CHAPTER 1: Introduction

Unequivocally, the two most commonly stated instructor goals for an introductory physics course are that students will learn fundamental physics concepts, and that students will improve their physics problem-solving skills. As such, physics instructors often use problem solving as the primary method of instruction, and assess student learning based on their problem-solving performances. Researchers from various fields have built up a large body of literature related to the problem-solving process (see for example, Newell & Simon, 1972; Cummings & Curtis, 1992; Foshay, 1998), and the effective teaching of problem solving. It is evident that in order to be a good problem solver, a student must possess the necessary domain knowledge, as well as an understanding of general problem-solving processes and heuristics (Maloney, 1994). The common instructional practice of having students solve traditional physics problems, however, appears to be counter-productive for reaching these goals. Research shows that many students leave the introductory physics course without the level of understanding of physics concepts and problem-solving skills valued by the instructors (Van Heuvelen, 1991). This may be because students often solve problems based on the recognition of surface features and rote memorization, rather than the analytical process that the instructors would like to have students implement (Chi, Feltovich, & Glaser, 1981; Maloney, 1994; Mazur, 1997; McDermott, 1993). Moreover, problem solving based on the recognition of surface features and rote memorization has a tendency to reinforce poor problem-solving procedures and ineffective knowledge structures (Maloney, 1994).

To improve the situation, researchers have developed a number of instructional strategies that have been shown to be effective in improving students' problem-solving performances. For example, one instructional strategy is to provide students with a problem-solving framework that requires them to practice all the necessary steps in the problem-solving process (Cummings, Marx, Thornton, & Kuhl, 1999l; Heller & Hollabaugh, 1992; Heller, Keith, & Anderson, 1992; Mestre, Dufrense, Gerace, Hardiman, & Touger, 1993; Reif & Scott, 1999; Van Heuvelen, 1991b). Another strategy utilizes "real" problems that require higher levels of analysis from the students and discourage poor problem-solving practices (Cummings et. al., 1999; Heller & Hollabaugh, 1992; Heller et. al., 1992; Van Heuvelen, 1991b). There are strategies that utilize concept maps in instruction to help students understand the relationships between major concepts and to develop a hierarchically arranged knowledge structure that is more similar to that of experts (Bango & Eylon, 1997; Bango, Eylon, & Ganiel, 2000), and others that foster collaborative problem-solving environments, where reconciliation of ideas among the students is encouraged (Cummings et. al., 1999; Heller & Hollabaugh, 1992; Heller et. al., 1992; Mestre et. al., 1993; Reif & Scott, 1999; Van Heuvelen, 1991b).

The Physics Education Research Group at the University of Minnesota is currently undertaking a multi-stage research program, funded by the National Science Foundation, of instructors' conceptions about the teaching and learning of problem solving in introductory calculus-based physics. The first stage of the program, recently completed, generated an initial explanatory model of physics instructors' conceptions of teaching and learning of problem solving that was based on interviews with six physics faculty from the University of Minnesota (see Henderson Dissertation, 2002). As part of the research team since the spring of 2000, the author has been involved with every aspect of the design of the interview and data analysis procedures from the beginning (Heller, Heller, Henderson, Kuo, & Yerushalmi, 2001; Henderson, Heller, Heller, Kuo, & Yerushalmi, 2001, 2002; Kuo, Heller, Heller, Henderson, & Yerushalmi, 2001, 2002; Yerushalmi, Heller, Heller, Henderson, & Kuo, 2000).

The purpose of the second stage of the research program is to modify, expand, and refine one part the tentative model from the first stage, specifically the conceptions of the problem-solving process. This will be accomplished by analyzing a larger sample of interviews (24) administered under the same protocol. This larger sample of interviews was conducted with physics faculty from 3 other types of higher education institutions; a) Associate Colleges; b) Baccalaureate Colleges; and c) Master's Colleges and Universities. Based on the results of the second stage, the third stage of the project will develop a closed-format survey and administer it to a national sample to determine the external validity of the model.

