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# TEACHING STRATEGIES FOR USING PROJECTED IMAGES TO DEVELOP CONCEPTUAL UNDERSTANDING: EXPLORING DISCUSSION PRACTICES IN COMPUTER SIMULATION AND STATIC IMAGE-BASED LESSONS

A Dissertation Presented

by

NORMAN T. PRICE

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

DOCTOR OF EDUCATION

May 2013

School of Education

Teacher Education and Curriculum Studies
Mathematics, Science and Learning Technologies

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Teaching Strategies for Using Projected Images to Develop
Conceptual Understanding:
Exploring Discussion Practices in Computer Simulation and
Static Image-Based Lessons

A Dissertation Presented

By

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## DEDICATION

To my parents, whose love of teaching and learning
inspire and support me
in all parts of my life:

Samuel Penfield Price, Sr.

and

Martha (Petey) Tinkham Price

And to my wife and children,
who are my constant source
of strength and joy:

Hei-Ja Martin

and

Charlotte and Owen Price

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**ABSTRACT**

TEACHING STRATEGIES FOR USING PROJECTED IMAGES TO DEVELOP CONCEPTUAL UNDERSTANDING: EXPLORING DISCUSSION PRACTICES IN COMPUTER SIMULATION AND STATIC IMAGE-BASED LESSONS

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The availability and sophistication of visual display images, such as simulations, for use in science classrooms has increased exponentially; however, it can be difficult for teachers to use these images to encourage and engage active student thinking. There is a need to describe flexible discussion strategies that use visual media to engage active thinking. This mixed methods study analyzes teacher behavior in lessons using visual media about the particulate model of matter that were taught by three experienced middle school teachers. Each teacher taught one half of their students with lessons using static overheads and taught the other half with lessons using a projected dynamic simulation. The quantitative analysis of pre-post data found significant gain differences between the two image mode conditions, suggesting that the students who were assigned to the simulation condition learned more than students who were assigned to the overhead condition. Open coding was used to identify a set of eight image-based teaching strategies that teachers were using with visual displays. Fixed codes for this set of image-based discussion strategies were then developed and used to analyze video and transcripts of whole class discussions from 12 lessons. The image-based discussion strategies were

refined over time in a set of three in-depth 2x2 comparative case studies of two teachers teaching one lesson topic with two image display modes. The comparative case study data suggest that the simulation mode may have offered greater affordances than the overhead mode for planning and enacting discussions. The 12 discussions were also coded for overall teacher student interaction patterns, such as presentation, IRE, and IRF. When teachers moved during a lesson from using no image to using either image mode, some teachers were observed asking more questions when the image was displayed while others asked many fewer questions. The changes in teacher student interaction patterns suggest that teachers vary on whether they consider the displayed image as a "tool-for-telling" and a "tool-for-asking." The study attempts to provide new descriptions of strategies teachers use to orchestrate image-based discussions designed to promote student engagement and reasoning in lessons with conceptual goals.

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# CHAPTER 1

# INTRODUCTION

## Purpose

Projected static overheads and computer simulations are common tools for developing student understanding of scientific concepts, yet it can be challenging for teachers to move beyond "show and tell" uses of these images and, instead, strategically employ them in large group discussions to promote active reasoning and scaffold the construction of dynamic visualizable models.

The purpose of this study is to examine, describe, and compare teacher large group discussion practices used in computer simulation and static overhead based lessons. The study attempts to provide new descriptions of strategies that teachers use to orchestrate image-based discussions designed to promote student engagement and reasoning in lessons with conceptual goals.

## Guiding Research Objectives

Previous psychological studies have indicated that words and pictures together are more effective instructional messages than either words or pictures alone (Mayer & Moreno, 2002) and that students need help interpreting complex visuals (Lowe, 2003). My interest is pursuing this line of research in a classroom setting where projected images can function like pictures and the class discussion can function somewhat like the words or narration used in these studies. I want to explore the strategies teachers employ during large group discussion as they use images to engage students in reasoning about models. Static and dynamic images appear to offer different advantages to teachers when

leading whole class discussions, but these affordances and accompanying strategies need to be described in order for teachers to utilize them. I will use the term image to refer to external images, such as projected overheads or computer animations.

## Significance of the Study

In this study I will attempt to explore the affordances of static and dynamic images for use in large group discussion and find new descriptors for certain strategies teachers use to help them exploit these affordances. I hope that with further refinements, such descriptors will help teachers communicate about strategies for using images to build conceptual understanding, as well as help teachers learn new strategies. It is hoped that this study's descriptions of approaches to the image and of image-based discussion moves will support the work of teachers, teacher educators, and researchers as they seek to understand what is involved with using images and whole class discussion to develop student reasoning and conceptual understanding.

## Outline of the Dissertation

Chapter 2 is a review of the literature about whole class discussion and teaching and learning with simulations. Chapter 3 outlines the research questions, study design, and data collection and analysis methods for this study. Chapter 4 provides a quantitative analysis of identical pre/posttests. Chapter 5 is a qualitative analysis of a smaller data base of one lesson taught by one teacher that introduces, describe, and define the image base discussion strategies that were observed in this lesson. Following Chapter 5, are three chapters (Chapters 6, 7, and 8) that each compare 2 teachers' use of simulation and overhead images. Those chapters provide a qualitative analysis of a larger database, and

will look at 12 Lessons, (4 lessons for each teacher). Chapter 9 examines each research question in light of the results, proposes a hypothesized model to speak to possible reasons for the quantitative gain differences, and discusses instructional implications.

# CHAPTER 2

# REVIEW OF PREVIOUS LITERATURE

## Research Articles that Describe Features of Traditional and Constructivist Whole Class Discussions

### The Challenge of Using Student Ideas to Reach Content Goals

As a classroom teacher with 25 years of experience teaching science to 12 to14-year-olds, I am aware of the numerous important dimensions of teaching that can be the focus of research. My interest in this study is to find ways to foster student conceptual change through model construction, and my primary focus is on meeting conceptual content goals by helping students acquire a target knowledge state.

A central question for teachers, which is shared by a number of researchers, is how to engage substantive student thinking, be responsive to student ideas, and still efficiently meet standard-based learning or content goals (Clement, 2002; Duckworth, 1987; Hogan & Pressley, 1997). How can teachers break their reliance on lecture and recitation as a means of reaching content goals and make room for more student thinking in class (Nassaji & Wells, 2000; van Zee & Minstrell, 1997)? Teacher change is challenging, and even after years of study, it is not easy for me to move away from more traditional teacher-centered and transmissionist discussion practices and enact more student-centered constructivist approaches.

Research based reforms in science education suggest that these goals are best met via teaching practices that engage students in the construction of knowledge (Duschl et al., 2007). National standards recommend the adoption of constructivist approaches, while other national and state policies have increased the pressures to reach

comprehensive state standards efficiently. Using constructivist methods to meet content goals takes time and new skills, so many teachers instead turn to traditional and familiar lecture and recitation (Tharp & Gallimor, 1988) with the hopes of efficiently reaching standard based content goals.

I am looking for tools that will help me to move my discussion practices from traditional to constructivist approaches and still meet my content goals. Many researchers have focused on large group discussion, because they see classroom talk as having a critical role in how teachers orchestrate and guide the construction of student models and mediate joint activity (Chin, 2006; Cazden, 2001; Dillon 1984; Edwards & Mercer, 1987; Edwards & Westgate, 1994; Mortimer & Scott, 2003).

In this chapter I will explore how researchers have characterized and described features of constructivist vs. traditional modes of large group discussion.

## Teacher Researcher Perspectives

As I begin to relate what features scholarly inquiry has revealed about these two categories of discussion modes, it is important to acknowledge my position as both teacher and researcher and to describe how this dual role influences my view of the literature.

### The Gap between Teaching and Research

Teachers face many influences and are, at times, besieged by other people's perspectives of "good teaching," be they students, parents, colleagues, or administrators. The voice of research does not often find its way into this mix. In other words, it is not common to find practicing teachers who make room for the voice of the research

literature in this chorus of perspectives. Although beliefs might be a better term than truths, I appreciate the fact that Lampert (1999) has noticed how teachers have a version of truths about teaching that exists alongside and is often not affected by research findings. For practicing teachers, the normal quantity and pace of interaction makes it difficult to move beyond an intuitive understanding of class discussion. Good and Brophy (1991) document how secondary teachers may interact with over 150 students on a daily basis. The theoretical perspectives from the literature are often buried in the noise of everyday teaching. One way to bridge the gap between these versions of teaching truths is to increase the signal from theoretical perspectives, via a focused study on a set of perspectives that seems most useful.

Research provides many productive and useful prescriptions and paths for teacher change, but the diverse theoretical frameworks used to describe teaching and learning are difficult for the novice to navigate. I hope that my review will be useful to teachers who want to begin to learn what research says about fostering constructivist discussion modes.

## The Tension between Teaching *Truths*

The research literature articulates problems and challenges, and this makes the problems and challenges more visible to other researchers and practitioners. As a teacher, I feel an internal pressure to act to solve the problems that are visible in my practice. Lampert (1999) sees pressures and tensions as being common to teaching and describes one challenge of teaching as being able to find ways to work with integrity while holding contradictory concerns. In my case, the contradictory concerns might be truths about teaching derived from experience and truths derived from the research literature. As a

teacher and a researcher, I am often aware of these contradictory truths and feel the gap between knowing a prescription for good practice and being able to implement it.

One goal of this chapter is to bridge this gap between simplistic prescriptions and practice with a set of theoretical tools that might actually help me to implement these prescriptions in the classroom. For example, the basic premise of constructivist teaching is well known: learning requires the active intellectual involvement of students and is influenced by a student's prior knowledge of science concepts. Most teachers and researchers agree that it is important to take student ideas into account in teaching, but it is difficult to know how this prescription is brought to life in a class with content goals. There is a tension between the realities of teaching, which encourage me to use traditional lecture and recitation discussion modes, and the intellectual community, which argues that learning is facilitated by more constructivist discussion modes. Lampert (1999) finds that teaching requires patience with the ambiguity and conflict that arises in the midst of such tensions. Patient research, study, and implementation are needed to resolve this tension in my own practice.

## Articulating My Practice

In this review, I have selected articles that help me to think and write about my teaching and better articulate what it means to know and practice good teaching. Lampert (1999) describes a goal of teacher research is "to develop a story of practice, not to celebrate it, but to draw meaning from it" (p. _). I hope this review will leave me strategically positioned to focus the tools of scholarly inquiry on my practice and to develop the ability to share accurately and rigorously what I find with both the researcher and teacher communities.

## Finding Theoretical Tools to Meet Pragmatic Goals

The aim of this review is theoretical and pragmatic. Like others, I believe that theoretical pluralism (Hogan, 1999) is useful for working in an applied discipline like education, and so I adopt a pragmatic goal of finding "theoretical tools" (p. ) that can serve the practical needs of my teaching and that may lead to improvements in my day to day practice. Specifically, I want to better understand a variety of discussion modes, so that I might regularly enact discussions that use student ideas to meet my content goals.

## Finding Theories that Allow for Incremental Change

My experience suggests that changing long standing habits of an experienced teacher involves a process of incrementally modifying existing skills to reach new goals. It is difficult for teachers to change their practice and reconcile constructivist theory of effective pedagogy with the practical realities of teaching in a standards-based classroom. Thus, it is especially important to find theoretical tools that facilitate incremental changes, tools that might help teachers meet the challenges of implementing a constructivist curriculum. (Hammer, 1995)

## More Detailed Goal of the Review

At a personal level, the goal of my literature review is to find frameworks and theoretical tools that will make the characteristics of traditional and constructivist practice more visible in my own teaching. The structures and functions of class discussion have been described and defined differently by many different authors. My review of the literature will examine how a number of researchers describe traditional or constructivist discussion modes, as a way of gaining a theoretical vocabulary to describe

issues in actual practice. The research included in this review has helped me to understand some of the theoretical issues that are important in meeting these pragmatic goals.

## Features of a Traditional Discussion Mode: Recitation

### What is Recitation? Basic Definitions

#### Recitation is Persistent

There is a large body of evidence showing that recitation is one of the most common and persistent forms of class talk in American classrooms (Bellack, 1966; Goodlad, 1984; Hoetker & Ahlbrand, 1969; Lemke, 1990: Mehan, 1979; Tharp & Gallimore, 1988).

#### The Basic Element of Recitation is the IRE Pattern

Mehan (1979) explains that there are three parts of a triadic dialogue' that take place in the classroom. Within this structure, the teacher initiates a question or a topic of discussion. With that initiation, the teacher invites the students to respond. After a student responds, the students receive an evaluation from the teacher, during which the teacher can either accept or reject the student's response. The components together are called an IRE (initiate, respond, and evaluate). (Cazdan, 2001; Lemke, 1990; Mehan, 1979) When trying to engage students in discussions, it has been shown that many teachers tend to follow the traditional IRE pattern in which students recite answers to questions asked by the teacher. (Cazden, 2001; Lemke, 1990; Mehan, 1979)

**Recitation has Benefits**

Some researchers have noticed the benefits of an IRE pattern, since by using the IRE mode, teachers can act as the content gate keepers, and serve to correct student mistaken ideas (Newman et al., 1989). Winne (1979) found that using recitation is an effective way to increase student scores on certain achievement tests. Later, I will describe how Mortimer and Scott (2003) and Chin (2006) have advocated how recitation is useful for the review of previously learned material and, at times, for authoritatively developing the orthodox view of science.

**Recitation has Costs**

A larger number of researchers have criticized the use of recitation because of the negative ways its quiz show framework impacts student learning by encouraging the memorization of facts, while implying that this is the goal of learning. (Herrenkohl & Guerra, 1998; Lemke, 1990; Polman & Pea, 2001; Sprod, 1997). Tweney (1981) has suggested that known-answer questions can rigidify and freeze mental models so that conceptual change becomes more difficult for students. Lemke (1990) views the IRE pattern as an outgrowth of teacher power and an imbalance of participation, which reduces room for students to think independently.

## Diversifying Discussion Modes

My intent is not to determine whether recitation is inherently good or bad, but to establish that reliance only on recitation is common and limiting. By gaining a better understanding of what recitation is and what alternatives are available I hope to diversify the range of discussion modes open to me. By examining alternatives to recitation, I hope

to gain a better understanding of why recitation is so persistent, and thus, find ways to break my reliance on it and open my practice to more methods. Lewellyn (2002) uses the instructional pie as a visual metaphor (Figure 2-1) to prompt teachers to reflect upon and represent the diversity of their practice. This pie chart offers a way to represent the goal of opening up my practice to more diverse modes of discussion. Part of my goal in this review is to find tools for building a more diverse practice.

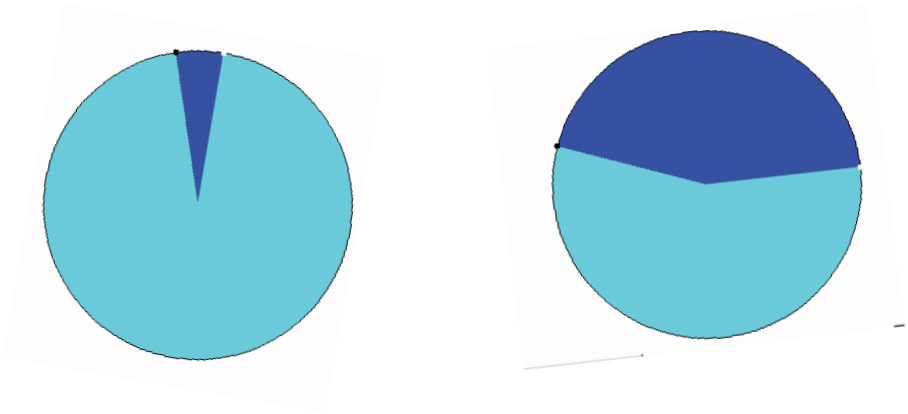


Figure 2-1
Visual Pie Metaphor for Diversity of Instructional Practice
(The dark area represents the percent of constructivist discussion modes used in class.)

## Features of Constructivist Discussion Modes

As stated in section one above, my basic goal is to explore how researchers have described constructivist and traditional modes of large group discussion. From this exploration, I hope to gain a theoretical vocabulary for describing issues involved with using student ideas to meet content goals. Therefore, in this main section, I will include a reaction to each major author concerning whether or not each addresses 1) how to use student ideas and 2) how to meet content goals. I do this in order to identify theoretical issues that might be applied in the classroom to meet these goals.

## First View: Recitation is a IRE Monoculture: True Discussion is Diverse

Dillon (1994) describes a conversation pattern that he calls true discussion and presents it as an alternative to recitation. Dillon summarizes findings from his work in a social studies classroom, and he exemplifies his distinctions using transcript evidence. He defines a discussion as a group interaction where members address a question of common concern and exchange and examine different views to form their answer. He carefully distinguishes true discussion from other forms of back-and-forth talk. He contrasts this mode to recitation, a form of interaction that he feels many teachers mistake for discussion. Dillon describes seven characteristics that delineate the differences between recitation and true discussion as follows:

### Typical Exchange

In recitation, the typical IRE exchange is nearly always played out: teacher-student-teacher. By contrast, this exchange pattern does not characterize true discussion, where one might hear a mix of statements and questions carried out by teachers and students. The difference here is not that one is the opposite of the other but rather that there is no characteristic pattern of exchange in a true discussion. In other words, there is a mix of moves by a mix of speakers. This difference in the types of exchange can help explain the next three differences.

### Predominate Speaker

In recitation, the teacher is the predominate speaker and speaks about two-thirds of the time or more, as contrasted to true discussion during which students speak about

half the time. This difference in talk time is due to the teacher speaking twice in an IRE exchange while only asking for a short answer or response from students.

**Predictable Sequence**

In recitation, the sequence of talk is almost always teacher, then student. In true discussion, one cannot predict the sequence of talk because it does not rigidly adhere to the IRE pattern.

**Overall Pace**

In recitation one hears many brief, fast exchanges (6-12/ minute), while in a true discussion, one hears fewer, longer, and slower exchanges. In the IRE pattern, the teacher speaks most of the time at a teacher defined pace and asks for short, quick answers from students.

**The Question**

In a recitation, Dillon argues, what is in question is not found in the content of the question itself. Rather, what is in question during recitation is whether the student can demonstrate knowledge of the answer. The teacher is gaining knowledge about whether the student has the correct answer. In a true discussion, however, the goal is not for the student to demonstrate his or her knowledge but rather for the student to gain or use knowledge. It is hard to tell what is intended by the question by looking at it in isolation. It is not until a student responds and a teacher gives feedback that the true intention of the question becomes known to a researcher. What can, on the surface, look like a question that is truly open, might, in fact, be intended as a call for some memorized idea, and often the student guesses this intention immediately based on past experiences in the class.

**The Answer**

The answer in recitation is pre-determined to be right or wrong for all students, while the answers in true discussions are indeterminate and must be resolved by the discussion. The difference is not that recitation only deals with fact and discussion only deals with opinions; the difference is that in a true discussion, students must discuss, not just recite, the answer. It makes no difference what the content of the question is: it can be higher order or lower, simple or complex, about fact or interpretation. What matters is only what type of answer is given and how the teacher responds.

**The Evaluation**

In recitation, one often only hears the teacher saying, "Right/wrong," in some way to students, whereas in a true discussion, one hears both the teacher and student say, "I agree/disagree," to each other. In recitation, the student never makes the evaluation and never disagrees with the teacher.

