skill by requiring students to reflect on how they use the skill in everyday life. Woods outlines in detail thirteen elements that help create this nurturing environment in the McMaster Problem Solving program:

1. Define target skill. All students want a clear idea of the skill they are learning.

2. Provide a rationale as to why the acquisition of this skill is important for their life.

To motivate, students want to know why this skill or attitude is important for them

3. Give a brief reflective pretest of their current awareness and skill with the target skill.

This is extremely important to capture the student's initial thoughts about their skill. This helps them to see progress and helps develop their confidence. Concentrating on "awareness" and "skill" are sufficient.

4. Read the learning objectives for the unit.

The behavioral objectives are the key to skill development. Behavioral objectives about the skills are needed for assessment and to develop understanding.

5. Explain where the skill fits into the larger context.

Provide the students with an appreciation of where this particular target skill fits into the overall skill. For example, where does "creativity" fit into the skill of "problem solving"?

6. Provide the route ahead for the unit.

This lists the activities in the rest of the lesson and provides the student advanced organizers.

7. Building activities with feedback and reflection.

The students now do activities and receive prompt feedback about their performance. After each activity, students should reflect on what they learned from the way they performed the skill. Try to select a context that is known by all.

8. Summarize research about how successful people use and apply the target skills.

Once the students have sampled the skill and received feedback, draw on the "novice" versus "expert" research evidence to describe the performance of the expert or successful person.

9. Bridging activities with feedback and reflection.

Give students opportunities to repeat the skill and incorporate and internalize the "expert" behavior in their subject domain reflecting throughout.

10. Brief reflective posttest of awareness and skill.

This is a revisit of element #3. Now that the unit is almost complete students reflect on how they have changed in awareness and skill.

11. Check that the objectives have been achieved.

In element #4, learning objectives were considered for the unit. Here these are revisited. Students use evidence collected from the lesson to rate the degree to which they have achieved the objectives.

12. Discovery.

The teacher can either summarize the Unit or can ask students to list what they have discovered and how they will apply that information/skill. Have the students summarize. This may take longer, but it provides feedback about the main ideas they experienced.

13. Extend

Require the students to keep a daily journal describing evidence of when they applied the skill in other situations and in everyday life. The journal should focus on the skills from the current unit. However, the application of previously acquired skills should also be included. This elaboration helps develop confidence and integrate the skills.

The McMaster program typifies the notion of scaffolding that is found in many problem solving instructional strategies in an addition to providing a practical approach to building and delivering learning. A review of like problem solving strategies reveals that most are based on cognitive and constructivist learning theory. However, to address the affective elements of problem solving one must infuse social/behaviorist learning theory elements as well.

Of the strategies reviewed, cognitive apprenticeship embodied the key elements of cognitive, meta-cognitive and dispositional components as well as aligned well with technology education. A review of literature reveals that cognitive apprenticeship shows promise as a model for enhancing both problem solving skills, as well as, disposition toward problem solving (Collins, Brown, & Holum, 1991). Cognitive apprenticeship combines cognitive and social learning theories with traditional apprenticeship to provide a framework for educators that will help guide students through the problem solving process in a nurturing learning environment.

Cognitive Apprenticeship

In 1989, Collins, Brown and Newman developed an alternative pedagogical method that combined the traditional apprenticeship model with situated cognition theory. They called their model *cognitive apprenticeship*. Situated Cognition suggests skills be acquired through authentic context and by working with peers and experts. The cognitive apprenticeship model provides practical steps for applying the Situated Cognition Theory. Students learn more effectively through observing experts and working on authentic tasks so that they can apply what they have learned into the real world situation. Cognitive apprenticeship model sets out to:

1. Identify the problem solving and critical thinking processes and make them visible to the students.

2. Situate abstract tasks in authentic contexts
3. Vary the diversity of situations and *articulate* the common aspects so as to increase the potential for transfer

The Collins-Brown model of cognitive apprenticeship incorporates the following instructional strategies or components.

1. *Content: Teach tacit, heuristic knowledge as well as textbook knowledge.* Collins et al. (1989) refer to four kinds of knowledge:

    a. Domain knowledge -- The conceptual, factual, and procedural knowledge typically found in textbooks and other instructional materials. This knowledge is important, but often is insufficient to enable students to approach and solve problems independently.

    b. Heuristic strategies - "Tricks of the trade" or "rules of thumb" that help people narrow solution paths while solving a problem. Experts usually pick up heuristic knowledge indirectly through repeated problem-solving practice; slower learners usually fail to acquire this subtle knowledge and never develop competence. There is evidence to believe, however, that at least some heuristic knowledge can be made explicit and represented in a teachable form (Chi, Glaser, & Farr, 1988).

    c. Control strategies -- Required for students to monitor and regulate their problem-solving activity. Control strategies have monitoring, diagnostic, and remedial components; this kind of knowledge is often termed *meta-cognition* (Flavell, 1979).

d. Learning strategies -- Strategies for learning; they may be domain, heuristic, or control strategies. Inquiry teaching to some extent directly models expert learning strategies (Collins & Stevens, 1983).

2. *Situated learning: Teach knowledge and skills in contexts that reflect the way the knowledge will be useful in real life*. Brown, Collins, and Duguid (1989) argue for placing all instruction within an "authentic" context that mirrors real-life problem-solving situations. Collins (1991) is less forceful, moving away from real-life requirements and toward problem-solving situations. For teaching math skills, situated learning could encompass settings "ranging from running a bank or shopping in a grocery store to inventing new theorems or finding new proofs. That is, situated learning can incorporate situations from everyday life to the most theoretical endeavors" (Collins, 1991).

   Collins cites several benefits for placing instruction within problem-solving contexts:

   - Learners learn to apply their knowledge under appropriate conditions.
   - Problem-solving situations foster invention and creativity.
   - Learners come to see the implications of new knowledge. A common problem inherent in classroom learning is the question of relevance: "How does this relate to my life and goals?" When knowledge is acquired in the context of solving a meaningful problem, the question of relevance is at least partly answered.
   - Knowledge is stored in ways that make it accessible when solving problems. People tend to retrieve knowledge more easily when they return to the setting of

its acquisition. Knowledge learned while solving problems gets encoded in a way that can be accessed again in similar problem-solving situations.

3. *Modeling and explaining: Show how a process unfolds and tell reasons why it happens that way*. Collins (1991) cites two kinds of modeling: modeling of processes observed in the world and modeling of expert performance, including covert cognitive processes. Collins stresses the importance of integrating both the demonstration and the explanation during instruction. Learners need access to explanations as they observe details of the modeled performance. Collins suggests that truly modeling competent performance, including the false starts, dead ends, and backup strategies, can help learners more quickly adopt the tacit forms of knowledge alluded to above in the section on content. Teachers in this way are seen as "intelligent novices" (Bransford et al., 1988). By seeing both process modeling and accompanying explanations, students can develop "conditionalized" knowledge, that is, knowledge about when and where knowledge should be used to solve a variety of problems.

4. *Coaching: Observe students as they try to complete tasks and provide hints and helps when needed*. These principles of coaching can be implemented in a variety of settings. Bransford and Vye (1989) identify several characteristics of effective coaches:

    - Coaches need to monitor learners' performance to prevent their getting too far off base, but leaving enough room to allow for a real sense of exploration and problem solving.

    - Coaches help learners reflect on their performance and compare it to others'.

- Coaches use problem-solving exercises to assess learners' knowledge states. Misconceptions and “buggy” strategies can be identified in the context of solving problems.

- Coaches use problem-solving exercises to create the "teachable moment."

5. *Articulation: Have students think about their actions and give reasons for their decisions and strategies, thus making their tacit knowledge more explicit.* Think-aloud protocols are one example of articulation. Collins (1991) cites the benefits of added insight and the ability to compare knowledge across contexts through the uses of such approaches. If learners' tacit knowledge is brought to light, that knowledge can be recruited to solve other problems.

6. *Reflection: Have students look back over their efforts to complete a task and analyze their own performance.* Reflection is like articulation, except it is pointed backwards to past tasks. Analyzing past performance efforts can also influence strategic goal-setting and intentional learning (Bereiter & Scardamalia, 1989). Collins and Brown (1988) suggest four kinds or levels of reflection:

   - *Imitation* occurs when a batting coach demonstrates a proper swing, contrasting it with your swing;

   - *Replay* occurs when the coach videotapes your swing and plays it back, critiquing and comparing it to the swing of an expert;

- *Abstracted replay* might occur by tracing an expert's movements of key body parts such as elbows, wrists, hips, and knees, and comparing those movement to your movements;
- *Spatial reification* would take the tracings of body parts and plot them moving through space.

The latter forms of reflection seem to rely on technologies--video or computer-- for feasible implementation.

7. *Exploration: Encourage students to try out different strategies and hypotheses and observe their effects*. Collins (1991) claims that through exploration, students learn how to set achievable goals and to manage the pursuit of those goals. They learn to set and try out hypotheses, and to seek knowledge independently. Real-world exploration is always an attractive option; however, constraints of cost, time, and safety sometimes prohibit instruction in realistic settings. Simulations are one way to allow exploration; hypermedia structures also allow exploration of information.

8. *Sequence: Present instruction in an ordering from simple to complex, with increasing diversity, and global before local skills.*

   - *Increasing complexity*. Collins et al. (1989) point to two methods for helping learners deal with increasing complexity. First, instruction should take steps to control the complexity of assigned tasks. They cite Lave's study of tailoring apprenticeships: apprentices first learn to sew drawers, which have straight lines, few pieces of material, and no special features like zippers or pockets. They progress to more complex garments over a period of time. The second method for controlling complexity is through scaffolding. Here the cases or content remains complex, but the instructor provides the needed scaffolding for initial performances and gradually fades that support.

- *Increasing diversity* refers to the variety in examples and practice contexts.
- *Global before local skills* refers to helping learners acquire a mental model of the problem space at very early stages of learning. Even though learners are not engaged in full problem solving, through modeling and helping on parts of the task (scaffolding), they can understand the goals of the activity and the way various strategies relate to the problem's solution. Once they have a clear "conceptual map" of the activity, they can proceed to developing specific skills.

The modeling, coaching and fading paradigm of cognitive apprenticeship relies heavily on this notion of scaffolding. Scaffolding provides learners with support at the appropriate levels and at the right time. The support can take the forms of suggestions or direct help (Feng-Kwei & Curtis, 2001). When the student can work on the task themselves, then the support should fade out. Or, the instructor can give the student a more difficult task and support the student on working on it.

During the modeling phase, the instructor shows students how to complete a task or solve a problem while verbalizing the process taken. This differs from typical school instruction because it is delivered within context of real world situations. Through modeling, students see, in real time, an expert problem solver solving a problem. It is important that the problem the instructor is solving is similar to the problem the students will solve. By modeling the desired intellectual process, students will discover that there are many ways to solve problems, that experts make mistakes, and that seemingly simple problems are very complex in the real world (Johnson, 1992).

After modeling the desired processes, teachers need to become coaches. This entails observing students while they are working, offering immediate feedback and sometimes providing hints or assistance if needed. In doing so, however, teachers must not take control of the problem. Students need to maintain ownership (Atkinson, 1999). As the students become more confident in their ability and more accomplished with their cognitive skills, less and less teacher intervention is necessary.

Within the cognitive apprenticeship model, the primary components of modeling, coaching and fading address the micro-scaffolding needed for development, but additionally there must exist macro-scaffolding. This means increasing complexity and diversity in lesson sequences (Johnson, 1992). All of this must exist within an environment that promotes intrinsic motivation, cooperation and competition (Collins, Brown, & Newman, 1989). What Johnson is referring to is creating a curriculum that supports year over year development with problem situations growing increasingly more complex as the learner progresses through the curriculum.

Prince and Hoyt (2002) support a similar approach in their proposal to create a curriculum that develops problem solving skills over the course of three years. Students would traverse through Introductory, Intermediate and Advanced levels of problem solving. The table below illustrates the staged levels of problem solving:

Course Level	Definition	Example	Bloom's Taxonomy
P1: Introductory Problem Solving	Recognition and application of routine algorithms	Calculate the heat flux through a wall of known composition	Knowledge, Comprehension, and Application
P2: Intermediate Problem Solving	Solution of poorly-defined problems requiring students to reformulate problem into a solvable form before applying algorithms	Determine why a room's heating system does not maintain a comfortable temperature	Analysis
P3: Advanced	Solution of open-ended, vaguely-defined problems requiring significant creativity. Comparing alternative design solutions.	Design a new heating system for a room that meets size and cost constraints.	Synthesis and Evaluation

Not that this staged approach would or should require three years to implement, or that each year would not contain elements of introductory, intermediate and advanced problem solving. This model merely contends that the focus within each year would reflect the scaffolding noted. This notion of macro-scaffolding is supported within the research on expertise. Due to the complex nature of problem solving skills and perhaps the cognitive maturation needed, it is unrealistic to think that educators can take learners from novice problem solvers to being expert during the span of one course let alone one unit. But growth can and will occur with each iteration if this growth is planned and nurtured. Because of the nature of technology education, technology educators have a unique opportunity to integrate macro-scaffolding or staged problem solving within the total technology education curriculum. The social and cognitive elements of cognitive apprenticeship offer both the micro and macro scaffolding needed to facilitate long-term growth for successful problem solving whether applied to a unit, course or curriculum.

Summary

In a typical classroom today, students are asked to reason about rules and laws determined by others, use common models and formulas, and resolve well-defined problems. This tends to produce fixed meaning which does not transfer well to new situations (Oliver, 1999). In contrast to this traditional approach consider a setting where students reason with unique models, act on authentic situations and resolve complex problems. This is the way most apprentices learn. It is more effective than the traditional approach because concepts "continually evolve with each new occasion of use, because new situations, negotiations, and activities inevitably recast it in a new, more densely textured form" (Brown, Collins & Duguid, 1989).

Problem solving and critical thinking involves complex skills that bridge multiple domains. The teaching of these complex skills does not suit the traditional instructional teacher-directed, content focused strategies found in schools today. Teachers must understand and facilitate the growth of problem solving skills and sub-skills. Learning environments must foster a non-threatening atmosphere that promotes a positive disposition and motivation toward problem solving. The review literature of presented theories about the nature of teaching problem solving, problem solving processes, the importance of the affective influence in problem solving, and instructional strategies teachers designed to enhance problem solving and critical thinking skills.

A common theme found within the literature points to a need to breakaway from traditional strategies for teaching problem solving. This teacher-directed, content driven paradigm leads students to blind application of formulas to well-defined problems presented out of context. Wager (1997, para. 5) describes the common criticism of tradition strategies is that these approaches are based in behaviorist learning theory and that there is an emphasis on lower level skills.

> This is often attributed to the reductionist (deconstructive) nature of behaviorist models to break complex skills into simpler component skills, and then to teach the component skills first (as opposed to addressing the complex skills first). The behaviorists talked of "shaping" behavior and "reinforcing "successive approximations" to a goal. One criticism is that the traditional model spends too much time teaching these lower-level skills out of context and not enough time with the higher-level skills.