Background

Problem Solving

Problem solving has been suggested as "the process of moving towards a goal when the path to that goal is uncertain" (Martinez, 1998). In trying to attain the unknown, good problem solvers would have a set of both general and specific heuristics, or strategies, at their disposal. Research in teacher education has generated social problem-solving models (Cummings & Curtis, 1992) intended to describe the total process of social problem solving in student teachers. Not surprisingly, the elements described in these models are remarkably similar to those generated in art education (see for example, Foshay, 1998; Sapp, 1995), and various other fields (see for example, Handerhan, 1993 – literacy and aesthetic education; Kagan, 1988 – clinical diagnosis; Schoenfeld, 1985 – mathematics education). Aside from the context-dependent language and levels of details, research has found consistent agreement, across disciplines, on the elements, or steps, of the problem solving process. These are:

1. Qualitative Analysis (e.g., visualize the problem, determine the goal)
2. Quantitative Analysis: (e.g., choose relevant information, construct a plan)
3. Arriving at an Answer (e.g., executing the plan)
4. Evaluation of Solution

There is also an element of continuous evaluation of progress embedded throughout the problem-solving process (Polya, 1973; Reif, 1995; Schoenfeld, 1992).

Differences between Expert and Novice Problem Solvers

In describing a problem solver, research has shown an inherent difference in the way novices and experts solve problems. When encountering a problem, experts, unlike novices, would initially engage in qualitative analysis of the situation (Larkin, McDermott, Simon, & Simon, 1980; Chi, et. al., 1981; Cummings & Curtis, 1992). It has been postulated that expert problem solvers analyze qualitatively in the early phases of problem solving because it involves the activation and confirmation of an appropriate principle-oriented knowledge structure (Chi, et. al., 1981; Cummings & Curtis, 1992). There is also a consensus that a qualitative representation of the problem, constructed initially, is a significant factor in driving the solution process. Experts also possess greater amounts of procedural and declarative knowledge, allowing them to attend to the cues for selecting the appropriate principles. Novices, on the other hand, tend to focus on features explicitly stated in the problem statement (e.g., "this is an incline plane problem"), and triggering the somewhat limited solutions methods based on surface-feature categorizations of the problem situation (Chi, Glaser, & Rees, 1982; Cummings & Curtis, 1992).

Summary of the Initial Explanatory Model

The goal of the first stage of the research program was to gain an understanding of how six university instructors view the teaching and learning of problem solving in introductory calculus-based physics. The result of the study was a set of concept maps that were designed to show the types and range of conceptions held by these instructors. The main objective of the first stage was to describe the range and nature of the conceptions that these six instructors expressed in an attempt to begin to define the "outcome space" for faculty conceptions about the teaching and learning of problem solving in introductory calculus-based physics. Here I will only describe the result from a small section pertaining to the current study. For a more extensive discussion of other aspects of the teaching and learning of problem solving, see the Henderson Dissertation (2002).

The Initial Explanatory Model of Solving Physics Problems (Figure 1–1) contains instructor beliefs about the process of solving physics problems. The map shows that all six instructors believe that the process of solving physics problems requires using an understanding of PHYSICS CONCEPTS and SPECIFIC TECHNIQUES. There are three qualitatively different ways that these instructors think about the problem solving process: (1) A linear decision-making process; (2) A process of exploration and trial and error; and (3) An art form that is different for each problem. The summary of these qualitatively different conceptions of the problem-solving process is provided in Table 1-1.

Figure 1-1: Initial Explanatory Model – Solve Physics Problems. The dashed box outlines the concepts that three instructors used to describe the details of the linear decision-making process

