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ABSTRACT

This paper describes the design and initial data analysis of an ongoing study to determine the important elements, as perceived by faculty, of the learning and teaching of problem solving in the context of an introductory calculus-based physics course. To elicit instructors' beliefs that inform their instructional choices, an interview around three concrete situations was designed: (1) instructors' solutions; (2) students' solutions; and (3) actual practice. This paper discusses the preliminary results of a comparison of two instructors who are known to differ primarily in their approaches to the teaching of problem solving. There is evidence to suggest that the main difference between these two instructors is not in their vision of the expert problem solving process, but in the presence and treatment of competing models of learning and instruction. (Author/KHR)

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WHY SOLVE PROBLEMS? – INTERVIEWING COLLEGE FACULTY ABOUT THE LEARNING AND TEACHING OF PROBLEM SOLVING

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ABSTRACT

In this paper we describe the design and initial data analysis of an ongoing study that aims to determine the important elements, as perceived by faculty, of the learning and teaching of problem solving in the context of the introductory calculus based physics course. To elicit instructors' beliefs that inform their instructional choices we designed an interview around three concrete situations: 1) instructors' solutions, 2) students' solutions, and 3) problems posed for students to solve. In each of these contexts we asked questions about 1) the perceived options, 2) instructional goals, and 3) actual practice. The interview was administered to 31 physics faculty. This paper, however, will discuss the preliminary results of a comparison of two instructors who are known to differ primarily in their approaches to the teaching of problem solving. There is evidence to suggest that the main difference between these two instructors (besides their actual practice) is not in their vision of the expert problem solving process. The main difference appears to be in the presence and treatment of competing models of learning and instruction.

1. INTRODUCTION

In the United States a sizeable fraction of all university students are required to take an introductory physics course. The traditional approach to this instruction is to teach physics through solving problems. Unfortunately, most of the students cannot solve these problems. In addition there is a growing body of evidence that even the students who are able to solve traditional test problems do not appear to understand the physics concepts on which the problems are based [1]. Curriculum developers have focused their efforts on two general ways of attacking this problem. Some emphasize directly building students' conceptual knowledge [2,3]. Others emphasize developing student problem solving skills [4-10]. Evidence exists that the curricula designed along both of these approaches can promote conceptual understanding [11] and that the latter can result in students possessing more expert-like problem solving skills than students taking traditional introductory physics courses [5,7,12-14]. Although aspects of many of these curricula are reflected in instructors' practices, seldom are they fully adopted. As Reif [9] points out, "Practical implementations are particularly difficult when they depend on the cooperation of other people." One solution is to develop teacher-independent curricula. Another is to identify the beliefs and knowledge of the instructors as well as the students and design curricula on that basis. It is this latter approach that motivates our study.

The goal of this study is to learn about the beliefs and actions of physics faculty in their roles as instructors. Much of the previous work of the Physics Education Research Group at the University of Minnesota has been aimed at the development of student problem solving skills. We align our curricular development with the instructional research in the field of physics problem solving that suggests that student problem solving skills can be improved [1]. Because of that we have chosen to focus this study on instructor beliefs as they relate to the teaching and learning of problem solving.

Our goal is to enable:

1) Physics instructors to communicate more effectively about the teaching and learning of problem solving, both with other instructors and with the physics education research community.
2) Curriculum developers to better match curricular designs to the concerns and commitments of physics faculty as well as the findings of educational research.
3) Curriculum developers to determine what type of education, if any, is necessary for physics faculty to use research-based instructional strategies.

In the first stage of this study an interview was used as an exploratory tool to elicit some of the important variables determining instructional choices. In the second stage of this study we plan to design a more directed survey, based on our analysis of the interview data, to probe a larger community of physics instructors.

In actual practice different events may result in activation of different instructor beliefs [15]. We wanted to capture instructors' rationale for their instructional choices as close as possible to their actual practice. We used an open-ended interview, designed around comparisons of a variety of concrete curricular artifacts, to induce reflection on practice and to allow us to probe instructor beliefs.

This paper will describe the interview tool, our considerations in its design, and the development of the analysis procedure.

2. DESCRIPTION OF THE INTERVIEW

2.1 Interview artifacts

One of the main techniques of our interview is the use of instructional artifacts. These artifacts, commonly used in physics instruction, are: 1) instructors' solutions to problems, 2) their evaluation of students' solutions, and 3) the problems themselves.

The artifacts were designed to span a range of common instructional practices, and the range of problem solving processes found in the research literature [1]. They were constructed to elicit a large amount of information from a small number of artifacts. The artifacts all dealt with the same physics problem. We chose this problem both for its richness of solution difficulties and the plausibility of its inclusion in an introductory physics course.

Instructor Solutions: The three instructor solutions used vary in the details of their explanation, efficiency, physics approach, and presentation structure. Instructor Solution I was a "bare-bones" solution; the type that is often found in textbook solution manuals. Instructor Solution II was a very detailed presentation of a logical problem solution. Instructor Solution III was a solution that indicated the decision making process of the solver.