Wager goes on to say that because the curriculum is designed by content experts the "model tends to focus on information learning and rule learning, and that drives most of what public school teachers do" (para.6). This in-turn drives how we assess the students. The "lack of success of the schools in teaching problem solving skills is the emphasis we place on testing knowledge" (para. 6). Perhaps schools focus on knowledge because of the difficulty in measuring problem solving skills or the ease of measuring knowledge.

"Most educators agree that problem solving is among the most meaningful and important kinds of learning and thinking" Jonassen (1997). This emphasis is not lost on technology education as evident in the Technology for All Americans (1996). However, little practical research is offered to assist the classroom teacher in this endeavor of enhancing problem solving skills. More research is needed that will test the theories presented and offer practical guidance to the classroom teacher. Zuga (1994) points out that few studies have focused on problem solving, cognition, and instructional methods and strategies. Foster (1999, p.33) calls for the need for additional research within technology education including "the nature of knowledge and skill; cognition and meta-cognition; pedagogical effectiveness." Rowell (2001, para.8) asked – "What is the nature of problem solving? How do children/adults learn to solve problems? What pedagogical practices support problem solving?"

Cognitive Apprenticeship offers a strategy that is a break from the traditional approaches to teaching problem solving. By combining cognitive learning theory with that of traditional apprenticeship makes this instructional approach uniquely suited for technology education curriculums. This study was designed to determine its suitability to enhance problem solving ability and disposition when used within technology education program

CHAPTER THREE

EXPERIMENTAL DESIGN AND METHODS

The purpose of this study was to determine the effects of teaching problem solving through cognitive apprenticeship on selected high school technology education students' problem solving disposition and skill. A review of literature supported taking a more student centered instructional approach that focuses on cognition and problem solving processes improves problem solving skills, attitudes and motivation. Mayer (1998) suggests that successful problem solving depends on skill, meta-skill and will and that each of these will be affected by instruction and the learning environment.

Pilot Study

In an effort to test this notion, a pilot study was conducted in 1996 through a grant provided by North Carolina State University. "Teaching Problem Solving as Content to Foster Critical Thinking Skills" used a quasi-experimental, repeated measures design to measure the effect of directly teaching problem solving sub-skills on general critical thinking ability.

The intent of the pilot study was to test the hypothesis that an intervention promoting meta-cognition, inquiry and reflection would improve students' overall critical thinking ability. In addition, student disposition toward problem solving will improve.

The research questions guiding this pilot study were:

(1) What is the short- and long-term effect of teaching PS sub-skills technological problem solving ability?

(2) What is the short- and long-term effect of teaching PS sub-skills on problem solving disposition?

(3) What is the short- and long-term effect of teaching PS sub-skills on general critical thinking ability?

Methodology

In order to obtain data to answer these questions, two groups of high school students were used in the study. One group served as the control group (those students not receiving any specialized instruction in problem solving) and another serving as treatment group (those students who did receive specialized instruction in problem solving). Two high school Technology Education teachers were involved in the study. The subjects were 26 freshman technology education students involved in an introductory course in engineering theory. Both the control group and treatment group had 13 subjects. A control group was established with one teacher and the treatment group with another.

Both the treatment and control groups had similar exposure to the content of the course. The treatment came in the form of pedagogical approach. During the course, the treatment group was exposed to techniques to aid in organizing their knowledge. They were taught: keyword searching, breaking down complex systems into simple systems, using concept maps to express complex systems, and doing formal cause and effect analysis. The course outline was as follows:

Sketching and visualization

- 3D sketching and rendering
- Orthographic drawing

Studying the impacts of technology

Keyword Searching

Research

Problem solving and Product design

Design Loop

Product design

Design problem

Defining the true problem(s)

Systems and sub-systems

Concept mapping

Cause and Effect

Ideation

Realization

Evaluation

The treatment included lecture and exercises dealing with organizing new content knowledge in an effort to improve a person's ability to retrieve this information at a later date and apply it toward an ill-structured problem.

At the beginning of the 6-week study, students took a pretest to determine their ability to think critically. In addition, students took a self-assessment survey designed to assess disposition toward technological problem solving. These scores were then compared to the scores they achieved on a post-test at the end of the session. The test instrument used to assess critical thinking was the Watson-Glaser Critical Thinking Appraisal (CTA). The researcher designed the Disposition toward Technological Problem Solving survey.

The Watson-Glaser CTA (1989) was designed to measure five aspects of critical thinking, including the abilities to recognize problems, evaluate evidence cited to support claims of truth, reason inferentially, and apply the proceeding to problems. Goodwin Watson and Edward Glaser, who define critical thinking as a composite of attitudes, knowledge and skills, developed the test. The test is designed to assess the student's ability to recognize the validity of arguments, detect implications of statements, note inconsistencies in reasoning, and make valid inferences from data. The test is a widely used instrument that has acceptable levels of reliability and validity.

The Disposition toward Technological Problem Solving survey is a 15-item Likert-type instrument. This self-assessment survey measured confidence in three main areas as well as providing an overall score. The three areas centered around "when learning new technology…", "when a technology breaks…", and "when designing to solve a problem…"

Results

Data indicated no significant difference between groups after pre-test data were analyzed. The researcher concluded the students' critical thinking ability and disposition toward technological problem solving to be statistically equivalent for the two groups used in the pilot study. The treatment began the day after the pre-test was administered. Both the treatment and control groups had equal time to complete the problems. After the treatment, the post-tests were given. A multivariate analysis of the data revealed the treatment group scored significantly higher than the control group ($F=5.16$, $P=0.0324$). A paired t-test also revealed significant improvement in the treatment group, while the control group showed no significant difference pre- vs. post- (Experimental, $t = 2.46$, $P = 0.031$; Control, $t = 0.764$, $P = 0.460$). When looking at the data from a more granular level, the one CTA sub-tests that revealed the most significant difference within the treatment group was the interpretation sub-test. Through an ANOVA, the Interpretation sub-test of the Watson-Glaser CTA revealed significance ($F=4.63$, $P=0.042$). With regard to the survey, only the questions relating to Learning new technologies produced significant results ($F = 5.505$, $P = 0.028$).

Discussion

The intent of the pilot study was to test the theory that given certain instruction students would be better critical thinkers. The data indicates that the treatment used in the study shows promise for enhancing critical thinking and disposition. However, weaknesses in the study prompted the need for more research. It was decided that limiting factors associated with this research needed to be addressed before a final judgment of the pedagogical approach could be made -- some limiting factors included *sample size, instructional materials, course length, and test instrument.*

Sample Size

Both the control group and treatment group had 13 subjects. In future studies, either larger classes or more classes should be considered to improve reliability of the data collected.

Instructional Materials

Instructional materials for the study were not completed by the start of the study. Items were added and conceived of with time constraints, thereby compromising the product. In addition, the instructional materials were not collected in one document. Materials were disseminated in stapled “handout” form. It was therefore decided that further research and time would be need to be spent to create a professional looking, cohesive document.

Course Length

After completing the pilot, further research helped indicate that the 6-week duration of the study may be too long. The longer the duration of the study, the harder it will be to isolate the variables affecting the data. This, however, must be tempered with the fact that maturation plays a role in developing problem solving. This limitation further supported the notion that disposition may be a more appropriate variable on which to concentrate. With the understanding that the more motivated and engaged a person is the more successful they will become.

Test Instrument

The test instrument chosen for the pilot was the Watson – Glaser Critical Thinking Appraisal. This is a widely used instrument, however this instrument relies exclusively on a subject’s ability to read and comprehend scenario-based stories. This limits the true assessment of a person’s critical thinking ability when technological problems are posed. In addition, this instrument is quantitative in nature. A more authentic instrument should be developed that will account for various learning styles and the qualitative nature of technological problem solving. Furthermore, the Watson-Glaser CTA establishes a score based on pre-test scores that can result in a ceiling effect if a change in score is based on differences between pre- and post-test scores. That is, if a person receives a high score on the pre-test, the affect of the treatment may not be evident, because the difference from pre-test to post-test may not be significant.

Enhancing Problem Solving Disposition and Skills through Cognitive Apprenticeship

The study outlined is based on the findings of the pilot study and research conducted since the pilot study. The findings of the pilot study provided a solid foundation while offering opportunity for improvement. While the pilot study indicated promise for the instruction approach used, it fell short in properly accounting for the affective variables that play a part in all problem solving. With the benefit of a pilot study to support the notion that instructional approaches affect critical thinking and problem solving confidence, this study was designed to corroborate the previous findings, improve the design of the pilot study and to concentrate on disposition and authentic assessment.

As discussed previously, common approaches to teaching problem solving skills and disposition may fall short of truly preparing students to be problem solvers. This study proposes that an alternative method of instruction, cognitive apprenticeship, will produce significantly better results when compared to the traditional, prescriptive approach to teaching problem solving. Where prescriptive methods are geared toward rote application of method, the goal of cognitive apprenticeship is to make thinking processes visible to the learner while guiding them through the process. The modeling, coaching, and fading paradigm of cognitive apprenticeship has proven successful in enhancing cognitive skills and motivating learners to take control of their learning.

Through *modeling* learners see expert problems solving technique in a realistic context. During the *coaching* phase, learners receive guidance through the problem solving process while they attempt to solve open-ended problems. These two phases create the necessary scaffolding to support the *fading* phase, where learners independently solve problems. By facilitating proper technique and supporting new learning, learners not only gain skill, their disposition toward the new learning is enhanced.

The intent of "Enhancing Problem Solving Disposition, Motivation and Skills through Cognitive Apprenticeship" is to compare the traditional approach to teaching problem solving to that of a more student-centered approach - cognitive apprenticeship.

Research Questions and Hypotheses

The objective of this study was to test the theory that through the cognitive apprenticeship paradigm of modeling, coaching, and fading, students' problem solving performance and disposition toward problem solving will improve significantly over that of the traditional approach. The research questions guiding this study were:

1. What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on disposition toward problem solving?

The following null hypotheses were tested to answer this question:

$H0_1$: There is no significant difference in the problem solving disposition characteristic of patience between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_2$: There is no significant difference in the problem solving disposition characteristic of perseverance between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_3$: There is no significant difference in the problem solving disposition characteristic of self-confidence between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_4$: There is no significant difference in the problem solving disposition characteristic of attitude between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

2. What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on problem solving motivation?

The following null hypotheses were tested to answer this question:

$H0_5$: There is no significant difference in the problem solving motivation characteristic of mental focus/self-regulation between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_6$: There is no significant difference in the problem solving motivation characteristic of learning orientation between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_7$: There is no significant difference in the problem solving motivation characteristic of creative problem solving between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_8$: There is no significant difference in the problem solving motivation characteristic of cognitive integrity between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

3. What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on technological problem solving performance?

The following null hypothesis was tested to answer this question:

$H0_9$: There is no significant difference in problem solving performance between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

Design of the Study

A quasi-experimental, non-equivalent control group design was employed to conduct this experiment. This was required because of the circumstances present in educational settings limited true randomization of samples. It was required that the two technology education classes stay intact. However, the classes were randomly assigned to either the treatment or control group.

To help prevent threats to validity, several variables needed to be controlled. To establish equivalence between treatment and controls groups, the pre-test of Problem Solving Disposition Inventory was used to confirm the homogeneity of the treatment and control groups. To establish equivalence between the two teachers in the study, a survey was conducted that compared their teaching styles. In addition, interviews and observation were conducted to establish that each teacher taught problem solving in a similar fashion. To ensure both the treatment and control groups covered the same content, the researcher developed a curriculum and each of the teachers attended a workshop to ensure they were comfortable with the material.

To control for the Hawthorne Effect, the subjects in both the treatment and control groups were unaware of their respective roles in the study. In the pilot study, it was determined that the length of the study may have compromised validity due to the many variables that come into play in the maturation of a student. As a result, this study was limited to two weeks (10, 55-minutes class periods).

Sample

Demographic characteristics of the samples for this study are summarized in Table 2. Several requirements delimited the sampling frame for this study. Due to time constraints, the samples were drawn from a local school system. Because the study is a quasi-experimental design, samples were drawn from a high school that had two or more teachers teaching Fundamentals of Technology, a North Carolina Department of Public Instruction course that serves as the pre-requisite to all state high school Technology Education courses. After receiving permission from the school and system administration, two classes were selected. After selection, one class was randomly assigned as the treatment and the other selected as the control group.

Treatment Group

The treatment group was guided through the problem solving process using the cognitive apprenticeship paradigm of modeling, coaching, and fading. The teachers also used supporting exercises throughout the unit that focused on problem solving sub-skills.

Control Group

These students were taught using a typical approach to problem solving in technology education. The definition "typical" is based on the results of the DeLuca study "Survey of Technology Education Problem-Solving Activities", which stated "66% and 70.5% of the teachers responded that they always or usually used discussion and demonstration respectively" (Deluca, 1992, p. 29). As noted by the author, "the ratings seem to show that those methods that are associated with high level cognitive performance were used less frequently."

Teachers

After establishing that the participating teachers used similar teaching styles, each teacher attended a workshop to become familiar with the curriculum developed by the researcher. Each curriculum used identical content. However, the treatment curriculum included additional exercises which reinforced the problem solving and process skills which are the focus of the cognitive apprenticeship model.

Instruments and Data collection procedures

Instrumentation for this study included a pre- and post problem solving disposition survey (Appendix A), a standardized mental motivation instrument (Appendix B), and an problem solving task which focused on vehicle designs – one speed and one distance vehicle per team. In addition, the researcher conducted interviews after the study with the participating teachers to capture anecdotal information.

Problem Solving Disposition Instrument

The Problem Solving Disposition Inventory focuses on components of technological problem solving – troubleshooting, design, and process. The inventory was designed by the researcher and is based on the Deluca (1992) Likert-type survey which focuses on four sub categories – perseverance, self-confidence, positive attitude, patience and was administered on a pre and post basis. Each of these qualities is found in expert problem solvers (Wankat & Oreovicz, 1993). A person scoring high in each of these elements is positively disposed to perform at a higher level of technological problem solving.

Alpha coefficient reliability estimates for each of the sub-scales of the inventory were performed using SAS. The Cronbach Coefficient Alpha for Patience was .46, Perseverance was .68, Self-Confidence was .56, and Attitude was .72. Alpha coefficients for Perseverance and Attitude were considered sufficiently high enough to use in interpreting results, while the sub-scales of Patience and Self-Confidence were considered marginally reliable.

Mental Motivation Instrument

Problem solving motivation was assessed through the use of the California Measure of Mental Motivation (CM3) Level II (Insight Assessments, 1998). The CM3 measures the degree to which an individual is cognitively engaged and mentally motivated. The CM3 targets dispositional and motivational aspects of critical thinking as well as learning, creativity and problem solving. The CM3 is comprised of four major scales; (1) Mental Focus / Self - Regulation, (2) Learning Orientation, (3) Creative Problem Solving, and (4) Cognitive Integrity.

Mental Focus/Self-Regulation – A person scoring high in mental focus is "diligent, focused, systematic, task oriented, organized and clear-headed" (Insight Assessments, 1998). This person tends to be highly attentive and persistent during an activity. A low score indicates a disposition toward disorganization and procrastination.