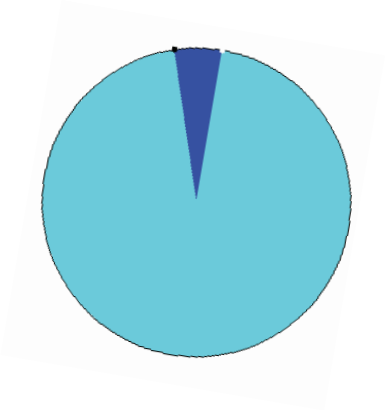
**Reactions to Dillon**

A key point from Dillon's comparison is that recitation is characterized by a predictable pattern of IRE exchanges and that true discussion is more diverse and relies on less evaluative and predictable exchanges. Dillon treats recitation and true discussion as mutually exclusive and dichotomous forms of large group discussion. This essential difference leads me to search for a metaphor that might help me to apply this idea. In one metaphor, class discussion is like an environment. Recitation is a monoculture of IREs and, thus, is like a field, seeded with only one kind of plant and bearing only one fruit. This metaphor suggests that by planting diverse alternatives to the IRE exchange, I might yield a crop of more diverse and interconnected student ideas. A simpler visual metaphor

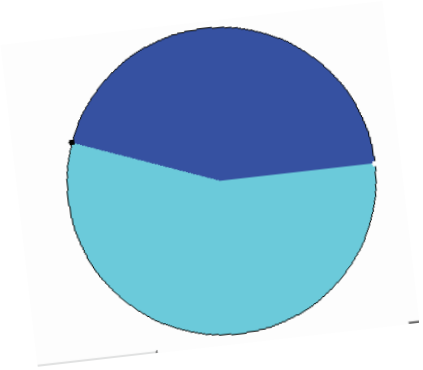
can be shown in a pie graph (Figure 2-2) where the IRE exchanges take up most of the space in class discussion (shown in the lighter color in Figure 2-2) and, thus, traditional recitation practice is closed to student ideas. As my repertoire of strategies for leading constructivist discussion modes expands, diverse types of non-IRE exchanges come to populate discussion, and the class opens up to more students' thinking.

Dillon does not share my content goals and, thus, offers no strategies for reaching them. When I pursue content goals, they are convergent and, thus, make it hard for me to adopt a goal of true discussion as described by Dillon. According to Dillon (1990), a true discussion cannot have a predetermined point of convergence. Dillon draws on Burbules (1993) in advocating that content coverage is often at cross purposes with true discussion because of the need for convergence. Content concerns impact the basic willingness of a teacher to have students discuss (Dillon, 1990). Dillon believes teachers need to possess a willingness to have true discussions in order to be successful leaders of discussions.

Though I agree that content concerns do often impact teacher willingness to discuss, I believe that discussion can converge on content goals. Perhaps this difference of belief is related to the differences between the disciplines of science and Dillon's field of social studies. Yet, natural and social scientists can limit themselves to questions that can converge on evidence based answers via a method of discussion (peer review), and this suggests that it might be possible to reach content goals using a constructivist discussion mode that considers student ideas.



A more traditional discussion mode



A more constructivist discussion mode.

Figure 2-2
Visual Metaphor for the Diversity of Discussion Practices
(The light area represents the percent of discussion that is devoted to IRE exchanges. The dark area represents the percent of discussion that is devoted to non-IRE exchanges)

**Listening Attentively to Student Ideas Generates Engagement**

Duckworth (1987) observed students becoming explainers when science teachers became listeners. Duckworth was a student and colleague of Piaget and an expert in the clinical interview methodology's use of exploring elementary students' thinking about science. She advocates the Piagetian belief that students have their own way of making sense, and she suggests that if a teacher does not understand the students "wrong answers," the teacher needs to probe or push for student meaning. She is a strong advocate for giving students a chance to explain and for giving teachers a chance to listen.

Duckworth's (1987) essays provide a narrative account explaining how these ideas enacted in elementary school classrooms, but she does not offer specific teacher moves or strategies for how to use divergent student ideas to meet content goals. She suggests that an open question style, linked with a non-evaluative, respectful listening, and a "pushing to see where thinking goes" ( p xx) approach brings students in direct

contact with the subject matter and not just in contact with someone else's words about the subject matter. She claims that getting students to explain their beliefs while the teacher expresses genuine interest generates a variety of positive benefits: student curiosity about the topic; motivation to explain; extended engagement in the process of their explaining; and student realization of the power of one's own mind.

**Reactions to Duckworth**

Large group discussion opens up to more student ideas when teachers use an open questioning style linked with non-evaluative listening. However, Duckworth does not describe how to use this approach to enable the students to converge on content goals. These essays provide a clear picture as to how an open science discussion might encourage students to be expressive and predictive. Duckworth provides a convincing case that this approach would generate student engagement in the process of explaining. She does not apply an IRE framework to analyze these student teacher exchanges, and later in the review I will discuss such a framework. Though students were able to put the science into their own words, she does not provide strategies for how to use their words to reach content goals.

## Conceptual Change Theory Suggests that Content Goals can be Achieved by Understanding Student Preconceptions

Content goals are addressed by conceptual change theory. Confrey (1990), in her review of conceptual change literature, describes how conceptual change requires teachers to know and take account of student preconceptions in their instruction. Students enter instruction with firmly held beliefs and explanations, and these belief systems are often resistant to change through traditional instruction. These alternative belief systems

can sometimes support or frustrate curriculum goals, depending on how compatible they are with curricula's content goals.

A key component in conceptual change is learning about students' firmly held beliefs, as opposed to learning what students have memorized and recited for an evaluation. Comfrey states that these beliefs are best identified through methods that encourage children to be expressive and predictive.

**Reactions to Confrey**

By fostering discussion modes that allow students to be expressive and predictive, one can learn more about their preconceptions. Whereas Dillon (1994) and Duckworth (1987) focus on engagement and motivation as the main reason for opening up discussion in the classroom, Confrey provides a second, cognitive reason. The more one knows about the source and strength of student naïve conceptions, the more hope one has of changing these conceptions.

## Using Non-evaluative Follow-up Moves Can Reveal More Student Ideas

Nassaji and Wells (2000) found positive effects of replacing an evaluative move, the IRE pattern, with the flexible and non-evaluative follow-up (F) move. Nassaji and Wells analyze transcript evidence from 44 grades 1 through 8 teachers who used science and literature activities to meet inquiry goals. Teachers often move through their agenda by interacting with their students and asking questions (I) that demand a response (R) from students. Nassaji and Wells found that a more flexible use of the third move as follow-up (F) vs. evaluation (E) allows a more flexible and extended discussion pattern to develop. This more extended and equal pattern of exchange created by using IRFs leaves

more room for student thinking, which in turn increases student participation and the length of their substantive responses.

The authors suggest an explanation for this finding by exploring a theory of why IRE exchanges result in unequal teacher–student participation. The reason that IRE exchanges cause an unequal behavior between teachers and students can be understood by looking at the knower role assigned to participants according to their role in the IRE exchange. Nassaji and Wells (2000) use the primary knower and secondary knower framework developed by Barry (1971) to explore how the IRE pattern of recitation functions in school conversations. For Barry, there are two critical features in an exchange: 1) who initiates the question and 2) who is the primary knower of the information at issue?

In school conversations, an IRE pattern of interactions is established when the teacher is 1) the primary knower of the information at issue in the discussion and 2) she initiates the question. By initiating a question as a primary knower, the teacher forces the student into the position of secondary knower. In short, the student is asked a question by someone who already knows the answer, and the student has come to expect that the reason for this is evaluative.

The IRE pattern found in recitation differs from everyday conversation. In everyday conversation, the person who asks a question is typically the person who needs information that they do not have and is, thus, the secondary knower (K2). For example, a person in a train station would be a secondary knower if he needed to ask a primary knower when the next train comes in. In everyday conversation, a question is initiated by a K2 because he needs the information. In everyday conversation, the person asking the

question is not expected to evaluate the answer he receives. He might simply acknowledge or thank the person for the information that he is given. It would be viewed as odd if the person seeking information evaluated the person giving him the train information, instead of simply thanking the informant.

In school conversations, not evaluating a student answer breaks well established patterns of talk. When science teachers initiate domain specific questions, students often expect that the teacher is in the K1 role and that student responses will be evaluated based on its correspondence to the teachers "correct" understandings. It is challenging to move away from an IRE pattern because of this expectation. Most questions asked by the teacher as K1 are to find out what students know and evaluate and correct student ideas. If the teacher does not confirm or reject the student response in the teacher's follow-up move, the IRE exchange does not feel complete. The participants will often elicit further exchanges, or dependent exchanges, until the initial or nuclear exchange is evaluated and deemed complete.

This evaluative expectation of the question-answer exchange can be changed. Nassaji and Wells (2000) believe that since the teachers in this study are pursuing inquiry goals, they do not follow strict IRE patterns. Nassaji and Wells found that many teachers do use a wide range of non-evaluative follow-up moves. Those teachers who do this are able to move away from a rigid IRE discussion pattern and are able to create a more extended IRFRF pattern (Intitiation-Response-Follow-up-Response-Follow-up). One of the ways the teachers do this is by positioning the student as the primary knower. The IRFRF pattern occurs when what is at issue is what the student thinks, not whether student thinking is correct or not.

The student is the primary knower of his preconceptions, and the teacher is the secondary knower. Viewing the relationship in this way makes it more closely mirror the knower relationships found in everyday conversations. In this relationship, teachers are able to move away from offering an evaluation and can try more diverse and elaborative follow-up moves. By casting the students into the position of primary knower, the teacher can choose follow-up moves that prompt students to express and elaborate what they know. Nassaji and Wells (2000) found that using non-evaluative follow-up moves created more equal modes of participation and a more exploratory environment.

The authors develop a taxonomy which categorized follow-up moves into two basic types: Give (= statements) or Demand (= questions). Give follow-up moves serve to evaluate or restate for the whole class (amplify) the answers offered by students. A Give follow-up move can be evaluative, but Nassaji and Wells (2000) found that when it is evaluative, discussion and student responses are shorter. Demand follow-up moves function like questions and ask for student suggestions or justification (Why do you agree?). The researchers found that most non-evaluative follow-up moves functioned to extend the discussion and elicited more substantive students thinking.

The teachers Nassaji and Wells (2000) studied created an IRFRF pattern by changing the types of questions they asked. Nassaji and Wells acknowledged that teachers have the responsibility for managing the work of the class and following the agenda and, thus, often control and determine the initiation moves by asking the questions. In a study of a group of teachers who had inquiry goals, they found that teachers used a more flexible triadic structure IRF by tending to ask questions about issues open to negotiation. In the initiation move, teachers with inquiry goals asked

questions about issues that did not have known answers. Nassaji and Wells felt that known information questions limits or restricts a student's opportunity to try out his own ideas. The goal of getting a student to "try out answers" replaces the goal of seeing if a student can "remember the right answer" to a known question.

Nassaji and Wells (2000) found that the follow-up move was even more predictive of student contributions than the type of question. They found that when teachers give evaluative moves, these sorts of moves tend to shorten discussion and suppress extended student participation. Conversely, even known information questions develop into more equal dialogues if in the follow-up moves, the teacher avoids evaluation and instead requests justification, connections, or counter arguments. Nassaji and Wells found that the characteristic of the third move has the most impact on extending discussion and increasing participation. The question is important, but it is the nature of the follow-up move that determines if students continue thinking or not.

**Reactions to Nessaji and Wells**

Taking a secondary knower position as the teacher might reorient my question asking intuitions, away from evaluation, and towards understanding student ideas. I find the primary/secondary knower framework useful in understanding Duckworth (1987) and how I might ask better questions. The use of a linguistic framework helps me to link Duckworth's observations to specific modifications of the IRE pattern found in recitations. Using this knower- lens, I view her as describing what happens when teachers take a secondary knower position. When teachers ask questions from a position of curiosity about what students know or think and are not concerned with immediate evaluation, students respond with greater substantive contributions, and classroom

discussion is opened up to more student thinking. When Duckworth talks about the power of genuine interest to open up class discussion, I see this genuine interest as a description of the secondary knower position. Both Nassiji and Wells (2000) and Duckworth found that when teachers allow students to be the primary knower of student ideas and treat these ideas as something we, the teachers, do not know but want to understand, then teachers can create discussion patterns that differ from recitation.

Replacing the evaluation move with a follow-up move can create IRFRF sequences in which students offer more substantive answers. That the follow-up move has more effect than the question (or "I" move), suggests teachers wishing to change discussion patterns can get some movement away from recitation just by focusing on diversifying their F moves. Teachers do not have to change immediately both the "I" and the "F" moves in order to move away from recitation. Categorizing follow-up moves as Gives or Demands may be simple enough to be useful during moment to moment decision making during whole class discussions.

The triadic dialogue is a flexible discursive tool that can serve elaborative and evaluative goals, but Nassaji and Wells (2000) do not offer higher level strategies for using this triadic dialogue for reaching content goals. Though they seem to favor the IRF, Nassaji and Wells suggest that IRF/E exchanges are not intrinsically bad or good. This suggests that it is more productive to ask what purposes these exchanges can be used for in a particular lesson. However, Nassaji and Wells do not discuss strategies for how to meet general or specific content goals.

## Using Silence Can Increase Student Participation

Tobin (1987), in a classic process product study, showed that the use of an average teacher wait time of between 3 and 5 seconds in whole class instructional settings is associated with a number of positive effects. When the average teacher wait time of 3 to 5 seconds is maintained, the quality of teacher and student discourse is improved and student achievement is enhanced. He suggests that the longer pauses between speakers are used for cognitive processing. Teachers tend to probe for additional student discussion rather than repeating or evaluating student responses. Consequently, the average length of student utterances tends to increase in extended wait time classes

### Reactions to Tobin

Tobin's work on wait time underlines the fact that even subtle teacher moves can have significant impacts on opening up the patterns of discourse. Tobin does not discuss how to meet general or specific content goals.

## Different Research Paradigms Ask Different Questions

A sociolinguistic perspective offers fine grained analysis of some of the complexity in discussion and offers insights into how simple teacher moves, like silence, might have large effects. In his review of research on questioning, Carlsen (1991) compares sociolinguistic research and process/ product research and explores how these paradigms view three characteristics of questioning: response, context, and content.

### Student Responses

The process/product research on questioning tries to account for student outcomes as a function of a teacher's discrete and independent verbal behaviors. For example,

when exploring how students respond to questions, they might look at how average teacher wait time affects long term goals of student achievement on psychometric measures of large samples of students. On the other hand, sociolinguistic research sees questioning as dependent on a dynamic context that is mutually generated by teachers and students during the conversation. When exploring how students responded to questions, research from a sociolinguistic perspective might focus on shorter term linguistic outcomes and offer more detailed, finer grain observations based on transcript evidence of small sample sizes. For example, they might examine if the longer student responses prompted by longer teacher wait times might be caused by the less inquisitorial context or participant structure generated by the slower pace of questioning. Or they might ask why many teachers still don't use this well published technique, even if they know about the positive effects of increased wait time. What other concerns, such as control or attention, are served by having a fast paced class with little wait time?

**Question Context**

The context of the questioning in the process/product paradigm is treated as the static situation the speaker is in, as identified by measures such as socio-economic status and age of the participants. In the sociolinguistic paradigm, context is a more complex and dynamic situation that can be modified by all the speakers, and it includes a description of the speakers' relationships, the rules or routines which govern how they speak, and how the rules are modified. For example, sociolinguists might explore how rules determine who has the right to ask questions or to change the topic.

## Question Content

The content of questions is its inherent topic and cognitive level in the process/product paradigm, while the sociolinguistic paradigm sees the level and topic as jointly constructed by all participants. Sociolinguists might ask how prior knowledge of participants affect the questions' level, and how participants understand the topic of the question.

## Reactions to Carlsen

The interest of sociolinguistics in the dynamic interdependence of language and situation can lead to a detailed analysis of the complexity of classroom talk. This paradigm does not appear to use their fine grained method of analysis to answer questions about how to reaching content goals. This sort of analysis, while clearly revealing complex aspects of class discussion, does not offer higher level strategies for lesson planning or moment-to-moment decision making during class discussion that is focused on content goals. However, the contrasts described by Carlsen (1991) exemplify how a research paradigm can broaden the scope of questions asked about class discussions, and how a research paradigm can affect the methodology chosen to answer these.

The sociolinguistic perspective does offer an important inference related to hearing student ideas. For sociolinguists, class routines that influence student participation are dynamic and mutually constructed by the actions and perceptions of both teachers and students. Though affected by their history, new routines can be established each time a conversation happens in the classroom, and thus participant structures are not static, but flexible, and can be modified through the use of particular IRF exchanges to serve the goal of hearing more student ideas.

## Using Certain Questions as a Follow-Up Move Can Help Extend Student Thinking

In a detailed case study of a high school physics class, van Zee and Minstrell (1997a) describe a specific follow-up move, called a reflective toss, and how it promotes reflective discourse. They define reflective discourse (1997b) as classroom discussions in which three conditions are frequently met: 1) Students express their thoughts and questions, 2) teachers and students engage in extended questioning exchanges in which students explain their beliefs and concepts, and 3) student-student exchanges occur in which one student tries to understand the thinking of another student.

To promote this kind of discussion, van Zee and Minstrell (1997a) used a question as a follow-up move, the reflective toss, which consists of a three-part structure: a student statement (often an answer to a prior question); a teacher question as follow-up; and additional student statements. The toss metaphor suggests a teacher catching the meaning of the student's answer and throwing responsibility for thinking back to the student and all those present in class.

The authors propose that this follow-up question may help teachers shift toward reflective discussion modes that help students to clarify their meanings, consider various points of view, and monitor their own thinking. van Zee and Minstrell (1997a) discuss other follow-up moves associated with reflective discourse, included restating student answers in a neutral manner and invoking long wait times and silence to foster student thinking. They argue that these techniques help teachers shift from traditional evaluative discourse, which judges student performance, to reflective discourse, which engages more student thinking and negotiations. van Zee and Minstrell developed a visual representation of this move and wonder if other visual and verbal metaphors might be

helpful to teachers as they attempt to adopt new practices that foster more reflective discourse.

**Reactions to van Zee and Minstrell**

The reflective toss is shown to function as a tool to extend student thinking. The use of the reflective toss is said to affect the content goal agenda of the teacher, but no higher level strategies are offered for making this agenda. By focusing on the work of an exemplary science teacher, van Zee and Minstrell (1997a) show how the reflective toss can foster reflective discourse in which students share their ideas and explain their beliefs in a whole class discussion. Verbal metaphors for catching and throwing seem to make these follow-up moves more accessible during discussion. It is said that the teacher is then able to use these student ideas to plan future lessons and more effectively reach content goals. However, I wish the researchers had said more about this process, since no higher level strategy is offered to explain how to set the agenda or select student ideas for further discussion.

## Using Comment-Questions Couplets Can Act as Elaborative Follow-up Moves

Chin (2006) develops a question-based discourse analytical framework that she uses to identify types of evaluative and elaborative feedback moves. Chin develops this framework by examining transcript evidence from two grade 7 science classes with a class size of 40 students in Singapore. By focusing the analysis on interaction involving questions, Chin is able to identify four different types of feedback moves; two feedback moves are explicitly evaluative and two are elaborative. She describes two follow-up moves which are explicitly evaluative and does not encourage extended student

responses. The evaluation cum direct instruction follow-up move affirms a student's correct answer and the explicit correction and direct instruction follow-up move evaluates and corrects the student's mistake. Neither of these moves asks for more student response, and instead both are followed by more direct instruction from the teacher. These moves sound like recitation, although Chin does not use this term. Instead, she postulates conditions in which these moves might be used, namely when introducing new scientific vocabulary, addressing concepts which are too hard for students to reason about, working under strict time constraints, or simply to match teacher skills and style preferences. She found that teacher talk following each of these moves is often authoritative and has a transmissive function, since the teacher responses consisted of statements containing content-related propositions.

Chin (2006) found that teachers can promote productive talking at levels above recall if they avoided explicit evaluation of student answers and instead use elaborative follow-up moves that pair non-evaluative comments (C) with questions (Q) that ask students to build on their previous responses.

