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Cognitive Steps for Solving Technical Problems

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Cognitive Steps for Solving Technical Problems

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By

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SIGNATURE PAGE

This research paper was prepared by Brian M. Whayland under the direction of Dr. John M. Ritz in the SEPS 636, Problems in Occupational and Technical Studies. It was submitted to the graduate program director as partial fulfillment for the requirements for the Master of Science degree.

Approved by: ______________________ Date: ________________

John M. Ritz, Advisor and Graduate Program Director

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Brian M. Whayland

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INTRODUCTION

The study of problem solving has advanced since Simon attempted to understand the cognitive processes involved in 1976. Originally Simon studied chess players, both experts and novices. He attempted to define what cognitive processes players were performing in preparation for their next moves. What he found in his study however was that the ability to think ahead and prepare moves did not vary between experts and novices. In fact both skill level of players were only able to think ahead about five steps. This was not a factor of artificial intelligence but rather the processes they used when planning moves (Simon, 1976).

Problem solving is viewed as a great asset to one's skills. When an individual is able to conceptualize the problem and establish a solid frame around the problem, they are more likely to reach an end goal (Basadur, 1995). Because this skill has been regarded as a great strength, it is beginning to appear more frequently in classroom lessons (Kirkley, 2003).

Students are constantly confronted with new issues and technical problems in school, as well as throughout their daily lives. The ability to systematically break down a task and derive a solution is known as the ability to problem solve. While the learning potential of this ability is known to be profound, little research has been done to show the sequence of cognitive steps students use. This study attempts to identify what cognitive steps university students take when approaching a new, technical challenge. In this research study, students will be asked to complete a variety of technical laboratory problems while the thinking process is stated out loud and analyzed.

STATEMENT OF THE PROBLEM

The purpose of this study was to describe the cognitive steps that university students use when solving technical problems.

RESEARCH GOALS

Through the analysis of problem solving skills used by students, the following goals will be answered in this research study.

RO_1: Identify the cognitive steps used in planning to solve technical problems.

RO_2: Identify the steps taken to determine the technical processes that students use when solving the problem.

RO_3: Identify the cognitive steps used in decision making to solve technical problems.

BACKGROUND AND SIGNIFICANCE

Since the beginning of time, humans have been faced with unknown issues and have attempted to derive solutions to solve these problems. This is the foundation in which problem solving is built. During the early 1900's problem solving was viewed and taught as a mechanical, systematic, and often abstract set of skills. During this time in education, problem scenarios were given to students that often were based on logical solutions with a single correct answer (Kirkley, 2003).

According to research conducted by Robert McCormick (2004), this systematic approach to problem solving left many loose ends untied. McCormick pointed out that teachers often teach problem solving skills in a series of steps, or an order of processes that the student must go through to discover the solution. The problem with this however lies in the fact that following predetermined, problem-solving steps leads students only to a procedural understanding rather than a cognitive understanding of the material (McCormick, 2004). When this type of system is used, there is very little evidence that the problem solving ability learned in one area will transfer to another.

As more is understood about the cognitive learning theories, teachers have begun to modify their approach to compliment this learning. Recently, problem-solving activities have shifted to represent complex mental activities consisting of a variety of cognitive skills and actions (Kirkley, 2003). By transitioning students to this approach of learning, students are presented with tasks that may not have a clear solution. Similarly, models are used where more than one correct answer is possible. Using this approach, students rely on their ability to conceptualize, visualize, associate material, and reason to compile a solution. What makes this learning so effective is the obligation that students fulfill in developing their ability to reason and communicate, as well as capture their interests and curiosity.

Despite the tremendous educational value that previous research outlines for problem based learning, little is known about how these skills are utilized by students in various courses. The goal of this research is to outline and identify the conceptual steps that students go through when solving technical problems. By determining and grouping these cognitive steps, this research project attempts to derive a conclusion based on how university students use their problem solving skills to solve technical challenges.

LIMITATIONS

The following limitations were applied to this research study:

1. The length of this study was limited to a time period of approximately five months.
2. The study was limited to STEM education students attending Old Dominion University during the spring and summer semesters of 2012.
3. The study was limited to participants enrolled in laboratory classes during the spring and summer semester.
4. Participants worked in cooperative groups to complete laboratory activities but were interviewed and observed separately.

BASIC ASSUMPTIONS

The following assumptions were applied to this research study:

1. It was assumed that students who participated in this research were faced with new technical challenges they have not encountered before.
2. It was understood that the tasks in which students were observed completing were normal classroom laboratory activities.
3. It was assumed that using a sample of Old Dominion University students was sufficient to be able to generalize the results of this study to a population of all university students.
4. It was assumed that all participants have received previous instructions on the methods of problem solving in prior educational experiences.

5. It was assumed that students are working through activities that are above their technical skill level.

PROCEDURES

In order to determine the cognitive steps that university students use to solve problems, a number of students needed to be selected to participate. This selection of students came from individuals who were currently enrolled in an Old Dominion University, STEM education laboratory class during the 2012 spring and summer semesters.

Students were first asked several questions based on their perceived problem solving methods. Following the initial interview, students were observed after receiving a technical assignment that requires a technical operation to solve a problem. From this point on, students were questioned about their thinking processes during the remainder of the lab. Students would continue to work through the lab exercise and “think aloud” when solving their problems. The students’ responses would be recorded and analyzed for patterns in cognitive processing. These responses were then analyzed and grouped into three main categories, decision making, planning, and technical practices, based on responses that were provided during the observation process.

DEFINITION OF TERMS

The following terms associated with this study were defined to provide the reader with a better understanding in this research study:

<u>Cognition</u> - the act or process of knowing; perception (Basadur, 1995).

Cognitive - pertaining to the mental processes of perception, memory, judgment, and reasoning, as contrasted with emotional and volitional processes (Basadur, 1995).

Cognitive Learning Theories - learning that is concerned with acquisition of problem-solving abilities and with intelligence and conscious thought (Newell et al., 1958).

Conceptual Knowledge - is knowledge of classifications, principles, generalizations, theories, models, or structures pertinent to a particular disciplinary area (Newell et al., 1958).

Information Process - the beginning of problem solving where a frame is established around the problem (Simon, 1976).

Memories - symbolized information that is interconnected with past experiences (McCormick, 2004).

Primitive Information Processes - relationships established through a combination of previous experiences and memories (Newell et al., 1958).

Problem Based Learning (PBL) - is a student-centered pedagogy in which students learn about a subject in the context of complex, multifaceted, and realistic problems (McAllister, 1994).

Problem-Solving - a mental process that involves discovering, analyzing, and solving problems (McCormick, 2004).

Procedural Knowledge - comprehension about how something is done (McAllister, 1994).

Simplex Approach - a form of approach that defines specific steps in order to reach a desired outcome (Simon, 1976).

Technical - having special and usually practical knowledge especially of a mechanical or scientific subject (Simon, 1976).

OVERVIEW OF CHAPTERS

Chapter I, Introduction, established the foundational topic for this research study. In this chapter, the reader was introduced to the research topic, which was to identify and understand the cognitive steps that university students rely on when solving technical problems. Also outlined in this chapter were the goals for the study, which created the framework for the research. Finally, Chapter I outlined to basic procedures used to collect the data.

Chapter II of this research project, Review of Literature, discuses previous studies that have been conducted as they relate to cognition in problem solving. Chapter III, Methods and Procedures, discusses the interviews and observations that were performed to collect the data, instruments that were used, and how the data were interpreted. Chapter IV, Findings, establishes the results of the interview and observation that were conducted during the research. Finally, Chapter V, Summary, Conclusions, and Recommendations, completes the study by discussing how the data were analyzed and makes recommendations to other research studies that are defining the cognitive steps involved in solving technical problems.