Student Solutions: The five student solutions used were based on actual student solutions to the problem when it was given on the final exam of an introductory calculus-based physics course at the University of Minnesota. To save time during the interview, we explicitly pointed out any definite errors in the physics. The solutions were designed to represent features of both expert and novice practices. The solutions included evidence of different types of knowledge organization, types of knowledge, types of analysis, and general decision making processes. They also varied in the correctness of the physics used and in the amount of explanation.

Problems: The four additional problems were based on the original problem and represented a range of the types of problems used in introductory physics courses. There was a problem that included a diagram and was posed in three sub-problems, a multiple-choice problem, a problem set in a "real-world" context, and a problem that asked for qualitative types of analyses.

2.2 Interview questions

The interview was designed to illuminate the rationale physics instructors hold for their practices relating to problem solving in an introductory physics class. In particular, we wanted to construct a teaching model or models for each instructor based on the following:

1. What knowledge and skills do physics instructors think students bring to the class?
2. What do physics instructors do, or think they can do, to promote student learning with respect to problem solving?
3. What do physics instructors think students can, should, or actually do during the course with respect to problem solving?
4. What knowledge or skills do physics instructors want students to take from their course?
5. What considerations, beside student learning, influence instructional choices?

The interview triangulated these questions using the different interview artifacts. Several versions of the interview were developed and pilot tested. While pilot testing, using faculty and graduate student instructors, we encountered two main difficulties: the problem was too hard to be worked smoothly by the instructors within the interview, and it was hard to keep the instructors attention. We overcame those difficulties by sending the problem to the instructors prior to the interview, and by designing a story line for the interview.

The final interview took about 1½ hours to complete and consisted of four parts. The first three parts of the interview each dealt with one of the three artifacts, and started with a general question about how and why the instructor used that type of artifact. We then asked how they compare the artifacts to what happens in their classes and their reasons for making those choices. We concluded each part by asking the instructor to reflect upon the problem solving process, as represented in the artifacts, from the perspective of a student. During the first three parts, the interviewer wrote each of the features of the problem solving process that the instructor mentioned on a separate index card using the words that the instructors used. In the fourth part the instructors were asked to sort the index cards into categories of their choosing. We then asked several questions regarding these categories that focused on the 5 underlying questions.

3. DESCRIPTION OF THE ANALYSIS

3.1 Subjects

For the exploratory phase of our study we used physics faculty in Minnesota, who we have no reason to believe are significantly different from those in other parts of the United States. In addition, we limited our potential pool of interview subjects to those that could be visited and interviewed in a single day. Each randomly selected candidate was contacted, either in person or by telephone, and asked if they would participate in our study. Of the 36 faculty members that we contacted, only 5 declined to be interviewed. Our final sample consisted of 31 faculty members (from the 107 possible) roughly evenly divided between the following groups: 1) Community College, 2) Private College, 3) Research University, 4) State College. Each interview was videotaped and the audio portion was transcribed.

At a minimum, we wanted an interview that can distinguish between instructors who differ in their practice, and can elicit features of the problem solving process both from instructors familiar with the research literature and those who are not.

We began by comparing the interviews of the two faculty members that had been observed as part of a previous study [13]. Both are very active research physicists who have taught the same introductory calculus-based physics course for non-majors within the same departmentally-imposed structures (same labs, same structure for discussion sessions, common final exam among all sections). Both are respected full professors who have won teaching awards. The principal difference between the two instructors was in their approaches to problem solving and their experiences teaching physics courses for non-majors. One instructor (EPS -- Explicit Problem Solving) chose to explicitly use a problem solving strategy in instruction, while the other (TRD -- TRaDitional) did not. The EPS instructor has more experience teaching courses for non-majors.

3.2 Analysis of the data

Our analysis used a sorting mechanism that was based on first identifying units from the transcripts and then coding them into a set of categories.

Unit: We defined a unit as the smallest piece of text from the interview that can be understood as describing an action or internal state of a student or an instructor in the context of the introductory calculus-based physics course.

Categorization scheme: Units were assigned values in each of the following categories: 1) Aspect of problem solving, 2) When did it happen, 3) Who is referred to, 4) Reason, 5) Existence, 6) Instructor's attitude, 7) Type of Action.

Having the units categorized enabled us to sort and examine the data in three ways in order to answer our 5 underlying questions described in section 2.2.

Connecting units based on time sequence: Focusing on one part of the interview, we sorted all statements of each instructor into the following 8 groups based on who performed the action and the type of action:

	External	Internal Cognitive	Internal Affective	Unclear
Student				
Instructor				

We used these groups to assist us in mapping the instructor statements to the teaching model. For example, the actions of the instructor are often found in the instructor-external group.

After identifying one component of an instructor's possible teaching model, we identified statements related by time and specific internal references to that component and assigned them to the appropriate places in the model. After building all of the representations of the instructor's teaching model from one of the parts of the interview, we combined those that we believed differed only in minor details. The result is a small number of models that represent the instructional beliefs of an instructor that were elicited by that particular part of the interview.