Learning Orientation – A high score in learning orientation indicates that the person "strives to learn for learning's sake" (Insight Assessments, 1998). This person values the learning process and is eager to tackle challenging activities. The individual would use information gathering strategies to support an idea and are generally inquisitive. Individuals scoring low are satisfied with information at hand and will not pursue additional information to solve a problem.

Creative Problem Solving – A person with a high score in creative problem solving is one that is curious, creative, imaginative, and artistic. These people tend to enjoy complicated activities; whereas a person scoring low in the category might choose easier activities over more challenging ones.

Cognitive Integrity – People scoring high in the category are motivated to use their thinking skills. These individuals enjoy thinking and interacting with others having a different viewpoint while in search of the best solution. People scoring low tend to be hasty, indecisive and uncomfortable with challenging activities.

Cronbach Alpha Coefficient estimates of reliability were provided by the publisher for each of the four major scales of the CM3. The alpha coefficient for Mental Focus was .83, for Creative Problem Solving was .79, for Learning Orientation was .81, and for Cognitive integrity was .74.

Problem Solving Performance

In addition to collecting data on disposition, each of the vehicles designed and created as the problem solving task for the study were evaluated. The evaluation was specific to the type of vehicle created. Each team member designed either a speed vehicle or a distance vehicle. The speed vehicle was evaluated by the time, in seconds, it took speed vehicles to travel a distance of ten feet. The distance vehicle was evaluated by the distance, in feet, achieved by the distance vehicle.

Procedures

The study was conducted over a three-week period in February 2003 at Riverside High School in Durham, NC. The control group started 1-week prior to the treatment group.

Both groups completed the study in the allotted 10 school days. The lesson was designed to be similar to a technological problem solving activity found in the North Carolina Department of Public Instruction standard curriculum for Fundamentals of Technology. That unit was divided into 5 main subunits – Introduction, Scientific Theory, Design, Build/Test/Refine, Final test and summary. Each teacher was provided a unit plan (see Appendix C & D) and each followed a daily lesson plan as listed below. The differences in the unit plans reflected the two instructional approached the teachers were to employ. The control group teacher was provided a detailed unit plan with handouts to cover the content. The treatment group teacher was provided a similar detailed unit plan with handouts to cover content, but was also provided activities that supported and enhanced the cognitive apprenticeship strategy employed.

Control Group	**Treatment Group**
Day 1: Introduction / DEAL problem solver	Day 1 & 2: Introduction / Warm-up activity
Day 2: Design Ideas / Theory	Day 3: DEAL problem solver
Day 3-4: Designing Your Vehicles	Day 4: Design Ideas /Theory
Day 5-7: Build/Test/Refine	Day 5-6: Design Your Vehicles
Day 8- Final Test of Vehicles	Day 7 – 8: Build/Test/Refine
Day 9 – Technical Report / Summary	Day 9 – Final Test of Vehicle
Day 10 – Survey	Day 10 – Summary / Survey

On day one, the researcher introduced the lesson for both the control and treatment groups and fielded questions raised by the students. This was to ensure the unit was positioned consistently between groups. After the introduction, the students completed the problem solving disposition inventory. After the inventory was complete, the students were assigned in teams of two and given the kit of materials they would use for the problem solving activity. The kit of materials was used to create two vehicles, one speed and one distance vehicle. An inventory was conducted to ensure each team had the same materials. After administration of the inventory, the teams were given the design brief:

> *As a member of a team, Design and Construct a Speed or Distance vehicle solely powered by a combination of power sources.*

Upon receiving the design brief, teams spent time discussing options and asking any final questions for the opening session.

After the introduction day both the control and treatment groups followed the respectively unit plans. Key areas of difference between the two instructional strategies were found in how the teachers delivered to content and how they interacted with the students. For example, the treatment group engaged in a warm-up activity that introduced problem solving processes and provided an opportunity for the teacher to model “good” problem solving behavior for the students. This *modeling* component is a key attribute of cognitive apprenticeship. Specifically, the teacher modeled the problem solving process by attempting to solve a problem. As the teacher navigated through the solving of the problem the teacher talked aloud and used questioning to foster student involvement. This way the students can see an “expert” solve a problem, stumble on occasion, work through the obstacles and connect how the “expert” solved the problem all the while in a non-threatening environment.

After the modeling phase, the teacher has a practical example to draw from while in the coaching and fading phases.

In addition to the warm-up activity the treatment group had other activities that promoted good problem solving behaviors. During the warm-up activity the students formally analyzed the problem they were faced with and how they solved it (hindsight analysis/reflection). As the students learned about design ideas and theory, the instructor had the students use concept maps to aid in organizing this new information and providing interrelationships. The treatment group also engaged in mathematical modeling to allow students to better understand to technical aspects of the problem and attempt to predict outcome. Both the control and treatment groups were introduced to the DEAL problem solver, but the treatment group was overtly guided through the problem solving process. Finally, the treatment group was to reflect on their experience and offer suggestions for improving not only their product but the process they used to realize their product.

Statistical Treatment

JMP 5.0.1 statistical analysis software from SAS Institute Inc., provided by North Carolina State University Computing Services, was used to run the statistical modeling. To determine equivalence between the control and treatment groups a one-way ANOVA was performed. One-way ANOVAs were performed to determine whether there was a statistically significant difference between the groups on the problem solving post-survey, the CM3, and problem solving performance. For both of the survey instruments, subtest comparisons were made to provide further granularity. The performance score achieved was based on a formula that determined how successful the students were at solving the problem posed.

Summary

In this study, the researcher used analysis of variance and qualitative observation and interview data to determine the effects of using a cognitive apprenticeship instructional model on problem solving disposition and performance. The non-equivalent, quasi-experimental control group design was used to control for confounding variable as much as possible. It was hypothesized that the problem solving disposition and performance of the treatment group which received problem solving instruction through the cognitive apprenticeship approach would significantly exceed that of the control group which received instruction through a traditional approach. The reliability of the instruments used was considered high by the researcher. A pilot study was conducted to determine the revisions necessary for this study.

CHAPTER FOUR

FINDINGS

The objective of this study was to test the theory that through the cognitive apprenticeship paradigm of modeling, coaching, and fading, students' problem solving performance and disposition toward problem solving will improve significantly over that demonstrated by the traditional approach. The research questions guiding this study were:

1. What effect does teaching problem solving through cognitive apprenticeship have on problem solving disposition?

   The following null hypotheses were tested to answer this question:

   $H0_1$: There is no significant difference in the problem solving disposition characteristic of patience between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

   $H0_2$: There is no significant difference in the problem solving disposition characteristic of perseverance between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

   $H0_3$: There is no significant difference in the problem solving disposition characteristic of self-confidence between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_4$: There is no significant difference in the problem solving disposition characteristic of attitude between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

2. What effect does teaching problem solving through cognitive apprenticeship have on problem solving motivation?

   The following null hypotheses were tested to answer this question:

   $H0_5$: There is no significant difference in the problem solving motivation characteristic of mental focus/self-regulation between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

   $H0_6$: There is no significant difference in the problem solving motivation characteristic of learning orientation between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_7$: There is no significant difference in the problem solving motivation characteristic of creative problem solving between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

$H0_8$: There is no significant difference in the problem solving motivation characteristic of cognitive integrity between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

3. What effect does teaching problem solving through cognitive apprenticeship have on problem solving performance?

   The following null hypothesis was tested to answer this question:

   $H0_9$: There is no significant difference in problem solving performance between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group).

Independent and Dependent Variables

The independent variable in this study is found in the instructional approach, which compared traditional approaches to that of a cognitive apprenticeship approach. The traditional approaches rely heavily on lecture and demonstration and advocate a teacher-centric, prescriptive approach to teaching problem solving. The cognitive apprenticeship model uses a modeling, coaching and fading approach. This model stresses cognitive processes over product and uses scaffolding within a more student-centered learning environment.

The three dependent variables for the study were (a) problem solving disposition, (b) mental motivation, and (3) problem solving performance. One-way ANOVAs were computed for differences in mean scores between the control and treatment groups. Statistical testing was performed using JMP 5.0.1 statistical software for significance at an alpha level of .05. Problem solving disposition was determined by comparing the mean score of the Problem Solving Disposition Inventory. ANOVAs were run against the sub-test areas of perseverance, attitude, self-confidence, and patience. Mental motivation was determined by comparing the mean scores from the CM3 test. ANOVAs were run against each of the fourteen sub-tests (Process, Organization, Attention, Desire to Learn, Information Gathering, Innovation, Challenge Seeking, Inquisitiveness, and Open-mindedness) as well as the four major scales of Mental Focus/Self-Regulation, Learning Orientation, Creative Problem Solving, and Cognitive Integrity. An ANOVA was run to compare the performance scores of each group.

Sample Equivalence and Demographics

Two sections of high school students from the same school, taking the same course and being taught by teachers with a similar teaching philosophy were used during this study. To establish equivalence between the control and treatment groups, a one-way ANOVA was performed comparing the pre-test mean scores on the Problem Solving Disposition Inventory (see Table 1). A comparison of the control group (M= 3.60, SD= 0.21) and the treatment group (M=3.63, SD= 0.18) indicated no significant difference, $F(1,38) = 0.005$, p=0.94. The researcher assumed that the treatment and control groups were equivalent.

Table 1

ANOVA Summary Table for Problem Solving Disposition Inventory Overall Mean

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	0.004	0.004	0.005	0.941
Error	38	28.784	0.757		
C.Total	39	28.789			

The two groups were similar in racial background and class standing, though the treatment group did have a more than 2:1 ratio of African American students as compared to the control group(see Table 2). Both the control and treatment groups were comprised solely of male students and primarily freshman. The treatment group (n=27) had more students than the control group (n=18).

Table 2

Sample Demographics

Demographic	Group	
	Control[a]	Treatment[b]
Race		
African-American Males	5	13
Asian Males	2	1
Caucasian Males	8	6
Hispanic Males	2	4
Other Males	1	3
Class Standing		
Freshman	12	21
Sophomore	3	5
Junior	3	1

[a]n = 18, [b]n = 27

Findings for the Dependent Variables

Problem Solving Disposition

A one-way ANOVA of the Problem Solving Disposition Inventory's four sub-categories – patience, perseverance, self-confidence, and attitude was performed to determine if there were significant differences between the control and treatment groups to test Hypotheses 1-4.

Patience

A one-way ANOVA was performed comparing the post-test mean scores on the patience category of the Problem Solving Disposition Inventory and to test Hypothesis $(H_0)1$ (see Table 3). A comparison of the control group (M= 3.71, SD= 0.73) and the treatment group (M= 3.82, SD= 0.86) indicated no significant difference, $F(1,40) = 0.19$, $p = 0.66$. Hypothesis $(H_0)1$ was not rejected.

Table 3

ANOVA Summary Table for Problem Solving Disposition Inventory on Patience

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	0.12	0.12	0.19	0.66
Error	40	26.47	0.66		
C.Total	41	26.59			

Perseverance

A one-way ANOVA was performed comparing the post-test mean scores on the perseverance category of the Problem Solving Disposition Inventory and to test Hypothesis $(H_0)2$ (see Table 4). A comparison of the control group (M= 3.47, SD= 0.86) and the treatment group (M= 4.00, SD= 0.76) indicated significant difference, $F(1,40) = 4.38$, $p =$ .04. Hypothesis $(H_0)2$ was rejected.

Table 4

ANOVA Summary Table for Problem Solving Disposition Inventory on Perseverance

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	2.80	2.80	4.38	0.043
Error	40	0.64	0.64		
C.Total	41				

Self-Confidence

A one-way ANOVA was performed comparing the post-test mean scores on the self-confidence category of the Problem Solving Disposition Inventory and to test Hypothesis (H_0)3 (see Table 5). A comparison of the control group (*M*= 3.31, *SD*= 0.86) and the treatment group (*M*= 3.63, *SD*= 0.82) indicated no significant difference, $F(1,40) = 1.41$, $p = 0.24$. Hypothesis (H_0)3 was not rejected.

Table 5

ANOVA Summary Table for Problem Solving Disposition Inventory on Self-Confidence

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	0.99	0.99	1.41	0.24
Error	40	28.18	0.70		
C.Total	41	29.16			

Attitude

A one-way ANOVA was performed comparing the post-test mean scores on the attitude category of the Problem Solving Disposition Inventory and to test Hypothesis (H_0)4 (see Table 6). A comparison of the control group (*M*= 3.35, *SD*= 0.94) and the treatment group (*M*= 3.68, *SD*= 0.99) indicated no significant difference, $F(1,40) = 1.12$, $p = 0.30$. Hypothesis (H_0)4 was not rejected.

Table 6

ANOVA Summary Table for Problem Solving Disposition Inventory on Attitude

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	1.05	1.05	1.12	0.30
Error	40	37.77	0.94		
C.Total	41	38.81			

Mental Motivation

One-way ANOVAs were run CM3's nine minor scales (Process, Organization, Attention, Desire to Learn, Information Gathering, Innovation, Challenge Seeking, Inquisitiveness, and Open-mindedness) as well as the four major scales of Mental Focus/Self-Regulation, Learning Orientation, Creative Problem Solving, and Cognitive Integrity to determine if there were significant differences between the control treatment groups and to test Hypotheses 5-8. The major scales of the CM3 are comprised of combinations of the minor scales. Mental Focus/Self-Regulation is a combination of the Process, Organization and Attention minor scales. Learning Orientation is a combination of the Desire to Learn and Information Gathering minor scales. Creative Problem Solving is composed of the Innovation and Challenge Seeking minor scales. Cognitive Integrity is composed of the Inquisitiveness and Open-mindedness minor scales. The results of the ANOVAs are presented in Tables 7- 19.

Process

A one-way ANOVA was performed comparing the mean scores on the Process sub-test of the CM3 (see Table 7). A comparison of the control group (*M*= 20.13, *SD*= 9.45) and the treatment group (*M*= 28.83, *SD*= 8.08) indicated that the mean score of the treatment group was significantly higher than that of the control group, $F(1,38) = 975.11$, $p = .003$.

Table 7

ANOVA Summary Table for Process on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	728.02	728.02	975.11	.0034
Error	38	2837.08	74.66		
C.Total	39	3565.10			

Organization

A one-way ANOVA was performed comparing the mean scores on the Organization sub-test of the CM3 (see Table 8). A comparison of the control group (*M*= 31.18, *SD*= 11.26) and the treatment group (*M*= 29.92, *SD*= 9.82) indicated no significant difference, $F(1,38) = 0.14$, p = 0.71.

Table 8

ANOVA Summary Table for Organization on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	15.51	15.51	0.14	0.71
Error	38	4120.27	108.43		
C.Total	39	4135.78			S

Attention

A one-way ANOVA was performed comparing the mean scores on the Attention sub-test of the CM3 (see Table 9). A comparison of the control group (*M*= 25.63, *SD*= 10.98) and the treatment group (*M*= 30.58, *SD*= 8.36) indicated no significant difference, $F(1,38) = 2.63$, $p = .11$.