CHAPTER II

REVIEW OF LITERATURE

This research study was undertaken to determine what steps students use to solve technical problems. Previous investigations revealed the importance of problem solving skills among students but did not clearly define the steps that students utilize. The following information was provided to support the need for this assessment: What cognitive steps are used when a student plans to solve a problem? What technical processes do students use when solving technical problems? Finally, what cognitive steps are used in the decision making process for problem solving?

Cognitive Steps Used in Planning to Solve Technical Problems

When students face a problem, they begin to enter the first phase of their problem solving routine. Before the student can begin to work through the problem, however they first plan out the process. In this step the student frames a problem with several different variables. This planning phase can also be referred to as *information processes* (Newell et al., 1954).

Information processing systems are a combination of *memories* and *primitive information processes*. Memories contain symbolized information that is interconnected with past experiences. Students first call upon their own unique set of memories to help establish this framework for the problem (McCormick, 2004). In this step students are taking into account factors that include previous problems they have faced, previous outcomes derived from those problems, and a combination of knowledge and skills in an effort to determine an order of attack (Newell et al., 1954).

These memories then link the student to what Newell et al. define as *primitive information processes*. This process directly relates to the information in their memories and correlates to student's past experiences. Each primitive process is then linked together by an explicit operation for which known physical mechanisms exist. These definite sets of rules combine together to form *programs* of processing (Newell et al., 1954).

Essentially students first conceptualize the problem, and then link it together with a broad range of memories and experiences. These experiences are linked together to form primitive information processes where students begin to establish the parameters and variables of their problem. These processes are finally linked together to form a program in which the student calls upon throughout the entire problem solving approach. Programs, memories, and primitive information processes constantly evolve and change as students work new problems and witness outcomes of previous attempts thus leading to greater understanding of what factors define their problem. While this is a rough understanding of the procedures involved in problem solving, there are more defined ways to approach problems as well.

The Simplex process is a series of system approaches that define specific steps to help students reach their desired outcome. This system was developed by Min Basadur (1995), and it was popularized in his book, *The Power of Innovation.* This method helps provide a solid framework that can be applied to infinite problems and breaks down the process into eight logical phases. The Simplex system differs from other problem solving equations because it is represented as a continuous cycle that is constantly evolving rather than a straight-line process. This in turn means that problem solving does not stop once a solution has been implemented; rather, implementation of one cycle of improvement should lead directly to the next (Basadur, 1995).

The Simplex Approach is another problem solving model that breaks problems down into eight steps. Starting with the first step, problem finding, students begin to outline their problem and frame it as described earlier. Students are not always aware of the specific problem and it is important that it begins with a clear understanding of what they are trying to accomplish. This first step attempts to answer questions such as, what can we improve? What variable could function more efficiently if we improved it? Finally, what is failing in the process (Basadur, 1995)?

After establishing a clear understanding of the problem, students begin to move into the next phase of problem solving, fact finding. During this fact finding stage students begin to analyze the problem in more depth and attempt to develop a more concise understanding of what needs to be done. This rung focuses on questions such as, what do I know about the issue? How do other people see the problem? What solutions have been tried? And finally, what would be the benefits (Basadur, 1995)?

Now that students have developed an understanding of their problem and clearly framed it, they begin to lead themselves into the next step, which is defining the problem. In this step students begin to generate a hypothesis as to what is creating the problem and possible methods of solving the problem. It is important that students have a reasonable scope and understanding of the problem is this phase, as a narrow definition will only address symptoms of the problem rather than the problem as a whole. Conversely, too broad of a definition will create difficulties because they will have neither the time nor resources to investigate each variable. Basadur suggests asking “Why?” to broaden the problem and “What’s stopping you?” to narrow down the definition (Basadur, 1995).

Step four includes idea finding. In this step students begin to generate ideas on ways they plan to solve the problem. During this period students begin to theorize and develop hypotheses on solutions before they begin their work. This is an important step as this pulls brainstorming together with the student’s memories, experiences, processes, and help to develop various pathways that will lead the student to a testable solution.

The next step in the Simplex Approach is evaluation and selection. During this step students evaluate the ideas that have been developed and compare them against their ideas that were generated in the previous step. Students weigh their options against other alternatives and make a selection of what method they will use to move forward. During this step students answer important questions such as, is the option consistent with the outcome they hope to achieve? What impacts could the solution have (Basadur, 1995)?

Once a hypothesis and solution have been established, students begin to lead into the next phase of their problem solving approach. In this phase students determine the order in which they will approach the problem and what methods they plan to implement. If students are working in a group setting, this is when they begin to determine roles of each student and unique tasks associated with the steps included in their solutions.

Step seven is when students sell their ideas. This may mean selling the idea to the teacher evaluating the process, classmates working in their group, or to themselves as a problem solver. In this phase students combine their previous determinations and attempt to justify that their hypothesis is a viable solution. This step is often overlooked but a crucial part of the process. If this phase is skipped, students may not properly evaluate their decisions before jumping into implanting their ideas.

Finally the last step includes action. This is where the students have completed their preparation and begin to work towards a solution. It is in this step that careful planning and thinking pays off.

The 4 Steps to Problem Solving, written by Billstein et al. (2010), outlines another process that is similar to the Simplex approach. In their book titled, *A Problem Solving Approach to Mathematics for Elementary School Teachers,* they agree that understanding the problem is the first step. Following this step they conclude that devising a plan to solve the problem will lead the student to consider which options are available to them and allow them to make connections to previous experiences. Next, the students carry out their plan and implement the strategies they had selected in step two. Finally, the last step includes looking back at the problem and determining if they achieved the desired outcome or what variables may have influenced the outcome (Billstein et al., 2010).

Many problem-solving approaches are very similar and mimic the Simplex Approach or the 4 Steps to Problem Solving to some extent. While each method varies in the number and name of each step, there are almost always specific steps allotted for defining the problem, formulating a hypothesis, testing the hypothesis, and finally evaluating the outcome. The main difference between the different methods of problem solving however is whether they are described as being a linear process or continuous process.

Another way that students can plan to solve technical laboratory problem is through the use of technology. Computers available in classrooms may also be identified as a resource in which the student can use to plan an approach to solving their problem. If a student is still unclear after instructions from the teacher, the Internet maybe a viable resource to help the student understand information they may have missed or do not completely conceptualize. By employing the Internet as a resource, this will help the student find alternative explanations to the problem that may better suit the students learning personality.

Technical Processes Students Used when Solving Problems

Following the planning phase of problem solving, students begin to enter a stage where they either consciously or subconsciously utilize a systematic approach to begin their work. These approaches can be either a clearly defined, systematic approach such as the Simplex process, or it can be the result of subconsciously working through the steps that surround the problem. Typically the later resembles many of the key areas described in a definite systematic approach even though it may not be clearly defined (Basadur, 1995).

Once the student has planned to solve the problem and move into the technical aspects of the problem, a number of procedures can be utilized to help maintain the student's problem-solving course. Fact-finding is one method is which students can employ technical means to help through their problem. Fact-finding begins the discovery stage where the initial planning information begins to be processed. This stage consists of an inquiry to the students' investigation where information is procured, verified, and assembled. With this information the student can begin the actual "doing" part of the problem solving method and begin to receive feedback throughout the process. This feedback is then in turn taken into consideration on terms of whether it worked or did not work (Bransford et al., 1986).