She describes two follow-up moves that do this: focusing and zooming and constructive challenge. Focusing and zooming consists of a neutral follow-up comment to a correct or incorrect student answer and is then paired with questions which alternate between "big broad questions" and more "focused, narrow, subordinate" questions. The other follow-up move, constructive challenge, consists of a neutral follow-up comment to incorrect or incomplete student answers, paired with a question which throws responsibility for thinking back to the student, like a reflective toss. This comment-

question (C-Q) couplet cues the student to draw on her own conceptual resources to self-evaluate her own thinking, and invites other students to do so as well.

Each part of this C-Q couplet has characteristic features that help to facilitate extended student thinking. A characteristic feature of the teacher comment is that it is neutral or "covert in nature" in terms of evaluation, but it often serves to consolidate or reinforce correct ideas by restating, paraphrasing, or revoicing student answers in a manner which provides conceptual and linguistic scaffolds to those who might have difficulties verbalizing their ideas.

A characteristic feature of the question in the C-Q couplet is that it builds upon previous student contributions and uses them to make progress toward joint construction of the concepts under consideration. The question part of the couplet overlaps with the initiation or "I" move of the next IRF sequence, resulting in exchanges that are of the IRFRF pattern or of an IDRF type, where students discusses (D) questions in small groups before responding.

The questions in this couplet seems to have two intentions: 1) to draw out by probing and asking students to extend the conceptual line of thought or 2) to cue/provoke by challenging students to clarify or evaluate their answers. Chin (2006) uses the Structure of the Observed Learning Outcomes (SOLO) taxonomy (Biggs, 1983) to give an example of how questions can be used to nudge students along a continuum of answers types, from a pre-structural response (little understanding), to a uni-structural response (one concept in a complex case), to multi-structural response (several discrete unrelated concepts), to relational responses ( integration of multiple concepts), to extended abstract (application of concepts to domains beyond taught areas).

**Reactions to Chin**

Chin's (2006) elaborative follow-up move (the C-Q couplet) can nudge student responses to higher levels of cognitive complexity and, thus, is a useful discursive tool for extended student thinking. However, she does not offer any agenda setting strategies for using this extended thinking to reach content goals. It is difficult to reach content goals using the diverse and cognitively complex "right" and "wrong" answers that are generated using elaborative follow-up moves. Chin acknowledges this problem by discussing Morge's (2005) work on the challenges of constructivist management in the conclusion phase of inquiry projects. In the conclusion phase of inquiry projects, teachers have to make a decision on whether to accept student productions (answers) in response to a given task (question). Morge suggests that teachers avoid authoritative or evaluative responses and instead give control of the evaluation of student productions over to students, since this stance is both epistemologically and pedagogically consistent with the view that scientific knowledge is socially constructed. This suggests that students should be asked to evaluate other student ideas to further meet process goals, not content goals. Chin argues that asking students to evaluate other student ideas could further the process goals of 1) encouraging learners to use their own resources for self-correction and 2) improving a student's ability to self-monitor her thinking.

If prompting students to evaluate other students' ideas results in productive movement toward content goals, then the teacher might not need to take on the role of evaluator throughout the discussion. But students may need help with this evaluative task, or teachers might not have the time or skill needed to lead student centered discussion with only non-evaluative feedback moves. In order to reach to content goals, the

evaluative follow-up moves will likely be needed to provide the corrective intervention needed to meet content goals. However, Chin (2006) does not offer an explicit strategy for how to use these evaluative moves to reach content goals.

A key inference from Chin (2006) is that teachers should become "enablers of talk for thinking" (p xx) by using more elaborative C-Q follow-up moves, but there are times when more evaluative follow-up moves will be needed to construct concepts that students cannot successfully reason through, using only their own resources. Chin suggests that the work of Mortimer and Scott (2003) provides a framework for orchestrating this mix of evaluative and elaborative follow-up moves.

## Use of the Flow of Discourse to Diversify Discussion Modes

Mortimer and Scott (2003) offer a framework, called the communicative approach, which describes authoritative and dialogic dimensions of large group discussion. This framework provides a multidimensional perspective on traditional and constructive discussions. This framework was developed over a number of years through a series of detailed case studies of high school science lessons in Brazil and England, in which difficult science concepts were taught. The first dimension evolved from (and perhaps morphed significantly from) a construct discussed by Bakhtin (1981) and Wertsch (1991), which differentiates between authoritative and dialogic discourse. For my analysis in subsequent chapters, I will be using the concepts of authoritative and dialogic communicative approaches as defined by Mortimer and Scott (2003). It is important to note that while their work builds on concepts of authoritative/dialogic discourse developed by Bakhtin, these concepts have been significantly adapted, modified, and limited for the particular and pragmatic purpose of understanding and

encouraging different forms of student and teacher talk in secondary science classrooms. In particular, Scott's use of the phrase authoritative approach does not have the same meaning as Bakhtin's use of the phrase authoritative discourse. I will use the terms dialogic and authoritative communicative approaches to refer to their specific reinterpretation and use of Bakhtin's construct of dialogic and authoritative discourses.

The goal for Mortimer and Scott (2003) is not to resolve systemic teacher-student power differences or to characterize the nature of scientific knowledge in general but, instead, to develop a pragmatic communicative framework that encourages secondary science teachers to make room in student-teacher talk for the consideration of non-school science points of view, such as students' internally persuasive stories. They end up advocating that teachers with content goals should use both authoritative and dialogic approaches. In their work, they characterize an authoritative communicative approach as a focus on only one point of view. In secondary science classrooms with content goals, this one point of view is often the school science point of view or the currently accepted science concept or model. This use of the term authoritative to refer to the school science point of view does not, for Mortimer and Scott, imply that scientific knowledge in general is a dead discourse. Rather it is a pragmatic characterization that recognizes the responsibility practicing teachers often have for helping students come to shared understandings of particular and well defined science concepts. These concepts can change over time as scientific understanding evolves, but for the purposes and time scale of teaching with content goals, the conceptual goal of lessons are usually well defined and relatively fixed targets.

For Mortimer and Scott (2003), the authoritative communicative approach focuses on this single formal school science view perspective, while dialogic modes of discussion are open to considering different student points of view. In an authoritative communicative approach, the teacher is the gatekeeper of points of view, strictly follows a predetermined agenda, and maintains clear content boundaries. In a dialogic communicative approach, the teacher seeks greater symmetry in teacher-student interactions, and permits a flexible and potentially divergent agenda, which allows discussion to move outside of strict content boundaries, to invite and explore student ideas, even if these ideas do not help the development of the school science story. In the authoritative communicative approach, the teacher is the clear authority and uses this role to ignore, reject, or reshape student ideas that do not help the school science story. While using the dialogic communicative approach, the teacher intervenes only to seek clarification and elaboration of student responses. For Mortimer and Scott, this dialogic communicative approach does not suggest that teacher is no longer the authority, that she gives up her responsibility for setting the agenda, or that she no longer keeps the learning goals in mind. The purpose of the dialogic communicative approach is to encourage students to articulate their understanding, even if it diverges from the target concept. The authors believe that by articulating their understanding, students are able to compare and check it against the school science point of view. A dialogic communicative approach encourages student initiations, permits personal views, and asks students to listen, make sense of, and build on the ideas of others. An authoritative communicative approach asks students to converge on the target concept and be able to express that understanding using school science language.

The authors add a second dimension to this framework and differentiate between the interactive and non-interactive. The essential question here is if the teacher is interacting with students (interactive) or simply presenting material (non-interactive). Adding this dimension to the framework, teacher-student talk can be categorized along each of two dimensions, interactive-non-interactive and authoritative-dialogic, creating the four different classes shown below:

Table 2-1
Four Classes of the Communicative Approach (Mortimer & Scott, 2002, p. 35)

| | INTERACTIVE:<br>Teacher-Student exchange | NON-INTERACTION:<br>Teacher talks |
|---|---|---|
| DIALOGIC<br>considers multiple perspectives | Interactive/Dialogic<br>The teacher and student discuss the student point of view. | Non-interactive/Dialogic<br>The teacher describes or elaborates on the student point of view. |
| AUTHORITATIVE<br>considers only the orthodox science perspective | Interactive/Authoritative<br>Recitation or "fishing" for the answer. | Non-interactive/Authoritative:<br>The teacher lectures |

Attempts to map directly authoritative/dialogic dichotomies to traditional/constructive are complicated by these multiple dimensions. The essence of this framework is brought into clearer view by looking at the top row. In the interactive-dialogic communicative approach, the teachers discuss student-generated ideas; and in the non-interactive-dialogic, the teacher might be summarizing or reviewing different students' points of view. Notice that in this framework, a discussion can be considered dialogic even if no student talks. Student-teacher talk is interactive but not necessarily dialogic, unless the exchange is open to and considers multiple points of view. Thus, a discussion is not dialogic if the teacher ignores or reshapes non-conforming student ideas,

and the teacher only picks up and uses only those student ideas that help the development of the school science story.

The bottom row of Table 2-1 raises other essential elements of this framework. In a non-interactive/authoritative discussion, the teacher presents a specific point of view as in a lecture. In an interactive/authoritative (I/A) discussion, the teacher focuses on the school science point of view and leads students through a question and answer routine, with the aim of establishing and checking students' understanding of that point of view. This I/A discussion appears more consistent with other definitions of recitation: it marches toward a set end point, as teachers are only paying attention to the ideas that contribute to the development of the school science story.

### Managing the Flow of Discourse?

Mortimer and Scott (2003) argue that a teacher can use these forms of discussion to move toward the accepted scientific point of view. Scott describes a flow of discourse pattern, which he found in a case study of a Brazilian HS science class that focuses on content learning. In this study, he tracks the movement between authoritative and dialogic communicative approaches and found that lessons with goals of meaningful understanding of scientific concepts contain both authoritative and dialogic interactions.

The authoritative and dialogic dimensions are not seen as a dichotomy in which the whole is split into exactly two non-overlapping parts. Instead, Mortimer and Scott (2003) see a dynamic tensioned linkage between authoritative and dialogic, such that one approach gives rise to the other in support of concept learning. This linkage results in the flow of teacher student talk from dialogic to authoritative back to dialogic. The dialogic exploration of student ideas creates a tension that is resolved by the authoritative

guidance of the teacher. When the teacher encourages dialogic discourse to probe student everyday views, she found they are not consistent with the scientific view. Since this lesson has content goals, this creates a tension that is resolved by the teacher adopting an authoritative communicative approach to introduce the scientific point of view.

Since presenting the authoritative view is often not enough for meaningful learning to take place, the authoritative account of the scientific view demands a dialogic exploration by the students. So the teacher uses a dialogic communicative approach to encourage students to explore newly learned ideas through talk. In the dialogic mode, students are given a chance to play with the authoritative language of the scientific viewpoint and to try out constructions that are new to them. The communicative approach shifts throughout a sequence of lessons, as one communicative approach follows the other: authoritativeness generates the need for dialogicity and vice versa. The teacher uses this flow of discourse to balance the tension between developing student ideas via a dialogic approach, and developing the accepted scientific point of view via an authoritative approach. Both the authoritative and dialogic communicative approach help teachers guide the meaning-making interactions in the class, and prompt the evolution of student views from everyday to scientific.

**Why Use This Approach?**

Mortimer and Scott (2003) argue that by juxtaposing students' everyday views next to the accepted scientific concept, it helps students see how these two kinds of ideas fit together. Scott (2006) argues that this juxtaposing supports meaningful learning, because it helps students make connections between everyday and scientific views. However, this article does not present any evidence that shifts in communicative

approach can have a positive effect on measurements of student learning of science concepts.

Scott believes that the use of the interactive dialogic approach leads to productive disciplinary engagement (Engle & Conant, 2002), because it leads many students to express a passionate involvement and make substantive contributions that are related to other student ideas. In addition, he found that students re-engage and continue to be engaged over long periods of time. He points to evidence of productive disciplinary engagement in transcripts that show a significant portion of class to be involved and responding with answers of increasing length and conceptual complexity. He believes that a dialogic approach is potentially motivating because it legitimizes student ideas and ways of thinking.

## Why are Dialogic Interactions Rare?

In their extensive work with teachers, the authors notice that dialogic interaction in classrooms "is universally rare" (Scott & Mortimer, 2005, p. 622) and they wonder why so few teachers practice a dialogic approach. They suggest an answer to this question by pointing to a number of challenges facing teachers as they attempt to adopt a dialogic approach.

### Dialogic Teaching Might Not Conform to Teachers' Fundamental View of Teaching and Learning

The authors have found that if teachers hold a transmissionist or conduit metaphor of teaching, and see their job as presenting an accurate account of the science story, the teachers see no logical reason to engage in dialogic teaching.

### Teachers Often Confuse Interactive Authoritative Discourse with Dialogic Discourse

Teaches may engage in lots of interaction and turn-taking but focus only on a scientific view and ignore or evaluate the contributions that are not consistent with a scientific view. They do not know how to engage students in dialogic interactions. It is a challenge for teachers to avoid making evaluation moves, since there are many non-verbal clues that can reveal an evaluative intention: kinesthetic shifts (related to body movements); proxemic shifts (related to interpersonal distances between speakers); and prosodic shifts (changes in voice, intonation and pitch).

### Teachers Need to Know When it is Advisable to Spend Time Listening to What Students Have to Say

The authors suggest that teachers need to be able to gauge the learning demand of the concept to determine if a dialogic approach is warranted. The authors define learning demand as a measure of the conceptual gap or degree of difference between student everyday and scientific content being taught. For example, the concept of speed would have a smaller learning demand as compared to pressure, because students' everyday view of speed is close to the scientific view of speed, while the everyday view of pressure might involve more misconceptions and thus be farther from the scientific view. Discussions about a topic with a small learning demand will involve little or no dialogic interaction. Teaching experience and knowledge of student everyday views will help teachers make this judgment.

**Teachers Need to Know How to Manage the Agenda**

The authors see teachers as primarily responsible for orchestrating class discussion and managing the flow of discourse to reach content goals. However the agenda they create for dialogic teaching must be flexible enough to be responsive to student ideas, interests, and concerns. This kind of flexible agenda setting is a challenge, because it calls on knowledge that a teacher who only practices authoritative discourse might not have. Venturing into dialogic discourse is assisted if teachers have insights about the everyday ideas that students are likely to bring up in a lesson. This knowledge will help teachers with the critical task of constructing a response to those everyday ideas that function to move students along to more scientific ways of thinking. Perhaps the largest challenge of this reconstruction of student views is that it is "a spontaneous and situated process which is carried out on the edge of teaching and learning." (Roth, 2005, p. 158) It takes a high level of expertise to be able to see the everyday view in the diverse mix of student responses, articulate the view, and then develop an activity to challenge this everyday view and make the scientific account more intelligible, plausible, and fruitful (Posner & Strike, 1982).

## Reactions to Mortimer and Scott

This study resonates with a number of aspects of my evolving practice that I explored in my case study (Price, 2007). One key point of resonance is that the authors are not advocating a switch to an inquiry-based learning environment or a pursuit of only process goals, even though these contexts might be more naturally open to a dialogic approach. Instead, the authors are attempting to develop tools that will help make conventional forms of practice more visible and then widen these discussion practices to

include dialogic teaching. Their purpose in developing dialogic teaching is to advance content goals and meaningful conceptual learning by using the social plane of class discussion to help students evolve their everyday views into scientific views.

Another point of resonance is that this communicative framework begins to capture and address the questions about how to manage class discussion both on a larger theoretical level and on a smaller pragmatic or practical level. Broadly setting the agenda toward dialogic or authoritative goals might help steer lesson planning and the moment to moment decision making during class discussion. Scott and Mortimer's (2005) study attempts to use the theoretical description of dialogic teaching to examine (1) what knowledge is needed to make it possible for teachers to navigate the realities of practicing this theoretical approach? (2) What knowledge is needed for teachers to able to see the everyday views in the diverse mix of student responses acquired through a dialogic approach? (3) How can teachers articulate and draw attention to these student views, and then develop an activity to challenge student views and make the scientific account more intelligible, plausible, and fruitful?

The study also leaves me with questions about how the authoritative and dialogic categories function during agenda setting. What if a discussion elicits student generated ideas and reasoning that are both personally persuasive and contribute to the science story? This could be an indication that the learning demand is small, because the everyday idea is close to the scientific idea; or it could indicate that teacher questions are pitched so that students are kept in a zone where they can successfully reason. Would the authors still consider this to be dialogic? The authors state the need to have a flexible

agenda, but they do not say much about how the agenda is set or how this agenda setting meshes with the activity chosen to challenge the everyday views of students.

### Use of Models to Set the Agenda and Guide the Generation of Ideas to Meet Content Goals

Clement (2008) has developed a model based approach, called co-construction, that suggests agenda setting strategies for leading whole class discussions to reach content goals using student ideas. Clement's description of co-construction is based on an analysis of an innovative biology curriculum (Rea-Ramirez et al., 2004), which he co-authored, that was designed to support teachers to lead whole class discussions that co-construct content goals, using ideas from both the teacher and especially from the student. He argues that co-construction can address both content and student inquiry goals by using large group discussion to feed a process of model construction and evolution. He places this method at a point in between pure discovery learning and lecture.

A co-construction approach focuses on a model based content goal. Using a mental modeling framework, Clement (2008) describes a specific kind of content goal, a target model. A target model is a description of the desired knowledge state that we want students to attain after instruction. The target model is a simplified, grade level appropriate form of an expert model that embeds dynamic, cause and effect relationships between parts of the model, or model elements. For students, this target model is often a schematic drawing of structures, or model elements, combined with dynamic explanations of functions which they can use to reason about cause and effect relationships. The imagistic target model embeds cause and effect relationships. To

achieve this content goal requires that students attain a relational understanding of structure and function, such that the model is dynamic and "run-able" like a mental movie. These dynamic and relational features make a target model useful for reasoning about cause and effect relationships.

This co-construction approach views learning as model evolution. The goal of co-construction is the gradual process of transformation of student models. Student prior knowledge, or preconceptions, are not viewed automatically as ideas to be removed at once, but instead, these preconceptions are viewed as initial student models that are slowly modified, element by element, through the course of discussion. This piecewise revision and modification of models is called model evolution. The goal of co-construction is to use both student and teacher ideas to foster model evolution and eventually to bring student models into agreement with the target model.

The goals of co-construction approach are clarified by splitting two dimensions of large group discussion which are often conflated: idea generation and agenda control . To identify these dimensions, Clement (2008) asks two questions of a class discussion. 1) Who generates and evaluates the ideas? 2) Who directs the activity? The first question relates to who is contributing ideas to the discussion, and who is evaluating these ideas. The intention in the curriculum, which he describes in this article, is to have as many student-generated ideas as possible, given the constraints of time for each topic. This turned out to be a discussion that encourages students to generate about 60% of the ideas. This 60% goal underlines the belief that both teacher and student ideas are used to reach content goals. The student's role is to do a majority of the idea generation and evaluation, and the teacher's role is to contribute ideas strategically in ways which scaffold student

thinking. The second question relates to agenda: Who is planning the sequence of topics and directing attention to particular activities? The intention in the curriculum was for discussion to follow a teacher directed agenda about 85% of the time. Thus, the intent was for the ideas to be 60% student generated in their initial form, but for the agenda to be largely teacher directed.

Reaching a target model using co-construction involves strategic agenda setting. Clement offers some specific suggestions for how teachers can set agendas for lessons which aim to foster co-construction.

**Keep the Discussion in the Reasoning Zone**

To keep students engaged in model construction, the discussion has to be pitched so that students can reason about the questions at issue. By correctly pitching the discussion, students are kept in what Clement (2008) calls a reasoning zone. This idea is drawn from Vygotsky's (1986) notion of a zone of proximal development. Co-construction scaffolds student thinking and makes model based questions tractable for student reasoning. It also requires teachers to check in with their class to make sure students are following along. The curriculum offers support for teachers to help them decide which models can be co-constructed in discussion, and which should be introduced by the teacher.

