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Student Beliefs About the Learning Task in Physics

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Abstract

In an investigation of students' perceptions and experiences of learning physics open-ended interviews were undertaken with nine students in a university honors mechanics course. A thematic analysis of the interview transcripts showed that the students saw themselves learning primarily outside of the classroom as they solved the problems that made up the assignments. Students reported that they had been introduced to Newton's laws in high school and few new concepts were now being introduced. They saw themselves as having moved beyond the memorization of content to the use of this content in solving more realistic problems and in relating the solutions to their prior experience. Students' approaches to the learning task were also influenced by their interactions with classmates and friends and by their perceptions of the actions of the professor in the classroom. However the perceptions of the students were at times at odds with the intentions of the professor who saw the nature of physics as a major influence on his approaches and actions. Unless both teacher and student are prepared to come to a shared understanding of the learning task, misconceptions about both physics and the learning of physics will continue to impede learning.

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Résumé

Cette recherche comportant des questions ouvertes sur la perception que les étudiants ont de l'apprentissage de la physique et sur leur apprentissage de cette matière a été menée auprès de neuf étudiants d'un cours de mécanique offert dans le cadre d'un programme de baccalauréat spécialisé. L'analyse thématique de la transcription des entrevues révèle que les étudiants ont le sentiment qu'ils sentiment qu'ils apprennent surtout en dehors des cours, en résolvant les problèmes de leurs travaux et exercices. Les étudiants on dit qu'on leur avait enseigné les lois de Newton à l'école secondaire et qu'on leur présentait maintenant peu de nouvelles notions. Selon eux, ils avaient dépassé l'étape de la mémorisation de la matière des cours et se servaient maintenant de cette matière pour résoudre des problèmes plus pratiques et établir des liens entre les solutions et leur expérience antérieure. Parmi les facteurs influant sur leur façon d'aborder les activités d'apprentissage, on retrouvait leur interaction avec leurs pairs et leurs amis, ainsi que la façon dont ils percevaient les interventions du professeur en classe. Cependant, les perceptions des étudiants ne correspondaient pas toujours aux intentions du professeur pour qui l'enseignement de la physique devait être modelé par la nature même de cette matière. À moins que les étudiants et le professeur ne soient disposés à faire un effort pour en arriver à une compréhension commune de l'activité d'apprentissage, les idées fausses sur la physique et sur son apprentissage continueront de poser un obstacle à l'apprentissage.

As children run, jump, and throw objects they develop beliefs about how the world behaves. When, as students, they enter the physics classroom they bring these beliefs with them. They also bring beliefs about the nature, content, and methods of physics and beliefs about college: the attitudes, social climate, and other factors that allow the student to feel that he or she belongs at the college.

The present study focused on students' perceptions of the learning task itself, and on the viewpoints and beliefs of the students: how they defined the task, what they thought constituted learning, and the various factors they saw as influencing the task in physics. The purpose of this study was to increase understanding of student beliefs about the teaching/learning process, with the expectation that a better understanding of these beliefs and the ways in which these beliefs aid or hinder learning of physic, will point to ways of improving both the learning and the teaching of physics.

Background

In talking about content knowledge, Ausubel, Novak, and Hanesian (1978) posited that the most important single factor influencing learning is what the learner already knows. They advised teachers to ascertain what comprised students' entering conceptions and then to teach accordingly.

There is a large body of research that compares the conceptions about the content of physics held by students (novices) with those of expert physicists (Clement, 1982; Halloun & Hestenes, 1985; McDermott, 1984; Viennot, 1979). A number of authors (Champagne, Gunstone, & Klopfer, 1985; Hake, 1987; Mestre & Touger, 1989) have examined the consequences of these conceptions for the teaching of physics.