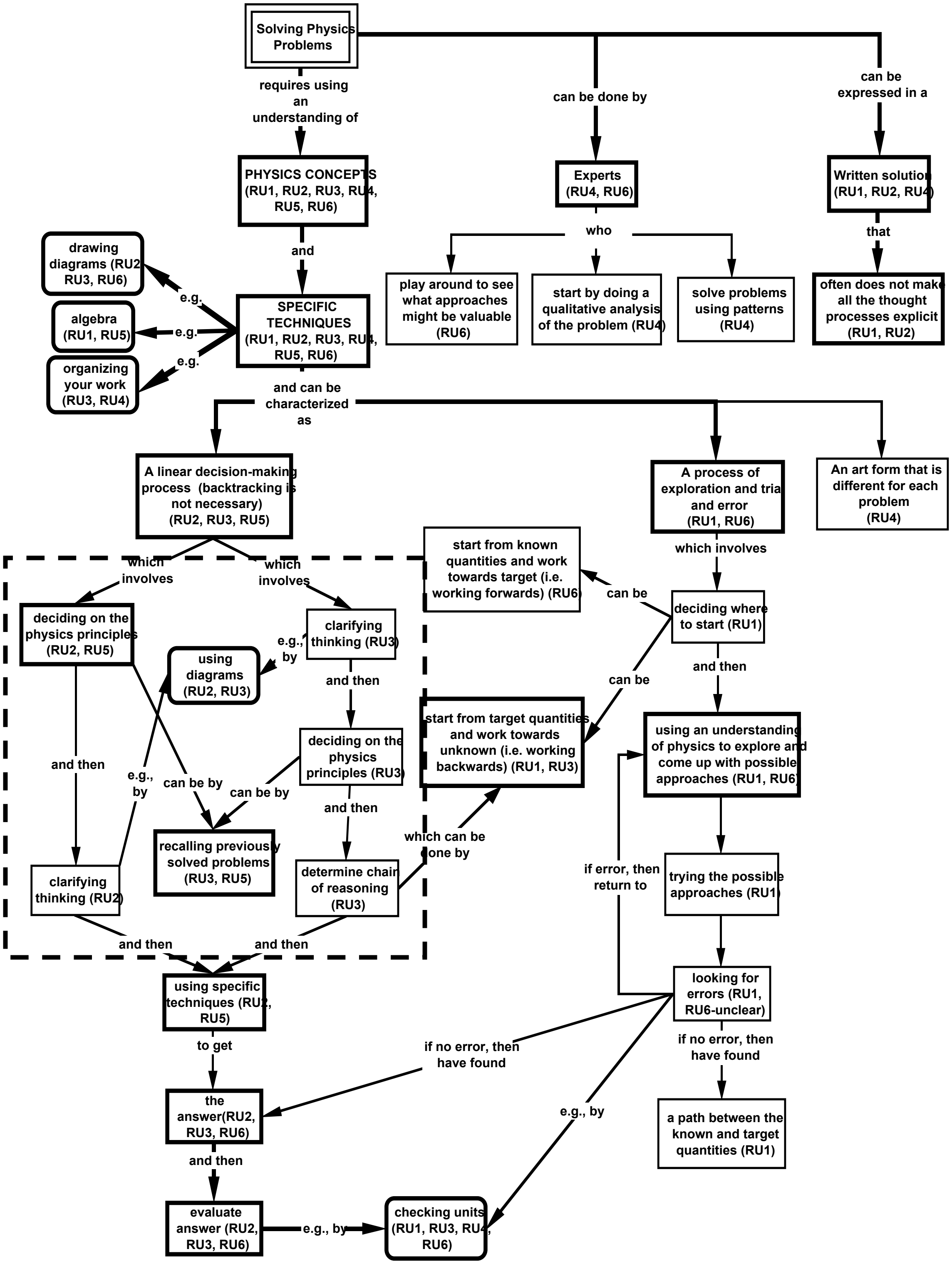
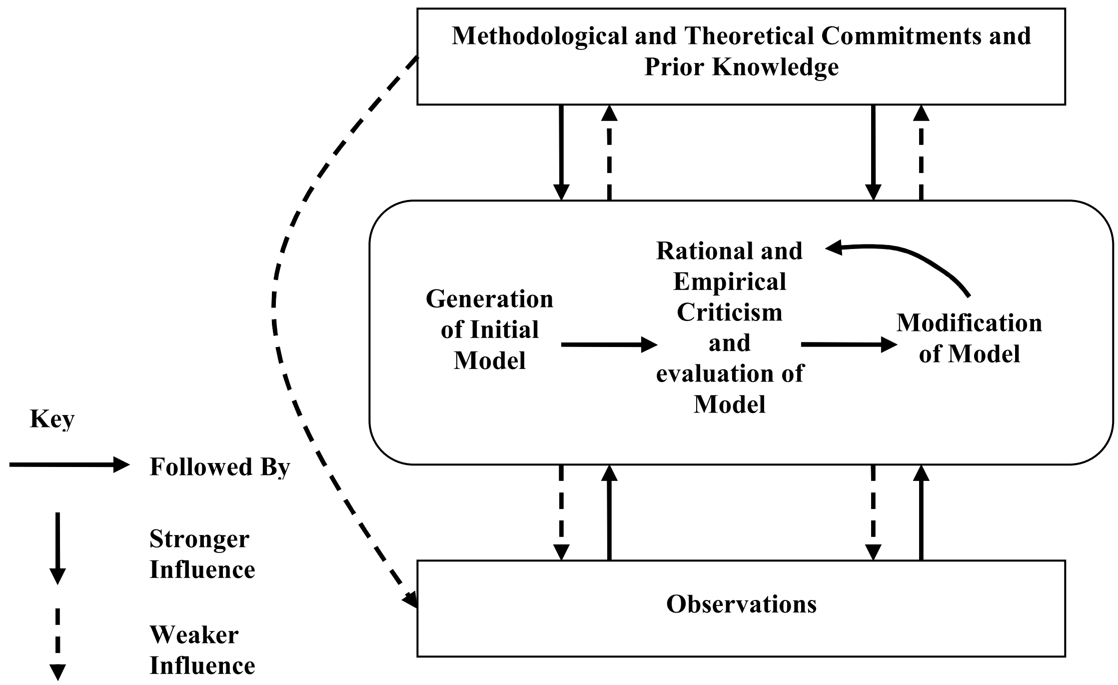