Table 9

ANOVA Summary Table for Attention on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	236.02	236.02	2.63	.11
Error	38	3415.58	89.88		
C.Total	39	3651.60			

Desire to Learn

A one-way ANOVA was performed comparing the mean scores on the Desire to Learn sub-test of the CM3 (see Table 10). A comparison of the control group (*M*= 25.63, *SD*= 7.19) and the treatment group (*M*= 29.71, *SD*= 7.10) indicated no significant difference, $F(1,38) = 3.14$, $p = .08$.

Table 10

ANOVA Summary Table for Desire to Learn on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	160.07	160.07	3.14	.08
Error	38	1936.71	50.97		
C.Total	39	2096.78			

Information Gathering

A one-way ANOVA was performed comparing the mean scores on the Information Gathering sub-test of the CM3 (see Table 11). A comparison of the control group (*M*= 28.56, *SD*= 8.27) and the treatment group (*M*= 31.33, *SD*= 10.43) indicated no significant difference, $F(1,38) = 0.79$, $p = 0.38$.

Table 11

ANOVA Summary Table for Information Gathering on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	73.70	73.70	0.79	0.38
Error	38	3529.27	92.88		
C.Total	39	3602.98			

Innovation

A one-way ANOVA was performed comparing the mean scores on the Innovation sub-test of the CM3 (see Table 12). A comparison of the control group (*M*= 32.31, *SD*= 11.76) and the treatment group (*M*= 33.58, *SD*= 8.33) indicated no significant difference, $F(1,38) = 0.16$, $p = 0.69$.

Table 12

ANOVA Summary Table for Innovation on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	15.50	15.50	0.16	.69
Error	38	3671.27	96.61		
C.Total	39	3686.78			

Challenge Seeking

A one-way ANOVA was performed comparing the mean scores on the Challenge Seeking sub-test of the CM3 (see Table 13). A comparison of the control group (*M*= 30.25, *SD*= 7.61) and the treatment group (*M*= 27.13, *SD*= 10.71) indicated no significant difference, $F(1,38) = 1.02$, $p = 0.32$.

Table 13

ANOVA Summary Table for Challenge Seeking on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	93.75	93.75	1.02	0.32
Error	38	3507.63	92.31		
C.Total	39	3601.38			

Inquisitiveness

A one-way ANOVA was performed comparing the mean scores on the Inquisitiveness sub-test of the CM3 (see Table 14). A comparison of the control group (*M*= 27.38, *SD*= 11.07) and the treatment group (*M*= 32.71, *SD*= 10.48) indicated no significant difference, $F(1,38) = 2.38$, $p = 0.13$.

Table 14

ANOVA Summary Table for Inquisitiveness on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	273.07	273.07	2.38	0.13
Error	38	4362.71	114.81		
C.Total	39	4635.78			

Open-mindedness

A one-way ANOVA was performed comparing the mean scores on the Open-mindedness sub-test of the CM3 (see Table 15). A comparison of the control group (*M*= 22.94, *SD*= 10.70) and the treatment group (*M*= 28.79, *SD*= 7.72) indicated no significant difference, $F(1,38) = 4.05$, $p = 0.051$.

Table 15

ANOVA Summary Table for Open-mindedness on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	329.00	329.00	4.05	0.051
Error	38	3086.90	81.23		
C.Total	39	3415.90			

Mental Focus/Self-Regulation

A one-way ANOVA was performed comparing the mean scores on the Mental Focus major scale of the CM3 and to test Hypothesis $(H_0)5$ (see Table 16). A comparison of the control group (*M*= 25.65, *SD*= 7.27) and the treatment group (*M*= 29.78, *SD*= 7.13) indicated no significant difference, $F(1,38) = 3.16$, p = .08. Hypothesis $(H_0)5$ was not rejected.

Table 16

ANOVA Summary Table for Mental Focus/Self-Regulation on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	163.90	163.90	3.16	.08
Error	38	1960.47	51.59		
C.Total	39	2124.38			

Learning Orientation

A one-way ANOVA was performed comparing the mean scores on the Learning Orientation major scale of the CM3 and to test Hypothesis (H_0)6 (see Table 17). A comparison of the control group (*M*= 29.84, *SD*= 5.95) and the treatment group (*M*= 31.00, *SD*= 9.72) indicated no significant difference, $F(1,38) = 0.18$, p = 0.67. Hypothesis (H_0)6 was not rejected.

Table 17

ANOVA Summary Table for Learning Orientation on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	12.83	12.83	0.18	0.67
Error	38	2704.36	71.17		
C.Total	39	2717.19			

Creative Problem Solving

A one-way ANOVA was performed comparing the mean scores on the Creative Problem Solving major scale of the CM3 and to test Hypothesis $(H_0)7$ (see Table 18). A comparison of the control group (M= 31.28, SD= 8.67) and the treatment group (M= 30.35, SD=8.58) indicated no significant difference, $F(1,38) = 0.11$, $p = 0.74$. Hypothesis $(H_0)7$ was not rejected.

Table 18

ANOVA Summary Table for Creative Problem Solving on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	8.25	8.25	0.11	0.74
Error	38	2821.22	74.24		
C.Total	39	2829.48			

Cognitive Integrity

A one-way ANOVA was performed comparing the mean scores on the Cognitive Integrity major scale of the CM3 and to test Hypothesis $(H_0)8$ (see Table 19). A comparison of the control group (M= 25.16, SD= 9.86) and the treatment group (M= 30.75, SD= 7.40) indicated that the treatment group scored significantly higher than did the control group, $F(1,38) = 4.20$, $p = 0.047$. Hypothesis $(H_0)8$ was rejected.

Table 19

ANOVA Summary Table for Cognitive Integrity on the CM3

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	300.38	300.38	4.20	0.047
Error	38	2717.36	71.51		
C.Total	39	3017.74			

Student Performance

Speed Vehicle

A one-way ANOVA was performed comparing the performance (time, in seconds) of the speed vehicles (see Table 20). A comparison of the control group (*M*= 0.56, *SD*= 0.06) and the treatment group (*M*= 0.48, *SD*= 0.13) indicated no significant difference, $F(1,16) = 0.82$, $p = .80$. Hypothesis $(H_0)9$ was not rejected.

Table 20

ANOVA Summary Table for Student Performance – Speed Vehicle

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	0.023	0.023	0.82	0.80
Error	16	0.453	0.028		
C.Total	17	0.476			

Distance Vehicle

A one-way ANOVA was performed comparing the performance (distance, in feet) of the speed vehicles (see Table 21). A comparison of the control group (*M*= 28, *SD*= 5.42) and the treatment group (*M*= 30.23, *SD*= 6.92) indicated no significant difference, $F(1,17) = 0.58$, $p = 0.45$. Hypothesis $(H_0)9$ was not rejected.

Table 21

ANOVA Summary Table for Student Performance – Distance Vehicle

Source	*df*	*SS*	*MS*	*F*	*p*
Group	1	23.76	23.76	0.58	0.45
Error	17	732.84	40.71		
C.Total	18	756.61			

Summary

Equivalence of the control and treatment groups was demonstrated by pre-test results from the Problem Solving Disposition Inventory indicating no significant differences between groups. After conducting interviews with the two participating teachers and comparing results of a teaching philosophy survey it was determined that the teachers held similar notions about how best to teach problem solving.

One-way ANOVAs were run to determine significant differences between the control and treatment groups against problem solving disposition, mental motivation, and problem solving performance. For each of the survey instruments, tests were run to compare sub-test mean scores for provide more granular information.

For problem solving disposition, results from the Perseverance sub-test indicated that the treatment group scored significantly higher than did the control group. Results from the Patience, Attitude and Self-Confidence sub-tests indicated no significant differences.

For mental motivation, results from the Process sub-test as well as the Cognitive Integrity major scale both indicated that the treatment group scored significantly higher than did the control group. Results from all other sub-test as well as major scales indicated no significant differences. However, it should be noted that although not significant at the .05 alpha level, the ANOVA results for the Open-mindedness and Desire to Learn sub-tests as well as the Mental Focus major scale had a statistical significance level of less than .10 thus representing a marginal statistical positive effect when learning problem solving through cognitive apprenticeship.

A comparison of vehicle performance, both speed and distance, between the control and treatment groups indicated no significant difference.

CHAPTER FIVE

CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

The purpose of the study was to determine the effects of teaching problem solving through cognitive apprenticeship on high school technology education students' problem solving disposition, motivation and skills. The effectiveness of the two instructional strategies was determined by an analysis of variance between the mean scores of the control group that received problem solving instruction by traditional lecture and demonstration and the treatment group that received problem solving instruction by the cognitive apprentice instructional model.

The following research questions were used to guide the study:

1. What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on disposition toward problem solving?
2. What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on problem solving motivation?
3. What is the effect of teaching problem solving through cognitive apprenticeship as compared to traditional methods on technological problem solving performance?

Summary of Methods

A quasi-experimental, non-equivalent control group design was employed to conduct this experiment. This was required because of the circumstances present in educational settings limited true randomization of samples. However, the classes were randomly assigned to either the treatment or control group.

To establish equivalence between treatment and controls groups, the pre-test of Problem Solving Disposition Inventory was used to confirm the homogeneity of the treatment and control groups. To establish equivalence between the two teachers in the study, a survey was conducted that compared their teaching styles. To ensure both the treatment and control groups covered the same content, the researcher developed a curriculum and each of the teachers attended a workshop to ensure they were comfortable with the material.

Two sections of high school students from the same school, taking the same technology education course and being taught by teachers with a similar teaching philosophy were used during this study. Each teacher was provided detailed unit guides to insure the same content was covered for each group. The content and design of the unit followed the North Carolina Department of Public Instruction standard curriculum for Fundamentals of Technology. The topic of the unit was problem solving and the activity to support the unit was technological problem solving activity designed by the researcher.

A pre-test of the Problem Solving Disposition Inventory was used to establish equivalence between the control and treatment groups. The post-test of the Problem Solving Disposition Inventory was used to establish problem solving disposition at the end of the study. The California Measure of Mental Motivation (CM3) was used to establish problem solving motivation. Problem solving performance was measured by observing the level of success achieved for the vehicle designs.

All data were analyzed using JMP 5.0.1 Statistical Package provided by North Carolina State University Computing Center. The alpha level for all test of significance was established at .05, and JMP provided all appropriate tests for significant differences, group means, and standard deviations on the two levels of independent variables.

Summary of Findings

A one-way ANOVA of pre-test mean scores on the Problem Solving Disposition Inventory showed the control and treatment groups had evenly distributed group means and standard deviations. No significant differences were found for Prob > *F* at .05 alpha level.

ANOVA tests were used to analyze the data for the two levels of the independent variable of instructional strategy. The ANOVA did not show significant differences in three of the four disposition scales. In addition, the ANOVA did not show significant differences in the three of the four major scales of problem solving motivation or problem solving performance. The ANOVA did show a significant difference in the Perseverance scale of the disposition inventory, as well as the Cognitive Integrity major scale of the CM3 (see Table 22).

Table 22

ANOVA Summary of Findings

Scale/Variable	*F*	*Prob>F*
Disposition		
Patience	0.19	0.66
Perseverance	4.38	0.04*
Self-Confidence	1.41	0.24
Attitude	1.12	0.30
Motivation		
Process	975.11	0.003*
Organization	0.14	0.71
Attention	2.63	0.11
Desire to Learn	3.14	0.08
Information Gathering	0.79	0.38
Innovation	0.16	0.69
Challenge Seeking	1.02	0.32
Inquisitiveness	2.38	0.13
Open-Mindedness	4.05	0.051
Mental Focus/Self-Regulation	3.16	0.08
Learning Orientation	0.18	0.67
Creative Problem Solving	0.11	0.74
Cognitive Integrity	4.20	0.047*
Performance		
Speed Vehicle	0.82	0.38
Distance Vehicle	0.58	0.45

* = *significance at alpha level* p<.05

The nine hypotheses, stated in null form, were tested. Hypothesis 1 stated that there is no significant difference in the problem solving disposition characteristic of patient between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). The hypothesis was not rejected. A comparison of the control group (M= 3.71, SD= 0.73) and the treatment group (M= 3.82, SD= 0.86) indicated no significant difference, $F(1,40) = 0.19$, $p = 0.66$.

Hypothesis 2 stated that there is no significant difference in the problem solving disposition characteristic of perseverance between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). A comparison of the control group (M= 3.47, SD= 0.86) and the treatment group (M= 4.00, SD= 0.76) indicated significant difference, $F(1,40) = 4.38$, $p = .04$. The treatment group scored significantly higher than the control group on the perseverance scale. Therefore, Hypothesis 2 was rejected.

Hypothesis 3 stated that there is no significant difference in the problem solving disposition characteristic of self-confidence between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). The hypothesis was not rejected. A comparison of the control group (M= 3.31, SD= 0.86) and the treatment group (M= 3.63, SD= 0.82) indicated no significant difference, $F(1,40) = 1.41$, $p = 0.24$.

Hypothesis 4 stated that there is no significant difference in the problem solving disposition characteristic of attitude between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). A comparison of the control group (*M*= 3.35, *SD*= 0.94) and the treatment group (*M*= 3.68, *SD*= 0.99) indicated no significant difference, $F(1,40) = 1.12$, $p = 0.30$. Hypothesis 4 was not rejected.

Hypothesis 5 stated that there is no significant difference in the problem solving motivation characteristic of mental focus/self-regulation between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). A comparison of the control group (*M*= 25.65, *SD*= 7.27) and the treatment group (*M*= 29.78, *SD*= 7.13) indicated no significant difference, $F(1,38) = 3.16$, p = .08. Hypothesis 5 was not rejected.

Hypothesis 6 stated that there is no significant difference in the problem solving motivation characteristic of learning orientation between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). A comparison of the control group (*M*= 29.84, *SD*= 5.95) and the treatment group (*M*= 31.00, *SD*= 9.72) indicated no significant difference, $F(1,38) = 0.18$, p = 0.67. Hypothesis 6 was not rejected.

Hypothesis 7 stated that there is no significant difference in the problem solving motivation characteristic of creative problem solving between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). A comparison of the control group (*M*= 31.28, *SD*= 8.67) and the treatment group (*M*= 30.35, *SD*=8.58) indicated no significant difference, $F(1,38) = 0.11$, $p = 0.74$. Hypothesis 7 was not rejected.

Hypothesis 8 stated that there is no significant difference in the problem solving motivation characteristic of cognitive integrity between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). A comparison of the control group (*M*= 25.16, *SD*= 9.86) and the treatment group (*M*= 30.75, *SD*= 7.40) indicated that the treatment group scored significantly higher than did the control group, $F(1,38) = 4.20$, $p = 0.047$. The treatment group scored significantly higher on Cognitive Integrity major scale, which is a composite score derived from the Open-Mindedness and Inquisitiveness. Therefore, Hypothesis 8 was rejected.

Hypothesis 9 stated that there is no significant difference in problem solving performance between technology education students receiving problem solving instruction through cognitive apprenticeship (treatment group) and technology education students receiving problem solving instruction through traditional strategies (control group). A one-way ANOVA was performed comparing the performance (time, in seconds) of the speed vehicles (see Table 20). A comparison of the control group (*M*= 0.56, *SD*= 0.06) and the treatment group (*M*= 0.48, *SD*= 0.13) indicated no significant difference, $F(1,16) = 0.82$, $p = .80$. A one-way ANOVA was performed comparing the performance (distance, in feet) of the speed vehicles (see Table 21). A comparison of the control group (*M*= 28, *SD*= 5.42) and the treatment group (*M*= 30.23, *SD*= 6.92) indicated no significant difference, $F(1,17) = 0.58$, $p = 0.45$. Hypothesis 9 was not rejected.