It has been suggested that for instruction to be effective, students must be encouraged to confront the cognitive dissonance or disequilibrium that can result when the predictions of a student's reasoning differ from what he or she observes as the outcome of an experiment or action (Dykstra, Boyle & Monarch, 1993, Hewson & Hewson, 1884; Renner, Abraham & Birnie, 1986; Trowbridge & McDermott, 1980). More recently, Chinn & Brewer (1993) postulate that there are seven distinct ways in which students respond to such anomalous data, "only one of which is to accept the data and change theories" (p. 1). They suggest that teachers can encourage reflective theory change by influencing the prior knowledge of the students, by introducing the alternate theory, by introducing anomalous data, or by influencing processing strategies.

Learning depends on more than the content knowledge of the student and whether or not the student's conceptions of that content agree with the beliefs of experts in the field. Some of the factors that must be considered include: the learning environment in which the learner finds himself or herself, the learning style or study approach of the student, the effects of assessment, the ways in which the student approaches problem solving, the effects of the student's conceptualizations of what constitutes learning (Hammer, 1991), and the teacher's conceptualizations of teaching. The application of the idea that the instructor must understand what is in the mind of the student must be expanded from a concern with content knowledge to an appreciation of the larger learning environment including teacher variables (Dickie & Farrell, 1991).

Moreover learning does not take place in isolation. The student is learning a particular subject, in this case physics, in a particular setting, the university, surrounded by other students and by professors. Ramsden (1991) has examined the ways in which students learn in natural educational settings and concluded that students modified their approach to learning to fit the perceived environment. Martin, Ramsden and Bowden (1989) found that students who focused on the similarities of learning at high school and learning at university were most likely to successfully adapt to the new institution. Dickie and Farrell (1991) explored the impedance mismatch between high school students' expectations of college and their subsequent experiences. They found that the students' definition of success at college often differed from that of the professor: they suggested that teachers should be aware of the factors that influenced the choices students made, and the efforts students applied to their studies.

While it is true that students can control the length of time and amount of effort they devote to the learning task, different students may adopt widely varying study approaches when faced with a particular task. The resultant learning has been shown previously to depend on the approach adopted (Biggs, 1978, 1989; Craik & Lockhart, 1972; Svensson, 1977; Wittrock, 1986). Distinctions have been made between three approaches: deep, surface, and achieving (Entwistle, Hanley, & Hounsell, 1979; Marton & Säljö, 1976, 1984; Ramsden, 1985). It has been determined that most students are somewhat versatile in their choice of approach (Laurillard, 1979; Marton & Säljö, 1976; Svensson 1977), the choice depending on factors such as interest in a topic, pressure of other academic demands, amount of content in the course, student perceptions of what will be required in subsequent assessments, and their personal academic motivation.

Student concern about assessment, and its impact on both motivation and approach to studying is reflected in the question: "Is this going to be on the test?" Indeed this is often the primary concern voiced by students when faced with a learning task and this question is an example of the ways in which tests and other forms of assessment influence greatly both the *how* and the *what* of the student's approach to the learning task (Crooks, 1988).

Another body of literature is concerned with identifying the ways in which students approach problem solving in physics (Fuller, 1982; Simon & Simon, 1978; Zajchowski & Martin, 1993), or comparing the performance of novices with that of experts (Chi, Feltovich, & Glaser, 1981; Larkin, *et al.*, 1980). More recently, the effects of group processes and social interaction on the quality of the solutions generated when students solve problems in groups have been examined by Heller, Keith, and Anderson (1992) and by Nespor (1990).

While interest in the misconceptions students have about content began in the 1970's with the work of Viennot (1979) and others, interest in the effects of student beliefs about learning and teaching is more recent (Duit, 1993). Hammer (1989, 1991) studied the effects of physics students' beliefs about learning on their learning in a first-year university physics class, and found that epistemological beliefs significantly influence problem solving and learning. He has pointed out, for example, that in a conventional lecture students may hold different beliefs about what to do with the content presented. The finding that students use the new information presented in a lecture in different ways can explain why only some students are able to learn in such a setting, and has important consequences for the teacher's conception of what constitutes teaching. In a study conducted in universities in Australia, Canada, and the United States of America, Donald (1993) found that students saw themselves learning physics through problem solving and were aware of the limitations of their own knowledge of physics vocabulary and concepts. In contrast, she found that physics professors conceptualized teaching physics as the development of intellectual skills and assumed that the students possessed the required background knowledge.