**Ask for Model Prior to Instruction**

The co-construction approach begins by drawing out student ideas. Large group discussion starts with a modeling question, which prompts students, before instruction, to invent and draw models and explain the model's function. These student ideas are taken

seriously. They are identified as initial models and displayed so that they can act as the starting points for further discussions.

**Break Student Ideas Down into Correct and Incorrect Model Elements**

Co-construction discussions can generate a complex mix of student ideas that are a challenge for teachers to use productively in discussion. If students accept the invitation to contribute ideas, their responses often result in a complex collection of correct, partially correct, and incorrect ideas. Using this diverse mix of correct and incorrect ideas to reach content goals is a knotty problem for teachers. To manage this complexity, Clement suggests that teachers first identify (1) student ideas that can serve as building blocks for model construction and (2) ideas that are incompatible with the target model. In co-construction, the initial goal of comprehending student responses and identifying the incorrect and correct ideas replaces the traditional goal of immediately evaluating student responses.

**Ask Students to Evaluate One Simple Model Element at a Time**

From the mix of initial student models, teachers need to devise an agenda prioritizing to work on first, second, and third, and then to determine how to scaffold student evaluation and modification of models that are in conflict with the target model. By choosing to work first on the most basic misconceptions, while postponing work on more complex models, teachers are more likely to keep the evaluation task in the reasoning zone. Teachers can foster student dissatisfaction with their model by asking discrepant questions that motivate model modification. Asking students to elaborate or evaluate other students' models can trigger model revision and lead to a sequence of

intermediate models which build on earlier models. The teacher can add a new idea which makes evaluation easier. In this way, “mild but focused” intervention by the teacher during whole class discussion can scaffold the evaluation of student models and lead to stepwise model evolution. In this way, large group discussions can fuel the model evolution process and help students move toward the target model. These four strategies above help to steer teacher decision about long term and short term agendas.

**Reactions to Clement**

Clement's (2008) description of co-construction is drawn from a mental modeling framework that is not explored by other articles in this review. This modeling framework views content goals as the target model, and learning as model evolution. The imagistic, dynamic, and relational characteristic of a target model is a different kind of knowledge structure than the more linguistically based list of discrete standards or objectives often found in traditional curriculum. This suggests that constructivist discussion methods, like co-construction, might be difficult to use within a traditional curriculum if the content goals are not reachable via stepwise reasoning about model elements.

When evolutionary pathways exist between student initial models and the target model, it offers the possibility that teachers could foster model evolution by engaging and scaffolding student stepwise reasoning about particular model elements. The elaborative follow-up moves discussed in other sections of the review would be invaluable tools for engaging and scaffolding student generative and evaluative reasoning. Because these elaborative follow-up moves generate a somewhat intimidating and diverse collection of student responses, it is important that the modeling framework suggests agenda setting

strategies that make it possible to prioritize and steer class discussion toward specific target models.

Clement's (2008) modeling framework offers a flexible track that can be used to focus and guide student thinking, which are revealed by the constructivist discussion strategies developed in other parts of the review. The elaborative follow-up moves and dialogic approaches discussed earlier in the review suggest ways to encourage high engagement and participation, but potentially generate a divergent and complex set of student ideas that are difficult for teachers to use efficiently in order to reach content goals. The modeling framework suggests a manageable way to use student reasoning to make this divergent thinking converge on specific content goals.

Just as students can construct a complex target model incrementally over many days, teachers can construct a diverse teaching practice by making incremental changes in their practice. One of the challenges teachers face in adopting a co-construction approach is that it can be counterintuitive to postpone evaluating incorrect ideas, if the teachers usually attempt to replace misconceptions all at once. A key feature of a co-construction approach is that transitory and incomplete or incorrect models are given serious consideration by science teachers who remain neutral to these models, while making the models the focus of discussion. This is very different from recitation, where any wrong ideas are immediately evaluated and removed from consideration.

## Conclusion

### There are Two Main Themes in this Collection of Work: Switch or Mix and IRF/Agenda

### Switch or Mix

One theme that emerges is how authors describe and position the usefulness of IREs: Should teachers switch from IRE to IRF or mix them? The articles that address IRE/IRFs in some detail fall into two basic categories: 1) those authors who argue against the use of IRE and push for the use of IRFs and 2) those authors who advocate for a mixed approach that uses both of IREs and IRFs. This division seems related to one's position on content goals. Those who advocate for a mixed approach appear to have a more explicit interest in reaching specified content goals.

Table 2-2
Division of Papers Based on IRF Advocacy

| Advocate a move from IRE to IRF | Advocate a flexible mix of IRE and IRF |
|---|---|
| Dillon (1994) | Chin (2006) |
| Nassaji and Wells (2000) | Mortimer and Scott (2003) |

Those who argue against using IREs, do so for good reasons. Dillon (1994) argues that using an IRE pattern forces certain characteristics on to the discussion. The nature of the question, : introducing scientific vocabulary; addressing concepts that are too hard for students to reason about; working under strict time constraints; or simply matching teacher skills and style preferences. She sees elaborative follow-up moves as prompting students to draw on their own cognitive resources, drawing out student ideas, and nudging students to higher levels of conceptual complexity. Chin (2006) and Scott and Mortimer (2005) see the elaborative and evaluative follow-up moves as having an important role in the dialogic and authoritative functions of large group discussion. These

authors don't see IRE and IRF as dichotomous but as offering a range of moves that can be mixed in order to pursue different objectives in the class. The mixed approach is the most useful to me because it offers a broader set of tools for reaching content goals. the pacing, the sequencing, the predominant speaker, and the evaluative function all can be traced back to the IRE pattern. For Dillon, the only way teachers can move away from IREs is by abandoning convergent content goals. Nassaji and Wells (2000) also encourage the use of IRF by emphasizing how IREs result in reduced student participation and less substantive responses. Nassaji and Wells advocate that teachers move away from an IRE pattern and substitute non-evaluative follow-up moves if teachers are interested in opening up discussion to more student ideas. Nassaji and Wells do not explicitly argue against convergent content goals, but the data from which they draw their conclusions is from teachers with predominantly inquiry, not content goals. Both of these papers see discussion as a way to open up to student ideas versus a way for teachers to reach authoritative content goals.

The other authors who advocate for a mix of IRE and IRF draw their conclusions from observations of classrooms with content goals. Chin (2006) describes both evaluative and elaborative moves having valuable functions in certain situations. She sees IREs being useful in the following contexts

**IRF/Agenda**

Another theme that emerges from these articles is how the authors set an agenda for using student ideas to reach content goals. These articles can be divided into two other categories: 1) those authors who focus on the details of how to interact with students and defer evaluation using IRFs and 2) those authors who focus on strategies for dealing with

student ideas to reach content goals. This division seems to relate to the different time scales at which IRF strategies (10 seconds) and agenda strategies (10 minutes) operate (Clement, 2008).

Table 2-3
Division of Papers Based on IRF/ Agenda Focus

| **Focus on interacting with student using form of an IRF** | **Focus on agenda setting to use student ideas to reach content goals.** |
|---|---|
| Nassaji & Wells (2000)<br>Tobin (1987)<br>Minstell & van Zee (1997a)<br>Chin (2006) | Mortimer & Scott (2003)<br>Clement (2008) |

The group of articles with an IRF focus offers rich linguistic alternatives for promoting non-evaluative student-teacher interactions. These authors operate on a small time scale of individual conversational turns, and they offer useful strategies for prompting students to share and elaborate their ideas. These articles, however, do not offer strategies for dealing with the complex student ideas that might be generated from elaborative follow-up moves. In short, they do not discuss the agenda setting that is needed to use student ideas to reach content goals.

Though Chin (2006) sees a role for both the evaluative and elaborative follow-up moves, she does not offer strategies for deciding what specific mix of these moves to use. Teachers need to set an agenda to guide how they will use student ideas to reach content goals. Mortimer and Scott (2003) provide a useful framework for a broad agenda in their authoritative /dialogic framework. This framework suggests that classroom discussion will naturally oscillate between these two dimensions. Dialogic discussions will generate a tension to converge on the authoritative science position, and this convergence on the

authoritative, teacher-dominated discussion mode will generate a counter tension to open the discussion back up to students, to see if they can apply the concept under consideration.

Clement (2008) offers a finer grain view of agenda setting that focuses on model based conceptual change theory in order to reach content goals. Using this framework, Clement argues that teachers can track where the students are in relation to the intended path of model evolution, which he calls the learning pathway (Clement, 2008). Student ideas are either close to this learning pathway, or they are far away. If they are far away, then students may have a misconception, and Clement offers strategies for how teachers can set an agenda that deals with the misconception. The modeling approach helps teachers as they plan for what will happen in the next few minutes or next lesson, as opposed to IRF strategies, which tend to focus on the next fraction of a minute. The modeling approach also provides a clear vision of the target model which offers directionality in the planning as the teacher tries to implement this mode. Clement's modeling framework provides a more detailed description of useful cognitive strategies for dealing with student ideas in order to foster conceptual change. This modeling perspective yields agenda setting strategies that can act as a scaffold for teachers to guide their decision making during planning and instruction.

## Two Sets of Tools

In my search of the literature for the features of a constructivist mode, I uncovered two broad categories of theoretical tools which might be useful in taking steps to diversify my practice. These are socio-linguistic tools and cognitive agenda setting tools.

### Socio-linguistic Tools

A large group of articles provide an important set of socio-linguistic interaction tools that have been shown to influence positively student participation and engagement. These linguistic tools often take the form of elaborative follow-up moves, but these moves alone do not have the structure needed to contain and guide the discussion so that it can reach the content goals of teacher. In other words, sociolinguistic tools do not operate at a higher level than an individual interaction.

### Cognitive Agenda Setting Tools

A small group of articles provided an important set of agenda setting tools that can guide decision making through key planning questions: how to prioritize, (do easiest misconception/model element first); how to frame (are we generating or evaluating ideas); and how to open or converge (dialogic vs. authoritative). Once these agenda setting decisions have been made, one can draw upon the linguistic moves that might engage the prior knowledge and reasoning capabilities of the student and use them to advance the content goals of the curriculum. By identifying these two types of tools, I have the beginnings of a manageable approach that might be useful to teachers wanting to use student ideas and to reach content goals.

## Teaching and Learning with Simulations

Images have been used throughout history to depict visible objects such as coastlines and sailboats, and, more recently, dynamic images have been used to depict complex dynamic mechanisms and models which are invisible to the naked eye. Over the past 30 years, technological innovations and theoretical work (Paivio, 1986) has set the

stage for more strategic uses of images by science teachers. Controlled psychological studies have demonstrated that animations and static graphic are more effective when they are presented with verbal information than when they are presented alone (Hegarty & Just, 1993; Hegarty, Kriz, & Cate, 2003; Mayer, 2001; Mayer & Gallini, 1990), but many questions remain about image use in classroom settings and what teachers must consider when they select and integrate images and discussion strategies into effective learning experiences. There is still open debate about what kind of image works best for different purposes. On the surface, animations would appear to offer benefits for instruction over static images since they can directly represent dynamic elements of a model, system, or process on instructionally useful time scales. However, the superiority of dynamic images over static ones remains in question because many studies have actually shown that there is no benefit of animations over static images (Hegarty et al., 2003; Tversky, Bauer-Morrisson, Betrancourt, 2002). If animations overwhelm (overload attention), or underwhelm (encourage passive learning), they may lower student performance relative to static images. (Lowe, 1999; Mayer & Moreno, 1993) How a teacher directs attention and thinking during a large group discussion will likely influence the effectiveness of any image mode selected, so examining how teachers use images is an important research agenda.

## Terms, Limitation, and Goals for the Review

### What is a Simulation?

I will be using de Jong's definition (de Jong & van Joolingen, 1998) of a computer simulation to be a program that contains a model of a system or a process. When I use the word simulation, I will always mean a computer simulation. The words

simulation and animation will be synonyms for this review, even though some authors reserve the word simulation for animations which have a high degree of user control of system variables (Hegarty, 2004). That distinction is important but not essential for the purposes of this review. I will use the term image broadly to refer to both internal images, such as mental simulations, and external images, such as drawings or projected computer animations. Usually the intent will be clear from the context but when it is unclear I will specify internal image or external image.

## What are the Limitations of this Review?

There is not space in this review to touch more than briefly on the current concerns about simulation use. Though review articles on simulations (Hoffler & Leutner, 2007; Lee, 1999; Tversky et al., 2002) provide an important overview of the historical and current debates about simulation effectiveness, most of this review will be dedicated to individual studies, so that I can focus on the details of particular issues which are relevant to my research agenda.

## What are the Goals of the Review?

My interest is in studies of instructional images use that may reveal the advantages and disadvantages of different image modes and help teachers to decide what kind of images to use, when to strategically employ these image modes, and how to support the use of the image in large group discussions.

The goals of this review are to:

- describe studies that investigate if simulations can be effective tools for conceptual development.
- describe studies that investigate the relative effectiveness of simulation and dynamic images.

- describe studies which investigate teachers' roles in supporting use of the simulation in large group discussion.

### Studies on Using Simulations Used to Build Conceptual Understanding or to Replace Other Activities

Simulations can support the development of mental models and problem solving skills. Memory of a computer simulation can aid student visualization of physics problems solved off-line (Monaghan & Clement 1999). Using think aloud interview protocols with three high school physics students, Monaghan and Clement found evidence of students using the memory of a simulation as a framework for visualization of relative motion problems. They found that, following an exposure to a simulation via a prediction, observation, and explanation treatment, students showed an increase in confidence in answers to physics problems that seemed to be due to an improved ability to visualize this type of problem. When working problems away from the computer, students in the study appeared to map memories of visual elements of the computer simulation on to the target problems and then run a mental simulation to help them solve the problems.

### Simulations Can Allow Students to Confront Their Preconceptions with Immediate Feedback

Using tests, surveys, focus groups, interviews, and class observations, Zhou, Brouwer, Nocente, and Martin (2005) evaluated physics computer simulations, and found that they helped to foster conceptual learning, especially in constructivist teaching environments where students were encouraged to confront their own misconceptions by working with and receiving immediate feedback from the simulation.

## A Computer Simulation Can Help Students Increase Their Understanding of Chemical Representations

Wu and Krajcik (2001) found that a computer-based visualizing tool helped improve high school student understanding of chemical representations. When using this visualization tool, students were highly engaged in discussions and made linkages between visual representations and concepts. The researchers hypothesize that these conversations may have deepened their understanding of chemical representations and concepts, and that use of the tool helped them generate mental images.

## Simulations Can Address Student Misconceptions about Osmosis and Diffusion, and Teacher Direction (Via Written Instructions) Helps to Direct Attention to Key Elements of the Simulation

Meir (2005) provides evidence that simulation based laboratories helped college students working individually and in pairs to overcome some common misconceptions about diffusion and osmosis. He observed that the simulation provided the tools needed to observe and experiment, but that most students did not use these tools unless instructions were written to guide the exploration. He hypothesizes that scaffolding provided by written instructions may make simulations more useful for confronting a misconception by directing students to focus attention on subtle aspects of the simulation. The researchers noticed that the simulation does not present the "real" pattern of nature for all combination of variables, and this suggested to me that both positive and negative elements of the simulation need to be made more salient to students for the tool to promote learning and address misconceptions productively.

**Simulations Can Be Used to Develop Understanding of Large Systems**

Bell and Trundle (2008) showed that a simulation used to teach lunar concepts and employed using a conceptual change model of instruction can promote scientific understandings. This study also demonstrated another advantage of a simulation is that it can recreate aspects of nature that would be too complex or time-consuming to explore in a classroom setting.

**Simulation Use Can Match the Conceptual Gains Provided by Real Materials. Animations Can Be Superior to Lecture for Developing Dynamic Mental Models of Particle Motion**

Abraham and Williamson (1995) found that college chemistry students who were taught using two animations conditions, one as a lecture supplement and one as lecture plus individual lab activity, did significantly better than their counterparts who were not shown an animation on the Particle Nature of Matter Evaluation Test (PNMET). The researchers hypothesized that this increased understanding may have been due to the construction of dynamic mental models of particle behavior.

**Students Using Simulated Lab Activities May Outperform Students Doing the Lab with Real Materials**

Finkelstein et al. (2005) investigated the effects of substituting a computer simulation for real laboratory equipment, and found that college physics students who used a computer simulation of an electric circuit laboratory outperformed their counterparts who did the lab with real light bulbs, wires, and meters on measures of concept and skill assembling circuits. The authors hypothesized that this gain might be due to the simulation's ability to give un-ambiguous data when experimenting, while giving access to conceptually salient details and representations. For example, students

with real labs could not always tell if bulbs were lighting or if wires were connected, while the computer simulation gave very clear feedback about these events. The authors also hypothesized that this gain might be due to the simulation's ability to productively constrain student "messing about" (Hammer, 2000 p, xx) with lab equipment. For example, students observed messing with the simulation were building and testing circuits, while students observed messing with real equipment were making bracelets out of the wires.

**Simulations Can Be as Effective in the Instruction of Engineering and Experimental Design Concepts as Real Materials**

Klahr and Triona (Klahr, Triona & Williams, 2007; Triona & Klahr, 2003) found evidence that, on several different measures, elementary school-aged students were able to learn as well with a computer simulation as with real physical materials. In an experimental study (Triona & Klahr, 2003) done with elementary school students, the authors substituted a computer simulation for hands-on equipment, and found that the computer simulation was as productive a learning tool as hands-on equipment for teaching students to design and make predictions from un-confounded experiments. In a similar study (Klahr et al., 2007) investigating engineer design concepts, students who designed virtual cars preformed as well as students who built actual cars. Both conditions were equally effective in producing significant gains in students' knowledge about causal factors, in their ability to design optimal cars, and in the students' confidence in their new knowledge. Since simulations have practical advantages (portability, safety, cost) and conceptual advantages (minimization of error, variability in speed of displayed outcome),

their instructional effectiveness should make them a viable tool for addressing some instructional goals that do not require the development of perceptual motor skills.

**Visualization Activities (Simulation or Drawing) are More Effective than Lecture for Developing Concepts of Molecular Genetics. Simulations were Superior to Drawing for Developing Dynamic Elements of the Model**

In an experimental study done with high school students, Rotbain, Stavy, and Marbach-Ad (2008) investigated how individual computer animation and drawing activities contribute to student understanding of molecular genetics. Using interviews and pre/posttests, they found that students in the visualization group (animation or drawing) had larger gains on posttests containing multiple-choice and open-ended written items than the traditional lecture group. The computer animation group outperformed the drawing activity group on the open-ended items and on items relating to dynamic aspects of molecular genetics, and this suggests that animation activities are superior for the learning of dynamic elements of the model. Drawing alone was as effective as animation for learning static structural elements of the model and the authors hypothesize that this may be due to the drawing activities being more active than the parallel computer animation lesson on structural features of the model. The interactivity of the drawing activity may explain why it resulted in larger learning gains than lecture on all parts of the assessment. The authors suggest that choice of visualization mode might be guided by the structural/ dynamic dimension of the target model.

## Reaction to Conceptual Studies

### Most Studies Focus on Small Group Uses of Computers and Further Research Needs to be Done on Large Group Uses

Reports of conceptual growth from simulations show that they can be used to teach difficult content like relative motion (Monaghan & Clement, 1999), circuit electricity (Finkelstein et al., 2005), and osmosis (Meir, 2005), as well as difficult process skills like experimental and engineering design (Klahr& Triona, 2007). While most of the strategies employed for using simulations to produce these gains did not involve any large group direct instruction, (i.e., Monahan and Clement used the simulation in a predict, observe, explain protocol), it would be interesting to explore if the simulations and methods used could be adapted to whole class use.

