CHAPTER 1
INTRODUCTION

What is research, but a blind date with knowledge.

-Will Henry

The purpose of this study was to examine the development of the problem solving skills of students during an introductory college physics course where the students were taught an explicit problem-solving strategy. The effectiveness of problem-solving strategies is well documented in the cognitive science and physics education research literature; however, few of these studies involved a cohesive curriculum change. Rather most were laboratory studies or limited classroom interventions. Furthermore, there is only one other study that examined the development of student's problem-solving skills. This chapter of this study will provide enough of a literature review to motivate the two research questions and then provide a brief overview for this thesis.

Rationale for Study

Through many generations of experimentation and theory-building, physics has

developed into a very powerful science. It is a science composed of well-founded

expectations of how the natural world should behave and it then uses the tools of

mathematics to describe these behaviors. Students of physics are expected to learn both

the descriptive, or conceptual, side of physics and the predictive, or problem-solving,

aspects of physics.

Unfortunately, traditional instruction in physics has not emphasized either aspect

of physics very well. Traditional instruction is typically comprised of a lecture that

introduces concepts either by demonstrations or by deriving equations which describe the

concept. The lecturer might also show the students how to solve a few problems and

occasionally suggests how to complete the mathematics cleverly. The students are

typically assigned homework that consists of reading the relevant chapters in a textbook

and completing the problems at the end of the chapter. There might also be a laboratory

associated with the course, whose instructional goals may or may not parallel those of the lecture. Finally, the student's knowledge of physics is tested by an exam composed of problems similar to those they have encountered while completing their homework. Traditional instruction has been shown repeatedly to be ineffective for the majority of students (Hestenes & Halloun, 1985; McDermott, 1984; Sweller, 1988). Students generally leave traditional instruction without gaining conceptual understanding or developing problem-solving skills.

Recently, physics educators have begun to explore how to overcome these difficulties with traditional instruction. Most of their efforts have focused on improving students' conceptual understanding of physics (Thornton & Sokoloff, 1990; McDermott, 1984; Laws, 1991). Another group of researchers have been trying to understand how students solve problems and if students can be taught better approaches to solving problems (Larkin, 1983; Chi, Feltovich, & Glaser, 1981; Reif & Heller, 1982). While there have been laboratory experiments showing that qualitative problem-solving techniques can be taught to students (Larkin, 1979; Larkin & Reif, 1979, Woods, 1987), there is a lack of published research exploring if it is possible to teach such techniques in conjunction with the traditional course content in a classroom setting.

There are essentially only four classroom-based instructional studies in physics problem solving. The first study is Wright and Williams (1986) and their WISE strategy used in general physics at a community college. The second study is Van Heuvelen (1991) and his Overview Case Studies (OCS). The next two studies are important to this project because they used the same problem-solving strategy used in this project, the Minnesota Problem Solving Strategy. The third study is Huffman (1994) who used a

quasi-experimental design with suburban high school students in two groups; those taught the Minnesota Problem Solving Strategy and those taught a textbook strategy. In the fourth study, Heller, Keith, and Anderson (1992) tested a version of the explicit problem solving strategy discussed in this project in the algebra-based physics course for non-majors at the University of Minnesota. Each of these studies will be examined in more detail later in this thesis. These four studies represent the extent of the published studies involving teaching an entire class an explicit problem-solving strategy.

The next step beyond the studies conducted by Huffman and Heller et. al. is to teach the Minnesota Problem Solving Strategy in a calculus-based course for scientists and engineers at the college level, and periodically examine the students for an entire academic year. This is a logical step since all four of the cited classroom studies were conducted in courses designed for non-science students. What has not been adequately tested is whether the Minnesota Problem Solving Strategy can be taught to students who have stronger math backgrounds and who have enjoyed previous success in solving problems. As the developers of Project Calc at Duke University discovered, "the students who protest the most [about Project Calc] are the ones who did the best under the old system" (Culotta, 1992). Also, most of these studies were looking for student improvement *after* instruction instead of the development *during* instruction. The development of problem-solving skills is a still under-researched question.

Given the general lack of classroom-based studies concerning teaching problem-solving skills to students and the under emphasis on the development of these skills, this study will examine a population of students in the three academic-quarter calculus-based physics course for scientist and engineers who have been taught an explicit problem-

solving strategy and track the students' development. Since there is a lack of research examining how student's problem-solving skills and conceptual understanding develop during *any* physics course, it would be difficult to interpret the role of the explicit instruction without knowing what actually happens in a more traditionally taught introductory physics course. While it might be possible to hypothesize what the student's behaviors should be by extrapolating from the research literature, it is more convincing and satisfactory to examine a well-taught, more traditional classroom using the same methods.