The mismatch between the beliefs about teaching and learning of the teacher and those of the student can lead to students placing different interpretations on activities and experiments to those intended by the teacher (Tasker & Freyberg, 1985). In addition Prawat (1992) has pointed out that teachers must be willing to rethink their beliefs about teaching to prevent these beliefs acting as obstacles to the adoption of constructivist approaches to teaching and learning. In a study of the epistemology of high school students in an all-boys school that had a predominantly objectivist tradition, Roth and Roychoudhury (1995) concluded that the effect of constructivist physics teaching could lead to students and teachers inhabiting, as it were, different worlds. Hammer (1995), has explored how a teacher's perspective of the epistemological beliefs of students might influence his or her instruction: the instruction could be oriented towards content or towards competencies, toward providing answers or providing means to obtain answers. Another implication of the mismatch between the objectivist, command and control, style of teaching adopted by many science professors in first year classes and the learning styles of students is that many able, 'second tier' students drop out of science (Felder, 1993; Tobias 1990). A different dimension of the difficulties faced by students and teachers is offered by McDermott (1991) who has suggested that the curriculum of the introductory physics course is not well matched to either the student or the instructor.

Subjects

Volunteers were sought in the first year honors mechanics course and of the forty students in the class, initially seventeen volunteered to participate in the study (a small honorarium was offered in return for an interview). Nine students kept the appointments and were interviewed. Of the nine volunteers, five were physics majors, three were in electrical engineering, and one was a graduate student in biophysics. Two of the students were female. The course was taught in the conventional lecture format by an experienced physics professor. In the province of Québec, students complete high school after grade eleven and those seeking post secondary education spend two years in a junior college or Cégep

(Collège d'Enseignement Général et Professionel). Most of the students in this study had completed Cégep, taking the three semester-long physics courses (mechanics, electricity and magnetism, waves and optics), and were entering university at a level comparable, in the rest of North America, to second year. Those who had not completed Cégep had taken an equivalent year of physics at the university. The honors program differs from the regular physics program in that only the best students are selected for the program: completion of an honors program is a normal prerequisite for admission to graduate studies in physics.

To further elucidate the student views, the professor who taught the course was interviewed to determine his views on teaching and learning and to clarify his aims and focus for the course; this interview was conducted after the preliminary analysis of the student interviews was complete and after the completion of the course.

Methodology and Analysis

Interviews, each lasting from one to two hours, were conducted with each subject by the principal investigator. The students were interviewed at the start of the academic year. The interviews were conducted in an open-ended format in the ethnographic tradition (Hammersley & Atkinson, 1983; Marton, 1988; Mishler, 1986), and they began with very general questions such as, "What is it that you are doing in that course?" and "Could you describe that physics course for me?" The student's responses guided subsequent questions and probes that were used to elicit their viewpoints. The interviewer's goal was to move towards more particular and personal questions such as, "What does learning mean for you?" and students were encouraged to take the lead as they replied in a narrative style about issues they felt were important to their learning. Although the direction of each interview was generally led by the students, specific probes and questions were asked of all subjects by the interviewer. All interviews were audio taped and completely transcribed.

The aim of the thematic analysis undertaken was to systematically characterize what students were saying about the learning task in physics and to provide further elucidation of what van Mannen (1990) has called the "lived experience" of the student. The categories into which the themes were sorted were allowed to emerge from the data as the analysis proceeded in the manner similar to that termed **phenomenography** by Marton (1988), or as **grounded theory** by Glaser and Strauss (1967). To assure the trustworthiness of the analysis (Lincoln & Guba, 1985), two sample interviews were provided to an independent consultant who was experienced in both qualitative analysis and science learning at the university. The consultant identified salient themes and potential analytic categories, then met with the researcher to share insights. After the themes and categories were finalized, the interviews were coded.