Fact-finding can also be a method used by the student to employ technology and other resources to help determine an answer. Some examples of fact-finding resources include library resources, using experts in the field, and the use of the Internet. The use of previous experiences in solving similar problems also helps the student gather enough information to work through a process. Finally, if the students are working in groups of teams, expertise of the different members of the team can also be conducive to the fact-finding process (Bransford et al., 1986).

Also involved in the technical process of problem solving is the ability to implement the plan that was established in the previous planning phase. The ability to implement this plan insures that students are aware of where they stand in the process as well as what steps are ahead of them. This implementation is riveted together with the ability to recognize changes as they occur throughout the plan. By identifying and understand which variables are affected by the course of the students work, students can then use this information to provide feedback (Bransford et al., 1986).

Cognitive Steps Used in the Decision Making Process to Solve Technical Problems

The cognitive steps that students display in their decision-making processes typically reflect many of the steps previously described in the problem solving method for technical processes. The distinction however is this is usually done subconsciously as students scan their problem. While they evaluate their problem, students begin to make mental markers, which helps them to further refine the concepts required to solve the problem. These mental markers begin to accumulate and further develop the parameters of the problem (Simon, 1976).

As students begin to conceptualize the problem, these markers begin to take the shape of how the student will go about solving the problem. It is during this phase where students begin to follow a diverse path of exploring options and solutions. It is important that during this phase of cognition, students develop the basis of problem solutions through using concepts from the specific subject matter. This premise means starting the problem solution by explicitly stating the relevant idea that directly responds to the question asked.

The next step occurs when students begin to implement their hypothesis and test the variables they have established using their set of markers. When doing this, students combine past memories, experiences, and understanding together and approach the problem from different ways and various techniques. This is particularly interesting because as students begin to work through their problem, their approaches often vary slightly and are a reflection of the mental markers they have established previously. Furthermore, these considerations imitate what is already stored in their memories (Simon, 1976).

Finally the last step in the problem solving cognitive process comes when students utilize a combination of synthesis and analysis skills to develop a greater understanding of what they have learned. According to Bloom's Taxonomy, these are among the highest levels of cognition in learning. By developing these skills, students should be able to have a more concise understanding of the problem in which they are attempting to solve (McCormick, 2004).

SUMMARY

Ultimately, technical problem solving includes three main issues. These factors include the student’s ability to plan a course of action for solving the problem, apply technical processes throughout the course of the problem, and implement an effective decision making process. By completing these steps students are able to gain an understanding of how to work through a technical problem. Essentially, difficult technical problems are the test of a student’s ability to effectively plan, execute, and amend solutions to arrive at a conclusion. The next chapter includes a detailed description of the methods used to collect and analyze data. The following chapter also covers how participants were selected for the study and the questions that were asked.

CHAPTER III

METHODOLOGY

The purpose of this study was to investigate and identify the cognitive steps that a student takes when solving a technical problem. In order to focus on these factors, this research will take a qualitative approach to better understand the human behaviors associated with cognitive thinking and how they apply to problem solving. By using this approach, the researcher will be able to uncover the why and how of the decision-making processes rather than merely the what, where, and when. This chapter will bring to light the instruments used in the study, and how the results were compiled. Following the introduction the population selection and size of the sample will be described. Next the instrument design and use will make clear the specific details of the selected instrument as well as state how it was used. Following this section, the researcher will clarify the methods of data collection followed by the statistical analysis of the data collected. Finally, a summary will complete this chapter.

POPULATION

The population of this research was composed of a small sample of students enrolled in STEM Education laboratory classes at Old Dominion University. Research was conducted during the spring and summer semester during 2012 where data were received from STEM 251, STEM 241, and STEM 110. This sample group was involved in extensive observations and testing to determine the steps they are using in the problem solving method. By keeping a smaller sample size during this type of investigation, the research was able to reflect more accurately on the cognitive processes performed and used by this sample of students. It will allow for a deeper analysis of the subjects and the data received.

The students involved in this research project were selected from a list of volunteers who were enrolled in a laboratory course for the spring and summer semesters of 2012. The sample size was 11 students that included students in STEM 241, STEM 251, and STEM 110. While this sample size will not be able to be generalized to the entire population of all university students, it will help this researcher generalize the cognitive thinking steps that were involved in the process of problem solving.

IINSTRUMENT DESIGN

The instrument used in this research project was a set of focused questions. These questions were developed from the literature on the research variables and were asked to collect student's thoughts on problem solving for technical problems. See Appendix A.

METHODS OF DATA COLLECTION

The researcher noted the answers to the interview questions and noted performances during the observation. By utilizing this approach, the researcher was able to gain an insight into the cognitive approaches utilized by participants. This is turn created a much deeper understanding of the steps being used in technical problem solving.

Interview. An interview is defined as the meeting of two people in a face-to-face setting and is used as an act of questioning to receive a desired answer that is necessary in solving a particular problem. This approach was utilized by this research project as the first step in the process of assessing students perceived methods of problem solving. These initial interview questions created by the interviewer were determined to be crucial to the problem solving process. The interviewer read questions to the participant and recorded the answers. The questions were in an open-ended format to allow for a higher degree of personalization in the question responses.

The interview helped establish a base line for what the participant believed was important to their cognitive problem solving skills. By providing this base line, the researcher could then compare the responses of other students to determine if there is a trend in the steps utilized. While these results would not be used in their full extent to speculate what steps are involved, it would provide validity and consistency to the data because it will establish a base line. By processing the data collected from the observational interviews, the findings could then be reflected back towards the initial interview data to determine if the perceived cognitive steps matched the actual cognitive steps involved in the problem solving routine.

Finally, data collected in the initial interviews would help the researcher code the data into useful groups that would later be used for analysis. By coding the data and determining common themes used in the problem solving method, categories could be generated to group responses for future interviews.

Observation/follow-up interview. Following the initial interview of the participants a second interview/observation took place. This follow-up interview took place at a later time to avoid the subjects over analyzing their responses in the initial interview and applying these changes to their current problem solving techniques.

Additionally, during the interview students were observed to determine if the steps they believed they used were actually what they displayed. The participants completed the questions for the follow-up interview while solving a complex problem they have not attempted in the past. Essentially, the participant was questioned throughout the entire course of the problem to determine what thoughts and techniques they were employing at the current time. The main question of the observer/interviewer during this process will be:

At this time, what considerations or steps are you utilizing to determine your next course of action?

By continuing to inquire about these steps throughout the course of the problem solving of the participant, the researcher was be able to gain a real time observation of the steps being implemented by the subject to solve the problem. This helped to provide a reflection-based sample that would allow the researcher to compare previous responses to the actual theories that were being used by the participant. This type of analysis also provided an insight into perceived problem solving ability and steps utilized and compare them to the actual steps and cognitive processes that the individual uses.

While the interview and student reflections were taking place, the researcher recorded the responses as the participant answered. The answers of the initial interview questions would be used to compile the data into different categories and help refine the coding categories. Once these categories had been established, the researcher grouped the subsequent observations/interviews into these categories in an attempt to locate a common theme among the responses. Following the compilation of the responses and categorization, the answers would be analyzed and compared against the research objectives and previous research to determine if the steps outlined previously in the cognitive process could be sustained or rejected.

STATISTICAL ANALYSIS

In order to analyze the data that had been collected throughout the interview process, the responses need to be grouped into distinct categories. These categories were established throughout the initial coding phase of interviews and would likely include grouping of the planning of problem solving, the process of problem solving, and changes in the problem solving process. By grouping responses into these categories, statistical analyses could then be applied to determine central themes and distinct steps used by students. This will also allow for variables in the data that maybe extraneous such as whether or not the student was successful in completing the problem that was presented to them.