Table 1-1: Summary of the qualitatively different conceptions of the problem-solving process in the Initial Explanatory Model

Conception of the Problem-Solving Process	***Number of Instructors***	***Summary of the Conception***
A linear decision-making process	***3***	*Problem solving involves using an understanding of physics concepts and specific techniques to make decisions and decide what to do next. The correct decision is always made and there is no need to backtrack.*
A process of exploration and trial and error	***2***	*Problem solving involves using an understanding of physics concepts to explore and come up with possible choices that are then tested. Making mistakes and backtracking is a natural and necessary part of problem solving.*
An art form that is different for each problem	***1***	*Problem solving involves artfully crafting a unique solution for each problem*

Figure 1-2: Cyclical process of generation and modification in the development of explanatory models (adopted from Clement, 2000, p. 554)



Model Generation and Testing

The goal of the current study is to use an expanded sample of physics instructors from various higher educational institutions to refine a part of the Initial Explanatory Model developed in the generative phase of the research program. The part of the Initial Explanatory Model that this study addresses will be the conceptions about the problem-solving process. This is in the same way that explanatory models in the physical sciences are generated and tested (Clement, 2000).

There are two basic types of studies that are essential in the development of scientific theories. *Generative* studies focus on generating new constructs and new elements of a theoretical model. *Convergent* studies focus on providing reliable, comparable, and empirical findings that can be used to test a theoretical model. Figure 1-2 illustrates the "cyclical process of hypothesis generation, rational and empirical testing, and modification or rejection" of a scientific model (Clement, 2000, p. 553).

As Clement argued,

> "The scientist aims to construct or piece together a theoretical model in the form of a conjectured story or picture of a hidden structure or process that explains why the phenomenon occurred….The initial hypothesis for a hidden mechanism … can be a creative invention as long as it accounts for the observations collected so far….However, it should also be a very educated invention, reflecting constraints in the scientist's prior knowledge about what might be the most plausible mechanisms involved….Then, the initial model is evaluated and revised in response to criticisms. This can involve evaluations by comparisons with new data, or it can involve evaluations via rational criteria such as simplicity and consistency. By such a process of successive refinements, we cannot arrive at absolute certainties, but a viable and successful explanatory model may be formed." (Clement, 2000, p. 554)