As a final step the general perceptions of the students were compared with the intentions of the professor who taught the course.

Themes

When asked about learning and where they saw the learning take place, students talked about their classes, their notes and textbook, about solving the problems that constituted the assignments, about their previous studies in physics, about the professors and their teaching behaviors, and about course grades. The emergent themes were clustered into categories: The influence of classroom practice; where the learning took place; learning physics is doing problems; physics is explaining the real world; and assessment.

Classroom practice and where the learning took place. When students were asked to describe what happened in a physics class they said: "A lot of science and math courses ... have standard methods of introducing something ... like covering it, like deriving it, and then like having examples." Students were familiar with the format of the class, they were used to it, had experienced it at school, and some even went so far as to say they liked it.

Students reported that the learning that took place in the classroom was influenced by their prior knowledge, by the style of the professor, and by the problem solving nature of physics. While students did say that learning occurred in the physics class, most saw themselves learning more outside the classroom: "I say the learning isn't in the classroom, I say it's afterwards."

Even though most students said that for them learning took place mainly outside of the classroom, the actions of the teacher in the classroom exerted an important influence, an influence that varied according to the observer. For example, when asked to describe the mechanics class, seven of the nine students talked about how the professor copied from his notes and the textbook. Their feelings about this practice varied widely. In the words of one student:

> ...he is copying from his notes, which is something I don't particularly like ... if the teacher is thinking at the same time as you they tend to think at the same speed.

On the other hand, another student saw this same action more positively,

> ...it's a bit peculiar with this teacher, he copies directly out of the book. That's something I noticed like from the second day. So it's in a way good because you don't have to take the notes and read the book. So it doesn't confuse you like a different notation.

Several other students discovered that they could follow the class paying attention to what was said, rather than having to take notes; however, a worrying consequence was noted: "it's a bit scary 'cause you get to the exam time and you don't have any notes."

From the class notes of those students who had come to see him for help, the professor had the impression that students took good notes in class and he considered that note-taking was important: if a class was missed a student would have a hard time covering the material from the text alone. He considered the textbook for the course, Kleppner and Kolenkow (1973), to be well organized and tried to follow it, "but not religiously;" in addition, he tried to follow the notation used by the book and he allowed that the book defined the course in some ways. In this regard he is agreeing with the finding of Nespor (1995) who has pointed out that physics professors describe the standards and objectives of a course by citing the text the course used (p. 60) and the publication date of the book, 1973, also fits Nespor's observation (p. 56, note 5) that texts in physics courses tended to be more than ten years old, in contrast to management where he found texts were usually published within the previous five years. The professor thought that the text contained quite difficult problems, and was also sensitive to the cost of the book; he saw the expense being justified by it also being used for the relativity section of an associated course.

Students held similarly divergent views of the professor's practice of omitting steps in derivations or problem solutions with the comment, "for you to do later." Some saw this as an attempt to save time and to cover the curriculum that had been dictated by the dean or by someone in authority. Others saw the omissions as part of a deliberate strategy to have them, the students, work through the algebra, the reasoning, and saw its purpose as being: "...just to help us brush up on our integration, or just to help us, by doing it ourselves we'd understand better you know."

The professor was clear about his motivation. If a derivation involved a standard mathematical process such as a Taylor expansion, this was omitted because the physics was involved at the start of a problem in the setting up and approach to the problem. In the middle was the algebra. The physics became important again at the end of the problem in the examination of the physicality of the answer. The professor did not see omitting steps as a way to save time. If the steps in a proof were important, they were covered.

Outside of the classroom, students saw themselves spending time solving the problems of the assignments: the assignments drove the learning: "I learn far more from my own reading and struggling through a couple of problems than I do just sitting there [in class]."