Once the data were complied and grouped, figures were used to help organize the data into models that could be further analyzed. One of the devices that will be utilized for analysis includes bar graphs. These figures will help the research analyze the data and aid in the critical thinking which in turn will help establish the confirmation of themes and considerations of new relationships or explanations. Once these visual aids were established, the research then analyzed the aids to determine if any relationships exist. To assist in evaluating the data, the researcher used the figures to help determine which answer was most common based on a percentage of the students what participated in the study.

SUMMARY

By using a qualitative approach for gathering data, this research project will be able to gather and reflect a greater understanding of problem solving cognition through the use eleven participant students. Furthermore, the technique of interviewing subjects allowed participants to provide more thorough responses and insight into the individual methods that each one utilizes to solve their difficult technical problems. Finally, analysis of the data will help reviewers better understand common themes and patterns used by students in solving technical problem based scenarios. By continuing to bring these steps to light, it was hoped that this research would bring new understandings and techniques that could be applied to teaching new material to students. In the next chapter, the researcher will present the findings from the interviews and observations. The data will be presented individually as well as in the context of each research question.

CHAPTER IV

FINDINGS

The purpose of this study was to determine if Old Dominion University students enrolled in a technical laboratory class used a problem solving approach when completing technical problems and what cognitive steps they utilized during the process. Furthermore this research sought to identify if the problem solving methods used by university students were predetermined solutions or a trial and error approach. This chapter will cover the responses received during the interviews.

PARTICIPATION RATE AND RESPONSE

The sample of students enrolled in STEM Education and Professional Studies laboratory classes during the spring and summer semester at Old Dominion University exceeded 60 students. Thirty-two students were approached and asked to take part in the research project and 11 agreed to take participate. The participation rate for this research was 34.3%.

REPORT OF INTERVIEW AND OBSERVATION

The initial interview questions were grouped under the first research objective because the interview was to take place before students began working on a technical problem. During this time students would be in the planning stages of their problem solving method because they had not received any concrete objectives in solving the problem and responses were based solely on how they presumed they solve problems. The questions asked during the initial interview can be found in Appendix A.

INITIAL INTERVIEW DATA

The initial interview asked four focused questions in order to determine how the students solved technical problems. The questions asked during this interview were, when faced with a difficult problem, is there a model or method that you utilize to work through the problem? What cognitive steps do you utilize when you are solving a technical problem that you do not have any previous experience with? Do you go through these steps subconsciously or do you walk through this process step by step? Would you consider the process a trial and error approach or methodological approach?

Student 1 described that he did indeed use a problem solving method when attempting new technical problems. In order to reach a solid conclusion student 1 stated that the application of previous knowledge was important to his ability to problem solve. Additionally, each step was thought through thoroughly and the operation was viewed as a methodological approach.

Student 2 described the problem solving method differently however. Problem solving to this participant was viewed as a trial and error process where individual steps were broken down into specific goals.

Student 3 believed that the problem solving method was a trial and error process, however he was unsure about how the process should be applied.

Student 4 stated he did in fact use a form of the problem solving method however this was not a concrete step-by-step approach. Student 4 was also unaware of how his approach was applied during the initial interview.

Student 5. During the initial interview, student 5 was uncertain if he used a problem solving routine and was unsure of how it should be applied.

Student 6 was also unsure if she used a problem solving method and how it was applied during the initial interview.

Student 7 stated she did use a problem solving method in order to break the problem down into smaller steps. Student 7 also believed that this was done subconsciously as a methodological approach.

Student 8 stated that he does use a problem solving method but he was unsure how it was applied. Student 8 did however believe the approach was subconscious and organized.

Student 9 stated he did use problem solving and relied on previous knowledge to help break down the problem. Additionally, student 9 believed problem solving was a subconscious approach that was performed in an organized application.

Student 10 believed that the problem solving method was a trial and error process in which the larger problem was broken down into smaller segments.

Student 11 indicated that they do use a problem solving method to break the problem down into small steps. Student 11 also noted that he thought about the specific steps as he completed problems and the approach should be methodological.

DATA ANALYSIS

Question 1- When faced with a difficult problem, is there a model that you utilize to work through the process?

This question was designed to determine if the participant had a certain method he/she used when solving technical problems. Additionally, this question was designed to allow students to respond with the particular approach they utilized or allow them to say they did not use any form of problem solving method when approached with a problem. Of the 11 students that participated in the research, six students (54.5%) replied that they did use a problem solving method when solving technical problems. Three students (27.2%) stated that this was a trial and error process and they did not rely on any specific approaches. The remaining two students (18.1%) stated that they were unsure of how they approach technical problems. The response to this question indicated that most students used a problem solving method when completing technical problems. See Figure 1.

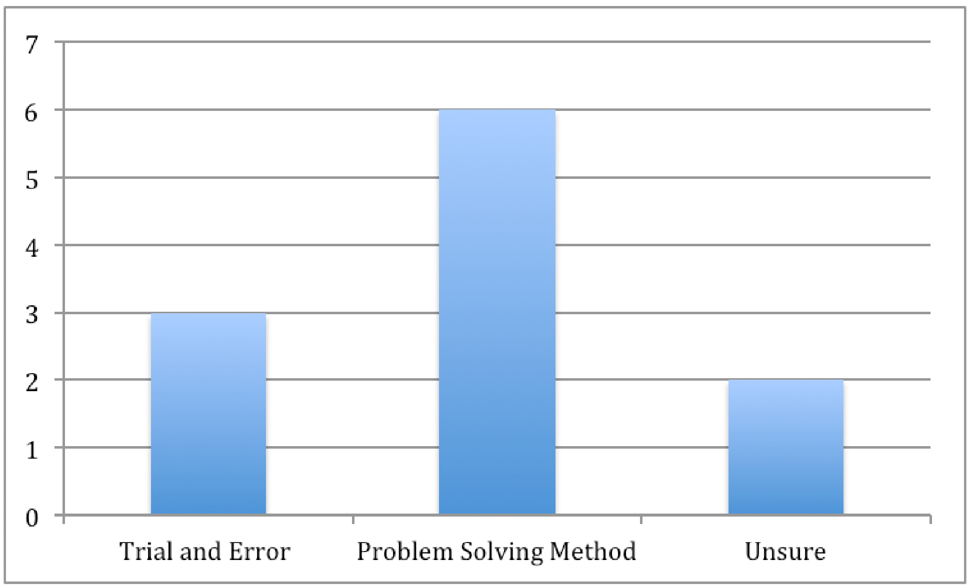

Figure 1. Question 1.

Question 2 - What cognitive steps do you believe you utilize when you are faced with a problem that you do not have any previous experience with?

This question was designed to be an open-ended question that allowed students to describe what cognitive steps they felt they used. Furthermore, this question was constructed in a way that allowed for more insight into the methods used by students during the technical phase of problem solving that may have not been established previously. Four students (36.3%) stated that they attempted to break the problem into smaller segments to better understand the problem they were trying to solve. Two students (18.2%) noted that they attempted to apply previous knowledge and experiences to the problem to better understand and predict what might happen. The remaining five students (45.4%) were unsure of what cognitive steps they used and the way in which they were applied to technical problem solving. The response to this question indicated that most students are unaware of the specific cognitive steps used in problem solving. See Figure 2.