Conclusions

After analyzing the findings, the researcher concluded the following:

1. The study results provide evidence that teaching problem solving through cognitive apprenticeship as compared to more traditional approaches effects certain components of problem solving disposition.

2. The study results provide evidence that teaching problem solving through cognitive apprenticeship as compared to more traditional approaches effects certain components of problem solving motivation.

3. The study results provide no evidence that teaching problem solving through cognitive apprenticeship as compared to more traditional approaches effects problem solving performance.

Discussion

Every effort was made to control the confounding variables associated with this quasi-experimental study. A comparison of mean scores revealed the student groups were similar in their overall disposition toward problem solving. Teachers were interviewed and observed by the researcher to ensure that they taught problem solving in a similar fashion. In addition, each teacher took a problem solving teaching survey and the results were compared and used to foster further discussion during the interview stage of the study prior to the start of data gathering. At the beginning of the study, both teachers considered themselves to be more product oriented rather than process oriented with regard to their views on teaching problem solving.

Problem Solving Disposition and Motivation

The review of literature supported that problem solving ability was composed of skill, sub-skills and a willingness to engage in the act of problem solving (Mayer, 1998). Furthermore, these elements could be affected by instructional strategies and the learning environment. Results from the Problem Solving Disposition Inventory indicated that the area of perseverance was affected by the instructional strategy of teaching problem solving through cognitive apprenticeship. This supports the findings of Wankat and Oreovicz (1993) where they list perseverance as a characteristic of expert problem solvers. ANOVA results also indicated that the areas of patience, self-confidence, and attitude appear to be unaffected. Cognitive apprenticeship focuses on process over product in a student-centered, nurturing environment. While dispositional factors tend to be inherent qualities, the researcher assumed that these factors could be influenced. Perhaps it is the coaching aspect of the cognitive apprenticeship model that afforded the students the needed scaffolding to not give up when the activity became frustrating. Each group noted in their technical report that they encountered problems during the unit. However, the treatment group seemed less affected by these hurdles.

Results from the ANOVAs tested on the CM3 revealed that the major scale of Cognitive Integrity and the minor scale of Process were both positive effected by the use of cognitive apprenticeship. Cognitive integrity refers to how motivated an individual is to use thinking and problem solving skills. Process refers to how at ease an individual is with engaging in problem solving. On both scales the treatment group score significantly higher than the control group and on the CM3 interpretive scale, the treatment group's mean scores (Cognitive Integrity, M=30.57; Process, M=28.83) were considered "somewhat disposed" and "ambivalent", respectively. The control group's mean scores (Cognitive Integrity, M=20.13; Process, M=25.16) were considered "ambivalent". Therefore, even though the treatment group did score significantly higher, the overall effect of teaching problem solving through cognitive apprenticeship is difficult to determine.

Problem Solving Performance

Results from an ANOVA comparing the composite scores from the vehicle performance indicated no significant difference between the control and treatment groups. In interviews with the teachers after the data gathering indicated that the control group scores may have been skewed. During the design phase of the unit, the majority of the control group was struggling to find a solution to the problem. As is indicative of novice problem solvers, teams tried their first idea and gave up when it did not work. One individual found a workable solution, and then half of the class benchmarked that solution and reproduced it just to solve the problem. On the other hand, the treatment group teacher pointedly steered the treatment group toward solving the problem within the team and not to use other team's solutions. The scores of the control group may have been elevated due to this event.

By confining the teams to work within group solutions, the treatment group designed more creative solutions. This too may have influenced the results of the Problem Solving Disposition Inventory and the CM3. By retaining ownership in the solution, the treatment group scored consistently higher on both instruments and tended to be more excited and motivated about the problem solving activity, as described by the teachers.

The literature on problem solving and teaching problem solving suggested that the skills and affect of a student can be influenced by the method of instruction used to teach problem solving (Collins, 1991; Mayer, 1998). While some areas of affect appear to be influenced by teaching cognitive apprenticeship, evidence does not support the contention that problem solving skills are affected. Limiting factors associated with the gather of the performance data may have contributed to the results found. More control over the assessment and vehicle design process would have improved the results. The affective characteristics, as measured by the disposition and CM3 scales, that showed stastical significance align directly with the cognitive apprenticeship model used in the treatment group. Specifically, Cognitive Integrity is the major scale of the CM3 that focuses on motivation. Results indicate that using a Cognitive Apprenticeship model to teach problem solving does influence motivation.

When interviewing the teachers after the study, the researcher noted an interesting difference between the two teachers. During the interview, the researcher asked following questions:

1. How did you feel about the experience?
2. Describe how the students reacted to the unit problem solving activity?
3. How would they improve the unit?
4. What did you learn from the experience?

The control group teacher tended to answer the questions very concretely. To improve the course materials he would add more process, and offer more design ideas for the students to use. He suggested having a “step-by-step” option for the students. Conversely, the treatment teacher had an epiphany during the study. He consciously used the coaching tips provided by the researcher and found that by giving students more room, the students were more excited about the process. Even students that became frustrated when they had an obstacle to surmount persisted. On a few occasions the teacher noted that he would coach the student through the obstacle with noticeable results. He commented that in one particular case, a student became visible elated when he was coached through the obstacle. By allowing the student to maintain ownership in the problem the student persevered and was motivated to complete not only this activity, but maintain his motivation for the unit that followed. This example exemplifies that effect of student-centered instructional strategies and corroborated much of the literature on the subject. Not only was the student affected by the cognitive apprenticeship approach, but so was the teacher.

Recommendations

After analyzing the findings and conclusions, the researcher offers the following recommendations:

1. Every effort was made to control the confounding variables associated with the quasi-experimental design used in this study. Assumptions were made at the outset of the study and decisions made to facilitate logistical concerns. As a result, the sample size for the study was smaller than first proposed. Having a larger sample from across the population would afford a more powerful design. Likewise, there were four scales that were

statistically significant at the alpha level greater than .05 but less than .08. Having a larger sample would help one to have greater confidence in the results for those scales.

2. The pilot study of 6-weeks prompted a response of this study being 2-weeks long in an effect to control confound variables uncovered during the pilot study. To really see the effect of cognitive apprenticeship, the researcher suggested a longitudinal study that fully integrates cognitive apprenticeship from the outset of the course. Thereby, addressing both micro-effects as found in this study as well as macro-effects can only be attained with a longer, more comprehensive study.

3. One weakness in the study was in the assessment rules for the performance measure. In addition, lack of control in the design and testing phases compromised a true comparison between the groups. A formal research design would impose more structure on future studies.

4. Effect of teaching problem solving through cognitive apprenticeship did not consider the effect on the teacher. Yet, during interviews after the study the researcher found that there appeared to be significant effect on the treatment teacher. More research in this area is needed to analyze the effect more formally.

REFERENCES

American Philosophical Association. (1990). *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction*. The Delphi Report: Research findings and recommendations prepared for the committee on pre college philosophy. P. Facione, (Project Director). ERIC Doc. No. ED 315-423.

Atkinson, E. (1999). Key factors influencing pupil motivation in design and technology. *Journal of Technology Education*, *10* (2), 4-26.

Berryman, S. (1991). *Designing effective learning environments*. New York: Columbia University, Institute of Education and the Economy. (ERIC Document Reproduction Service No. 337 689)

Berryman, S.E. (1993). *Designing Effective Learning Environments: Cognitive Apprenticeship Models.* (Document No. BI-1). Institute on Education and The Economy. New York, NY: Teachers College, Columbia University. Retrieved January 30, 2003 from http://www.ilt.columbia.edu/publications/papers/berry1.html

Bransford, J. D. & Stein, B. S. (1993). *The IDEAL Problem Solver: A Guide to Improving, Learning and Creativity.* Basingstoke – UK: WH Freeman & Co.

Brown, D. (1991). What To Teach: Technology Education or Funtime 101? *Journal of Technology Teacher Education*, *29* (1), 99-101.

Brown, J., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18* (1), 32-41.

Beyer, B. (1995). *Improving student thinking: A comprehensive approach*. Boston: Allyn & Bacon.

Cajas, F. (2000). Technology Education Research: Potential Directions. *Journal of Technology Education*, *12*(1), Retrieved on April 8, 2003 from http://scholar.lib.vt.edu/ejournals/JTE/v12n1/cajas.html

Cash, J., Behrmann, M., Stadt, R., & Daniels, H. (1996). Effectiveness of cognitive apprenticeship instructional methods in college automotive technology classrooms. *Journal of Industrial Teacher Education*, *34* (2), 29-49.

Chaffee, J., McMahon, C., & Stout, B. (1998). *Critical thinking, thoughtful writing: A rhetoric with readings*. Boston: Houghton Mifflin.

Childress, Vincent W. (1996). Does integrating technology, science, and mathematics improve technological problem solving? A quasi-experiment. *Journal of Technology Education*, *8*(1), 16-26.

Christensen, K.W. & Martin, L. (1992). Teaching Creative Problem Solving. *The Technology Teacher*, *52* (12), 9-11.

Collins A., Brown, J., & Holum, A. (1991). Cognitive Apprenticeship: Making thinking visible. *American Educator*, *6*(11), 38-46

Collins, A., Brown, J.S., & Newman, S.E., (1989) Cognitive apprenticeship: Teaching the crafts of reading, writing, and arithmetic. In L.B. Resnik (Ed.), *Knowing, Learning, and instruction: Essays in honor of Robert Glaser*. Hilldale, NNJ: Erlbaum.

Cote, B.S. (1984). A Paradigm for Problem Solving Instruction. *Journal of Technology Teacher Education*, *21* (4), 17-30.

Deluca, V.W. (1992) Survey of Technology Education Problem-Solving Activities. *The Technology Teacher*, *52* (2), 26-30.

DeBellis V. A. & Goldin, G. A. (1997) 'The Affective Domain in Mathematical Problem-Solving', in E. Pehkonen (Ed.) (1997) *Proceedings of the 21st Conference of the International Group for the Psychology of Mathematics Education,* Lahti, Finland, vol. 2, pp. 209-216.

Dennien, R. T., Gunn, S. E., Swinswood, J. K. & Tawney, D. A. (1973). Devising Evaluation Instruments for Technological Problem Solving. *Journal of Curriculum Studies*, *5* (2), 122-132.

Dewey, J. (1916). Democracy and education. New York: Macmillan.

Dewey, J. (1933). *How We Think: A Restatement of the Relation of Reflective Thinking to the Educational Process*. Lexington, MA: D.C. Heath.

Duncan, S. L. S. (1996). Cognitive Apprenticeship in classroom instruction: Implications for industrial and technical teacher education. *Journal of Industrial teacher Education, 33* (3), 66-86.

Facione, P., Facione, N., & Giancarlo, C. (1997). The motivation to think in working and learning. *New Directions for Higher Education*. San Francisco: Jossey-Bass Publishing.

Facione PA, Giancarlo CA, Facione NC, & Gainen J. (1995). The disposition toward critical thinking. *Journal General Education*, *44*(1),1-25.

Feng-Kwei, W. & Curtis J. (2001) *A Design Framework For Electronic Cognitive Apprenticeship*. Retrieve June 18, 2003, from http://www.aln.org/alnweb/journal/Vol5_issue2/Feng-Kwei/Feng-Kwei.htm

Flowers, J. (1998). Problem Solving in Technology Education: A Taoist Perspective. *Journal of Technology Education. 10* (1). Retrieved on January 20, 2002 from http://scholar.lib.vt.edu/ejournals/JTE/v10n1/flowers.html

Foster, W.T. (2001). *Developing a Research Agenda for Technology Education*. Paper presented at the Second AAAS Technology Education Research Conference in Washington, D.C. Retrieved on June 15 from http://www.project2061.org/meetings/technology/Foster/Foster.htm

Foster, W. T. (1999). A research agenda for technology education. *Technology Teacher, 56* (1), 31-33.

Frye, E. (1996). *Engineering problem solving for mathematics, science and technology education.* Hanover, NH, Dartmouth College.

Greenfield, L.B. (1987). Teaching Thinking Through Problem Solving. *Developing Critical Thinking and Problem Solving Abilities.* J.E. Stice, ed. San Francisco: Jossey-Bass, Inc., 5-22.

Gourgey, A.F. (1998). Metacognition in Basic Skills Instruction. *Instructional Science*, *26* (1-2), 81-96.

Hollingsworth, R. & McLoughlin, C. (2000). *Developing First Year Students' Problem Solving Skills: Can We Do it Online?* Paper presented at ASCILITE 2000: Learning to Choose, Choosing to Learn Conference. Retrieved June 5, 2003 from http://www.ascilite.org.au/conferences/coffs00/papers/rowan_hollingworth.pdf

Insight Assessment. (2001). *The California Measure of Mental Motivation*. Retrieved July 8, 2003 from http://www.insightassessment.com/test-cm3.html

International Technology Education Association [ITEA]. (1996). *Technology for all Americans: A rationale and structure for the study of technology.* Reston, Va.: Author.

International Technology Education Association [ITEA]. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

International Technology Education Association [ITEA]. (2003). *Advancing excellence in technological literacy*. Reston, VA: Author.

Johnson, S. (1992). A framework for technology education curricula which emphasizes intellectual processes. *Journal of Technology Education*, 3 (2).

Johnson, S. (1994). Problem Solving Behavior Research Model for Industrial Education. *Journal of Industrial Teacher Education,* 25 (3).

Johnson, S & Thomas, R. (1994). Implications of Cognitive Science for Instructional Design in Technology Education. *Journal of Technology Studies*, *20* (1), 33-45.

Jonassen, D. (1997). Instructional design models for well-structured and ill-structured problem solving learning outcomes. *Educational Technology Research and Development*, *45* (1), 65-94.

Kay, S. (1994). From Theory to Practice - Promoting Problem-Finding Behavior in Children. *Roeper Review*, *16* (3), 195-197.

Kerka, S. (1992). Higher order thinking skills in Vocational Education. ERIC Digest No. 127. *Columbus: ERIC Clearinghouse on Adult, Career, and Vocational Education* (ED 350 487).

Lee, L.S. (1996). Problem –solving as intent and content of Technology Education. *Paper presented at the International Technology Education Conference 58th Annual Conference*, Phoenix, Arizona.

Leonard, W.J., Gerace, W.J., & Dufresne, R.J. (1999) *Concept-Based Problem Solving: Making concepts the language of physics.* UMPERG technical report 1999#12-NOV#3-18pp.

Maley, D. (1986). *Research and Experimentation in Technology Education.* Reston, Va., ITEA.

Masui, C. & De Corte, E. (1999) Enhancing Learning and Problems Solving Skills: Orienting and Self-Judging. *Learning and Instruction,* 9(6), 517-542.

Mayer, R.E. (1998). Cognitive, Metacognitive and Motivational Aspects of Problem Solving. *Instructional Science, 26*(1-2), 49-63.

