CHAPTER 1

INTRODUCTION TO ISSUES

UNDERSTANDING PHYSICS LEARNING IN INTERACTIVE GUIDED INQUIRY ENVIRONMENTS

This dissertation is an investigation of some of the social and other influences on students' learning in a physics course. Classrooms are social and cultural settings in which structured interactions are intended to lead to learning. Viewing them as such can lead to insights into what students learn, and how and why they learn what they do. These insights can in turn inform curriculum development and teaching.

Guided inquiry course designs create social and cultural structures that are different from those in traditional lectures. It is not enough to simply evaluate these designs, to test which variation results in the most learning. In order to know what works and why, we must develop some sense of what goes on in inquiry courses. We have to understand what happens, as well as how and why it happens.

By comparison to traditional lecture courses, students' roles are perhaps more apparent in inquiry courses. If the teacher rarely lectures and does not tell students what to think, then conversations between students and the making of sense by student groups become major features of the course activities. When groups of students are given a larger responsibility for developing the ideas in a course, then we have to understand the nature of student interactions if we want to understand the classroom learning situation.

The dissertation represents an attempt to understand and systematize some of the ideas and interactions in an inquiry based physics course. One might represent the course in a very simple way with the diagram on the next page:

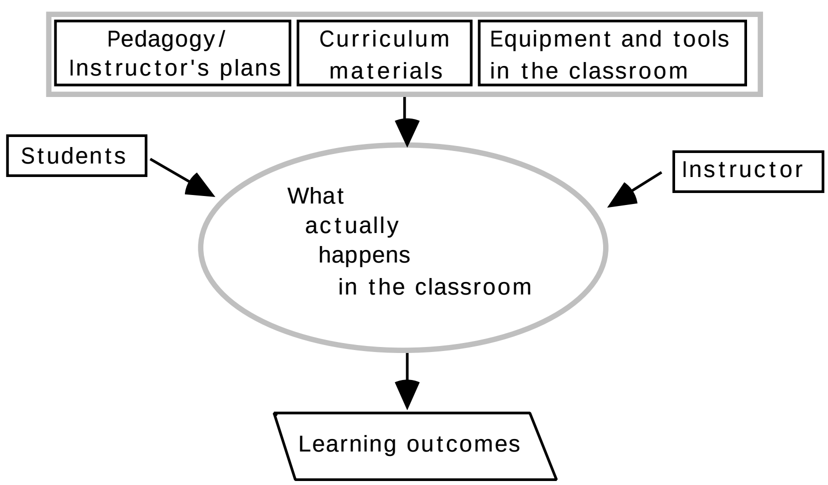

Figure 1-1: Simplified model of classroom processes

The upper rectangle represents "things prepared for the course before students walk in the door." The instructor makes plans, has an idea of how to teach the course, selects or has curricular materials (textbooks, for example,) and the classroom has tools and equipment (for example, desks and a chalkboard, and sometimes experimental apparatus). When the class begins each day, things happen. All of this activity is represented inside the central oval. At the end of the day or the end of the course, students have learned something. These outcomes are represented by the shape at the bottom of the diagram, some of which hopefully satisfy course goals.

Experimental research designs involve varying the conditions at the top of the diagram, measuring results at the bottom, and then seeking statistical connections between the two. The actual classroom activity is sometimes not similarly carefully characterized. Relatively little research attempts to characterize what happens in the classroom. This dissertation, however, is concerned with making sense of some of the classroom activity represented by that central oval, and with making sense of the ways that the pedagogy, curriculum, and classroom tools affect it. The interactions are complicated, so only a few aspects of the classroom activity will be studied. For reasons explained below and in more detail in Chapter 2, the aspects studied in this dissertation are: (1) the development of models of magnetic materials in the class, (2) the processes that students engage in while constructing group text and pictures, and (3) the development and influences of patterns of expectation and obligation, or classroom norms.