Reports of simulations effective equivalence to real materials for producing learning gains in conjunction with their practical advantages of cost and portability, may lead US policymakers to push for the increased use of simulations. This has already happened in the UK, where teachers are strongly encouraged to use an approved set of simulations in classrooms (Osborne & Hennessy, 2003). While studies have shown these materials to be effective in small group settings, not all school districts will have the computer lab resources to take frequent advantage of small group mode. None of these studies describe with any detail how to use simulations in whole class mode and much needs to be learned in order to support teachers in this mode of use.

## Studies that Compare the Effectiveness of Static and Dynamic Images

### Reviews on Simulations

There are multiple features and forms of simulations but it is still an open question if they are more effective than static images (Lee, 1999; Hoffler & Leutner, 2007; Tversky et al. 2002). Lee (1999) completed a meta-analysis of studies and found that simulations can offer advantages of promoting active involvement and reinforced practice, but his work but did not examine studies which compared simulation and static image effectiveness.

Tversky et al. (2002) carried out a review of studies on static images and found that well designed and targeted images can be effective for developing understanding of complex concepts if they conform to the Congruence Principle, which states that the content and form of an image should match the content and from of the target concept. Applying this principle to simulations, they hypothesized that simulations would be more effective at building dynamic concepts than static images, but that prediction is not borne out by the studies the authors reviewed. A closer look at the studies which reported a greater effectiveness of the simulation, found these gains could be attributed to other factors, like interactivity of the simulation, rather than its dynamic nature.

Hoffler et al. (2007) did a meta-analysis of 26 studies comparing equivalent static images and non-interactive use of animations, and found that animations have an advantage over static images even when considering many moderating variables. Features of the animation, learning tasks, and study features were grouped into 11 variables and used to code the studies. These variables were then used to attempt to define moderating conditions in which the animations have an advantage in terms of the

weighted effect sizes they generate. Of these variables, the role of animation and knowledge requested generated large effect size differences. Representational animations (i.e. conceptual models) had larger effect sizes than decorational animations (i.e., cartoon narrators). In the knowledge requested variable, the animation produced the larger effect size when the knowledge requested was procedural (how to do something) compared to animations effects on gains on declarative or problem solving knowledge tasks.

## Cognitive Studies of Perception of and Comprehension of Animations

### Mayer

Viewing pictorial and verbal information together produces the greatest learning effects, as long as the split-attention effect is avoided (Mayer, 1994, 1997; Mayer & Anderson, 1991; Mayer & Moreno, 1998). Mayer and his group have investigated the effect that various arrangements of verbal information and multimedia have on learning and has shown that a strategic coordination of pictorial and verbal information produces the largest gains on measures of knowledge and problem solving. The goal is to prevent pictorial or verbal parts of the presentation from splitting the learner's attention.

Moreno et al. (1998) proposed the following five principles for the design of multimedia based on their research.

- The multiple representation principle: Words and pictures are better than words alone.
- The contiguity principle: Display words and pictures together versus separately.
- The split attention principle: If an image is using the visual channel, present words via the auditory channel.
- The coherence principle: Do not use extraneous words and pictures in explanations.
- The individual differences principle: Students with low prior knowledge benefit most from these principles.

**Lowe**

Viewing complex animations may split attention with visually salient elements receiving more attention than conceptually salient elements. Lowe (2003) found evidence of a split-attention effect, even without verbal information, when learners attempted to extract information from a complex animation. Lowe described how dynamic images are different from static graphics in their ability to display three types of temporal change directly:

- Transformations- Entities change in size, shape, color or texture.
- Translations- Entities change in position changes or move relative to the border or background.
- Transition – Entities appear or disappear off the display.

He found that while students receive dynamic information from an animation that is not found in static graphics, they face larger cognitive demands from these features of dynamic displays that make it difficult for them to extract conceptual information. College students with low prior knowledge who were shown animated weather maps made superior predictions about future states compared to a control group. However, the best predictions were about the most visually salient elements of the animation, which suggests that dynamic elements of the animation received selective, attention and, thus, more processing occurred than with the more subtle but conceptually relevant changes in the background of the animation. Lowe provides evidence that students, when viewing an animation, extract most of the information from components that have a distinctive coherent structure and dynamic qualities. If one part of a complex display attracts more attention, learners may neglect relevant information in another part. This lack of perception leads to reduced comprehension.

## Reactions to Lowe and Mayer

Taken together, Lowe's (2003) and Mayer's findings suggest that effective animation use by teachers will include them productively managing the cognitive load of students by directing student attention to the most conceptually relevant components of the animation. Teachers may benefit by assuming a split attention effect and checking in with students to see if the students have observed and considered all of the conceptually relevant elements of the animation. Then teachers can help students generate a meaningful whole by linking various fragmented observations of the display. The research literature provides teachers with general recommendations to provide these supports, but research does not articulate more specific smaller scale strategies that would help teachers manage some of the complexity involved with actually enacting these recommendations in front of students. One of the questions these authors do not address is how teachers support the comprehension of a simulation in a class setting when displaying and interacting with the simulation as part of a large group discussion. I am interested in exploring and describing, in some detail, the many ways that teachers might provide this support in a large group discussion.

## Hegarty, Kriz, and Cate

Both static and dynamic (external) images can stimulate internal (mental) animations which affect the generation of causal chains (Hegarty, Kriz, & Cate, 2003). Hegarty et al. investigated the effects of animations on students' mental models through an elegant but complex set of experiments which varied image mode (static or dynamic) and verbal information (text, commentary, or no text) and questioning (prediction question or no prediction question). They found no evidence that animations led to

significantly better understanding than static images in any of their three experiments but did find that predicting motion from static diagrams and verbal descriptions of dynamic elements independently enhanced understanding. Figure 2-3 reproduces a graph from their paper below and provides a summary of their results which will be helpful in the discussion of their results and their implications.

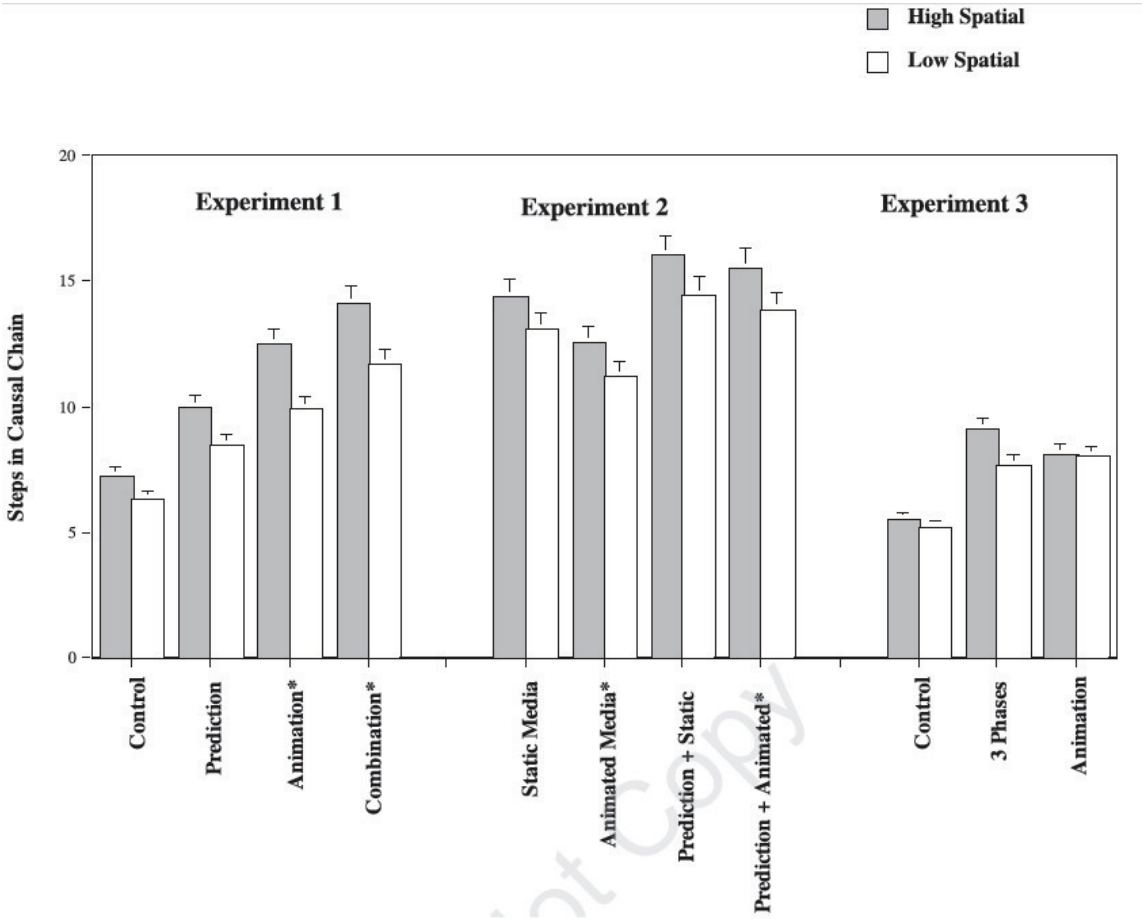



Figure 2-3
Hegarty's Experimental Results
The graph shows the length of causal chains used by subjects after viewing different combination of images and text. Note that experiment condition 1 and 2 were both accompanied by verbal description but Experiment 3 was image only (Hegarty, Kriz, & Cate, 2003, p. 339)

Examining the details of their experiments helps in the understanding of Hegarty's theories about why animations and static images may produce similar learning

gains. These equivalent effects did not result from using a single static image. Students who viewed a single static diagram (control condition in Experiment 1 and 3) made fewer inferences about the systems behavior than students in the animation condition. Instead, the equivalent effect came from asking students to predict motion from a phase diagram, a set of three static diagrams depicting different but sequential stages in the motion of the mechanism.

The researchers hypothesize that use of prediction while viewing a phase diagram produced the same result in that it engaged students' mental animation and enabled them to infer individual movements of the parts of the mechanism and arrange them in step by step causal chains. Creating this sort of sequential (stop-action) internal representation from an animation may be more difficult, because perception and comprehension do not always keep up with the rate at which an animation is presented. Animations can become very difficult to process and comprehend in a single viewing, and this is especially true if different parts of a mechanism are changing simultaneously but in different parts of the display. In an animation, images appear and disappear from view, whereas in static images the eye can trace back and forth, as it does in reading, to review or tie together what is happening. User control of an animation helps to address the transience of the image in an animation, but in this study the animations utilized user controls but could only be viewed for a short time (6 minutes).

Perhaps the most salient result visible in Figure 2-3, is that students in experiment 1 and 2, who received verbal descriptions of the mechanism, gained more understanding than students in Experiment 3, who received no verbal descriptions. This large effect may be due to the verbal nature of the assessment instrument being more sensitive to the

verbal information provided by the text. It may also reflect the ability of language to describe invisible forces, to direct attention to the most salient parts of the image, or to link separate and simultaneous events in meaningful ways. An analysis of the causal steps that students describe showed that students who received both images and verbal descriptions demonstrated the most complete mechanistic understanding of how all the parts of the machine functioned together.

**Reactions to Hegarty et al.**

This study demonstrated that animations showed no advantage over static screen shots and raised questions about how complex visual displays and language may impact learning in a classroom setting. It raises questions about how the information value of an image changes based on multiple features, since it may be rare for a teacher to have a choice between information equivalent static and dynamic images. A teacher may want to use a phase diagram prediction, text, and an animation, since the largest gains in understanding came from the condition which combined prediction about phase diagrams and animations. In addition, I am intrigued by the possibility that the teacher's ability to describe causal chains verbally during his explanation of a complex mechanism may in some way mirror these subjects' ability to generate causal chains. In other words, is it possible that quality and number of causal chains used in a teacher explanation may be influenced by the type of image the teacher is referencing during improvised episodes of whole class discussion?

## Top Down Processing and Bottom Up Processing

Top down processing may be more important to comprehension of a simulation than design enhancements which improve its ability to be perceived (bottom up processing) (Grant & Spivey, 2003; Kriz &Hegarty, 2007; Schwan & Riempp, 2004 ).

Schwan and Riempp and Grant and Spivey found that directing attention to the important locations in an animation (signaling) and giving control over pacing (interactivity) can improve student comprehension of animations. Kriz and Hegarty showed that even these bottom up perceptual enhancements can be undone by a student's lack of top down prior knowledge, since low prior knowledge seems to impact negatively a student's ability to use these enhancements to extract meaningful information from a dynamic display.

While text or verbal narrative can provide a powerful influence on what part of the display students attend to (signaling), it does not prevent students from ignoring parts of the display which contradict their prior conceptions about the material being studied. Kriz and Hegarty (2007) hypothesize that problems with learning from animations will not be solved by bottom up design features alone, but will involve teachers iterative versus one-time animation use in a context which asks student to articulate and frequently compare their top down mental models relative to the animation.

## Model of Comprehension

Principles of multimedia should focus on a model of comprehension. (Narayanan & Hegarty, 2002). Narayanan and Hegarty (examined the assumption that dynamic presentations are superior to static graphics and found no advantage for animation over static images. Their experimental results suggest that effectiveness of a multimedia

presentation is more related to its incorporation of six design principles for supporting comprehension than with the interactivity or dynamic nature of the display.

The six principles are:

- The decomposition principle: Break process into simpler components.
- The prior-knowledge principle: Use words and pictures to Connect to Prior knowledge.
- The co-reference principle: Clarify linkages between deictic words (pronouns) and objects.
- The lines-of-action principle: Use words and pictures to build causal connections.
- The mental simulation principle: Ask students to predict before providing an animation.
- The basic law principle: Describe basic principles of the displayed system.

## Cognitive Load of Simulations

Adding enhancement and supports may increase cognitive load of simulations (de Jong & van Joolingen, 1998). de Jong and van Joolingen reviewed studies of discovery learning in simulation environments and described instructional support measures programmed into the simulations that attempted to help students engage in planned and conclusive experimentation. The support measures that seemed to influence learning outcomes most positively were as follows: 1) providing links access to domain knowledge on a need-to-know basis, 2) providing students with assignments in the form of questions, objectives or games, and 3) using a model progression design in which the full complexity of the simulation is revealed gradually in a step-wise fashion. Adding support measures to simulations may increase the cognitive load of the simulation.

**Reactions to de Jong and van Joolingen and Narayanan and Hegarty**

These articles raised a number of issues relating to support for simulations. First, its curious to note that in de Jong 's (2008) review of studies, they found that "instructional support for prediction" did not yield conclusive evidence of gains, whereas Hegarty et al.(2003) found strong evidence for the value of prediction. In fact, she posits it as a design principle which increases the efficacy of a multimedia presentation. One explanation for this difference in findings could be found in the fact that de Jong was referring to instructional support features built into the simulation interface, and that the interface may have been distracting, whereas Hegarty used a simple set of written instructions to accompany a set of phase diagrams in her experiment. Maybe in Hegarty's case, a simple set of diagrams and text was more effective at focusing attention and processing on the prediction task than a complex interface imbedded in a dynamic simulation.

The possibility that the interface used to access the prediction support might influence whether or not prediction "works" or not, points to the need to explore and articulate some of the complexity around what it means to ask prediction questions of simulations in real classrooms. de Jong (1998) does not describe the graphic user interfaces (GUIs) for support features, and yet the GUI likely influenced the functionality of the enhancements of the simulations. What counts as distracting or helpful instructional support will depend on the ability of the ever-evolving GUI to be understood by the user, whose own understanding of GUIs in general is based on her level of technology use (smart phones, video games). In small group work, the GUI-user interactions may produce wide ranging results, since the pacing and level of processing

being called for by support features, like prediction questions, will rely more on a student interpretation of the interface rather than on a teacher's direction. Exclusive small group work, while maybe more interactive for the student, could magnify the digital divide, since novices may learn less from the complex interface than more experienced users.

Large group use of computers might offer some instructional and methodological advantages, since the teacher's interpretation of the GUI and purpose and use of the support will more uniformly influence the student's perception and comprehension of the simulation. Describing the features of teacher expertise in the use of a simulation is thus an important research priority, since it could make these skills more transferable to other teachers. An expert teacher, who uses a simulation in a large group discussion, will employ its advantages and avoid its disadvantages. This may lead to more equitable distribution of the benefits of this technology and help bridge the digital divide between students who have access to technology and those who do not.

## Studies of Teachers Using Simulations in Large Group Discussions

### A Socio-cultural Perspective

There are very few studies that focus on the cognitive strategies teachers use to employ simulations in large group discussion. A survey of the literature on simulation use from a socio-cultural perspective is beyond the scope of this review, but a few articles from this theoretical perspective begin to describe some of the issues associated with teacher use of a simulation in a large group setting which overlap with my research agenda.

**Dialogic, Open Simulation and Closed Simulation**

Dialogic, open simulation use was observed in large group mode and authoritative, closed simulation use was observed in small group mode (Hennessy & Deaney Ruthven, 2006). Hennessy et al. used a case study methodology to investigate science teaching strategies for using a simulation by observing ten lessons and interviewing five teachers. In contrast to what research rhetoric and teacher aspirations might suggest, Hennessy found many of the teachers in her study were using a simulation for structured tasks rather than to promote student driven experimentation.

Hennessy used the following descriptions of teacher knowledge and behaviors as features of expert simulation use:

- Teachers will be aware of the advantages and disadvantages of a simulation and the instructional enhancements which can support its use in domain specific learning.

- Teachers will know how to use the simulation and its enhancements in actual enactments to exploit successfully its advantages or overcome its disadvantages while supporting domain specific teaching and learning.

- Teachers will recognize that technology use will need to be adapted for particular groups of students and in particular contexts.

Two teachers were compared to exemplify two of the most common structures of simulation use: whole class and small group. One teacher structured and supported learning using a dialogic whole class discussion that tested student ideas, and another used a more authoritative approach during a worksheet driven lesson completed by pairs of students working at multiple computers.

## Large and Small Group Use of a Simulation

Large group use of a simulation was accompanied by more collaborative talk than small group use of a simulation (Smetana & Bell, 2009). Smetana and Bell explored the use of simulations in whole class and small group settings in high school chemistry class. Both large group and small groups showed the same gains in understanding but more frequent collaborative talk and meaningful teacher student interaction was observed in the large group. The authors suggest that large group instruction may make more simulation work possible, since technology has not penetrated schools sufficiently to make frequent small group work with the computer possible. They hypothesize that how a teacher uses a simulation is just as important as the simulation itself in reaching the desired results.

## Teacher Expertise and Interactive Technology

Teacher expertise and interactive technology can interact to create a collaborative space that supports the co-construction of knowledge (Warwick, Mercer, Kershner, & Staarman, 2010). Warwick et al. used a case study of an elementary school classroom and observed teachers using an interactive white board (IWB) to create a collaborative environment that supported the co-construction of knowledge. This collaborative space was the product of the technology and the teacher's view of the IWB as a tool with affordances for collaboration. The technology, combined with the teachers' technological and pedagogical expertise, allowed the IWB to help the teachers devise tasks that used the technology to develop collaborative class norms and provide active support for the dialogic activity.

## Observing Student Talk

Simulations can be used as a tool to observe student talk about science (Roth, 1995). This study focused on how a teacher used a simulation of Newtonian mechanics to engage students in conversations about forces depicted in the simulation. The teacher used the simulation to observe how students "talked science" and used strategies to help make forces visible to students. The authors approach this study from a theoretical perspective, which views science as a process of acquiring discourse and cultural practices, versus a process of acquiring and refining mental models, so pre and post test data was not used in this study.

## Interaction of Teacher Perceptions and Technological Features

Affordances of a simulation are a complex interaction of teacher perceptions and technological feature (Barnes et al., 2005; Sutherland et al., 2004; Sutherland & John, 2005). Many studies use the concept of affordance as defined here: "The perceived properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. A chair affords (is for) support and, therefore, affords sitting" (Norman, 1988, p. 9).