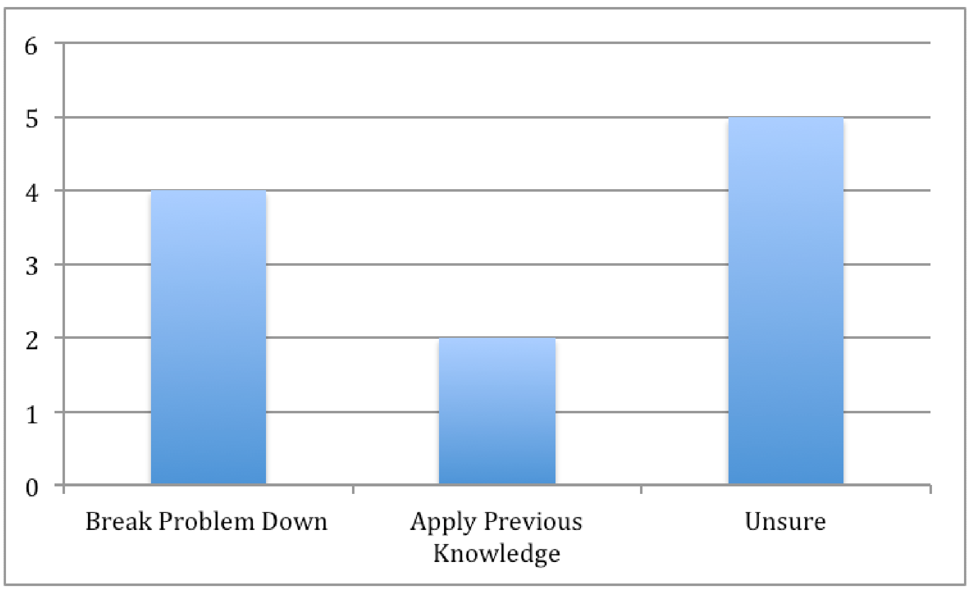

Figure 2. Question 2.

Question 3- Do you go through these steps subconsciously or do you walk through this process step by step?

The formatting of this question was intended to ascertain whether the students that used a specific problem solving approach applied their methods on a step by steps basis or if their method was implemented subconsciously. Of the six students (54.5%) that stated they used a specific problem solving approach, four students (66.6%) stated that the approach was applied subconsciously. The remaining two students (33.3%) noted that they thought about the order of each step and apply it to the specific problem step by step. The responses to this question indicated that most of the students that use the problem solving method, do so subconsciously. See Figure 3.

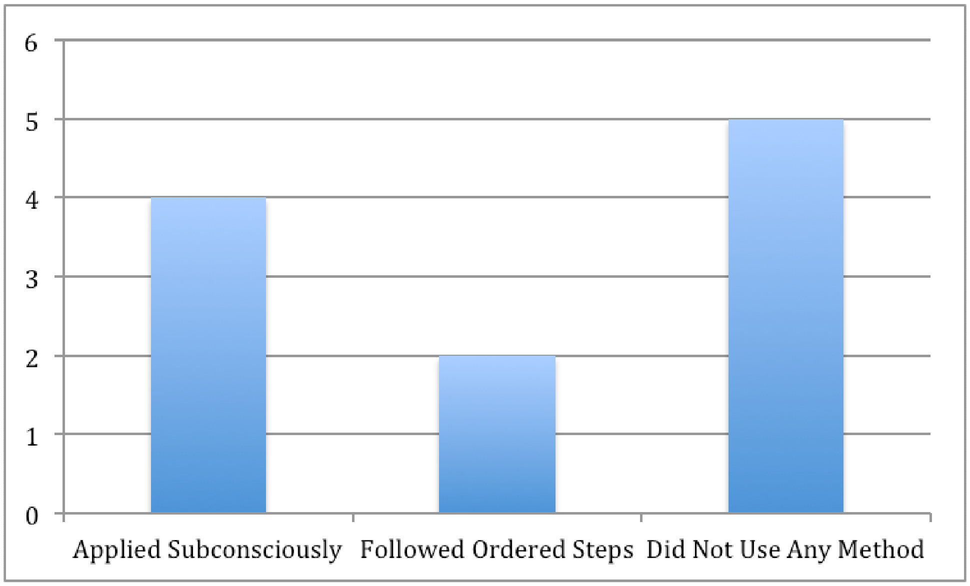

Figure 3. Question 3.

Question 4- Would you consider the process a trial and error approach or a methodological approach? Please explain.

This question was constructed to determine if students thought of problem solving as a trial and error approach or if it was methodological. The reason this question was included as the last question was to provide the researcher with consistent data by providing a measure of all the participants and how they felt about the method of problem solving. Seven students (63.6%) noted that the problem solving method was a methodological approach in which certain steps should be applied to generate outcomes. Three (27.2%) students stated that they viewed problem solving as a trial and error process in which outcomes dictate the next solution to attempt. Finally, one student (9%)

was unsure. The responses to this question indicated that most students viewed problem solving approaches as methodological. See Figure 4.

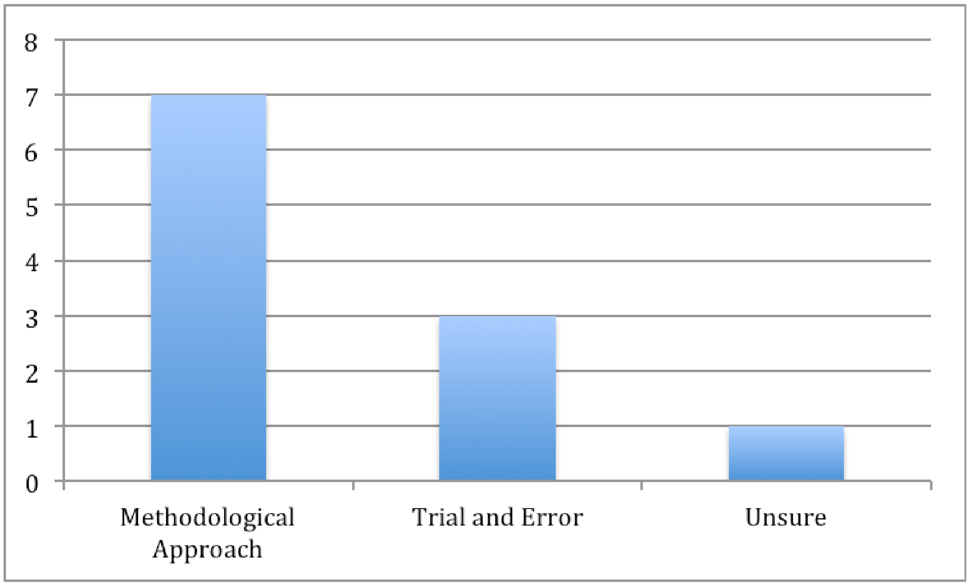

Figure 4. Question 4.

OBSERVATION DATA

Student 1- While being observed during the planning stages of the problem, student 1 stated that he tried to think of all the possibilities before starting. During this time the student read through the entire problem and reviewed all the directions before beginning. During the technical stages of the problem, the student used additional resources such as a textbook, teacher, or a peer that could also be helpful in working through the problem. The decision-making qualities from student 1 indicated that he used a blended approach by combining previous experiences, his hypothesis, and the outcome he wished to achieve before making a decision.

Student 2 - When observed, the student did not appear to have any planning procedures started before he began. When questioned about his plan the student said that he tries to go step-by-step, but jumping too far ahead confused him. The researcher noted that the student did use a blended approach for the technical and decision-making processes. The majority of the problem solving methods with student 2 included a trial and error method to gain progress, however the student did ask for help from peers and the teacher, which indicated he used fact-finding. When it came to making decisions, student 2 relied on help from his peers, reactions during the trial and error attempts, and what he wanted from his overall goal.