A relevant research tradition is that of phenomenography. Developed by Ference Marton and colleagues in the early 1970's "out of common-sense considerations about learning and teaching" (Marton, 1986, p. 40), the general goal of a phenomenographic study is to develop an understanding of the qualitatively different ways that people can think about, or conceptualize, some specific portion of the world (Marton, 1986). There are two basic assumptions that all phenomenographic research are rooted in. First, there are a limited number of qualitatively different ways that people view a particular phenomenon. The second basic assumption is that a single person may not express every aspect of a conception (Marton & Booth, 1997; Sandberg, 1995). Thus, phenomenographic research requires the combination of data from multiple individuals in order to better understand the different ways of thinking about the phenomenon. This research tradition will be discussed in more detail in Chapter 3 (p. 62)

The current study is the second stage of a three-stage research program. The primary goal of the data analysis procedure in this second phase is to modify, expand, and refine the part of the initial explanatory model dealing with physics instructors' conceptions about Solving Physics Problems. Therefore, this study will follow the methods of a phenomenographic convergent study.

Research Questions

This phenomenographic convergent study will address the following research question:

To what extend does the Initial Explanatory Model of instructors' conceptions about the problem solving process need refinement and expansion?

To answer the research question, there are consequently, and logically, three sub-questions to be answered.

When the sample of instructors is increased from 6 to 30:

1. Do the three qualitatively different conceptions of the problem-solving process in the Initial Explanatory Model remain the same?
2. Where appropriate, can the lack of detail in the problem-solving process be filled?
3. Are the different conceptions of the problem-solving process really qualitatively different?

Methodology

The methodology chosen for this study will be that of a phenomenographic convergent study. This study uses adaptations of the Grounded Model Construction and Explicit Analysis techniques to criticize and refine elements of the initial explanatory model developed in the previous stage. These two analysis approaches are in line with the convergent, confirmatory types of studies (Clement, 2000), which complements the purposes and focus of this convergent study.

Designing the Interview

After considerable development and pilot testing, the final interview protocol, used by Henderson (2002) during the first stage of the research program, consisted of several features:

1. The interview was based on one physics problem selected from the exam archives of the University of Minnesota Physics Department.
2. The interview was structured around four situations: (1)Four examples of different problem types that instructors could assign; (2) Five examples of student problem solutions containing various errors; (3) Three examples of instructor problem solutions with varying degrees of detail; and (4) During the previous three situations the interviewer wrote down features of the problem-solving process that the instructors mentioned, and in this final situation the instructors were asked to sort these features into categories of their choosing.
3. The questioning during each situation ranged from general in nature (e.g., "What is your purpose in providing solved examples?") to those specifically rooted in the instructional artifacts (e.g., "How are these instructor solutions similar or different from your solutions?").

For the full text of the interview protocol, see Appendix B (p. 199). The interview tool, along with its development, will be discussed in more detail in Chapter 3 (p. 64)

<u>Sample</u>

A stratified random sample of physics instructors was selected within the state of Minnesota based on the criteria of how recently the instructors taught the introductory calculus-based physics course, their willingness to participate in the study, and the ease of accessibility to the instructors. The resulting sample consisted of 30 physics instructors from various types of higher education institutions. For the first stage of the research program, the interviews with the six physics instructors from the University of Minnesota were analyzed. This decision was based on the belief that these six physics instructors might be the most homogeneous, and thus increasing the possibility of finding common conceptions, if any existed.

The sample for the current study consists of 24 physics instructors (from 87 possible) from various other types of higher education institutions in the state of Minnesota, as based on their Carnegie Classification: 1) Associate Colleges; b)

Baccalaureate Colleges; and c) Master's Colleges and Universities. With the sample expanded, there now exists a need to undertake a more targeted analysis.

Data Collection Procedure

The interviews were both audio- and video-taped, and averaged 1.5 to 2 hours in duration. A hired professional transcribed the audio portion of each interview, and a member of the research team verified the transcripts, each approximately 30 pages of text. Notes about visual cues from the video portions were added to the transcripts during the verification process. After many iterations and refinements of the analysis procedures, an adaptation of concept maps (Novak, 1990; Novak & Gowin, 1984) were used as both an analysis tool and a representation of the initial explanatory model during the first stage.