The course studied, taught at San Diego State University, was a trial testing course for the CPU Project (Goldberg, 1997). The CPU pedagogy employs cooperative groups, carefully sequenced tasks, physical experimentation by students, and curricular materials on paper and in computer software which both guide and support students' sense-making activities. In this course, the students were given the task of developing their best model of magnetic materials. In doing so, many groups constructed a variety of initial and intermediate models before coming to agreement on models that were very similar to the magnetic domain model of ferromagnets. The question is, how did they do it? One has to look at the classroom activity (represented above by the oval) to answer this question. Finding useful ways to do this is part of the goal of this dissertation.

TAKING MULTIPLE PERSPECTIVES ON LEARNING PROCESSES

How should we organize our observations of classroom activity? How do we select a theoretical perspective that will allow us to characterize the important aspects of the interactions? Anna Sfard (1998) has characterized two major metaphors for learning that appear to be at the root of some debates in education research. One she calls the "acquisition" metaphor, and the other "participation." "Acquisition" is the one that most of us grew up with and the one we are likely to find the most familiar. Under this metaphor, knowledge is thought to be something that one can "get," and learning is a process of "getting it." Sfard employs this metaphor to encompass not only the notion of transmission of concepts, but also construction and conceptual change, because these perspectives still focus on what individuals know, and on how they end up with knowledge.

Sfard used the word "acquisition" to imply that the mind carries knowledge. While the ideas are more complex than this, the notion of acquisition may be most compatible with "in the head" views of cognition that take the mind to be a processor of knowledge, and the world outside the skull to consist of sources of stimuli. The acquisition metaphor is taken to be useful for thinking about students' ideas and wholly internal processes of change.

Socially-oriented perspectives, on the other hand, consider cognition to arise primarily from interaction. Sfard associated with these perspectives the metaphor of "participation," to emphasize their common views of learning as a process of developing ways to effectively engage or participate in activities. Using a participation metaphor, learning is largely a process of enculturation, and knowledge is evidenced by ability to act in a skilled way. "Knowing" is a way of characterizing people's actions. Perspectives that take the participation metaphor offer the promise of providing insight into how people learn because they highlight relations between learning processes and learners' surroundings.

The word "participation" suggests that important aspects of learning and cognition can be identified in interactions between individuals and with their surroundings. Thus perspectives that use the participation metaphor provide alternatives to traditional in-the-head individual cognition perspectives. Sfard, however did not rank one metaphor over the other. She instead suggested that there is a complementary relation between the metaphors of acquisition and participation. Each one focuses attention on different but important aspects of learning, and that by employing both metaphors, Sfard suggested that researchers can form a more complete picture of learning.

In a recent book chapter, Duit and Treagust (1998) also suggested that different perspectives can complement each other, rather than competing for preeminence. In discussing constructivist and social constructivist views, they wrote: "Further research should not focus on the differences but present an inclusive view of learning and conceptualize the different positions as complementary features that allow researchers to address the complex process of learning more adequately than from a single position." It appears that Sfard, and Duit & Treagust were saying similar things.

It is clear that understanding interactions in a physics classroom requires understanding the ideas that students worked with, as well as the interactions that led to development of these ideas. This dissertation will do this by employing both "participation" and "acquisition" perspectives. The study of group models in Chapter 4 is intended to provide some semblance of an acquisition perspective. This will be complemented by analyses of activity types and classroom norms in Chapter 5. Together, these analyses hopefully will provide a useful understanding of the learning that took place in this course. Figure 1-1 shows learning outcomes as the result of things that happen in the classroom. Both types of learning - development of thinking via participation, and learning as accumulating knowledge - will be considered in this dissertation. Both types of analyses are important, for reasons explained below.

The importance of being aware of students' ideas in inquiry based physics courses.

In order to successfully construct innovative and effective physics courses, course designers have to know what ideas students are likely to develop. Since students' initial ideas serve as starting points for later constructions (Smith, diSessa, and Rochelle, 1993; Minstrell, 1992), and since students' ideas may develop along particular "learning pathways" (Niedderer, 1995), it is important to know how students are likely to be thinking, so that the course materials can help them move toward more desirable ways of thinking. Knowledge of the ideas that students tend to start with, and that students generate as their thinking progresses, can help course developers make better choices for selecting and sequencing activities.