Student 3 - When observed this student stated that planning was an important part of his problem solving. While planning he attempted to figure out what he was trying to accomplish in the end of the problem before he began to work. The student also used a blended approach for the technical aspects as well as the decision-making procedure. During the technical work, student 3 used mainly a trail and error process to achieve his results, however he did follow the skeleton outline of a problem solving method. During the decision-making procedures, student 3 relied heavily on his hypothesis but also considered results from the trial and error procedures as well as the success that other classmates were having.

Student 4 - As observed, student 4 followed a problem solving routine loosely. During the planning stages of the problem the student did pause briefly before beginning. When questioned, the student stated that he was trying to figure out a hypothesis and predict what would be the best route to take. Many of the technical areas were applied through the consideration of what steps were next when implementing their planning. When questioned about what factors were important in decision making, student 4 stated that previous experiences with the problem was how he made important decisions.

Student 5 - While observing student 5 it was clear that a problem solving method was not present. During the planning phases the student did not pause before beginning. As soon as instructions were given and the assignment was passed out, the student began working immediately. When questioned about planning the student replied that he would figure it out as he went. Student 5 relied heavily on trial and error to solve technical challenges and did not have a clear direction. When making decisions, student 5 continued to rely on previous outcomes in order to decide what to do next.

Student 6 - During observation, it was noted that student 6 did use a rough form of problem solving in which she developed a hypothesis and attempted to systematically break the problem down. The student paused for a while before beginning and talked about what she predicted was going to happen. From here she stated her hypothesis and began to work. For the technical aspects of the problem, student 6 followed the steps she initially set forth before beginning the problem. On the decision making side, student 6 relied heavily on her hypothesis and attempted to arrive at a conclusion through the use questioning and predicting. One of the things that student 6 stated was that before making decisions she likes to compare previous errors and successful attempts within the problem in order to assess the probability that her conclusion would work.

Student 7 - While observed, this student used several resources to complete the problem. The student consulted with peers, textbooks, notes, and the teacher to help understand the problem. During the planning phase of the problem, the student asked for several clarifications of the assignment before beginning. The student stated that he was not sure how to begin and started working without forming any type of hypothesis or predictions. Also, student 7 used a trail and error approach when completing the problem that indicated the student relied on a blended approach for the technical aspects of problem solving. Additionally, the decision making process was also a blended approach because the student used their hypothesis, previous experiences, and the input from peers to make difficult decisions.

Student 8 - When observed, the student did not display any qualities that indicated that he was using a problem solving method. Student 8 began working immediately and stated that he was unsure what the outcome of the problem would be. The student also relied heavily on fact finding in order to complete the technical portions of the problem. The student sought the teachers' help the most, but he did ask other students and reviewed notes as he worked through the problem. In order to make decisions, student 8 used a combined approach. The student often sought input from outside sources and the outcomes of previous attempts.

Student 9 - When observed, the student displayed many of the characteristics involved in problem solving, but he used a blended approach for the technical areas. During the planning stages the student did establish a hypothesis and laid out several steps. For the technical aspects of the problem, however much of the work was preformed through a trial and error process. When making decisions student 9 also used a blended approach. The student focused heavily on his hypothesis but also sought the feedback from the teacher and peers before continuing.

Student 10 - When observed the student did not make any efforts of planning before starting the work. When questioned about his planning stage for the problem he stated he does not plan out what he is going to do, however he evaluates the outcome as he works through the problem. The student remained consistent in the respect that his approach was a trial and error approach when dealing with technical aspects of the problem. Additionally, decision-making choices came from past experiences with the problem. The student considered these experiences and results when making a decision.

Student 11 - When observed this student followed a rather detailed problem solving routine. The student described many of the steps that he focused on which consisted of problem identification, planning, acting, and evaluation. Before beginning the problem, the student made guesses at what would happen and developed a hypothesis. During the technical areas of problem solving the student stated that it was very important to continue to implement the plan he had created in the beginning. Additionally, many of the decisions made during the course of the problem were derived from original hypothesis and implemented based on how the student believed the problem would be impacted.

RESEARCH OBJECTIVE 1

Research Objective 1 was to identify the cognitive steps used in planning to solve the problem. The data that comprised this section of the research came from the observations conducted during the beginning of a problem. Students were asked to describe what considerations they make before beginning their work on the technical problem to better understand what steps are being used while planning to solve the technical problem. Of the 11 students that participated in the research, four students (36.4%) stated that they did not use any form of planning before beginning. Additionally, all the students that stated they did not use problem-solving methods responded that they used a trial and error process instead. Five students (45.5%) indicated that before beginning to work through the problem, they start by forming a hypothesis. Two students (18.2%) formed clear, written hypothesis before starting, while the other three students (27.3 %) spoke about their predictions and hypothesis. The remaining two students (18.2%) reread the directions during their planning phase after the instructor had presented the directions. The responses to this research objective indicated that most students create some type of hypothesis or predictions before beginning to work. See Figure 5.

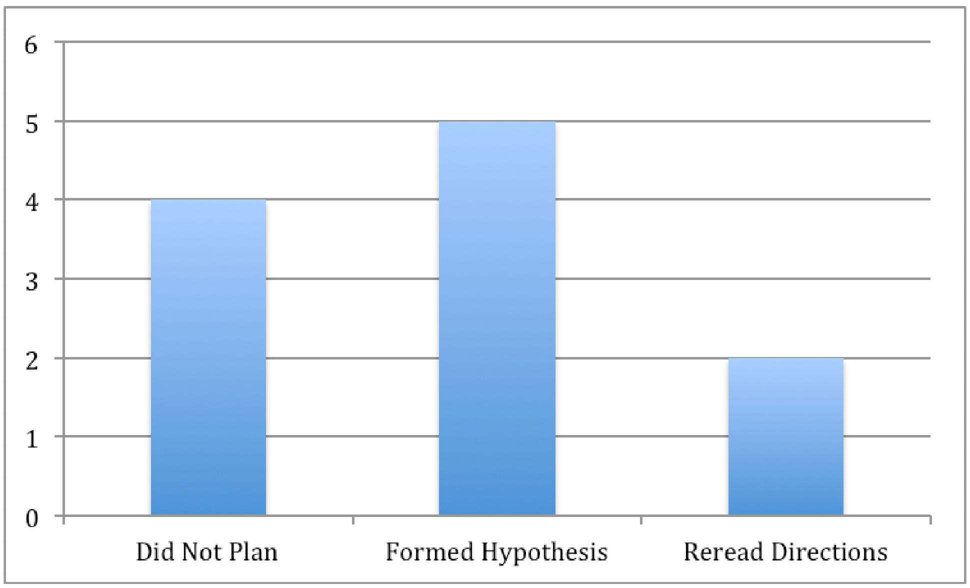

Figure 5. Research Objective 1.