Examining Reasons: In many cases, although asked, instructors did not give reasons for their actions. We examined all of the reasons given by the instructor for their actions and used these to triangulate our understanding of the models developed by the previous method.

Connecting units based on content: We sorted all statements made by each instructor during the interview into the 8 groups described above. Each group was then further divided into 5 sub-groups based the aspect of problem solving (Knowledge Organization, Knowledge Type, Analysis Type, General decision making processes, Other problem solving aspect). We compared the aspects of problem solving that each of the instructors mentioned and looked for relationships between internal and external actions performed by both the student and the instructor.

4. PRELIMINARY RESULTS

Since this paper describes a work-in-progress, we are not presenting results, but rather features that will characterize the final analysis.

4.1 Models of learning and instruction

In the analysis based on time sequence we examined the first part of the interview (the artifact was Instructor Solutions). We found that three teaching models could describe the TRD instructor's statements:

1) "Revealing the structure of the problem solving process": This model can be described as: The instructor action is to provide structured solutions to the students. The instructor expects students to learn from these solutions by reading and extracting the structure. As a result of this, the instructor wants students to understand the structure and to use this understanding when solving other problems. The instructor did not mention the initial state of the student.
2) "Appealing to students": Instructional actions were based on perceived student likes/dislikes.
3) "Gearing instruction towards higher-level students": Instructional actions were aimed at the needs and abilities of the top students in the class.

In the analysis of the EPS instructor we found that all of the instructor's statements could be described by one model very similar to the TRD instructor's first model. The primary difference was that the EPS instructor did have a picture of the initial state of the student based on difficulties students have when solving problems (e.g. "Students don't tend to evaluate their solutions."). While the models looked similar, upon closer examination, the TRD instructor gave only vague external manifestations of what structure means (e.g. "[I] demonstrate what a professional physicist strategy for the problem solving would be."). The EPS instructor, however, gave many more details on the external actions of the instructor or student that describe this structure (e.g. "The students need to write down their own thought processes on how they got from the question to how they're going to think about doing it.").

Our understanding of the models described above was further strengthened when we looked at the reasons that each instructor explicitly gave for his actions throughout the entire interview. Two types of reasons were found to be prevalent in the interview with the TRD instructor. One was the importance of having students become familiar with a "professional strategy". The other was that the TRD instructor mentioned basing his actions on the perceived likes or dislikes of his students.

The EPS interview also revealed two prevalent types of reasons. One type involved being very explicit about showing students everything that they were expected to do or understand. The other type involved the necessity of taking students in whatever condition they come to the course and attempting to build their skills from that point (e.g. "The students are who the students are.").

4.2 Aspects of problem solving

Both instructors referred to all of the aspects of problem solving found in the literature. There were differences, however, in what they included in each category and in the emphasis they placed on each category in their instruction. The TRD instructor was highly aware that students often have a knowledge organization based on surface features rather than physics principles. He described the exploratory nature of the problem solving process that consists of trial and revision. He also paid much attention to student beliefs about the process of problem solving and how their beliefs about their ability to be successful in it affect their success. The EPS instructor emphasized the qualitative visual part of the analysis and the need to weigh choices when making decisions. While also paying attention to student beliefs about the process of problem solving, the EPS instructor did not mention student perceptions of their own abilities.

We further analyzed how each aspect of problem solving was represented in their instruction. Both emphasized aspects of decision making. Both noticed many external student actions representing good and bad decision making behaviors. The EPS instructor actions were all focused on promoting good decision making and extinguishing bad decision making while the TRD instructor described actions based on the interaction of his three competing models (e.g. "I want to see their reasoning.", "I am not particularly in favor of knocking people off ... if they see an answer and go right to it.").

5. FINAL REMARKS

Based on the preliminary results from the two instructors, there is evidence that the basis of their different practices is not in their vision of the expert problem solving. The essential differences are in the details of their teaching models and in the way they treat competing models. The EPS instructor has a coherent model from which he derives all of his actions. The TRD instructor, on the other hand, has several competing models that were triggered in different contexts. These competing models often seemed to suggest contradictory actions.

Although we have only begun the analysis of the interviews of other instructors, there is evidence that physics faculty do hold coherent, although often contradictory, teaching models. For example, a conflict arose in several instructors when they were asked to grade a very brief student solution that had no explanation of the student's reasoning. Many instructors wanted to lower this student's score because no reasoning was shown. They did not know, however, how they would justify this grading choice to the student if the student complained about the grade.

In many cases instructors did not appear to be aware of their competing models. Occasionally, however, we were able to promote an awareness of two competing models through the interview questions. For example, almost all instructors interviewed mentioned that they want students to compare their own solutions to the instructor solutions and to diagnose their mistakes. Most instructors also believed that students do not often do this type of comparison. Once aware of these two models, instructors typically realized that they held contradictory ideas, though few suggested ways to remedy the situation.

Our examination of this rich interview data is continuing. So far we have demonstrated that we can develop an analysis that can distinguish between the two subjects known to have different classroom approaches to teaching introductory physics using problem solving. We will continue our analysis by examining other interviews.

6. ACKNOWLEDGEMENTS

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