Moore, B. (2000). *Higher Level Thinking Skills and Individual Differences: Bridging Gaps with Technology.* Paper presented at the Society for Information Technology and Teacher Education International Conference 2000. Retrieved on August 11, 2003 from http://dl.aace.org/451

Oliver, K. (1999). *Situated Cognition and Cognitive Apprenticeship*. Retrieved on February 19, 2003 from Virginia Polytechnic Institute and Sate University, Educational Technologies website: http://www.edtech.vt.edu/edtech/id/models/powerpoint/cog.pdf

Parker, F.W. (1894). *Talks on Pedagogics*. New York: A.S. Barnes and Co.

Paul, R., Binker., A., Jensen, K., & Kreklau, H. (1990). *Critical thinking handbook: A guide* *for remodeling lesson plans in language arts, social studies and science.* Rohnert Park, CA: Foundation for Critical Thinking.

Petrina, S.(1994). Curriculum Organization in Technology Education: A Critique of Six Trends. *Journal of Technology Teacher Education*, *31* (2), 44-69.

Prince, M.& Hoyt, B. (2002). *Helping Students Make the Transition from Novice to Expert Problem Solvers.* Paper presented at the 32nd ASEE/IEEE Frontiers in Education Conference in Boston, MA. Retrieved on June 26, 2003 from http://fie.engrng.pitt.edu/fie2002/papers/1192.pdf

Potts, B. (1994). Strategies for Teaching Critical Thinking. *Columbus: ERIC Clearinghouse on Adult, Career, and Vocational Education* (ED 385 606).

Pugalee, D.K., Douville, P., Lock, C.R., & Wallace (2002). *Authentic Tasks and Mathematical Problem Solving*. Paper presented at The Mathematics Education in the 21st Century Project Conference in Palermo, Italy. Retrieved July 10, 2003, from http://math.unipa.it/~grim/SiPugalee.PDF

Rosenshine, B. and Meister, C. (1992). The Use of Scaffolding for Teaching Higher Level Cognititive Strategies. *Educational Leadership*, *49*(7), 26-33

Rowell, P. (2001). *Looking Back, Looking Forward: Reflections on the Technology Education Research Conference*. Paper presented at the AAAS Technology Education Research Conference, Washington, D.C.

Rubinstein, M.F. & Firstenberg, I.R. (1987). Tools for Thinking. *Developing Critical Thinking and Problem Solving Abilities*. J.E. Stice, ed. San Francisco: Jossey-Bass, Inc., 23-36.

Secretary's Commission on Achieving Necessary Skills [SCANS]. (1991). *What Work Requires Of Schools*. Washington, DC: U.S. Department of Labor.

Seldon, Annie & John. (1997). What does it take to be an expert problem solver. *Teaching and Learning: Research Sampler No.4*. Retrieved on February 10, 2003 from http://www.maa.org/t_and_l/sampler/rs_4.html

Smith, D.E., Knudsvig, G.M., & Walter, T. (1998). *Critical thinking: Building the Basics.* Wadsworth.

Snyder, K., Farrell, R., Baker, N. (2000). *Online Mentoring: A Case Study Involving Cognitive Apprenticeship and a Technology-Enabled Learning Environment*. Paper presented at ED-MEDIA 2000. Retrieved on March 20, 2003 from http://www.research.ibm.com/AppliedLearningSciWeb/Snyder/edmedia.htm

Sprinhall, N., Sprinthall, R. & Oja, S. (1994). *Educational Psychology: A developmental approach.* New York: McGraw-Hill, Inc., 373-375.

Thomas, J. (2000). *A Review of Research on Problem Based Learning*. Retrieved on May 29, 2003 from http://www.bie.org/tmp/research/researchreviewPBL.pdf

VanDemark, N. (1991). *Breaking the barriers to everyday creativity*. Buffalo, NY: The Creative Education Foundation.

Wager, Walter. (1997). *Information Overload: Man Over Board!.* Retrieved July 7, 2003, from http://it.coe.uga.edu/itforum/paper23/paper23.html

Wankat, Phillip and Oreovicz, Frank (1993). *Teaching Engineering*. McGraw Hill Inc.: New York, NY.

Wicklein, Robert C. (1997). Curriculum Focus for Technology Education. *Journal of*

Technology Education, *8* (2), 72-79.

Winek, G and Borchers, R. (1993). Technological Problem Solving Demonstrated. *The Technology Teacher, 52* (2), 23-25.

Woods, D.R. (1998). The MPS program: the McMaster Problem Solving program. Retrieved on November 5, 2000 from http://www.chemeng.mcmaster.ca/MPS/

Woods, D.R., Hrymak, A.N., Marshal, R.R., Wood, P.E., Crowe, C.M. Hoffman, T.W. et al. (1997). Developing Problem Solving Skills: The McMaster Problem Solving Program. *Journal of Engineering Education*, *86*(2), 75-91.

Woods, D. R. (1993). PS-- Where are We Now? *Journal of College Science Teachers*, *22* (5), 312-314.

Woods, D.R. (1987). How Might I Teach Problem Solving*? Developing Critical Thinking and Problem Solving Abilities*. J.E. Stice, ed. San Francisco: Jossey-Bass, Inc., 55-71.

Wu, Tain-Fung, Cluster, Rodney L., Dyrenfurth, Michael J. (1996). Technological and personal problem solving: Is there a difference? *Journal of Technology Education*, *7*(2), 55-71.

Zuga, K. F. (1994). *Implementing Technology Education: A Review and Synthesis of the Research Literature. Information Series No. 356.* ERIC Document Number ED372305.

APPENDIX A

Problem Solving Disposition Inventory

Technological Problem Solving Survey

Name ____________________________ Grade ______

People often have to fix technologies that break, or design new devices. Rate each statement below by circling the number that best represents your opinion from **strongly disagree** to **strongly agree**. Use the following scale:

1 = I strongly disagree with the statement. It does not describe me.
3 = No strong feelings one way or another.
5 = I strongly agree that this statement describes me.

	Strongly Disagree				Strongly Agree
When a technology you use breaks...					
I get mad and frustrated and don't fix it	1	2	3	4	5
I usually try to fix things that break	1	2	3	4	5
If I can't fix something, I learn more and try to figure it out	1	2	3	4	5
I keep trying until I get it fixed.	1	2	3	4	5
I like fixing things	1	2	3	4	5
When Designing to Solve a Problem					
I am concerned I will fail or look silly in front of others	1	2	3	4	5
I'll try to design things but I'm not good at it	1	2	3	4	5
If my first idea doesn't work, I give up	1	2	3	4	5
I enjoy designing and building new things	1	2	3	4	5
I usually come up with many possible solutions	1	2	3	4	5
I usually look at example solutions to the problem to get ideas	1	2	3	4	5
Designing and making things is frustrating	1	2	3	4	5
I enjoy the challenge of solving technical problems	1	2	3	4	5
I feel confident in my ability to solve technical problems	1	2	3	4	5
I get frustrated when I have trouble building what I design	1	2	3	4	5

APPENDIX B

Control Group Unit Lesson Plan

MPV Unit Plan

Day 1 –

Introduction

- Design Brief
- Technical Report and Matrix

Resources: *Design Brief Handout*
Technical Report Handout

Problem Solving and Systems Models

- DEAL
- Universal Systems Model
- Sub-Systems – Vehicular Subsystems

Resources: *Problem Solving and Systems Models Handout*
Problem Solving and Systems Models Overhead

Notes: Day one is the day to introduce the project to the students.

- Handout the Design Brief and Technical Report sheets and briefly discuss the requirements with the students. This should only take about 20 minutes
- Establish the teams for the unit
- During the Problem Solving and Systems Models discussion draw on past project to create comparisons. Use the overhead to discuss the content. This material is testable. The handout is for the students to take home and read. At the end of the lecture portion of the lesson, discuss with the students how the vehicular sub-systems relate to their car and how these subsystems relate to one another.

Day 2 –

Getting Starting

- Design Ideas – Teacher Uses whiteboard and an activity kit to discuss:
  - Propulsion Systems
  - Materials
  - Options
- Theory
  - Potential Energy
  - Kinetic Energy
  - Friction
  - Static Friction
  - Sliding Friction
  - Momentum
  - Inertia
  - Torque
  - Lever Arm

Resources: *Activity Kit*
Theory Handout and Overhead

Notes: This lesson is devoted to providing the foundational knowledge the students will need to better understand and solve the design problem.

During the Design Ideas the intent is to familiarize the students with the project by discussing different design, propulsion and material options. Using one of the Activity Kits, explore with the students what they have to work with.

If you are unfamiliar with the various design options, take some time to investigate the site above and play with creating your own vehicle.

This portion of the lesson should only take about 20-25 minutes.

The second half of the period should be spent discussing the Theory associated with the unit. Students should be prepared to take a quiz at the end of the lesson relating to the DEAL Problem Solver, Systems Models and the vocabulary discussed in the Theory lesson.

Days 3-4 –

Designing your vehicles

Resources: Graph Paper, rulers

Notes: Students will generate ideas as a team and produce thumbnail sketches, then a working drawing for each vehicle.

- At the beginning of the Design Phase distribute the Activity Kits to the teams.
- I suggest you take a group inventory of the Kits and have the students label their bags.
- The students will measure the parts that need to be drawn, but remind them to not break or lose any as the kit they receive is all they will get.
- The working drawing need only be a two-view drawing – front view and top view
- If the students have never had to create a scaled drawing or a working drawing, it will be necessary to go over what they would need to do.

Days 5- 7 –

Build / Test / Refine

Resources: Activity Kit

Notes: Student teams will use this time to build what they designed on graph paper, informally test their prototype and make any final revisions before the formal vehicle testing on Day 8.

- The students will be very excited about start their vehicles as soon as possible. But it very important that they have a clear plan of what they are going to build before they start. They have a limited quantity of materials. As a result, I suggest you require that the working drawing be complete before they are allowed to start building. It will save you a lot of headache in the long run.
- The best place to test the vehicles is in the hallway. At many schools the tiles in the hallway are 12" x 12". That will make it easy to establish the 10' speed track and how far the distant vehicle travel. If the hall does not have 12" x 12" tile it may be necessary to use a tape measure.
- Place a piece of masking tape on the floor to indicate the start and finish lines for the speed vehicle. The distance vehicles can use the same start line for their testing.
- You will need a stop watch for the speed vehicles
- Please do not overlook safety during this phase. The students will work with razor blades and hot glue guns to fabricate their vehicles. I suggest you create an area in your room for each operation and place card board of wood on the surface to protect against cuts and burning.

Day 8 – Final Test of Vehicles

Notes: Using the same track setup listed above, allow the students to run their vehicles for record. When each team is done they can calculate their team score using the formula on the Design Brief sheet.

Day 9 – Unit Summary

- Summary
- Students work on technical report
- Quiz on Content Covered

Notes: Students will work on their technical reports today. In addition, summarize the key concepts covered, what worked well, what didn't, how well the teams worked together to solve the problem and how they could improve their designs. In the last 20 minutes of the class have the students take the quiz on key concepts covered.

Day 10 – Survey and Turn in technical report

Notes: Have the students take the survey provided. The survey should only take about 20-30 minutes to complete. Please take time to carefully go over expectations of the survey. It is important that the students take the survey as serious as possible to insure there input is accurately reflected.

APPENDIX C

Treatment Group Unit Lesson Plan

MPV Unit Plan

Day 1 & 2 – Warm-up: Hovercraft *Concentration* - *Modeling*

Day 3 – Introduction / Problem Solving and Systems Models

Day 4 – Getting Started: Design Ideas and Theory *Concentration* – *Modeling*/ *Coaching*

Day 5 & 6 – Designing your Vehicles *Concentration* - *Coaching*

Day 7 & 8 – Build / Test / Refine *Concentration* – *Coaching* / *Fading*

Day 9 – Final Vehicle Test / Technical Report / Unit Summary

Day 10 – Survey / Quiz

Day 1 & 2 – Warm-up: Hovercraft

- Design Brief
- Team Design/Build Activity
- Introduce the MPV Design Brief

Resource: *Design Brief Handout*
Problem Solving Analysis Sheet
MPV Design Brief Overhead
Problem Solving Pre-survey

Notes: The intent of the warm-up activity is to provide context for the students by having them solve a similar problem as the MPV. This also levels the playing field. During the course of the unit, you will be using a Cognitive Apprenticeship approach – Modeling, Coaching and Fading. For you part, please concentrate on *modeling* good problem solving behaviors during this exercise.

As a reminder, *Modeling* provides opportunities for students to observe and learn from experts' works. As the novice watch the expert's performance, they observe the steps and perform task with the expert. They learn how to think like experts, and also how to deal with the problems they face during their learning as the experts do. It is important for the expert to relate the activity to some form of prior knowledge held by the novice in order to obtain their 'learning attention'.

As a result, you should start by introducing the problem, explaining what the expectations are and what materials they have to work with. Be sure to stress to the students to importance of having a plan as they have a limited amount of material and time to work with. After introducing the problem you should being to work through the process to solve the problem as though you are going to solve the problem with the students. This will give the students a view into how an expert problem solver solves the problem in a real situation. Talk aloud about the process you are using to address the issues. Understanding the thought process you use will help them with a starting point. As we go further into the unit you will concentrate on coaching, then fading. By the end, the hope is that the students will be able to deal with the problems on their own.

- Handout the Design Brief and Technical Report sheets and briefly discuss the requirements with the students. This should only take about 20 minutes
- Establish the teams for the unit
- Immediately after discussing the problem, hand out the Problem Solving Pre-Survey

Day 3 –

Introduction

- Design Brief
- Technical Report and Matrix

Resources: *Design Brief Handout*
Technical Report Handout
Problem Solving Log Sheets

Problem Solving and Systems Models

- DEAL
- Universal Systems Model
- Sub-Systems – Vehicular Subsystems

Resources: *Problem Solving and Systems Models Handout*
Problem Solving and Systems Models Overhead
Tools of Problem Solving Handout
Tools of Problem Solving Overhead
Concept Mapping Overhead

Notes: Day three is the day to introduce the project to the students.

- Handout the Design Brief and Technical Report sheets and briefly discuss the requirements with the students. This should only take about 20 minutes
- Establish the teams for the unit. Make sure the students are aware that each team member is responsible for both a vehicle ***and*** technical report.
- During the Problem Solving and Systems Models discussion draw on the ACV Warm-up project to create comparisons. Use the overhead to discuss the content. This material is testable. The handout is for the students to take home and read. At the end of the lecture portion of the lesson, discuss with the students how the vehicular sub-systems relate to their car and how these subsystems relate to one another.

Day 4 –

Getting Starting

- Design Ideas – Teacher Uses whiteboard and an activity kit to discuss:
    - Propulsion Systems
    - Materials
    - Options
- Theory
    - Potential Energy
    - Kinetic Energy
    - Friction
    - Static Friction
    - Sliding Friction
    - Momentum
    - Inertia
    - Torque
    - Lever Arm

Resources: *Activity Kit*
Theory Handout and Overhead
Mathematical Modeling Overhead
Mathematical Modeling Exercise Sheet

Notes: This lesson is devoted to providing the foundational knowledge the students will need to better understand and solve the design problem.