It is of interest that students saw the mechanics problems they were solving as developments of ones that had been seen before:

> ...in college you learn how to calculate the tension in a massless string; in university you learn how to calculate the tension in a string of mass. That's like an analogy; It's a bit simplified in College, and when you get to university you learn how to do the more general case, but you have to know what tension is ...

Not only did you have to know what the dictionary definition of tension was, but:

> You have to know what it represents, like the word. Not necessarily the dictionary definition but the physical definition of tension. You have to know what it represents as a general concept, and you have to know how to calculate … using the tension, you have to know the whole process.

Rather than acquiring declarative knowledge the students saw themselves applying this knowledge to more realistic situations. Students had first been introduced to Newton's laws in high school and no new laws or concepts were being presented to them in the class: they were now just exploring further applications of familiar rules. The problems were becoming more like the real world, becoming more realistic:

> ...physics is more of the problem solving in the sense that you have a physical problem that's part of the world, part of the universe, and the way to solve that problem is using math.

Students believed that solving problems on their own was essential, for example;

> ...the assignments lead my learning I guess … when I understand why you go from one line to the next in an assignment … I guess that's where the learning of the fundamental principle that underlines that (going from one line to the next) gets done; that's where the learning gets done

Learning physics is doing problems. The professor considered that problem solving was important in teaching physics because that was the way physicists did research. There was a problem, one looked at from different sides, one turned the problem around and found that, "If you do it like this it's two lines and if you do it like this it's two pages." In teaching the course, one of his aims was to pass on to students the ability to look at problems at an abstract level, to turn a complicated problem around until you saw a simple way to look at it, and to use ones intuition to guide this process.

Given that both the professor and the students thought physics was a problem solving course or a course in which students learned by doing problems lead to the question: "How did students approach a problem?" Students talked about the different ways they tackled problems they saw as easy, compared with those they saw as hard. When understanding failed there were several different strategies that could be invoked. First, there was "all the steps you're supposed to go through." Students described a problem solving sequence similar to those detailed in study skills texts such as Pauk (1974): read the problem through, making sure you know what they are really asking; figure out what you have been given; draw up a picture; perhaps break the problem into manageable parts; solve the algebra; see if the solution makes sense and agrees with one's intuition.

Students said that this sequence had been adopted after watching a high school or college teacher use it to solve problems, and sometimes after explicitly instructing the students to use such a scheme. However, many complained that when teachers required a rigid adherence to such a system, it was seen as being too time consuming and they resented this rigidity. Students reported such a sequence being used in the courses and said that following such a sequence was good because: "...you can feel secure in it because like it's there's little doubt of its validity but I think it takes a little bit of the interest out sometimes."

A second strategy for overcoming difficulties in a mechanics problem was to search through one's notes or textbook for a similar problem. This strategy was often elaborated by the same student who had described the problem solving sequence at a different point in the interview. It did not appear that there was a distinct division between those adopting one or other of these strategies but rather both seemed to be available and either could be called upon when one strategy did not lead to a solution, or when the student had gotten stuck.

The final step in the problem solving process that was described was checking that the answer was consistent with one's own experiential experience, that it 'makes sense.' This theme of making sense, of checking the answer against one's intuition, was frequently elaborated with an example: "...you can visualize a pulley and a block and what happens there: so if you ended up with an answer that shows that ... your block went flying into the sky you would think; OK, something's wrong here."

Students reported that in other physics courses such as thermodynamics, electromagnetism or relativity, where they did not have access to everyday intuition, it was more difficult to 'make sense.' In such cases, answers were compared with the answers of previously solved problems, or with the textbook.