Teachers of inquiry courses also need to know what kinds of ideas their students are likely to express. Teachers can have more confidence in their students, their course, and themselves if they can anticipate and recognize the foundational value of students' ideas. In order to respond in appropriate ways to students' ideas, teachers must be able to recognize ideas, know whether and in what ways they are problematic, and how and whether to address them later in the course (National Committee on Science Education Standards and Assessment, 1997). Of course, these latter kinds of teacher abilities involve pedagogical knowledge beyond simply recognizing students' ideas, but part of a teacher's daily preparation for an inquiry course is to know what students are thinking, and to anticipate what ideas may come up that day.

There are other aspects of physics courses that a teacher should be prepared to deal with in the classroom. Classroom interactions seem to have significant effects on learning. It is important have ways to understand interactions as well.

The importance of being aware of interactions in inquiry based physics courses.

Learning is a social process

Inquiry based courses explicitly involve students in the development of ideas. When students are generating ideas, the ways that they talk to each other make a difference in how ideas are produced, and could determine whether particular ideas ever emerge. Researchers have to pay attention to the social aspects of students' talk because it simultaneously serves social and educational purposes. This is the position taken by Lemke and others, who claim that no discourse is politically or socially neutral (Lemke, 1995). In this view, students' statements about magnetism also convey social information, and at the same time, social relations between students will affect their talk about magnetism. Social factors determine, for example, whose ideas are heard or not heard, they define what constitute accepted ways of making explanations, they influence whether students try to agree with or understand each other. Social structures may affect participants without their being explicitly aware of them.

It is likely that the structure of the pedagogy, among other things, affects patterns of social interaction in a class. Careful course designers would want to provide classroom conditions which promote patterns of social and intellectual activity that are beneficial to learning. We would want to know what these patterns are, or can be.

Some social patterns can be characterized as norms. The concept of norms has been developed for mathematics classrooms by Yackel and Cobb (1996), who characterized the patterns of obligations and expectations in a second grade math classroom. These authors found that developing particular kinds of classroom norms is part of the process of creating an atmosphere of mathematical inquiry. A teacher interacting with students often promotes particular mathematical behaviors, such as looking for elegant solutions to problems. Students respond to the teacher's actions in particular ways. The ensuing process of give and take between teacher and students can eventually constitute a specific norm for what counts as an elegant solution, and students' awareness of and their seeking for elegant solutions leads to more powerful and useful thinking by students.

The concept of sociomathematical norms might fruitfully be applied to science courses, but there are differences to take into account. One is the subject matter. Research has not been reported on norms in science classrooms. Important norms that influence desired scientific thinking are probably different from mathematical norms reported by Yackel and Cobb. Also, Yackel and Cobb identified norms that arose primarily in whole class discussions. However, the students studied for this dissertation worked much of the time in small groups. Because of the different interaction structures, norms might emerge differently in these two different settings. Taking into account these differences, this dissertation will attempt to document those norms that seemed productive for a group of three students.

Interactions are cognitive processes

While social norms explain some relations between social and cognitive processes, they certainly are not the only important features of a classroom environment. For instance, the students in this class used experimental apparatus, and they worked closely in small groups with computers. The ways that the small groups used these tools can be explained from a perspective which takes interaction to be the fundamental basis of cognition. Ed Hutchins (1995) claims that researchers can gain a better understanding of cognition by placing the boundary of the unit of cognitive analysis not inside the skull, but around whatever interacting system seems to be getting the cognitive job done. One can consider a group of people working together at a computer as a cognitive system, which might explicitly include the computer as a representational and rhetorical tool (Kelly & Crawford, 1996). Hutchins promotes the idea that people's interactions with their environment comprise cognitive processes. Using this perspective, the conversations that students had in this class represented part of the functioning of a distributed cognitive system. Their interactions performed cognitive tasks whose accomplishment couldn't be credited to any one individual.

This "distributed cognition" approach might contribute to understanding how groups of students develop ideas. In the class studied for this dissertation, groups of students sometimes did appear to develop new ideas, and conversations in the groups sometimes showed levels of understanding apparently deeper than any one student in the group had expressed up to that point. It seems plausible that students who contributed to the development of ideas might be able use them again later, and so we would say they learned.