Barnes et al. (2005) use a case study to explore the teacher perception side of the affordance concept. They use an example (from Gibson, 1979) that a chair will afford sitting only if we are wanting to sit, and may afford standing just as easily, if we are trying to change a light bulb. They see an example of this idea in their case study in which an interactive white board, IWB, and a simulation afforded certain modes of dialogic interaction only if the teacher perceived the possibility of this use. The IWB and simulation did not afford the same sort of collaborative interactions when the teachers

perceived technology as a presentation tool. What a student learns from a simulation will relate to how it is used, and how the simulation is used relates to the teacher's expertise, purpose, and perception of the technology. The authors believe that studying a teachers' perspective is critical to the understanding of effective uses of technology, and the authors see research partnerships as a way to bridge the gap between academic research and classroom practice.

Other studies reiterate the importance of studying the teachers' role in seeing an affordance and navigating the actual enactment of that affordance. Teachers may see the affordance of the simulation, but they still must integrate it into their setting, pedagogy, content knowledge, and planning in order to enact it (Sutherland et al., 2004). Effective learning depends on the complex relationship between a teacher's pedagogy, the domain of study, and the technology. Sutherland (2005) calls for more research in this area to explore how the complex mixture of a teacher's subject, together with her pedagogical, and technological understanding, are translated into planning and practice.

## Reactions

These studies point to the potential of integrating simulations into large group discussion as a way of creating collaborative spaces for dialogic exchanges and the co-construction of concepts, but most of these studies do not collect data about student understanding generated by these experiences with the simulation. These studies suggest that future investigations of teachers' use of simulations in whole class settings will allow researchers to develop descriptions of strategies that teachers can employ to maximize the advantages and minimize the disadvantages of a simulation. The concept of an affordance as a perceived advantage reveals that another challenge for research is to expand

teachers' view of simulations beyond their use as a presentation tool and to help teachers see ways that in class discussion of simulations can be used to explore student thinking and develop conceptual understanding.

## Implications of the Review for My Research Agenda

One function of technology is to extend human abilities and contexts for social interactions (Bransford, Brown, & Cocking, 1999). One way for simulation technology to extend teaching abilities and contexts for learning is for teachers to see simulations as useful tools for generating discussions that engage and challenge student thinking about the concepts represented by them. I have identified and reviewed some studies that have explored the effectiveness of simulations and static images for building conceptual understanding, but these have mostly been focused on small group uses. I have identified other studies that have commented on how simulations and other technologies may be able to extend teacher practice, but these have been case studies that have not gathered data on student learning gains. There is very little literature on effective use of simulations for producing learning gains that has focused on whole class uses, and the few that have commented on this (Abrahamson & Williamson, 1995; Smenta & Bell, 2009) do not examine the effectiveness of static versus dynamic images. In addition, the literature includes hardly any studies that describe specific strategies teachers employ for using different image modes in whole class discussion, and even fewer reports attempting to link this descriptive work to measures of student learning that might contribute to the ongoing debate over the relative effectiveness of static and dynamic images.

My dissertation work hopes to contribute to the literature by exploring questions that I have not seen addressed together in one study:

- What whole class discussion strategies were used with image displays by teachers to scaffold the development of a visualizable model of a gas
- How are lessons with common content goals planned and enacted differently when using different image modes (static overheads vs. simulations)?
- Are there differences in how different teachers provide a context for and employ an image display to discuss an explanatory model?

# CHAPTER 3

# METHODOLOGY

## Purpose and Theoretical Perspective of the Study

The literature review on large group discussions revealed that there have been a large number of studies that have investigated classroom dialogue from a social constructivist perspective, but only a few studies explore discussion from a cognitive perspective and describe strategies for using teacher-student dialogue to engage student reasoning and reach robust conceptual understanding goals. The literature review on simulations revealed that there have been a number of studies that have investigated how dynamic and static images can be effective to promote learning, but only a few describe how these images are strategically integrated with large group discussions to reach content goals. A perceived limitation of these studies was the lack of research on strategies used with visual displays. In this study I have attempted to focus on whole class discussions using visual displays (simulations or overheads) in order to identify discussion strategies and patterns in interaction modes used in that context. This study will attempt to contribute to these areas of research by examining the large group discussion practice teachers use during static and dynamic image-based lessons.

Briefly, I conducted a mixed methods study analyzing teacher behavior in lessons using visual media about the particulate model of matter taught by three experienced middle school teachers. Each teacher taught one half of their students with lessons using static overheads and taught the other half with lessons using a projected dynamic simulation. Each simulation-overhead lesson pair had similar content goals, lab activities, and handouts but differed in the type of image mode used during large group discussion.

Identical pre- and posttests were used to measure learning. The main purpose of the quantitative analysis was to motivate and provide a result to be explained by qualitative analysis of video and transcript evidence in a set of case studies rather than to project a result onto a population outside the study. Open coding was used to identify image-based teaching strategies that teachers were using with visual displays. Fixed codes for this set of image-based discussion strategies were then developed and used to analyze video and transcripts of whole class discussions from 12 lessons.

## Research Questions

Based on the literature reviews of previous studies in related fields the following research questions were identified:

1. **Learning Gains**. Was there a difference in content learning between students who were taught with a set of simulation based lessons and students who were taught with a set of static overhead based lessons?

2. **Identifying Discussion Strategies**. What whole class discussion strategies were used with image displays by teachers to scaffold the development of a visualizable particulate model of a gas?
    a) What image-based discussion moves (small time scale strategies spanning 4seconds to 4 minutes) were used by teachers to navigate image-based discussions?
    b) To what extent did teachers employ these strategies in overhead and simulation lessons?

3. **Differences between Simulation and Overhead Discussions**. How were lessons with common content goals planned and enacted differently when using different image modes? What advantages and disadvantages do static overheads and dynamic simulations have for planning and enactment of these lessons, and how do teachers exploit these advantages?

4. **Differences between Teachers in Discussions**. Were there differences in how the different teachers provide a context for and employ the image to discuss the model? If so, how can these differences be described?

## Study Design

The data collected in this study were part of a larger National Science Foundation study of visual modeling strategies in science teaching. A set of lessons was selected from an exemplary curriculum on the particulate nature of matter, which uses static images to help students construct explanatory models. Each lesson had a particular content goal and student handout, and was designed to run for most of a class period (45-50 minutes). Each overhead lesson employed an overhead as described by the curriculum. Each simulation lesson used the same lesson structure and handout, but teachers adapted the lesson to replace the overhead part of the lesson with a computer simulation. Each teacher taught two of their four classes using a series of overhead lessons. Each teacher taught the other two of their classes, or the other half of their students, using a series of simulation lessons. Thus, roughly half of the students in the study experienced an overhead condition, which consisted of a series of overhead lessons, and the other half experienced the simulation condition, which consisted of a series of simulation lessons. For each lesson, there was an overhead and simulation condition that had the same content goal, student worksheet, and non-image-based parts of the lesson. To the extent possible, all classes used the same handouts and other lab equipment in the two conditions, and the same number of class periods to cover the material. The lesson plans and handouts were developed by the teachers in consultation with the research team. By observing lessons in which teachers used two different image modes, static overheads and dynamic simulations, I was able to explore through case studies how teachers used images in the two conditions.

The primary focus of this study was on the large group discussions that occurred during a set of lessons adapted from Matter and Molecules (Lee, Eichinger, Anderson, Berkheimer, & Blakesee, 1993). Matter and Molecules was selected because it has been shown to foster meaningful growth in science understanding, and it addressed the content goals relevant to the school's curriculum standards. In developing the curriculum, Lee et al. examined students' ability to learn and demonstrate an understanding of kinetic molecular theory. They found that student misconceptions around molecular theory were multitudinous and persistent, with students clinging to their scientifically inaccurate conceptions even after exposure to lessons that taught them the expert explanations. These findings support previous studies that have found kinetic molecular theory to be an area of particular difficulty for science students. The curriculum provided detailed readings, activities, overheads, and worksheets to accompany the lessons, each designed to address a specific misconception or set of misconceptions. However, the authors of the curriculum provide little specific guidance on how to run or manage the classroom discussions that surround the activities and explicate the concepts of the lessons. The curriculum employs complex static overhead images as a key element of the instruction but was developed at a time when computer simulations were not widely available. In this study, a simulation lesson was created by substituting a computer simulation for the overhead provided in the Matter and Molecules curriculum. Three matched Sim-OV lesson plans were written, and each teacher taught each OV and SIM lesson twice. Each cell in Table 1 represents a class, and researchers videotaped 23 of these 36 classes. Of these 23 videos, 12 videos were selected for analysis to allow a balanced comparison by teacher of matched sets of lessons (shown in green on Table 3-1).

The simulations used in this study were available alternatives chosen by teachers as part of a naturalistic study of the use of overhead and simulation images and thus this study did not attempt to control the amount information available in the images or limit the teacher's use of the image's affordances. The study will attempt to control for time on task in that the same number of lessons [periods] will be used in each condition. It will not attempt to control for equal time on image displays within these lessons, because I wish to understand whether teachers naturally utilize one type of image for a longer period of time, as well as any differences in how the image is used. So the question is, given an equal number of lessons and different image tools, are there differences in the way teachers design lesson plans, spend time with each image, and use discussion leading strategies with each image to achieve conceptual understanding goals?

It is important to note that the amount of information in an image does not alone determine how much learning will occur. In reality, a complex image takes time and discussion in order for students to understand it; Lowe (2003) and Hegarty (Hegarty & Just, 1993; Hegarty, Kriz, & Cate, 2003) found that adults can have marked difficulties in interpreting animations. More options similarly do not imply more learning. In practice, more options means that teachers will face more decisions about how to employ the image, and this may create difficulties. Therefore , this study is not an experiment that is attempting to change one small feature of the image and to narrowly control all other variables to study just the effect of that feature. The center of this study is a set of qualitative case studies that attempts to discover what teaching strategies were used in addition to the presence of the image itself in two conditions, where there were multiple differences between each condition.

Table 3-1
Comparative Case Studies of Simulation-Overhead Lesson Pairs
(examined a lesson that uses an image to discuss a central modeling question. Twelve lessons balanced for each teacher, were analyzed with the coding definitions developed in the study to speak to research question 3).

| **Teacher** | **Chapter 6 Compressed Air in Tire Lesson** | | | | **Chapter 7 Air Pressure in Syringe Lesson** | | | | **Chapter 8 Clean Air and Scent Lesson** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | What is happening to the air as it is pumped into and released from the bike tire? | | | | Why can't you push the plunger in all the way when you have air in it? | | | | How does the scent travel from where it was released to your nose? | | | |
| | OV | | SIM | | OV | | SIM | | OV | | SIM | |
| Mr. T | | | | | | | | | | | | |
| Mr. R | | | | | | | | | | | | |
| Mr. S | | | | | | | | | | | | |

Note: Light green indicates overhead lessons and dark green indicates SIM lessons.

## Participants, Context, and Setting

The study was conducted with 224 science students during a four-week unit on matter and molecules, in an eighth grade classroom at a public middle school in a small suburban town in New England. Each teacher's room contained a PC computer with high speed internet access, a LCD projector, and an overhead projector. To display the images, each teacher used a single computer projected onto white board in front of the class or an overhead projector with transparencies. Each teacher guided a whole class discussion as students worked through the lab activities and handouts provided by the curriculum. This series of lessons took place approximately two weeks into the unit, and no simulation was shown to students during the first two weeks of the unit. The three lessons in this study attempted to help students construct visualizable particulate models to explain how scent travels from its source to a nose and how air behaves when compressed and expanded.

The three teachers involved with the study taught four class sections of heterogeneously grouped students. The author of this study was one of the teachers (Mr. T). The teachers were selected for this study because they had experience teaching this age group (each has between 8-15 years of middle school teaching experience), and they were familiar with this science content, and each teacher had demonstrated interest in participating in the planning and enacting of these complex lessons. The selection of simulations to be used in these lessons was completed jointly by the three teachers in consultation with my research group.

## Data Collection Methods

### Pre/Post Instruction Test

Before instruction, all students completed a nine-item test containing a mix of multiple-choice, modified multiple-choice, and long answer questions. The test asked students to explain different macroscopic situations in terms of a microscopic model of a gas. Upon completion of the 2 week lessons series, students in both the overhead and simulation groups completed an identical posttest. The following are examples of the pre/posttest items (see Appendix A for full pre/posttest):

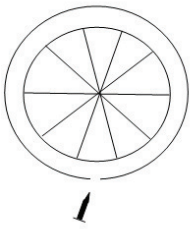
1A. Explain what happens if you run over a nail on your bicycle and the tire gets punctured and starts to leak. Include molecules in your response if you can.

1B. As the air escapes, you can hear a hiss. After one minute, you still hear the hiss. Is the air coming out as quickly it was when it was first punctured?

Yes_____ No_____ Why or why not?

1C. A few minutes later, you still hear a quiet hiss. Your tire does not yet look flat but now it feels soft when you touch it. Draw dots to show molecules of air inside and outside of the tire in each case. Remember that air is still escaping from the tire.

Right after the puncture



Several minutes later

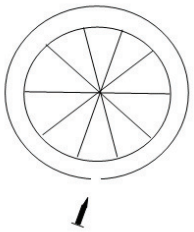
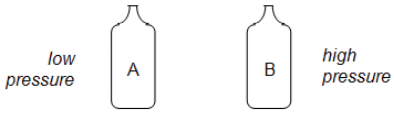


Figure 3-1
Sample Long Answer Question

5A.




Oxygen in tank A is under low pressure. The oxygen in tank B has been compressed a lot by putting more oxygen in under high pressure. Why does oxygen come out of tank B faster than it does out of tank A when the tanks are opened?

5B. By "faster," we mean that:

a) each molecule is moving faster.
b) more molecules are coming out each second.
c) Both a) and b).
d) Neither a) nor b).

Figure 3-2
Sample Modified Multiple Choice Question

### Classroom Observations

Data collected includes open observations in class, videotapes, and student work samples. Over the course of the 4 weeks of study in the Matter and Molecules unit, approximately 18 hours of large group classroom activity were videotaped and later transcribed and analyzed using Transana video software (Woods & Fassnacht, 2007). My research team videotaped each teacher during a series of overhead lessons and a series of simulation lessons.

## Quantitative Data Analysis Method

### Pre/Post Instruction Test

Short answer questions for overhead and simulation groups' pre/posttest were scored with a key. Long answer questions were scored using a rubric developed in consultation with the research group. I scored the long answer tests 2 years after they were given, and I was blind to student, teacher, and condition. Comparisons of the short answer results and long answer scores were done using an analysis of variance (ANOVA) with an alpha value of 0.05 to establish whether significant gain differences exist between overhead and simulation groups. Through these analyses, I addressed Research Question 1: Was there a difference in learning between students who were taught with a set of simulation based lessons and students who were taught with a set of static overhead based lessons?

## Qualitative Data Analysis

### Constant Comparative Methodology

As an exploratory study in an understudied area, analysis focused mostly on open coding of video episodes, using constant comparison techniques, in order to differentiate and refine new constructs describing teaching strategies (Chin, 2006; Glaser & Strauss, 1967). The purpose in general of such an exploratory case study is to provide existence demonstrations of newly observed behavior patterns that promote the generation of hypotheses about useful teaching strategies. The constant comparison method was used to develop descriptions and categories of teacher discussion practices and strategies that were intended to engage student reasoning and construction of explanatory models. This involved the interpretive analysis cycle of segmenting the data; making observations from each segment; formulating a hypothesized model that can explain the observations; returning to the data to look for more confirming or disconfirming observations; and criticizing and modifying, or extending the interpretation (Clement, 2000a). Since I was a teacher in the study, I was able to add an inside perspective. A second researcher, who had taken field notes while observing the lessons, offered critiques of the constructs and rubrics being developed, and provided an important outside perspective and source of validity for the initial analysis of the lessons.

During a second phase of the analysis, I coded the remaining 10 lessons in consultation with other members of the research team, who checked codes for consistency. During this phase, refinement of the codes continued as they were sharpened in response to new episodes. As the honing process progressed, I refined codes and then applied these rubrics to earlier transcripts until the coding process produced consistent

results. At each step of the analysis, I consulted with members of my research team to check the consistency of my procedures.

## Specific Case Study Methods

### Microanalysis of Image-based Discussion Strategies

Chapter 5 is a detailed narrative micro analysis of one teacher's use of image displays and has as its main purpose to identify and describe image-based discussion strategies used by the teacher as he employed the image. Even though this analysis in Chapter 5 is presented first, it is the end result of a four-year process of video analysis and coding that had as its goal carefully refined construct development.

The initial step in the analysis of the videos was the repeated viewing of a pair of lessons, one lesson using a simulation and one lesson using an overhead, taught by the author, each of which had matched lesson plans and content goals but differed in the type of image used (Table 1). During the first phase of the analysis of the first simulation and overhead lesson pair, a second researcher, Abi Liebovitch, and I did joint coding. A first step was to identify when displayed images are used with large group discussion to develop the content goal of the lesson. Once these episodes of the class were identified I examined the large group discussions occurring during the use of the image.

Starting from open coding, a constant comparative method was used, and the emerging and evolving descriptions of strategies were linked to the video and verbatim transcript data. Notes taken during this analysis were used to begin to describe and categorize 4 second to 4 minute time scale teaching strategies that appeared to be intended to encourage student reasoning. This occurred during the discussion of the image as the teacher attempted to use the displayed image of the particulate model to

explain macroscopic events. After the episodes of image-based discussion were identified, a detailed rubric was prepared and used to develop more formal names and descriptions of observed image-based teaching strategies. Hypotheses about how these connect to the affordances of the image medium used were formulated. This self-study of a pair of lessons was informed by an inside perspective on teacher thinking as it unfolded during the lessons. It used and built on the theoretical perspectives developed in the literature review and drew on discussions that explore how the teacher manages issues of convergence and divergence. I consulted frequently with other members of my research team to gain an outside perspective during my analysis and to triangulate and verify descriptions of the teaching strategies with their observation, field notes and analysis of the video.

After the initial joint coding of the first lesson pair, I worked alone and applied the strategy constructs identified to analyze other paired overhead and simulation based model discussion episodes in the other 10 lessons in the data set. During this process, I consulted frequently with other members of my research team for their reactions to my descriptions of the teaching strategies and their links to transcript episodes. Since members of the research team were present in most classes as observers they were able to act as informed reactants and critics and influenced revisions to my coding constructs as they were applied to exemplars during development. When the refined list of strategies and their definitions became fixed, it was used to code and in some cases re-code the targeted sections of the 12 lessons.

As mentioned, Chapter 5 presents a narrative microanalysis of a simulation lesson taught by the author using the refined and final list of image-based discussion strategies. The goals of this chapter are to 1) to introduce the final version of image-based strategies definitions and 2) to describe how these strategies unfolded during this image-based discussion. This SIM lesson was selected since all the strategies were observed here and the narrative analysis benefited from the inside perspective of the author who taught the lesson and the outside perspective of Leibovich who did the initial joint coding of this lesson. The Overhead lesson of this lesson pair will be discussed in a later chapter. This microanalysis of a simulation lesson addresses Research Question 2. (What whole class discussion strategies were used with image displays by teachers to scaffold the development of a visualizable particulate model of a gas?)

**Lesson Comparison Case Studies of an Overhead Lesson and Simulation Lesson Taught by Two Different Teachers (2x2)**

The purpose of each 2x2 comparative case study is to compare how the image-based strategies were used with different image modes. (How often are strategies used and which are most common?) and how did different teachers enact the same lesson plans (How did they use strategies differently?)

A lesson refers to an episode of large group discussion that is intended to address a challenging and central element of the model and lasted approximately 20-40 minutes. Each 2 x 2 comparative case study examined a total of 4 lessons. I used the previously developed code definitions of Image-Based Discussion moves to understand and characterize how teachers used images (Chapter 5, Table 5-2). In addition, to better understand how the difference in teachers may have affected discussion, I coded for four

patterns of interaction: presentation, IRE, IRF, and other (chapter 6, Table 6-10). After codes developed were revised and refined over multiple transcripts and I used them to count instances and time spent on the teaching strategies used during an overhead—simulation pair of lessons taught by two teachers. A narrative and counting code analysis was used to generate hypotheses about (1) research question 3 concerning how teaching in the simulation and overhead modes can differ; and (2) research question 4 concerning how two teachers may differ in their approach to instruction using projected imagery.