Data Analysis

With the Initial Explanatory Model represented in concept maps, efforts to corroborate or refute the general features (concepts and relations between concepts) will be undertaken based on a more detailed analysis of specific cases (Clement, 2000), using 24 interviews collected during the first stage. The analysis for the current convergent study is a variation of the Grounded Model Construction and Explicit Analysis techniques as suggested by Clement (2000):

> Grounded Model Construction: Analysts generate descriptions (as in an Exploratory study – first stage). In addition, some initial observation concepts are identified that describe patterns of behavior. Investigators analyze smaller segments of transcripts and begin to separate theoretical concepts (partial models or process characteristics) from observations. They also begin to connect theoretical models to specific observations that support them, triangulating whenever possible. Interview procedures are standardized that are needed to provide a stable context for those observations that will be compared across different subjects and episodes.

Explicit Analysis: Investigators criticize and refine observation concepts and theoretical concepts (model elements) on the basis of more detailed analyses of cases; articulate more explicit definitions of observation concepts (definitions of observations should approach independent codeability); code for certain observations over a complete section of transcript according to a fixed definition or criterion; if the study has a theoretical component they will point to sets of observations in a transcript and explain them by means of a model; articulate more explicit descriptions of theoretical models; and describe explicit triangulated lines of support from observations to theoretical models.

Addressing Sub-Question 1

When the sample of instructors is increased from 6 to 30, do the three qualitatively different conceptions of the problem-solving process in the Initial Explanatory Model remain the same?

In the first phase of the analysis in the current study, modifications and expansions will be incorporated into the initial explanatory model by adding, deleting, and/or modifying the categories (qualitatively different conceptions). This convergent study will focus specifically on the section of the initial explanatory model dealing with instructor conceptions about *Solving Physics Problems* in terms of a problem-solving process. Below are discussions of what modification and expansion could mean in this convergent study.

For some features of the initial explanatory model, each instructor holds only one of several qualitatively different conceptions, resulting in conceptions that are seemingly mutually exclusive. As discussed earlier, the Initial Explanatory Model of *Solving Physics Problems* consisted of three qualitatively different ways that the six physics faculty from the University of Minnesota described the problem-solving process. The six instructors expressed these three qualitatively different conceptions of the problem-solving process in varying amounts of details and descriptions.

The types of modification and expansion of the initial explanatory model that this convergent study will determine are the answers to questions such as:

- Are there any additional conceptions that instructors have for the problem solving process in the larger sample of instructors?
- Does the "artistic" analogy brought up by only one instructor in the first stage analysis remain idiosyncratic, or is it a conception held by a significant proportion of the larger sample of instructors?
- Can the qualitatively different conceptions of the problem-solving process, such as the Linear Decision-Making versus the Exploration and Trial and Error conceptions, be interpreted as mutually exclusive when analyzing data from the larger sample of instructors?

Addressing Sub-Question 2

> *When the sample of instructors is increased from 6 to 30, where appropriate, can the lack of detail in the problem-solving process be filled?*

The next phase of the analysis in this current study of the research program will be the refinement of the details of the modified and expanded model of faculty conceptions about the problem-solving process. Each of the major categories of the modified and expanded explanatory model will have varying amounts of details and descriptions. This refinement phase will investigate the nature and range of the specific concepts that instructors have for each of the modified and expanded categories. For example, the linear decision-making process involves several seemingly idiosyncratic concepts (see dashed-box region in Figure 1-1, p. 6), those that are mentioned by only a single instructor. The refinement procedure will provide information on the nature and range of the specific concepts and their relationships, and answer questions such as:

- Are there any additional concepts used by the larger sample of instructors to describe the linear decision-making metaphor for problem solving?

- Do idiosyncratic concepts remain idiosyncratic, or is there a significant proportion of the larger sample of instructors with the same concepts and relationships?
- Does the complexity of the concepts and relationships in linear decision-making conception for problem solving change for the larger sample of instructors?