This perspective offers a way to understand aspects of the complex interactions of small groups with computers and experimental apparatus. It will be used in this dissertation to make sense of one particular aspect of classroom interaction, namely, what happened when students in a group of three jointly constructed representations on the computer screen and on white boards. Having to write or draw something that represented the group's thinking often sparked long discussions, which sometimes led to development of ideas within the group. It is important to understand how the process of jointly constructing representations can lead to the development of group ideas.

SUMMARY

This dissertation attempts to integrate an examination of the ideas generated by students in the classroom with studies of norms and other patterns of activity that seemed to play important roles in the students' development of ideas. In doing so, the unifying focus will be on changes that individual students made in their presented models for magnetic materials. Students and groups were asked repeatedly to write down, draw, or talk about what they thought was going on to cause magnetic effects. What changes students and groups made, and how they made these changes, are topics for this dissertation.

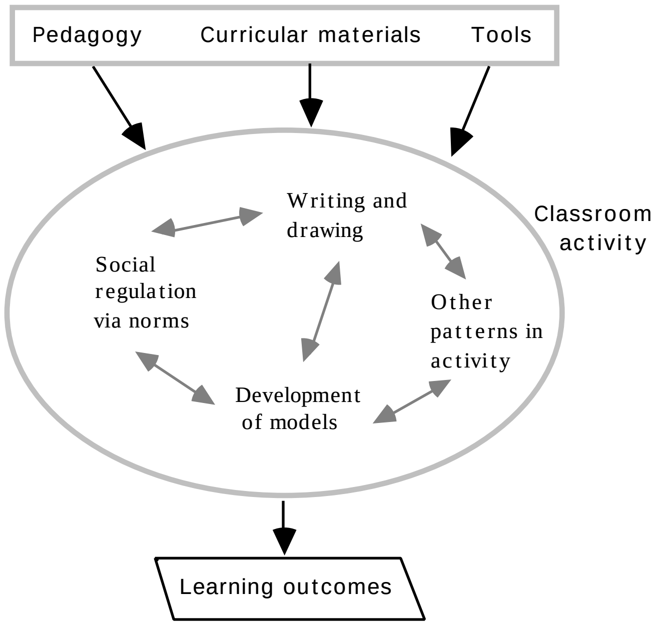

Figure 1-2: A few details of classroom activity

This diagram emphasizes the features of classroom activity that are the focus of this research. The features inside the oval are not really separate from each other. Small groups of students tend to develop their models while they are typing them into a computer, for instance. But for the purposes of the following analyses, each of the three features, social regulation via norms, patterns of activity, and developing models, will be considered somewhat separately at first, and then recombined in detailed descriptions in Chapter 5.

Put simply, the questions for this research are "what models did the students and groups present?" and "what contributed to their making significant changes?" These questions require identifying and classifying the major ideas and models for magnetic materials that students and groups produced in the course. This goal, which is necessary to an informed study of changes in students' thinking, is represented in research question 1 below. Results from this analysis will be used to identify significant changes made by students and groups. Then interactions between students will be examined for social norms and activity types which particularly seem to be involved in the identified changes. This objective is reflected in research question 2. The specific research questions guiding this dissertation are:

1: What were the group ideas, and how can one organize them? That is,

a) What types of models for magnetic materials did groups and individuals present in the class?

b) What was the time progression of groups' model types in this classroom?

2: What were some social patterns or structures evident in groups' interaction that seemed to affect students' learning? That is,

a) What types of activities did groups engage in when they shared the task of constructing group representations?

b) Using Cobb and Yackel's framework, what norms relevant to learning activity of the two groups can be found?

c) How can the activity types in a) and the norms found in b) be related to students' development and changes of ideas in this setting?

The next chapter will detail some of the relevant literature on student learning of magnetism, social/cognitive use of text and diagrams, and classroom norms, and it is intended to illustrate the theoretical perspective(s) taken in this research. Chapter 3 will describe the course in detail and the methods used to collect and analyze data. Chapter 4 will summarize and discuss the models that individuals and groups presented in the class. That is, questions 1a and 1b will be answered in that chapter. The topic of Chapter 5 is analyses of the interactions in the whole class and within a small working group of students. Questions 2a through 2c are addressed there. The final chapter will discuss implications and conclusions that can be drawn from those analyses.