During the Design Ideas the intent is to familiarize the students with the project by discussing different design, propulsion and material options. Using one of the Activity Kits, explore with the students what they have to work with.

If you are unfamiliar with the various design options, take some time to investigate the site above and play with creating your own vehicle.

This portion of the lesson should only take about 20-25 minutes.

As with the warm-up activity, help the students by modeling good problem solving process by asking open-ended questions to illicit positive response on good problem solving behavior.

The second half of the period should be spent discussing the Theory associated with the unit. Students should be prepared to take a quiz at the end of the lesson relating to the DEAL Problem Solver, Systems Models and the vocabulary discussed in the Theory lesson.

As you work through the mathematical modeling exercise with the students, discuss the key terms associated with the problem.

When the students work on the exercise in class, you should position yourself as a Coach. Avoid answering too many questions. Instead pose discovery questions back to the students to have them figure it out. If the students do not finish the exercise before the end of class they should complete it for homework.

As a reminder, during the *coaching* phase, the instructor offers students helpful hints, scaffolding, feedback, modeling, goal settings and reminders while they are carrying out tasks. Also, it's time for instructors to evaluate the students' activities, discuss problems that students have, and challenge or offer encouragement toward students. Instructors can provide help at the problem solving level and provide help when the student needs it. It is also during the coaching phase that students could, and in some cases should, get coaching help from their partner. After all this is a team project even though each team member is responsible for their own work.

Days 5 & 6 – Designing

Designing your vehicles

Resources: Graph Paper, rulers

Notes: Students will generate ideas as a team and produce thumbnail sketches, then a working drawing for each vehicle.

- At the beginning of the Design Phase distribute the Activity Kits to the teams.
- I suggest you take a group inventory of the Kits and have the students label their bags.
- The students will measure the parts that need to be drawn, but remind them to not break or lose any as the kit they receive is all they will get.
- The working drawing need only be a two-view drawing – front view and top view
- If the students have never had to create a scaled drawing or a working drawing, it will be necessary to go over what they would need to do.

Again, you are concentrating on Coaching during this portion of the unit. As a reminder, during the *coaching* phase, the instructor offers students helpful hints, scaffolding, feedback, modeling, goal settings and reminders while they are carrying out tasks. Also, it's time for instructors to evaluate the students' activities, discuss problems that students have, and challenge or offer encouragement toward students. Instructors can provide help at the problem solving level and provide help when the student needs it.

Days 7 & 8 –

Build / Test / Refine

Resources: Activity Kit

Notes: Student teams will use this time to build what they designed on graph paper, informally test their prototype and make any final revisions before the formal vehicle testing on Day 8.

- The students will be very excited about start their vehicles as soon as possible. But it very important that they have a clear plan of what they are going to build before they start. They have a limited quantity of materials. As a result, I suggest you require that the working drawing be complete before they are allowed to start building. It will save you a lot of headache in the long run.
- The best place to test the vehicles is in the hallway. At many schools the tiles in the hallway are 12” x 12”. That will make it easy to establish the 10’ speed track and how far the distant vehicle travel. If the hall does not have 12” x 12” tile it may be necessary to use a tape measure.
- Place a piece of masking tape on the floor to indicate the start and finish lines for the speed vehicle. The distance vehicles can use the same start line for their testing.
- You will need a stop watch for the speed vehicles
- Please do not overlook safety during this phase. The students will work with razor blades and hot glue guns to fabricate their vehicles. I suggest you create an area in your room for each operation and place card board of wood on the surface to protect against cuts and burning.

During this portion of the unit, you are still *coaching*, but working toward *fading*. During this *fading* stage the student assume control solving problems independently. Usually, instructors set general goals and teach exploration strategies. Students are then encouraged to focus on particular sub-goals or even revise the general goals in order to come up with their own problem solutions.

Day 9 – Final Test of Vehicles / Technical Report / Unit Summary

Vehicle Test

Notes: Using the same track setup listed above, allow the students to run their vehicles for record. When each team is done they can calculate their team score using the formula on the Design Brief sheet.

Technical Report / Unit Summary

- Summary
- Students finish and turn-in Technical Report

Notes: Summarize the key concepts covered, what worked well, what didn't, how well the teams worked together to solve the problem and how they could improve their designs. Tie this discussion with the Technical Report by linking some of the sections of the Report to the discussion.

Day 10 – Survey and Quiz

- Problem Solving post survey
- CM3 Survey
- Quiz

Resources:

Problem Solving post survey
CM3 Survey
Quiz

Notes: Have the students take the survey provided. The survey should only take about 20-30 minutes to complete. Please take time to carefully go over expectations of the survey. It is important that the students take the survey as serious as possible to insure there input is accurately reflected. In the last 20 minutes of the class have the students take the quiz on key concepts covered.

APPENDIX D

Treatment Group Teacher Notes and Handouts

Applying the Cognitive Apprenticeship Model

Before formal schooling, people gained new skills and knowledge through the mentoring of an expert. This apprenticeship model was the most common way of learning. Today, formal schooling is the primary method of instruction. While formal schooling works well at teaching conceptual and factual knowledge, it falls short when teaching complex, cognitive skills like problem solving.

In 1989, Collins, Brown and Newman developed an alternative pedagogical method that combined the traditional apprenticeship model with situated cognition theory. They called their model cognitive apprenticeship. Situated Cognition suggests skills be acquired through authentic context and by working with peers and experts. The cognitive apprenticeship model provides practical steps for applying the Situated Cognition Theory. Students learn more effectively through observing expert and working on authentic tasks so that learners can apply what they have learned into the real world situation. As it relates to problem solving, a review of literature reveals that Cognitive Apprenticeship shows promise as a model for enhancing both problem solving skills, as well as, disposition toward problem solving (Collins, Brown, and Holum, 1991).

In its purest state, the cognitive apprenticeship has three stages – Modeling, Coaching and Fading. Though the cognitive apprenticeship model uses these three elements the emphasis is on cognitive skills rather than physical skills. Additional components include: Scaffolding, Articulation, and Reflection.

During the modeling phase, the instructor shows students how to complete a task or solve a problem while verbalizing the process taken. This differs from typical school instruction because it is delivered within context of real world situations. Through modeling, students see, in real time, an expert problem solver solving a problem. It is important that the problem the instructor is solving is similar to the problem the students will solve. "By modeling the desired intellectual process, students will discover that there are many ways to solve problems, that experts make mistakes, and that seemingly simple problems are very complex in the real world" (Johnson, 1992).

After modeling the desired processes, teachers need to become coaches. The coaching stage includes observing students while they are working, offering immediate feedback and sometimes providing hints or assistance if needed. In doing so, however, teachers must not take control of the problem. Students need to maintain ownership (Atkinson, 1999).

As the students become more confident in their ability and more accomplished with their cognitive skills, less and less teacher intervention is necessary. During this fading stage the student assume control solving problems independently. Usually, instructors set general goals and teach exploration strategies. Students are then encouraged to focus on particular sub-goals or even revise the general goals in order to come up with their own problem solutions. This is sometimes referred to as Exploration.

In addition to the three primary components, cognitive apprenticeship also includes several other defining characteristics. The primary components address the micro-scaffolding needed for development, but additionally there must exist macro-scaffolding. Scaffolding provides learners with support at the appropriate levels and at the right time. This means "increasing complexity and diversity in lesson sequences" (Johnson, 1992). All of this must exist with an environment that promotes intrinsic motivation, cooperation and competition (Collins, Brown, and Newman, 1989).

Articulation

Articulations can include students engaging in a dialogue, verbalizing their thoughts, or assuming the role of monitor or critic in cooperative activities. It's the time to let student make knowledge available to be used in other tasks, compare strategies to different contexts, and make the student see the problem from another student's point of view.

<u>Reflection</u>

It's time for students to externalize their meta-cognitive processes and hence open them for evaluation. It enable them to compare their own problem -solving processes with those of an expert and other students.

<u>Exploration</u>

The goal of cognitive apprenticeship is to make the thinking processes of a learning activity visible to both the students and the teacher. The teacher is then able to employ the methods of traditional apprenticeship (modeling, coaching, scaffolding, and fading) to effectively guide student learning.

Teacher Handout

Balloon Hovercraft – 2 Days

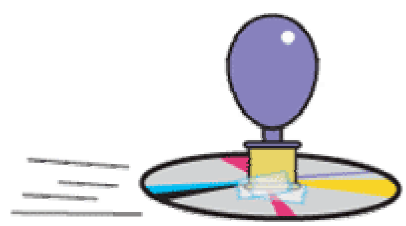
Hovercrafts ride suspended on a thin bubble of air. The main technical challenge in building a hovercraft is to control the shape, flexibility and leakage of that bubble. Too much air leaking out of the hovercraft will empty the balloon air supply before the craft has a chance to slide along the surface. Too little air and the hovercraft will fail to rise above the surface.

Simple balloon hovercrafts are nothing more than a flat disk with a hole in the center fed by the air from a balloon. As long as the disk sits on a very flat surface it will skid along quite nicely on a very thin skin of air. However, even a small piece of debris is sufficient to hold the disk in place. Likewise, a dent in the table will bleed air out from under the disk so quickly that the bubble of air collapses and the hovercraft stops hovering.

Thus, most real hovercrafts employ a flexible skirt along the bottom edge of the air bubble. This skirt will yield when encountering debris, and flows into dents and grooves to prevent air leakage. Even a simple balloon hovercraft toy benefits from a flexible skirt.

Supplies

- Used computer CDs
- Various plastic or wooden spools and tubes with different diameter openings
- (2) Round balloons
- 12 " of Tape
- Scraps of paper or cardboard
- Bendable straw
- (1) Cup



***Each kit should be the same

Directions

- Line the holes up and attach the spool tightly to the print side of the CD with tape
- Attach the balloon to the other end of the spool
- Inflate the balloon from underneath the CD and pinch it so no air escapes
- Set the hovercraft down on a large, smooth, flat surface and let go of the balloon
- Experiment with control of the hovercraft. Add paper fins or streamers to direct its movement.
- The hovercraft rides a cushion of air that lifts it off the surface, minimizing the friction with the CD and allowing it to move without resistance.

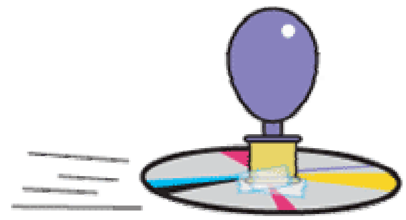
Notes

- The point of this exercise is to get the students thinking and problem solving using the materials and scientific principles they will encounter during the follow-up project.
- Be sure to discuss with the students the **Key Considerations** before they begin construction. It will help them when they encounter problems. Note: Friction – Good and Bad -- In certain cases, friction is good (e.g. tires and the road); in other cases, fiction is bad (e.g. wasted heat generated by a motor).
- This exercise is designed for two 55-minute class periods:
  - Day One – Introduce the topic
    - Discuss Key Considerations
    - Design Brief
    - Student R&D
    - Students test design
  - Day Two – Final design changes
    - Redesign/Fix in needed
    - Final vehicle testing
    - Problem Solving Analysis
    - Summary Discussion – What did you learn that you can apply later in the MPV?
- The activity should only take about half of Day Two. During the other half of Day Two you should have the students work on their Problem Solving Analysis sheet. Time permitted, transition into the MPV project, making correlations between the MPV and ACV they just completed.
- The MPV will reinforce all concepts covered in this activity.

Student Handout

Hovercraft (Air Cushioned Vehicle)

Problem Statement:



Using provided materials, design and construct an air cushioned vehicle (ACV) that will travel the furthest distance as compared to your class.

Limitations:

1) Size
   a) Maximum length 8"
   b) Maximum width 5"

2) Cost - nothing should be purchased specifically for this design problem

3) Process - No power tools can be used during construction

4) Time - You will have approximately 2 hours of class time (e.g. 2 class periods) to design, construct, test and improve your design before the final test event.

5) Testing Location - Hallway

6) Testing situation - Each vehicle will start with the front of the vehicle at the start line. Once released the vehicle can not be touched. Distance will be measured from the start line to the furthest edge of the vehicle.

7) Complete solution must travel with vehicle

8) A common house fan will be set at medium speed for testing. The direction of the wind will be parallel to the floor. The teacher will control use of the fan. The fan will aid the ACV by providing directional propulsion (a pushing force).

9) You will work in teams of two.

10) Key considerations:
    - Weight
    - Balance
    - Control
    - Propulsion
    - Friction - Good and Bad.
    - Potential and Kinetic Energy

Air-Cushioned Vehicle
Problem Solving Analysis

1. Trace the process you used to come to your final design. Explain how you solved the problem. What was the basis for you final design? Was this your first choice? If not, how did you arrive at this design? What was your strategy?

2. Log the problems you encountered and explain how you solved them.

3. Below, sketch your final solution

Problem Solving and Systems Models

A problem exists when people encounter a difficulty.
Example: cracking open a walnut when tools are unavailable

Two conditions exist: (1) There is a goal (cracking open the walnut) and (2) there is no clear path from the present state to the goal

Problem solving is a natural process. To make it easier to understand what is happening when we solve problems, some people use problem solving models. The D.E.A.L. Problem Solver is one of those models.

- **D**efine the problem and develop an understanding through observation and investigation
- **E**xplore possible solutions
- **A**ct on one solution and develop a plan for solving the problem
- **L**ook back and evaluate the plan and solution

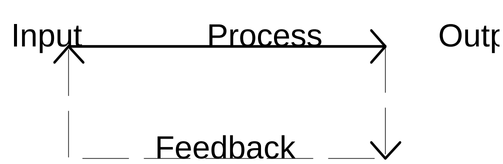
During the problem solving process, many methods are typically used – troubleshooting, trial & error, and modeling are just a few. As you progress through this activity, you will use all of these methods. After all, there is more than one way to solve a problem. What works for you, might not work for someone else.

Systems and Sub-systems

Technological problems come in many forms and can be very complex. In an effort to fully understand the complexity of the problem we must try to simplify it. This is done by breaking down the complex problem into smaller (simpler) parts. This is known as the **scientific method.** Even the most complex technologies can be broken-down to very simple scientific and design principles. When we see the problem in this new, simple state it is easier to identify possible solutions to the problem.

In the study of technology is usually handled through what is called a *systems approach.* **A system** is a group of parts that work together to achieve a goal. These parts include: *input, process, output and feedback*, which make the **Universal Systems Model**.

Universal Systems Model



Inputs - The elements that go into solving a problem, including: people, information, materials, tools and machines, energy, money, and time.

Processes - The act of making or doing, including: designing the product and its parts, making the parts, and assembling the product.

Outputs - The end result, including: the solution to the problem, and impacts.

Feedback is information about the output that is sent back to the system, like whether or not the product was effective for the consumer.

These individual parts found in systems are known as **sub-systems**. If you add together the sub-systems, you will have the whole system. As a result each sub-system can affect the whole system. This makes the study and design of a technological product very complicated. Breaking down these complex systems help people isolate problems.