RESEARCH OBJECTIVE 2

Research Objective 2 was to identify the steps taken to determine technical processes that students use when solving the problem. The data collected from this research objective came directly from interviews conducted during the observation periods of students while they solved technical problems. Periodically throughout the process of solving the problem, students were asked to describe what considerations they were taking into account before moving forward. From the 11 students that participated in the project, two students (18.1%) described what is known as fact finding. During fact finding students were utilizing all available resources to help work through a problem. This could be textbooks, notes, teacher aids, the Internet, etc. Three students (27.3%) described in detail that the technical processes they utilized were the consistent implementation of the steps and objectives they have outlined during the planning phase of problem solving. Two students (18.1%) indicated that the technical area of problem solving that they were relying on was the use of a trial and error approach. During this method students were taking feedback from the solutions they have tried and reformatting them based on the outcome of their attempt. Finally, four students (36.4%) responses indicated that the technical areas they relied on were a combination of at least two or more of the above technical problem solving areas. The responses to this research objective indicated that most of the students used an amalgamated approach to problem solving and draw conclusions and work through technical problems. See Figure 6.

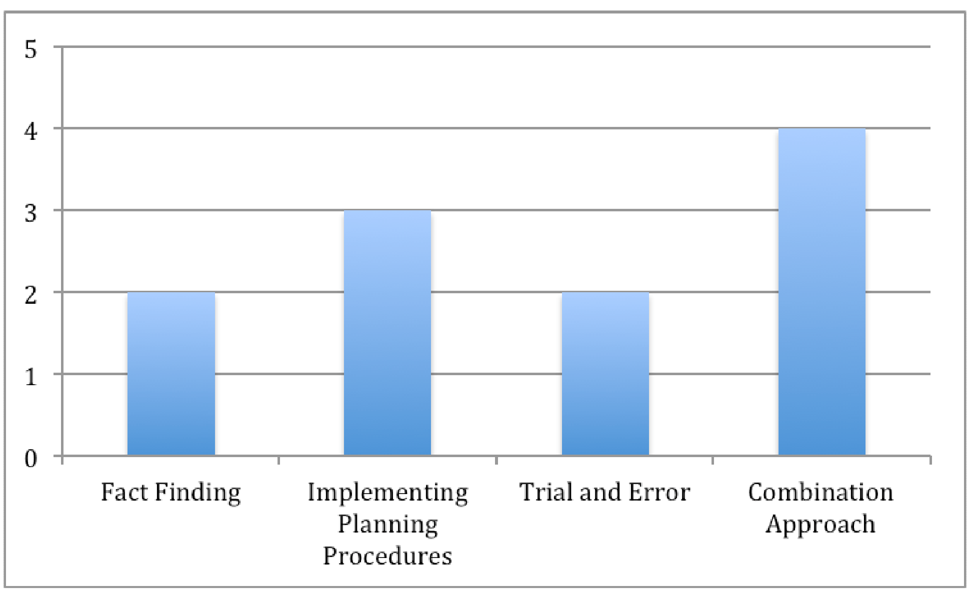

Figure 6. Research Objective 2.

RESEARCH OBJECTIVE 3

Research Objective 3 was to identify the cognitive steps used in decision making to solve the problem. The goal of this research objective was to determine what cognitive steps were used in the decision making process when solving technical problems. Again these data came directly from interviews conducted during the observation periods where students were observed and asked to describe what they were thinking. Out of the 11 students that participated, three students (27.3%) noted that the criteria used in making decisions came from the previous experiences they encountered with the problem. This included solutions that did work, solutions that did not work, and feedback they received from the problem as they worked through it. Two students (18.2%) indicated that the conditions they considered in decision-making were derived from the outcome they were hoping to achieve combined with their predictions on how their solution would work. One additional student (9.1%) specified that his decision-making measures came from the input received from teachers or peers based on their experiences. Finally, the remaining five students (45.5%) noted that their decision making process was a combination of at least two or more of the above methods. The responses to this objective indicated that students used a blended approach that incorporated several considerations when making decisions on solving a technical problem. See Figure 7.

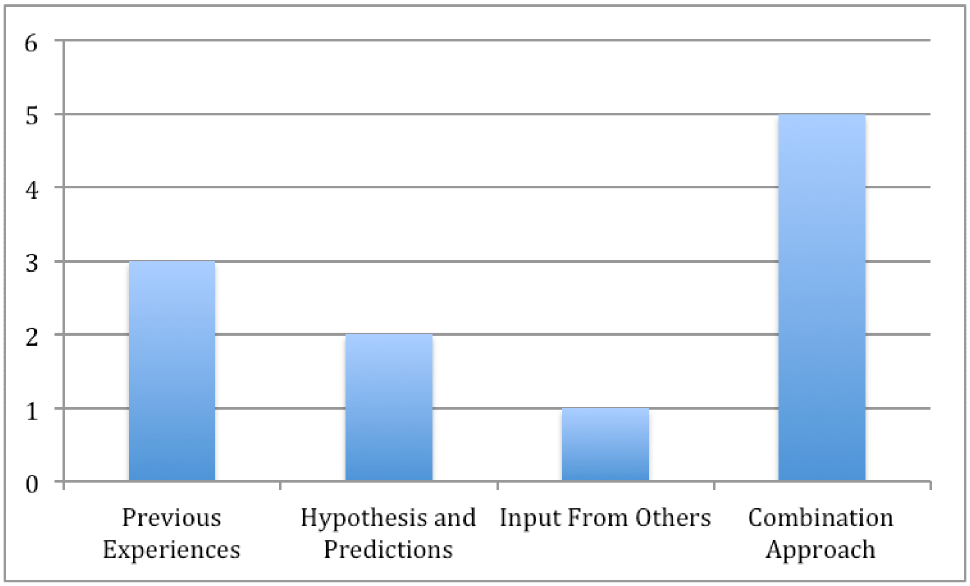

Figure 7. Research Objective 3.

SUMMARY

This chapter provided answers to the research objectives outlined by this research project. By analyzing these data provided by students who were solving technical problems, decisions can be made. Through the utilization of two interviews, the researcher was able to determine perceived problem solving strategies and compare the planning of technical problem solving to their displayed methods in order to identify trends.

By comparing the results of an interview and observation, it was noted that most students used some form of procedural method to work through problems even though most were unaware of the systematic approach they were using. While most students did not use specific steps in solving their problems, they viewed the process as a methodological approach. Furthermore, students displayed a blended approach during the technical and decision-making process that combined at least two or more of the categories from each approach.

In the following chapter, the researcher will provide a comprehensive summary of the research. Additionally, conclusions will be drawn about the cognitive steps used in problem solving by university students. Finally, recommendations for future studies will also be presented.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter will summarize the research project. The chapter will include an overview of each component of the study as well as explain the significance of the data received during the study. The researcher will also provide his opinions on how the findings relate to the research objectives. Finally, recommendations for implementing or duplicating the research will be addressed.

SUMMARY

The purpose of this study was to determine the cognitive steps that university students used when solving technical problems. By studying this information, teachers can better understand what steps were important to focus on when teaching a classes involving technical laboratory problems. There were three research objectives that were used to guide this research:

RO_1: Identify the cognitive steps used in planning to solve technical problems.

RO_2: Identify the steps taken to determine the technical processes that students use when solving technical problems.

RO_3: Identify the cognitive steps used in decision making to solve technical problems.

Despite the educational value that previous research outlines for problem based learning, little is known about how these skills are utilized by students in various courses. The research topic was of particular interest because there was a lack of research that indicated the cognitive steps that university students used when solving problems. With the information concluded from this research, teachers will be able to more effectively address classroom needs while problem solving in a laboratory.

Several other factors also impacted the research project. Basic limitations and assumptions were first made to set parameters for the study. The limitations included that the project was going to be limited to approximately five months and that the study was limited to Old Dominion University students. Additionally, the study was limited to participants enrolled in laboratory classes during the spring and summer semesters of 2012.