Another type of information that the refinement procedure will provide is in the way in which instructors describe the underlying managerial processes that are inherent in any problem-solving process. This type of information will answer questions such as:

- Do instructors explicate how one should manage the process of solving problems?
- What types of managerial processes do instructors feel are necessary in relation to problem solving?
- Do instructors value each type of managerial process equally?

Addressing Sub-Question 3

When the sample of instructors is increased from 6 to 30, are the different conceptions of the problem-solving process really qualitatively different?

The final phase of the analysis in this current study of the research program will be the determination of whether the different conceptions of the problem-solving process in the Refined Explanatory Model are indeed qualitatively different. There are many other sources of information about instructor conceptions about various aspects of the teaching and learning of problem solving in this data set. Some of the information can be used as checks against the results of the Refined Explanatory Model. This explicit triangulation will serve to validate the results of this current study as a viable explanatory model of physics instructors' conceptions about the problem-solving process. These checks will answer questions such as:

- Do instructors with a particular conception address other aspects of the teaching and learning of problem solving that are consistent with that conception?
- Do instructors with different conceptions address other aspects of the teaching and learning of problem solving in different ways?

- Do the instructors with different conceptions differ in other ways?

Once the modification, expansion, and refinement has been completed, the resulting refined explanatory model for instructor conceptions about the problem-solving process could inform the development of the measurement instrument for the next stage of the research program.

Implications

Contrary to many areas of educational research, little is known about the mental structures of physics instructors with respect to their conceptions about the teaching and learning of problem solving, and how such structures inform their instructional decisions. This research program will attempt to establish a baseline for future research on this topic. The refined explanatory model from this convergent study will be further tested for external validity and generalizability during the third stage of the research program in an attempt to profile the physics instructor community.

Theoretical Implications

This research program is the first of its kind in developing an explanatory model of the conceptions that physics instructors have about the teaching and learning of problem solving. As such, it contributes to the literature in the field of educational research, and provides a baseline for launching a new branch of research. Not only will the results inform future research on teacher conceptions about the teaching and learning of problem solving at the post-secondary level, inferences can be extrapolated to extend to the elementary and secondary levels of education as well. Moreover, this convergent study will generate more questions that will require further exploration and research, such as the possible connections between teacher conceptions of teaching and learning problem solving and their actual behavior in classrooms.

Practical Implications

Research has shown that the majority of students in introductory physics courses make little progress in learning effective problem-solving strategies (Maloney, 1994; Reif, 1995). Such strategies include, for example, choosing effective representations to analyze a complex and unfamiliar situation, and planning and monitoring the progress toward a solution (Chi et. al., 1981; Larkin, 1980; Larkin et. al., 1980). As mentioned before, curriculum developers, through combined research and development efforts, have constructed materials and pedagogical techniques that teach effective problem solving to students at the introductory physics level. These materials and pedagogies are based on strategies that have been shown to improve students' problem-solving performance as well as their understanding of physics concepts (Cummings et. al., 1999; Foster, 2000; Heller & Hollabaugh, 1992; Heller et. al., 1992; Mestre et. al., 1993; Van Heuvelen, 1991b).

Curricula based on these strategies, however, have not been widely adopted by physics instructors. There could be numerous reasons for this lack of adoption. Results of a relevant study on high school physics teachers (Yerushalmi & Eylon, 2001) imply that one of the reasons may be that curricular materials should be explicitly expressed in congruence with teachers' conceptions. That is, curricular change will be most effective if instructors' concepts are integrated into the design of a curriculum from the outset. Moreover, effective professional development for instructors (currently funded by the National Science Foundation) depends on knowing the prior knowledge of the instructors. There have been no research studies, however, that have investigated instructors' conceptions about the teaching and learning of problem solving.

The results of this convergent study can lead to improvements in the teaching and learning of problem solving by first enabling physics instructors to communicate more effectively, both among themselves and with the physics education research community. Second, curriculum developers can utilize the knowledge gained from this convergent study to better match curricular designs to the concerns, commitments, and language of physics instructors. As indicated above, this is an important aspect of facilitating an effective curricular change. Finally, the results of this convergent study can inform universities and funding agencies to determine what type of professional development, if any, should be offered to physics instructors.