There are many different ways to divide a large system into sub-systems. During this unit you will not only be concerned with the universal systems models but also sub-systems associated with vehicles.

Vehicular Sub-Systems

The five sub-systems used to describe a vehicle include: **guidance, control, propulsion, structure, and suspension**.

Guidance- This system deals with the information needed to control the vehicle. For example, the odometer in a car or a global positioning system is guidance systems.
Control- This system deals with speed and direction
Propulsion- This system includes forces that produce power for motion
Structure- The physical frame of the vehicle is the structural system
Suspension- This system includes vehicle support systems, like shocks, wheels and axles.

It is important to know these systems, but it is more important to know how each of the sub-systems works together. If or when a problem occurs, you can use these systems to help troubleshoot the problem.

An easy way to understand all the parts that make up a complex technology is to diagram all the parts so we can see how they relate to each other. One method to do this is known as **concept mapping** or web diagramming. We can use this diagram throughout the problem solving process.

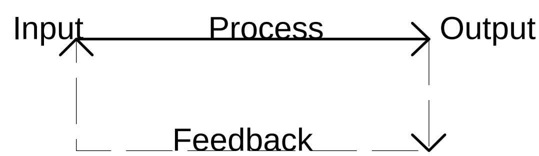
During the design, construction and testing of your MPV you will encounter many problems. Use your understanding of the vehicle sub-systems to help locate the problem in order to fix it.

Student Handout

D.E.A.L. Problem Solving Method

(**I** - *Idenify* the Problem)
D - *Define* the Problem
E - *Explore* all the different options
A - *Act* by choosing the your best option
L - *Look* back at your results

Universal Systems Model



Inputs – the elements that go into solving a problem
people
information
materials
capital (money)
tools
machines

Process - the act of making or doing
designing / planning
directing / managing
building
using

Outputs - the end result
products
solutions

Feedback - taking your results and feeding it back into a new set of inputs
Analysis
Evalution

Vehicular Sub-Systems

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Theory

Potential Energy

The energy which a body has because of its position or structure rather than a result of its motion.

What is a mousetrap vehicle's source of ***Potential Energy****?*

Kinetic Energy

The energy which a body has because it is in motion.

How PE & KE relate:
E (total energy) = KE (kinetic energy) + PE (potential energy)

Friction

Force opposing motion between two objects that are in contact

Static friction

Static friction refers to the forces that opposes the start of motion between two surfaces not in motion

Example- pushing a heavy box along a floor, difficult to start

Sliding friction

Sliding friction refers to the forces between two surfaces that are in motion

Example- pushing a heavy box along a floor ... Difficult

To start **but** easier once started... Friction is less

What are some of the likely sources of friction in the vehicles?
Axles, bearing surfaces, spring, wheels

How can you minimize friction?

Lubrication, bearings

Are there any areas that the friction is actually desirable?
Between wheel ***and*** *the floor... To a certain degree*

Momentum

= Product of an object's mass and velocity.

> **Example -** If you rolled a ping pong ball and a bowling ball at the same speed, which would be more difficult to stop?

Same type of question ... But now you roll two bowling balls at two different speeds, which is now more difficult to stop?

Mathematical Modeling

What does this have to do with math?

Using math you can estimate the travel of your vehicle before it is even built

What basic bits of information are required in order to estimate vehicle travel?

- Wheel radius, diameter or circumference
- Axle radius, diameter, or circumference
- Length of string that is wound around axle

How the calculation works.

Ultimately what you are trying to figure out is how what is my total drive distance. In order to determine that you need to know how many times to drive wheel will turn. This calculation does not factor in momentum.

1 rotation of the axle = 1 rotation of the drive wheel(s) or ***revolutions***

# of revolutions is determined by the number of times you can wrap the string around the axle = the length of string / circumference of the axle

Drive Distance = # of revolutions (wraps around the axle) * drive wheel circumference
Circumference
= the distance around a circle
= diameter * PI
= 2 (radius) * PI

String & Axle Information

- The length of string used in the calculation must be only that string that is wrapped around the axle
- The axle diameter used in the formula is must come from the part of the axle that is wrapped with the string

What does this tell you about the design of your vehicle, in terms of the drive wheel size, axle diameter & string length and lever arm length?

Large wheel circumference, small axle circumference & a long string \mth a small diameter

How do you get more string around the axle?

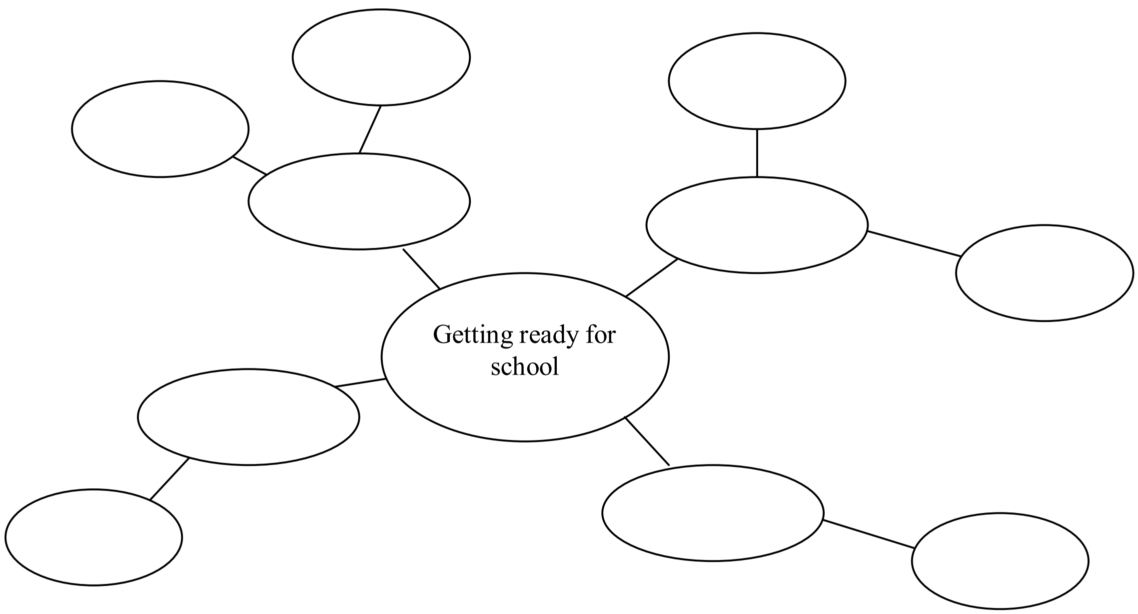
Increase the length of the lever arm & use a small diameter string

Concept Mapping

Concept Mapping is a graphical representation of a complex system and its subsystems.

It allows us to better understand how the parts of system relate to one another. In this activity, we will start by simplifying the complex idea of a Multi-Propulsive Vehicle (MPV) into common vehicle subsystems first. The five subsystems used to describe a vehicle include: guidance, control, propulsion, structure, and suspension. But before we tackle the MPV, let's take a closer look at concept maps. You can take any problem and approach it using the systems approach

Let's consider a problem you face everyday – getting ready for school



Now, let's consider the problem at hand – the MPV. As stated above, we will start with the five subsystems of a vehicle.

Guidance- Information needed to control the vehicle
Control- Speed and direction
Propulsion- Forces that produce power for motion
Structure- The physical frame of the vehicle
Suspension- vehicle support systems

After developing a way to analyze a problem, we are ready to consider methods for solving problems.

Steps in Making a Concept Map

- Write down major terms or concepts about a topic.
- Identify the most general, intermediate, and specific concepts.
- Begin drawing the concept map:
    - Concepts are circled
    - Place the most general concepts at the top
    - Place intermediate concepts below general concepts
    - Put specific concepts on bottom
- Draw lines between related concepts.
- Label the lines with "linking words" to indicate how the concepts are related.

Revise the map

Multi-propulsive Vehicle
Technological Problem Solving

Design Brief

As a member of a team, Design and Construct a Speed or Distance vehicle solely powered by a combination of power sources.

Specifications:

- Power sources per vehicle: (1) mousetrap; (2) rubber bands; (2) balloons
- Any combination of power sources is acceptable
- All materials will be provided
- Complete solution must travel with vehicle
- Maximum size of vehicle - The vehicle must fit into the 4"x6"x12" Go/No Go Gauge without being disassembled
- Speed Vehicle track is 10 feet
- Distance vehicle must be designed to travel a minimum of 25 feet

Team Specifications:

Team will be comprised of two individuals. The objective of each team is to design and construct two vehicles: a distance vehicle and a speed vehicle. Each team member will be responsible for the design, documentation and construction of on eof the vehicles. Grading will be on an individual basis. At the final testing of the prototypes, teams will receive a score based on the combined effort of the team. This score will be based on the distance achieved by the distance vehicle divided by the time of the speed vehicle over a distance of 10 feet.

$$\frac{\textbf{Distance Achieved (Distance Vehicle)}}{\textbf{Time (Speed Vehicle)}}$$

Key Considerations

Weight
Structural integrity of given materials
Friction (positive and negative)
Momentum
Inertia

Design Ideas

Propulsion Systems
Mousetrap, Balloon, Rubber Band

Mousetrap Car Design Tips
http://www.docfizzix.com/construction_tips.htm

http://www.docfizzix.com/help.htm

Balloon Vehicles
http://www.mcpasd.k12.wi.us/mhs/gallery/engineeringdesign/beglinger/ballooncar2/

Step-by-Step instructions
http://www.life.uiuc.edu/boast1/lesson_kits/rocketcars/steps2-a.html

NASA rocket car
http://www.lerc.nasa.gov/WWW/K-12/TRC/Rockets/rocket_car.html

Rubber Band Cars
http://www.nscsd.k12.ny.us/schools/nsjhs/Academics/Technology_Dept/Rubber_Band_Cars/rubber_band_cars.htm

http://www.wsalem.k12.wi.us/WSHShome/Science/student_projects.htm

Notes:
During the Design Ideas the intent is to familiarize the students with the project by discussing different design, propulsion and material options. Using one of the Activity Kits, explore with the students what they have to work with.

If you are unfamiliar with the various design options, take some time to investigate the site above and play with creating your own vehicle.

This portion of the lesson should only take about 20-25 minutes.

The second half of the period should be spent discussing the Theory associated with the unit. Students should be prepared to take a quiz at the end of the lesson relating to the DEAL Problem Solver, Systems Models and the vocabulary discussed in the Theory lesson.

MPV Materials List

(2) CD's
(2) front wheels
(2) back wheels
(2) rubber bands
(2) balloons
(1) Victor mouse trap
(1) drinking straw
(2) bar straws
(2) 3” metal axles
(3) cardboard wheels
(1) clothes hanger
(1) 3" X 12" foam board
(1) 3/16" X 9" dowel
(1) 1/4" X 10" plastic rectangular tube
(1) 1/8" X 1/2" X 9" wood stock
(2) separator spools
(1) 1/2" X 3” plastic tube
(1) 1/4" X 3” plastic tube
(1) cardboard cone
(1) foam block
(1) foam tube
(2) note cards
sand paper
6’ of kite string
12” of masking tape

Construction Tips

- Reinforce the mousetrap... Where the staples connect to the wood (drill & wire)
- Extend the arm (clothes hanger)
- Reduce friction when appropriate, increase friction as required (low friction materials, graphite)
- Mount axles etc. Parallel to each other
- Don’t go crazy with the hot glue... Especially near plastic straw axles

Wheels that wobble are those that cost you distance when using thin materials for wheels, consider reinforcing them around the axle for greater support

Problem Solving Analysis

Name:_________________________

Part 1 - List Specific Problems you encountered:

1. ____
   ____
2. ____
   ____
3. ____
   ____
4. ____
   ____
5. ____
   ____

Part 2 - What do you feel was the cause of the problem? Put the problem number next to the cause.

__________ Lack of knowledge
__________ Lack of technical skills
__________ Equipment failure
__________ Other (please specify): ____________________________________

Part 3 - How did you solve the problem? Put the problem number next to the cause.

__________ Trail and Error – randomly tried ideas until you found a solution
__________ Troubleshooting – isolated the problem, identified possible causes, tested, implemented a solution, evaluated the solution.
__________ Experimented – observation, develop a hypothesis, experiment, draw conclusions
__________ Design – Brainstorm ideas, identify possible solutions, create a prototype, finalize design

Part 4 - List the specific steps you took to solve each of the problems listed in Part 1.

1. ____
   ____
   ____
   ____
2. ____
   ____

3.

4.

5.

Evaluation
Multi-propulsive Vehicle

Your evaluation will consist of two main parts: The Technical Report and the Prototype.
Technical Report
The purpose of the Technical Report is to document the process you took during your research. The Technical Report should contain all information necessary for the reader to understand your intent, method and result.
Prototype
The Prototype will be evaluated based on Quality of Craft, Creativity, Evidence of Applied Theory, and Functionality.

Part 1 - Technical Report (Design Brief) Evaluation

A) Problem Identification / Problem statement
(Given)

B) Research/Design
1) Provide thumbnail sketches of at least three designs
2) Full scale working sketch you used as a template during construction
3) Concept Map (to be used after your first attempt for troubleshooting)
4) Theoretical drive distance (given the use of a mousetrap)

C) Problem Solving
1) Problems Encountered Chart
2) Problem Solving Analysis

D) Students Written Evaluation
Evaluate yourself and the process you chose for this design problem. Address:
- A brief summary of how you approached the problem. What was your strategy?
- Whether or not you solved the problem. If you did not, offer reason why.
- What worked well and what did not.
- Recommendations for improvements

E) Presentation
This section is not actually in your report. The grade represents how effectively your total report is presented. The more organized and clear your report to better.

Part 2 - Product Evaluation:

A) Form:
1) Creativity - How creatively did you use available information and materials to solve the problem
2) Craftsmanship

B) Function:
1) Performance - Did you solve the problems present (i.e. did your speed vehicle go a minimum of 10 feet, did your speed vehicle go a minimum of 25 feet)
Evidence of Applied Theory - Did you use "sound" theory in your design

Evaluation Matrix
Multi-propulsive Vehicle

THIS MATRIX SHOULD BE THE LAST PAGE IN YOUR TECHNICAL REPORT

Part 1 - Technical Report (70 POINTS)	***Superior***	***Above Avg.***	***Average***	***Fair***	***Poor***
A) Problem Identification / Problem statement	-	-	-	-	-
B) Research/Design					
1) Working Sketch	10	9	8	7	6
2) Thumbnail Sketches	10	9	8	7	6
3) Concept Map	10	9	8	7	6
4) Theoretical Drive Distance	10	9	8	7	6
C) Plan of Work (methodology)					
1) Problems Encountered Chart	10	9	8	7	6
2) Problem Solving Analysis	10	9	8	7	6
D) Students Written Evaluation	10	8	6	4	2
		Sub-Total			
E) Presentation (extra credit)	5	4	3	2	1
		REPORT GRADE			

Part 2 - Product (30 POINTS)

A) Form					
1) Creativity	5	4	3	2	1
2) Craft	5	4	3	2	1
B) Function					
1) Performance	10	9	8	7	6
2) Evidence of Applied Theory	10	9	8	7	6
			Sub-Total		
			Total		