If neither the text nor the notes yielded a probable solution, another strategy was to ask a friend. Consulting with a friend or working through an assignment with a study group, has been determined to be a complex social process that mixes the cognitive and the cultural (Heller, Keith & Anderson, 1992; Nespor 1990). While students' attitudes to group work were influenced by professors' expressed views: "...you know the lecture about not copying each other's assignments and stuff like that...", most saw working with friends as useful and took a positive view. In the words of an engineering student:

> I try really hard ... [but] I've tended to more this year discuss my problems with others; they say in engineering you cannot survive on your own and definitely the attitude even as promoted by teachers is that you should work together on assignments. I don't think that's the same way in physics; I get the impression it's much more on an individual kind of thing,

but then again a physics student talked about the social context of learning:

> I learn probably as much from kind of sitting around working out an assignment and spending a lot of time with my friends trying to work out ... as I do, you know, in class and everything ... it's always give and take.

Both physics and engineering students talked positively about using groups to solve problems and also said that providing an explanation to a friend helped their own understanding even when, as in this remembered extract from a conversation with a room-mate who was not taking physics:

> If I've got a block and it's sitting on this inclined plane, don't you think that this is what's going to happen?" and she'll say "Well, yeah, but couldn't [pause]. Does this interfere at all?" and so you get different points of view, and even if she suggests something that is entirely absurd, as long as I can shoot it down logically, then at least I know I might be on the right track.

Finally, if none of the three strategies worked, students talked about asking the professor, although few said they had actually gone to see the professor. For his part, the professor saw himself as encouraging students to come and see him, as well as encouraging students to work together. His view was that this was because if you had a problem when doing physics, you first looked at it in different ways, then you shared your questions with colleagues in order to get their feedback and insights.

Assessment. When asked about what they thought the exams in the mechanics course would be like, students talked about the consistency of the examinations, assignments and course syllabus: "I expect in this course it will be problems ... problems similar to the type we did in the assignments"

Students expected the exams to follow the assignments, they did not expect to have to know facts such as "when Newton lived and stuff"; in other physics courses where the assignments required derivations, the students said they expected derivations on the exam. For his part the professor made the examinations from previous years available and thought of the midterm as providing a 'wake-up call' to encourage the students to spend more time studying for the course. He was pleased that one consequence of the low average in the mid-term was that more students came to see him in his office to ask for explanations of what had been said in the lectures.

Discussion

While students saw themselves learning from the lecture, they saw more of the learning taking place outside of the classroom either through their reading of the textbook or, most importantly, from solving problems on the assignments.

All of the students who were interviewed mentioned both the teaching and implementation of a standard problem solving sequence. All of the students saw the final step in the sequence as making sense of the answer by comparing it with their intuitive ideas. Donald (1993) reported that physics professors said that physics courses began with mechanics because in everyday life people confront mechanics and so acquire familiarity with its workings and consequences. In this course, the first university level course in mechanics for most students, the professor sought to make the students look at concepts they thought they knew in more mathematical, more sophisticated ways. He wanted the students to gain experience and confidence in applying apparently simple concepts that in fact had deep implications for the unity of different parts of physics. At the same time, he saw that in mechanics students could rely on their intuition in ways that they could not do in subjects such as quantum mechanics: he saw intuition as a guide to, for example, "how would friction go, would it go this way or that way?"

Students perceived an external authority such as the dean requiring the professor to cover large quantities of content, resulting in limiting the time that could be devoted to answering questions in class or completing the solutions to examples in class. They were apparently unaware of the pressure felt by professors to cover the material because of the sequential nature of physics (Donald, 1993). In this course, however, the professor had identified for himself the areas that he must cover and saw himself as having the flexibility to control the time spent on a topic depending on how he perceived the progress of the class. He saw himself constantly asking questions in the class to get "some level of interaction," and his approach was influenced by the feedback he obtained. This points to the dilemma for the professor as to whether the students are best served by coverage of content or by attention to skill development and conceptual development in students who are concerned enough to ask or respond to questions in class.

For most students, learning physics was not just memorizing content; learning in physics involved, "understanding the material and the implications." It involved more than just the accumulation of knowledge but also the ability to apply that knowledge, and to feel comfortable with it, and to be able to make sense of it.