Limitations

This convergent study is an in-depth examination of the conceptions that 30 physics instructors have about the phenomenon of solving physics problems in introductory calculus-based physics. The goal of this convergent study is to modify, expand, and refine the initial explanatory model generated by the analysis of interview data with 6 of the physics instructors during the first stage of the research program. Although the number of instructors used in this convergent study is larger than the first stage, it is still not of adequate size for the results to be generalizable to the larger physics instructor community. As stated earlier, the results of this convergent study will be tested for external validity and generalizability in the next stage of the research program. Nonetheless, the resulting refined explanatory model can provide a sound starting point from which to understand the nature and range of conceptions that some physics instructors have about the teaching and learning of problem solving in introductory calculus-based physics.

The author was part of the research team involved with the development of the initial explanatory model. Unavoidably, the analysis to modify, expand, and refine the model will be influenced and guided somewhat by the interpretations and inferences of the first stage. To limit the possible biases and "tunnel-vision", the author will actively look for contradictory evidence in analyzing the interview data in this current study.

The Research Team

At the time this convergent study was conducted, the author was a graduate student in the Department of Curriculum and Instruction at the University of Minnesota with a research emphasis on physics education. In addition to his formal academic work in physics and curriculum and instruction, the author has had experience teaching physics and astronomy at the introductory level, as well as course development at the same level, and worked as a mentor teaching assistant and co-instructor of the Teaching Assistant Orientation for the Physics Department at the University of Minnesota.

In addition to the author, three other researchers were involved in various aspects of the current and previous stage of this research program. Throughout this dissertation, the contributions of the other members of the research team will be noted where appropriate. One of the strengths of the research results reported in this dissertation is that they were informed by the diverse backgrounds and viewpoints of the various members of the research team.

Patricia Heller: Patricia Heller is a professor of Science Education at the University of Minnesota. She has developed curricula for introductory calculus-based physics courses and has led many workshops for physics instructors on the use of these curricula. Dr. Heller is also regarded as an expert on problem solving in physics.

Charles Henderson: Charles Henderson was the primary investigator of the previous stage of the research program as a graduate student in Physics Education at the University of Minnesota, and is currently an assistant professor of Physics at Western Michigan University. He was the primary developer of the initial explanatory model. He has had experience with course development, served as a mentor TA for the University of Minnesota Physics Department. He has worked with many physics instructors from several colleges and universities.

Edit Yerushalmi: Edit Yerushalmi is currently an assistant professor of Science Education at the Weizmann Institute for Science in Israel. She was a post-doctoral research associate with the University of Minnesota Physics Education Research Group during the first two years of this research program. Dr. Yerushalmi has had considerable experience working with physics teachers in Israel.

Important Terminology

Phenomenon: The object of interest in a phenomenographic study. In this case it is the problem-solving process.

Problem Solving: The process of moving towards a goal when the path to that goal is uncertain.

Statement of Relevant Meaning: A single idea as expressed by the interviewee. Statements were used as the raw data for the construction of concept maps.

Conception: A general term used to describe beliefs, knowledge, preferences, mental images, and other similar aspects of a mental structure.

Concept Map: A schematic device for representing the relationships between concepts and ideas. The boxes represent ideas or relevant features of the phenomenon (i.e., conceptions) and the lines represent connections between these ideas or relevant features. The lines are labeled to indicate the type of connection.

Individual Concept Map: A concept map of an individual instructor's conceptions about the phenomenon.

Composite Concept Map: The highest-level concept map representing the synthesis of the individual maps.

Major Component: An item in a conception within the refined explanatory model that is supported by at least 30% of the instructors in that conception.

Overview of This Dissertation

The following provides a brief guide to the remaining chapters in this dissertation:

Chapter 2: Literature Review

This Chapter provides a review of research relevant to this convergent study.

Chapter 3: Methods

This chapter presents a detailed description of the methods designed to collect and analyze data for this convergent study.

Chapter 4: Results and Conclusions

This chapter presents the results of this convergent study.

Chapter 5: Implications

This chapter reports the conclusions that can be drawn from the results of the study and discusses the implications for further work.

References

Appendices