This part of the analysis included a study of the lesson plans and attempted to track how these parts of the lesson plans were enacted by the teacher. By examining how external images were planned to be used and then how the external images were actually used by teachers to lead discussions of internal imagistic models, a description and comparison of image use for planning and during enactment was made. In general, the transcript examples of these teachers attempting to engage student reasoning about this model are not being presented here as exemplars of expert teaching but instead serve as snapshots of these teachers developing the skills needed to manage a discussion of a complex visual. Through this analysis of lesson plans and selected imagistic model discussion episodes in simulation and overhead lessons, an extended, in-depth, 2x2 comparative case study of two teachers teaching one lesson topic with two image modes is presented in Chapter 6. Thus this comparative case study examines a total of 4 lessons.

**Lesson Comparisons for Six Pairs of Overhead-Simulation Lessons Taught by Three Different Teachers (2x2x3 design )**

I then used these methods to complete a similar analysis of two other 2 x 2 sets of classes, one set for each lesson topic. The three sets are shown in three different colors in

Table 3-1 in terms of coded teacher behaviors. Each set will correspond to chapters 6-8. That is, each set will compare two teachers on a single lesson, and teacher behaviors in each condition will be coded and compared. Differences in behaviors across teachers will also be described. Analysis in b) and c) above will address Research Question 3 (How were lessons with common content goals planned and enacted differently when using different image modes?) and Research Question 4 (Differences between Teachers in Discussions. Were there differences in how the different teachers provide a context for and employ the image to discuss the model? If so, how can these differences be described?)

## Limitations and Generalizability in the Design

This is not a traditional experimental design with all but one narrow variable held constant. Rather, there are multiple differences between the two conditions, centered around the use of a static or dynamic display in a naturalistic setting. Such a rich contrast should facilitate finding new phenomena in the comparative case studies. Common patterns as well as differences across these comparisons will be noted in the conclusions. Sample sizes and the fact that it was not possible to assign students randomly to conditions limit the statistical inferences that can be made from the quantitative portion of this study. Consistent with this, conclusions will primarily take the form of exploratory hypotheses suggested by the data rather than being able to make rigorous statistical generalizations to a population.

The fact that I am strongly hedging any claims to statistical generalizability from the sample to a population does not mean that I am giving up what Clement (2000) calls theoretical generalizability and Yin (2003) calls analytical generalizability. New

strategies or principles identified in the qualitative portion of this study are theoretical ideas that can be tried out by readers in other contexts they deem similar and that may have a good chance of applying to those contexts. Kelly (2007) points out that such generalized principles or strategies take the form of heuristics; they are not guaranteed to work in a somewhat different sample, but they are valuable things to try to apply nevertheless. And their estimated power will then grow further if they are successfully applied in other contexts. van den Akker (2007) writes:

> Readers/users need to be supported to make their own attempts to explore the potential transfer of the research findings to theoretical propositions in relation to their own context. Reports on design research can facilitate that task of analogy reasoning by a clear theoretical articulation of the design principles applied and by a careful description of both the evaluation procedures as well as the implementation context. Especially a "thick" description of the process-in-context may increase the 'ecological' validity of the findings, so that others can estimate in what respects and to what extent transfer from the reported situation to their own is possible.

What the statistical portion of this study should do is to focus me on any findings within my sample that beg explanation; thereby motivating the qualitative case studies. Any theoretical findings and constructs from the qualitative study should generalize analytically (Yin, 2003) where readers find that they can explain some of their own observation patterns using the constructs.

# CHAPTER 4

# QUANTITATIVE PRE-POST ANALYSIS

## Pre-Posttest Analysis: Introduction

The primary purpose of this dissertation is to use qualitative case studies to formulate new descriptions of teaching strategies used with image displays to foster conceptual learning. Pre-post test results cannot speak directly to this purpose. However, it seems natural to ask whether the case studies will be examining classrooms where some learning occurred. So a first purpose of pre-post analysis is to indicate whether some learning occurred in each condition and for each teacher being studied. For this purpose I will simply ask whether the posttest was significantly higher than the pretest for each group of interest.

A second possible purpose for pre-posttests is to test for learning differences between groups with the goal of projecting any significant differences to a larger population outside the study. Because the classes chosen to be Simulation and Overhead groups were ones to which students had been assigned by the schools, the participants in this study cannot be considered truly randomized. So if differences are found, one will need to hedge any suggestions of projecting to a population outside the study by describing any such result as exploratory. Another purpose of looking for gain differences is to simply describe any differences in learning between groups inside the study. These results will provide a context that motivates the central case studies in later chapters. Those studies will expose details in what was happening in each condition in the form of teaching strategies and these details may be able to explain the quantitative differences inside the study.

In the absence of randomization, one can use pretest results as an indicator of group similarity within the study. In this study, a comparison yielded that the pretest scores of the SIM condition and OV condition are not significantly different. An ANOVA comparing the differences in pretest scores by Image conditions found p greater than 0.05, suggesting that there was no significant difference between the two groups of students with respect to prior knowledge of the topics of the lesson [(Short: $p = 0.07$), (Long: $p = 0.17$) ]. The short answer test showed close to a significant difference in favor of the overhead condition. An ANOVA comparing the pretests of the three teachers' groups yielded no significant difference by teacher on the short answer pretest [$p = 0.42$] but a significant difference by teacher for the long answer pretest [$p = 0.03$]. This suggested that the groups of students differed somewhat with respect to prior knowledge.

Table 4-1a
Tests of Between Subject Effects for the Short Pretest Dependent Variable

| N=224 | | | |
|---|---|---|---|
| **Source** | **df** | **F** | **Sig.** |
| Condition | 1, 212 | 3.289 | .071 |
| Teacher | 2 | .869 | .421 |
| Teacher * Condition | 2 | .184 | .832 |

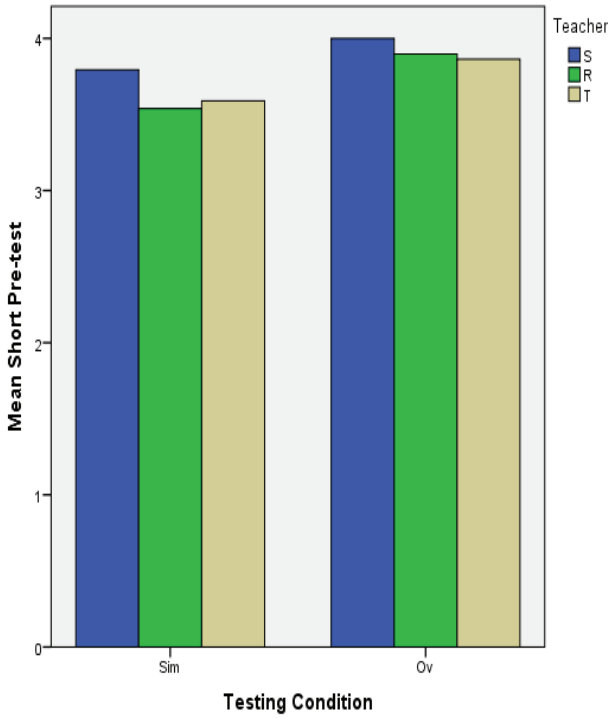



Figure 4-1a
Mean Short Pretest for Each Teacher in Each Condition

Table 4-1b
Tests of Between Subject Effects for the Long Pretest Dependent Variable

| N= 224 | | | |
|---|---|---|---|
| **Source** | **df** | **F** | **Sig.** |
| Condition | 1 | 1.909 | .169 |
| Teacher | 2 | 3.520 | .031 |
| Teacher * Condition | 2 | 2.528 | .082 |

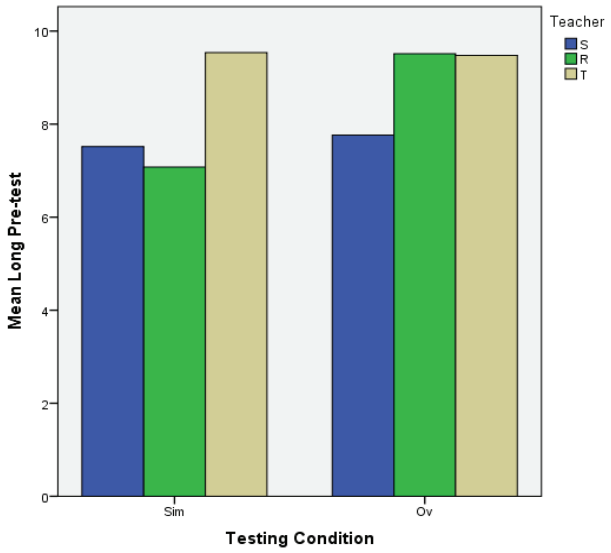



Figure 4-1b
Mean Long Pretest for Each Teacher in Each Condition

## Examining Gains: Did Some Learning Occur?

Rather than examining raw pretest and posttest scores via repeated measures, the dependent variable was the difference score between pretest and posttest, that is, the gain. The significance was tested using percent gain not the raw gain score. Thus percent gains from pretests to identical posttests are used for comparisons. Percent gains were computed for both the multiple choice section (short answer) and long answer questions section. One purpose of pre-post analysis is to indicate whether some learning occurred in each condition and for each teacher being studied. For this purpose I will simply ask whether the posttest was significantly higher than the pretest for each group of interest. Statistical analysis using an analysis of variance (ANOVA) with an alpha of 0.05 determined that the students in this study who received instruction in either Simulation- or Overhead-based lessons experienced significant pre-posttest score gains (Table 4-2). The students who received Simulation-based lessons scored significantly higher on their posttest than on their pretest [(Short: $p = 0.00$), (Long: $p = 0.00$)]. The students who

received overhead based lessons also scored significantly higher on their posttest than on their pretest [(Short: p = 0.00), (Long: p = 0.00)].

Table 4-2
Pre/Post Gains by Condition

| **SIM** | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 8.1 | 13.5 | 5.4 | 21.5 | 1 | 201.432 | .000 |
| (N=107) | Std. Deviation | 4.1 | 5.7 | 4.5 | 17.85 | | | |
| SHORT | Mean | 3.6 | 4.2 | 0.6 | 11.2 | 1 | 25.180 | .000 |
| (N=107) | Std. Deviation | 1.1 | 0.9 | 1.1 | 22.2 | | | |
| | | | | | | | | |
| **OV** | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
| LONG | Mean | 9.0 | 12.7 | 3.7 | 14.8 | 1 | 115.055 | .000 |
| (N=117) | Std. Deviation | 4.3 | 5.2 | 4.0 | 15.9 | | | |
| SHORT | Mean | 3.9 | 4.2 | 0.3 | 5.3 | 1 | 8.177 | .005 |
| (N=117) | Std. Deviation | .0.93 | 0.9 | 0.9 | 18.6 | | | |

Statistical analysis using an analysis of variance (ANOVA) with an alpha of 0.05 determined that the students in this study who received instruction by any teacher in the study experienced significant long answer pre-posttest score gains (Table 4-3a-c). The students who were taught the lessons by Mr. R and the students who were taught the lessons by Mr. T both scored significantly higher on both their long and short posttest than on their pretests [Mr. R (Short: p = 0.00), (Long: p = 0.00)], [Mr. T (Short: p = 0.00), (Long: p = 0.00)]. The students in the study who were taught the lessons by Mr. S scored significantly higher on their long posttest than on their long pretest. There was not

a significant difference between this groups short pretest and posttest [Mr. S (Short: p = 0.384), (Long: p = 0.00].

Table 4-3a
Pre-Post Gains for Students in Mr. S's Classes

| | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 7.65 | 11.86 | 4.206 | 16.83 | 1 | 92.232 | .000 |
| (N=63) | Std. Deviation | 4.080 | 4.662 | 3.543 | 14.17 | | | |
| SHORT | Mean | 3.90 | 4.00 | .0952 | 1.90 | 1 | .771 | .384 |
| (N=63) | Std. Deviation | 1.073 | .984 | 1.027 | 14.172 | | | |

Table 4-3b
Pre-Post Gains for Students in Mr. R's Classes

| | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 8.29 | 10.51 | 2.2179 | 8.8718 | 1 | 24.532 | .000 |
| (N=78) | Std. Deviation | 3.824 | 4.425 | 4.0729 | 16.29147 | | | |
| SHORT | Mean | 3.72 | 4.13 | .4103 | 8.2051 | 1 | 13.430 | .000 |
| (N=78) | Std. Deviation | .966 | .931 | .99917 | 19.98334 | | | |

Table 4-3c
Pre-Post Gains for Students in Mr. T's Classes

| | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 9.51 | 16.36 | 6.8554 | 27.4217 | 1 | 305.568 | .000 |
| (N=83) | Std. Deviation | 4.506 | 5.260 | 3.75835 | 15.03339 | | | |
| SHORT | Mean | 3.73 | 4.37 | .6386 | 12.7711 | 1 | 35.834 | .000 |
| (N=83) | Std. Deviation | 1.094 | .744 | 1.00703 | 20.14056 | | | |

The pre-post analysis indicates that some learning occurred in each condition and for each teacher being studied. The gain on the short answer test was not significant for Mr. S. and, as shown below, Mr. S had a negative short pre-post gain for his overhead classes. However, his gain on the long test was significant.

Another purpose of pre-post analysis is to indicate whether some learning occurred for each teacher being studied in each condition. For this purpose, I ask whether the posttest was significantly higher than the pretest for each teacher in each condition. Statistical analysis using an analysis of variance (ANOVA) with an alpha of 0.05 determined that the students in this study who received instruction in Simulation based lessons experienced significant pre-posttest score gains on the long answer portion of the test for all three teachers in this study (Tables 4-6, and Figures 4-3ab, 4-4ab, 4-5ab). The students who were taught the simulation-based lessons by Mr. R or by Mr. T scored significantly higher on their short posttest than on their short pretest [Mr. R's SIM Short: $p = 0.00$), Mr. T's SIM Short: $p = 0.00$)]. There was not a significant difference between short pretest and posttest for students taught simulation based lesson by Mr. S. [Mr. S SIM short: $p = 0.206$].There was not a significant difference between groups' short

pretest and posttest in the Overhead groups for Mr. S and Mr. R. [Mr. S OV Short: p = 0.705, Mr. R OV short: p = 0.09].

Table 4-4
Pre-Post Gains for Mr. S's Students in Each Condition

| **Mr S SIM** | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 7.5 | 12.5 | 5.0 | 20.0 | 1 | 46.853 | .000 |
| (N=29) | Std. Deviation | 4.0 | 4.7 | 3.9 | 15.6 | | | |
| SHORT | Mean | 3.8 | 4.1 | 0.3 | 5.5 | 1 | 1.680 | .206 |
| (N=29) | Std. Deviation | 1.1 | 1.0 | 1.2 | 23.2 | | | |
| | | | | | | | | |
| **Mr. S OV** | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
| LONG | Mean | 7.8 | 11.4 | 3.6 | 14.4 | 1 | 43.505 | .000 |
| (N=34) | Std. Deviation | 4.2 | 4.6 | 3.1 | 12.6 | | | |
| SHORT | Mean | 4.0 | 3.9 | - 0.1 | -1.2 | 1 | .145 | .705 |
| (N=34) | Std. Deviation | 1.1 | 1.0 | 0.9 | 17.7 | | | |

Figure 4-2a
Mr. S Long Answer Pre-Postest Means Over Time in Each Condition

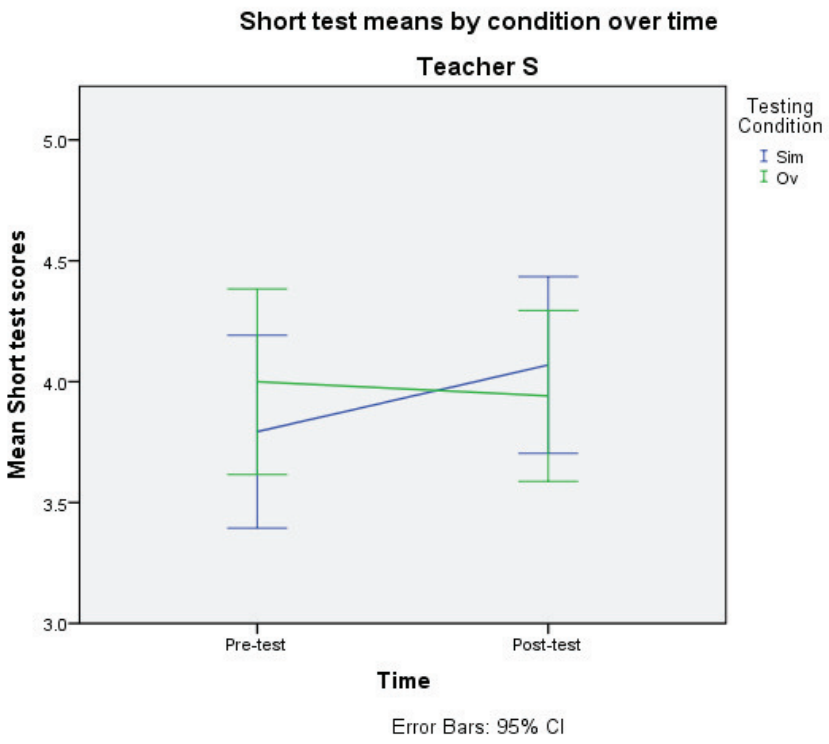



Figure 4-2b
Mr. S Short Answer Pre-Post Means Over Time in Each Condition

Table 4-5
Pre-Post Gains for Mr. R's Students in Each Condition

| **Mr R SIM** | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 7.1 | 10.0 | 2.9 | 11.8 | 1 | 20.1 | .000 |
| (N=39) | Std. Deviation | 3.7 | 4.6 | 4.2 | 16.8 | | | |
| SHORT | Mean | 3.5 | 4.1 | 0.6 | 11.2 | 1 | 11.108 | .002 |
| (N=39) | Std. Deviation | 1.1 | 1.1 | 1.1 | 21.4 | | | |
| | | | | | | | | |
| **Mr R OV** | | **Pretest** | **Posttest** | **PrePost Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
| LONG | Mean | 9.5 | 11.0 | 1.5 | 5.9 | 1 | 5.626 | .023 |
| (N=39) | Std. Deviation | 3.6 | 4.2 | 3.9 | 15.5 | | | |
| SHORT | Mean | 3.9 | 4.2 | 0.3 | 5.1 | 1 | 3.037 | .090 |
| (N=39) | Std. Deviation | 0.8 | 0.8 | 1.0 | 18.2 | | | |