This study was designed to answer the following two research questions:

(1) To what extent do students' problem-solving skills develop in a physics course taught by an instructor who emphasizes the Minnesota Strategy?

(2) To what extent do student's problem-solving skills develop in a physics course taught by an instructor who does not emphasize a problem-solving strategy?

Definitions

Throughout this thesis, various words or abbreviations will be used which have specific meanings. As an advanced organizer for these terms this section will provide a centralized place for the definitions. More complete definitions can be found in the thesis when the terms are first introduced.

Problem Solving Skills

The phrase problem solving skills refers to a particular set of skills supported by the expert-novice physics problem-solving literature, which will be reviewed in the next chapter. The set of skills for this study is General Approach (GA), Specific Application of the Physics (SAP), Logical Progression (LP), and Appropriate Mathematics (AM). A student's General Approach is what physics principles they believe to be relevant to solving the problem. The problem-solving skill of Specific Application of the Physics measures how well students apply what they know *given their General Approach*. Logical Progression is a measure of the overall cohesiveness of the student's solution.

Appropriate Mathematics measures the students use of mathematics in a physics content. There are other problem solving skills, such as neatness, evaluating solution, and forming alternative arguments, which will not be studied in this thesis.

The measure of each skill is determined from a coding rubric. The code found from the rubric is different from either the grades given to the students by the course instructor or the score found by adjusting the code for problem difficulty.

Development Graph

The principle data for this study is a plot of the students problem-solving skill on each problem versus time. The resulting curve on these plots is called a development graph. However, creating a development graph was not a simple endeavor. The codes found from the problem-solving skill coding rubric needed to be converted into a score by accounting for the difficulty of each problem.

Skill Bands

Skill bands are a feature of the development graphs. They show how the codes from the rubric relate to the student's average development of problem solving skill. The bands are useful for interpreting what skills the students possess and how they develop through the skills in time. A skill band is found by multiplying the problem difficulty factor for each problem by exactly the same skill code (e.g. the 26 difficulty ranks are multiplied by three to find the Logical Progression = 3 skill band). Next the problems are averaged together based on when they were given and plotted on the development graph.

Term

This study took place over an academic year of introductory physics. The course was subdivided into three academic quarters. Since the word "quarters" could potentially

be confusing, the word term is used instead. This has ramifications since a nomenclature is based on this. T1 is the first term (quarter), T2 is the second term and T3 is the third term. During the year, 26 problems were given to the students. They are identified by when they were given: F for final exams and Q for quizzes. For example, T1-F2 is the first term final exam, problem 2; and T2-F is the average of all the second term final exam scores.

Cohorts

The cohorts are those 24 students selected from the two classes being studied in this thesis. The EPS cohort is composed of students from the class that had explicit problem solving instruction. The TRD cohort comprised of students from the more traditionally taught class. The abbreviation TRD and EPS will also be used to identify students. For example TRD14 is one of the students in the TRD cohort who was matched with EPS14, a different student in the EPS cohort.

Clusters

Each student's individual development graph was compared with the other graphs in the cohort. Similarities in shape and magnitude lead the students to be grouped together. These holistically-sorted groups are called clusters. They vary in size from one student to up to 12, although this number was not predetermined.

Overview of Dissertation

A review of the literature pertinent to this study is provided in Chapter 2. Included in this review is the research on expert-novice physics problem-solving and details of the four instructional attempts to teach problem-solving in addition to the regular content in physics classrooms.

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A description of the research methods and the two classroom settings is provided in Chapter 3. Included in this chapter is a detailed discussion of the instructional setting for both classes, their differences and similarities. The discussion on research methods includes a rating scheme for problem difficulty, how the problem-solving skills were coded and how development graphs with skill bands are created. Then these tools are used to select the two cohorts of students to represent each class

Since this is an interpretive case-study, it is important to check the validity of the results when ever possible. Chapter 4 presents several arguments in defense of the methods used in this study. Included is a discussion of the effectiveness of creating two matched cohorts of students and the utility of the difficulty ranks.

Chapter 5 presents the results of the study. Included is the definition of development and initial conclusions based on the development graphs. This section covers each problem-solving skill in turn.

Chapter 6 provides a discussion of the results of this study. In addition to this discussion, Chapter 6 also includes a discussion of the limitations of this study and implications for instruction.

There are also several appendices were various supporting documents can be found.