In talking about working with other students, most spoke negatively about dividing up an assignment "you do question one, I'll do question two ..." or just trading answers. All said that working cooperatively helped their learning and spoke positively about "bouncing ideas off one another," and discussing concepts and problem solving procedures with their friends. This finding agrees with that of Heller, Keith, and Anderson (1992), that well-functioning groups shared their conceptual and procedural knowledge and that such groups obtained solutions that were better than individual solutions (regardless of student ability). An unanswered question, however, is whether this superior group performance will translate into better individual performance on examinations. In the present study, the same students who spoke against trading answers or dividing up assignments (5/9) also said that they learned best alone, in contradiction to the findings of Heller et al. This same dichotomy between self-reported learning-style preference and accepted best practice has also been reported by Siebert (1992) who found that 84% of students surveyed at her college [small, private, principally for women, in Los Angeles] said that they preferred to study alone. This result is contrasted with the finding by Tobias (1990) who reported that students, particularly women, prefer studying in groups. Seymour (1992) in an examination of student-reported reasons for either persisting in or switching out of science or engineering found that students who persisted found support and encouragement in peer study groups while switchers sought to struggle on alone. A speculative question is: Do students feel that they need to know, for themselves, that they know and understand the material because the final exam is, almost by definition, an individual task?

There was no stated consensus among students as to whether they saw professors encouraging or discouraging group work; rather, it came about because they had gotten stuck at some point in working the problems on an assignment in trying to meet the assignment deadline or it arose as a part of social interaction. Such results support the findings of Nespor (1990) who pointed out that social, group-efforts became the dominant format for working problems in the cohort of physics students he observed.

There is a dilemma for the teacher. Students recognized the shortcomings of trading answers and similar short-term strategies. Should the teacher encourage group learning and collaboration on assignments? Do students do significantly better on physics exams because of cooperative learning? It is possible that such an approach can have immediate impact on the learning, and have a long term advantage in terms of students' future as research physicists, either in academia or industry, given the increasingly collaborative nature of physics research (Kleppner, 1985; Memory, *et al.*, 1985). This was a point emphasized by the professor in the course who encouraged students to work together because that was how physics research was done: if you had a problem you talked about it with your colleagues.

Conclusions

In ethnographic studies, such as this one, the data are the descriptions by the students of their understandings and experiences. These data can only be obtained by listening as the students relate their perceptions and experiences. It became evident that at times the perceptions of the student were at odds with the intentions of the professor. Many of the professor's actions were predicated on "how physics works," while the students ascribed his actions to time pressure, his wanting them to practice techniques, and did not recognize his encouragement of cooperative work.

While students saw themselves learning physics in the classroom they saw the main task of the learning as the solving of the problems assigned in the classroom. They thought that the exams would consist of problems similar to the ones on the assignments. All the students saw themselves learning physics by solving problems, by struggling with the ideas either alone or with others, rather than by merely listening to an exposition of the ideas. When talking about problem solving, most students talked about interpreting the answer in terms of their intuitions, their experiences of the real world, and about 'making sense.' They also talked about the influence of friends and of classmates when they were working together on the assignments, and about the contradictory messages they received from the professors about cooperation and collaboration.

In the mechanics course, the students saw themselves applying and extending the rules and principles that had been acquired in high school or college to the problems. It is only by listening to what the student has to say that the professor can learn what are the student's conceptions of these rules and principles. Is the professor prepared to take the time to understand the conceptions of the student before continuing to cover the material of the course? Is the professor prepared to provide the students with opportunities to express new concepts in ways that connect to the students' own experiences?

Research has shown how misconstrued content knowledge interferes with the learning of physics. However, one must look beyond beliefs about content to beliefs about learning. Unless professors and students are prepared to spend the time necessary to come to a shared understanding of what constitutes the learning task in physics, learning will continue to be inhibited.

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