The researcher also drew several basic assumptions before beginning the research. First, it was assumed that students who participated in the research were faced with new technical challenges they have not encountered before and were completing normal course activities. It was also assumed that using a sample of Old Dominion University students was sufficient to be able to generalize the results of this study to a population of all university students. Finally, it was assumed that all the participants had received previous instructions on the methods of problem solving in prior educational experiences and were working through activities that could be above their technical skill level.

The review of literature provided was used to establish what was already known about cognitive problem solving and also what has not been addressed. The three main categories that guided the research were the planning phase, technical aspects, and the decision making process in solving technical problems. It was understood that several factors played into each step and the human brain relied heavily on markers and the ability to recall and relate challenges.

Data were collected from Old Dominion University students that were enrolled in a STEM Education and Professional Studies laboratory class during the 2012 spring and summer semesters. Students that meet the criteria were asked to participate in the research and signed consent forms. Eleven students agreed to participate in the study and provide data. This composed the research sample.

CONCLUSIONS

This study allowed several conclusions to be drawn with respect to the way that university students solve technical problems. The following conclusions were made based on the research objectives.

RO_1: Identify the cognitive steps used in planning to solve a technical problem. The responses to this question indicated that most students use a problem solving method when completing technical problems, but they were unaware of the specific cognitive steps used in solving technical problems. Over half of the students (54%) said that they do use a problem solving method when completing technical problems. It was determined however that when students are using a problem solving method that most of them believed they were doing it subconsciously. This is significant to the planning of solving problems because students are using certain steps subconsciously in their mind to strategize how to approach a problem. Of the 11 students that participated, six students (54.5%) used a blended approach where they combined the process of forming a hypothesis, making predictions, and evaluating input from outside sources. Despite most students establishing planning steps, the majority of the participants (63.6%) related problem-solving methods to a methodological approach and most students were unaware of the specific cognitive steps that were preforming to solve the problem.

Of the 11 students that participated in the research, three students (27.3%) stated that they did not use any form of planning before beginning, thus indicating that there were no specific steps used when planning to solve a technical problem. Furthermore, all the students that stated they did not use problem-solving methods responded that they used a trial and error process instead. This indicated these students relied more heavily on the technical steps in problem solving rather than planning. Four students (36.4%) indicated that before beginning to work through the problem they planned for the problem by forming a hypothesis. By forming a hypothesis students were beginning to make predictions on what the solution was and what variables might effect their predictions. Two students (18.2%) formed clear, written hypothesis before starting, while the other two students (18.2%) spoke about their predictions and hypothesis to the research when questioned about what they were thinking at the start of the problem. The remaining two students (18.2%) reread the directions during their planning phase after the instructor had presented the directions. The planning steps for these two students indicated that a clear understanding of what needed to be accomplished was a priority before beginning to work.

The data indicated that students were more likely to use a problem solving routine during the planning of a solution even if they were not consciously aware of the processes they were performing. In order for the students to move forward, they first began to assess the problem and began devising a method of how they would approach the problem. Additionally, most students did not believe this was a trial and error process.

This was also significant because even though they were not consciously thinking about specific steps, they still had a desire for an organized, systematic approach.

RO_2: Identify the steps taken to determine technical processes that students use when solving technical problems.

When it came to the technical processes of solving the problem the researcher noticed that there were many different ways that students worked through technical problems. From the eleven students that participated in the project, two students (18.1%) described what is known as fact finding. During fact finding students were utilizing all available resources to help work through a problem. This could be textbooks, notes, teacher's aid, the Internet, etc. Three students (27.3%) described in detail that the technical processes they utilized were the consistent implementation of the steps and objectives they had outlined during the planning phase of problem solving. For this group of students, planning, predicting, implementing, and evaluating were necessary to continue to progress through the technical problem. Two students (18.1%) indicated that the technical area of problem solving that they were relying on was the use of a trial and error approach. During this phase students were taking feedback from the solutions they have tried and reformatting possible solutions based on the outcome of their attempts. Finally, four student (36.4%) responses indicated that the technical areas they relied on were a combination of at least two or more of the above technical problem solving areas which included fact finding, implementation of previously established steps, and a trial and error approach.

The response to this research objective indicated that most of the students used an amalgamated approach to problem solving and drew conclusions to work through the technical problems. This blended approach to technical processes was significant because this meant that students used very unique ways of working through problems. However most of them incorporated similar traits that included fact-finding, implementation of previously established steps, and a trial and error approach. This could mean that different technical processes used by students compliment the learning style with which the student was most comfortable. Another interesting conclusion from this research question was that students were willing to try a variety of approaches when working through a problem and they were not likely to pick only one approach.

RO_3: Identify the cognitive steps used in decision making to solve technical problems**.**

The conclusions from the previous research objectives helped to clarify the influences that students used when making decisions during problem solving. Out of the eleven students that participated, three students (27.3%) noted that the criteria used in making decisions came from the previous experiences they encountered with the problem. This included solutions that did work, solutions that did not work, and feedback they received from the problem as they worked through it. Two students (18.2%) indicated that the conditions they considered in decision-making were derived from the outcomes they were hoping to achieve combined with their predictions of how their solutions would work. Two additional students (18.2%) specified that their decision-making measures came from the input received from teachers or peers based on their experiences. Finally, the remaining six students (54.5%) noted that their decision making process was a combination of at least two or more of the above methods. The responses to this objective indicated that students used a blended approach that incorporated several considerations when making decisions on solving a technical problem.

What makes these data significant was that a trend begins to emerge. Analogous to the technical processes students used, the decision-making processes were also found to be a blend of several different reasoning. By using two or more of the approaches, students were verifying several different variables that appeared to be influenced by the technical processes that they completed throughout the course of the problem solving. What was also interesting was the possibility that this blended approach could also compliment the student's individual learning style.

RECOMMENDATIONS

The researcher found there needed to be more research performed on the topic of the cognitive processes that students used to solve problems before researchers could come to a clearer conclusion. In order to achieve more definitive answers, changes can be made to the parameters of the research to clear possible confusion.

One potential parameter change that could be made in future studies would be constructing questions that do not allow for open-ended responses. Because the researcher allowed students to express their opinions rather than give them examples of specific steps, the participants seemed to be unclear about the steps they were performing. By revising each research objective into common steps performed during each sub-section, the researcher would then be able to allow the students to choose which method describes their procedures the closest. It would also be reasonable to allow students to express what they felt was important if the steps they used were not included in the list, because this would allow for any other answers.

Another change that could be made to the research would be to increase the size of the sample. This could be accomplished easily if the questions were close-ended questions rather than open-ended questions because it would allow the researcher to collect data much more efficiently. Also, a larger sample size would allow the study to reflect the findings of a larger group of students and also provide more accurate data. While the 11 students that participated in the research provided good data, a larger size would more accurately reflect the cognitive steps performed by students.

Finally, by using two or more observations/interviews the researcher would be able to compare the results for each student. Also, if this was completed while the student worked on two separate problems, it would allow the study to reflect the planning, technical processes, and decision-making processes related to specific problems. This would establish more consistency of data and would allow students to express how they handled different challenges. While these recommendations to improve this study may be helpful, it was certainly not a comprehensive list. Other modifications could be easily applied to the research to improve the validity of the data found.

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APPENDIX A

INTERVIEW QUESTIONS

1) When faced with a difficult problem, is there a model that you utilize to work through the process?

2) What cognitive steps do you believe you utilize when you are faced with a problem that you do not have any previous experience with?

3) Do you go through these steps subconsciously or do you walk through this process step by step?

4) Would you consider the process a trial and error approach or methodological approach? Please explain.