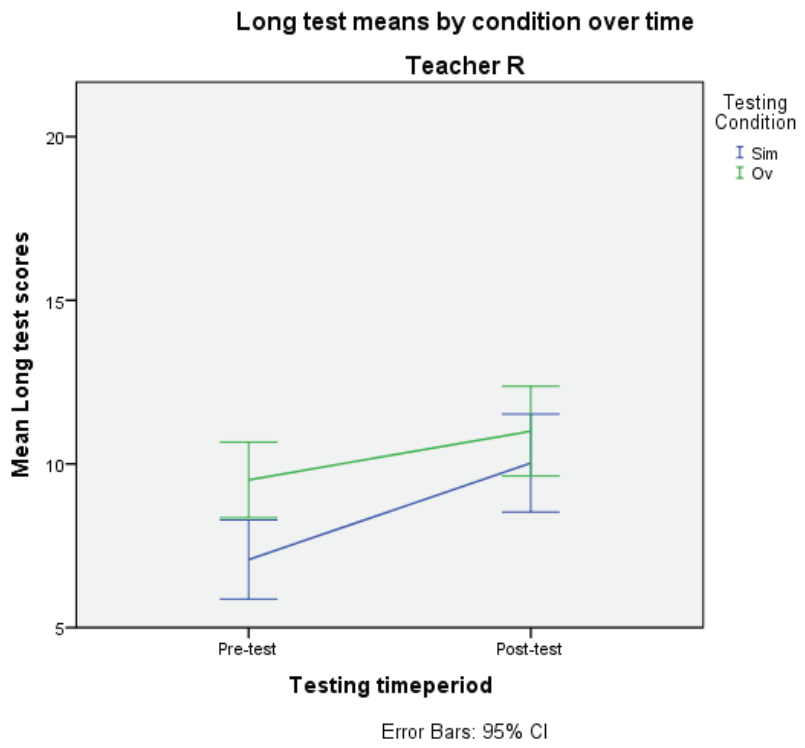



Figure 4-3a
Mr. R Long Answer Pre-Posttest Means Over Time in Each Condition

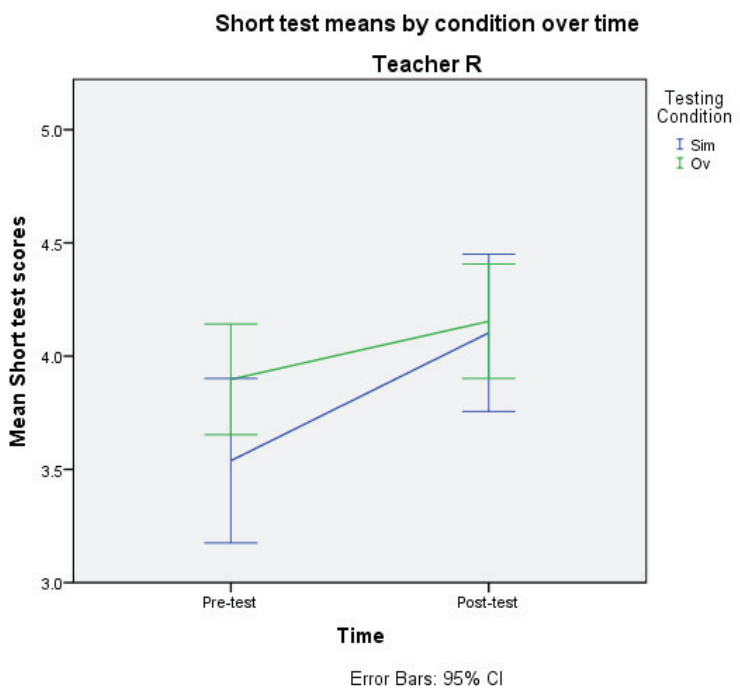



Figure 4-3b
Mr. R Short Answer Pre-Posttest Means Over Time in Each Condition

Table 4-6
Pre-Post Gains for Mr. T's Students in Each Condition

| **Mr.T SIM** | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 9.54 | 17.67 | 8.13 | 32.5 | 1 | 203.011 | .000 |
| (N=39) | Std. Deviation | 4.1 | 4.6 | 3.6 | 14.3 | | | |
| SHORT | Mean | 3.6 | 4.4 | 0.8 | 15.4 | 1 | 20.629 | .000 |
| (N=39) | Std. Deviation | 1.2 | 0.7 | 1.1 | 21.7 | | | |
| | | | | | | | | |
| **Mr.T OV** | | **Pretest** | **Posttest** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
| LONG | Mean | 9.58 | 15.20 | 5.73 | 23.0 | 1 | 108.846 | .000 |
| (N=44 | Std. Deviation | 4.9 | 5.6 | 3.6 | 14.4 | | | |
| SHORT | Mean | 3.86 | 4.39 | .52 | 10.45 | 1 | 14.649 | .000 |
| (N=44) | Std. Deviation | 0.96 | 0.78 | 0.93 | 18.55 | | | |

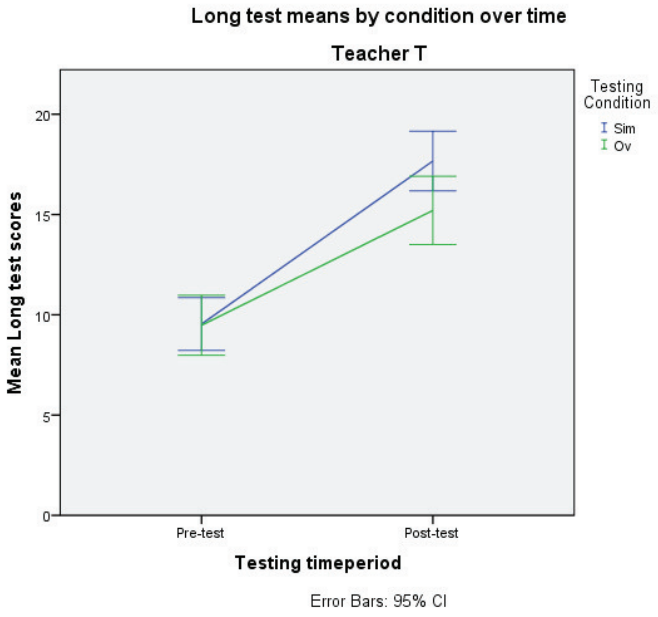



Figure 4-4a
Mr. T Long Answer Pre-Posttest Means Over Time in Each Condition

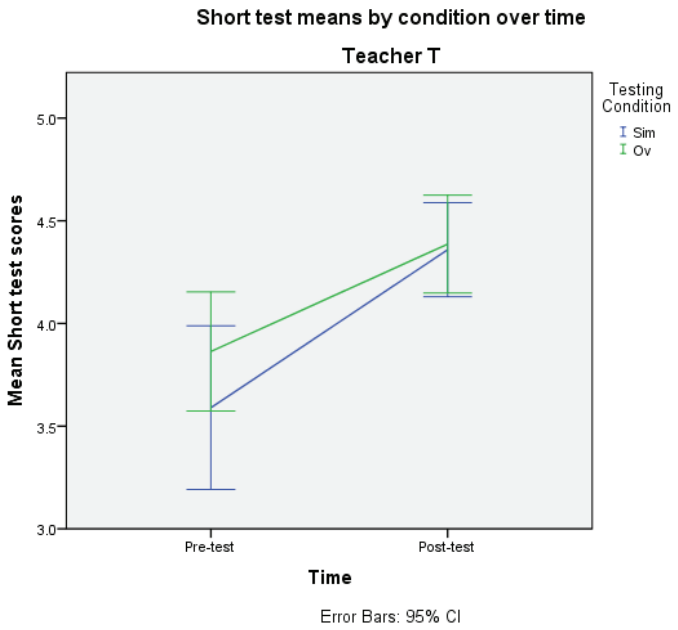



Figure 4-4b
Mr. R Short Answer Pre-Posttest Means Over Time in Each Condition

## Comparison by Condition using Short and Long Answer Pre-Post Results

An analysis of variance test was used on the 3 teacher x 2 condition x 2 classes design. No significant interaction between teacher and condition [(Short: $p = 0.93$), (Long: $p = 0.70$)] was found. Since there was no significant interaction between teachers and condition, there is evidence that students responded to the condition similarly, and thus, an analysis of variance of these results by Condition alone and by Teacher alone was conducted similarly. On the long answer and short answer pre-post, a Condition difference [(Short: $p = 0.03$), (Long: $p = 0.00$)] and Teacher difference [(Short: $p = 0.01$), (Long: $p = 0.00$)] were found (Table 4-2a and 4-2b).

Table 4-7a
Tests of Between-Subject Effect for the Short Percent Gain Dependent Variable

| N = 224 | | | |
|---|---|---|---|
| **Source** | **df** | **F** | **Sig.** |
| Condition | 1 | 4.826 | .029 |
| Teacher | 2 | 4.848 | .009 |
| Teacher * Condition | 2 | .073 | .930 |

Table 4-7b
Multiple Teacher Comparisons for the Long Percent Gain Dependent Variable

| N = 224 | | | |
|---|---|---|---|
| **Source** | **df** | **F** | **Sig.** |
| Condition | 1 | 12.896 | .000 |
| Teacher | 2 | 31.555 | .000 |
| Teacher * Condition | 2 | .363 | .696 |

Statistical analysis using ANOVA with an alpha of 0.05 determined that the students in this study who received instruction in Simulation-based lessons experienced significantly greater pre-posttest score gains than the students who received instruction in Overhead-based lessons [(Short: $p = 0.02$), (Long: $p = 0.00$)]

Table 4-8ab
ANOVA Results which Examined Changes in Student Scores in Short Answer Pretest to Posttest for Each Condition
(Combines results from 3 teachers: 6 SIM classes (N=107) and 6 OV classes (N=117)

| **Table 4-8a** | | **Short Pretest** | **Short Posttest** | **Short Post Gain** | **Short Percent Gain** |
|---|---|---|---|---|---|
| SIM SHORT N=107 | Mean | 3.6 | 4.2 | 0.6 | 11.2 |
| | Std. Deviation | 1.1 | 0.9 | 1.1 | 22.2 |
| OV SHORT N=117 | Mean | 3.9 | 4.2 | 0.3 | 5.3 |
| | Std. Deviation | 0.9 | 0.87 | 0.9 | 18.6 |

| **Table 4-8b** | **SIM Short Percent Gain** | **OV Short Percent Gain** | **df** | **F** | **Sig** |
|---|---|---|---|---|---|
| Mean | 11.2 | 5.3 | 1, 212 | 4.826 | .029 |
| Std. Deviation | 22.2 | 18.6 | | | |

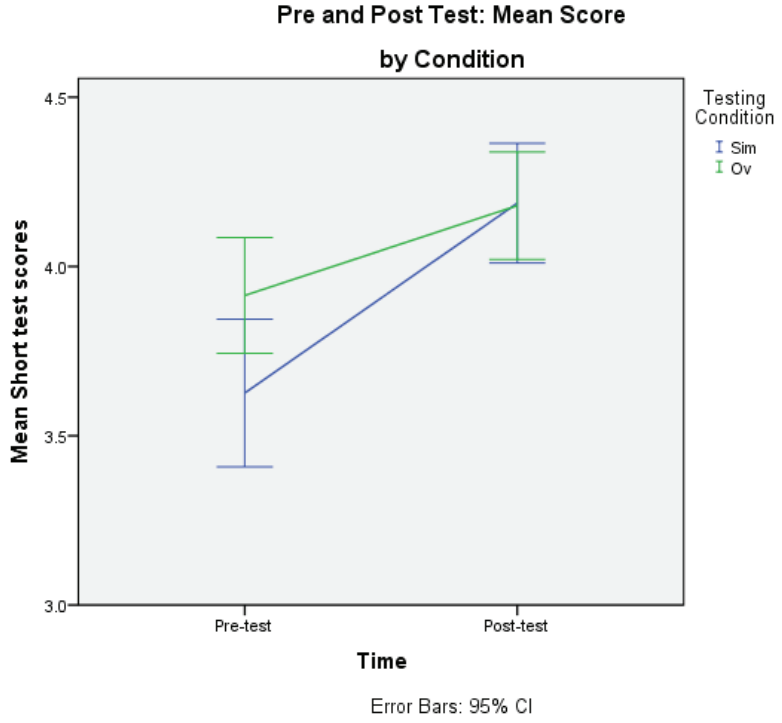



Figure 4-5
Short Answer Pre- and Posttest Means of the OV and SIM Groups

Table 4-9ab
ANOVA Results which Examined Changes in Student Scores in Long Answer Pretest to Posttest for Each Condition
(Combines results from 3 teachers' 6 SIM classes (N=107) and 6 OV classes (N=117)

| **Table 4-9a** | | **Long Pretest** | **Long Posttest** | **Long Post Gain** | **Long Percent Gain** |
|---|---|---|---|---|---|
| SIM LONG N= 107 | Mean | 8.1 | 13.5 | 5.4 | 21.5 |
| | Std. Deviation | 4.1 | 5.7 | 4.5 | 17.85 |
| OV LONG N=117 | Mean | 9.0 | 12.7 | 3.7 | 14.8 |
| | Std. Deviation | 4.3 | 5.2 | 4.0 | 15.9 |

| **Table 4-9b** | **SIM Long Percent Gain** | **OV Long Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|
| MEAN | 21.5 | 14.8 | 1,212 | 12.9 | 0.000 |
| Std. Deviation | 17.85 | 15.9 | | | |

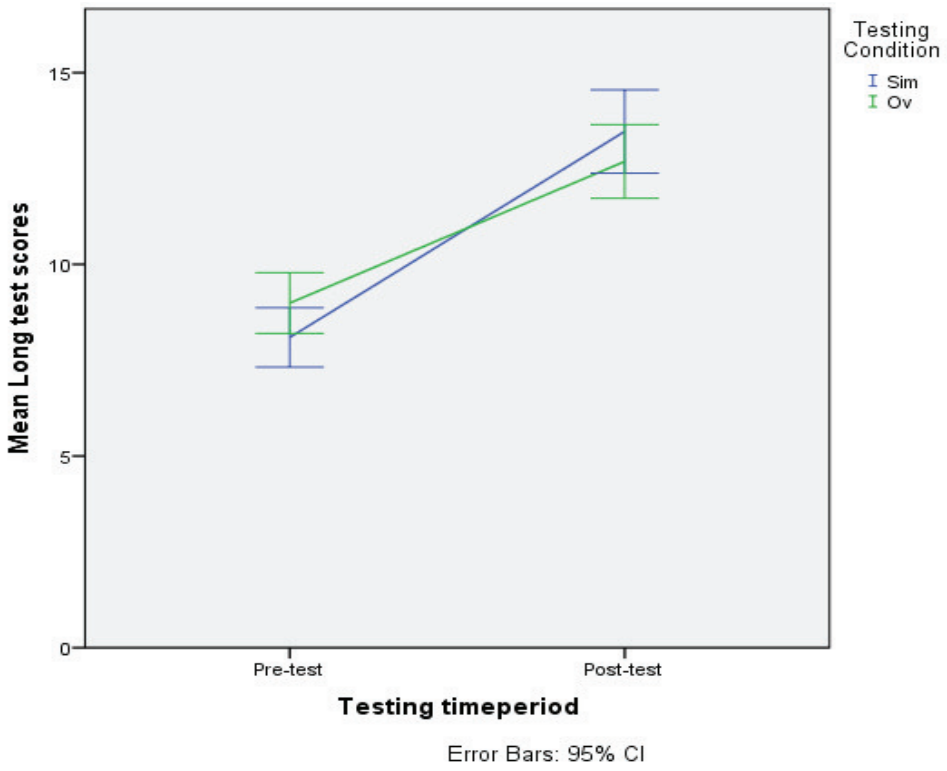



Figure 4-6
Long Answer Pre- and Posttest Means of the OV and SIM Groups

## Comparison by Teacher using Short and Long Answer Pre-Post Results

An ANOVA by teacher revealed significant gain differences between the three teachers for the long answer pre-post and significant gain differences between two teachers for the short answer pre-post (Table 4-10ab)

Table 4-10a
Multiple Teacher Comparisons for the Short Percent Gain Dependent Variable

| (I) Teacher | | Mean Difference (Teacher - Comparison) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| S | R | -6.3004 | 3.40098 | .155 | -14.3277 | 1.7269 |
| | T | -10.8663* | 3.35489 | .004 | -18.7849 | -2.9478 |
| R | S | 6.3004 | 3.40098 | .155 | -1.7269 | 14.3277 |
| | T | -4.5660 | 3.16620 | .321 | -12.0391 | 2.9072 |
| T | S | 10.8663* | 3.35489 | .004 | 2.9478 | 18.7849 |
| | R | 4.5660 | 3.16620 | .321 | -2.9072 | 12.0391 |

Tukey HSD Based on observed means.
The error term is Mean Square(Error) = 403.110. The mean difference is significant at the 0.05 level

Table 4-10b
Multiple Teacher Comparisons for the Long Percent Gain Dependent Variable

| Multiple Comparisons Dependent Variable: Long Percent Gain | | | | | | |
|---|---|---|---|---|---|---|
| (I) Teacher | | Mean Difference (Teacher - Comparison) | Std. Error | Sig. | 95% Confidence Interval | |
| | | | | | Lower Bound | Upper Bound |
| S | R | 7.9536* | 2.52915 | .005 | 1.9841 | 13.9231 |
| | T | -10.5963* | 2.49488 | .000 | -16.4849 | -4.7076 |
| R | S | -7.9536* | 2.52915 | .005 | -13.9231 | -1.9841 |
| | T | -18.5499* | 2.35456 | .000 | -24.1073 | -12.9924 |
| T | S | 10.5963* | 2.49488 | .000 | 4.7076 | 16.4849 |
| | R | 18.5499* | 2.35456 | .000 | 12.9924 | 24.1073 |

(Tukey HSD) Based on observed means.
The error term is Mean Square(Error) = 222.929. *. The mean difference is significant at the 0.05 level.

## Conclusion

The significant gains in pre-posttests suggests that learning occurred in the both image conditions (Tables 4-3ab), and, in most cases, for each teacher (Tables 4-4abc). The significant gain differences found between image mode conditions suggest that the students who were assigned to the simulation condition learned more, on average, than students who were assigned to the overhead condition. It will be interesting to see whether the qualitative findings later in this study can provide grounded hypotheses for explaining this difference.

In conclusion, in response to Research Question #1: "Was there a difference in content learning between students who were taught with a set of simulation based lessons and students who were taught with a set of static overhead based lessons?" the answer regarding the sample studied, as measured by the pre- and posttests, appears to be "yes". An analysis by teacher yielded a significant difference in learning gains between all the teachers on the long answer test and between one pair of teachers on the short answer. These gain difference suggests that teaching behaviors used to employ different image modes is an interesting topic to study. These findings also suggest that the image mode is not the only variable at work here. The specific nature of the teaching strategies and teacher behaviors employed in these lessons will be investigated further in the following case study chapters.

Again it is important to note that because of limitations on the sample used in this study, these statistical findings must be considered exploratory, and one cannot project the findings to a population outside the study in a rigorous way. I am using them

primarily as part of a mixed methods approach to provide quantitative descriptions to any differences in learning between groups inside the study.

# CHAPTER 5

# TEACHING STRATEGIES FOR USING IMAGES IN THE CLASSROOM: A DESCRIPTIVE CASE STUDY OF A SIMULATION-BASED LESSON

## Plan for the Next Four Chapters

Chapter 5 is qualitative analysis of a smaller database of one lesson taught by one teacher. This qualitative study will introduce, describe, and define the strategies that were observed in this lesson. Even though this analysis in Chapter 5 is presented first, it is the end result of a four-year process of video analysis and coding of all 12 lessons that had as its goal carefully refined construct development. The strategy categories developed through this process were used for coding the other lessons. Following Chapter 5, are three chapters (Chapters 6, 7, and 8) that each compare 2 teachers' use of simulation and overhead images. Those chapters provide a qualitative analysis of a larger database, and will look at12 lessons, (4 lessons for each teacher.)

## Chapter Overview

This case study analyzes a discussion from a simulation-based lesson on molecular motion taught by the author. The goal of this study is to introduce and define as a set of short time scale image-based discussion moves (4 seconds to 4 minutes) that the teacher used to employ an image in a lesson. This Simulation (SIM) lesson was selected since all the strategies were observed here and the narrative analysis benefited from the inside perspective of the author who taught the lesson and the outside perspective of the Leibovich who did the initial joint coding of this lesson. The Overhead (OV) lesson of this lesson pair will be discussed in Chapter 8. Chapter 5 will describe how these moves were used chronologically as the lesson unfolded and will provide a

definition and transcript example of the moves that will be used to code other lessons as part of comparative case studies in later chapters. These image-based discussion moves, such as orienting, highlighting, linking, and framing, were intended to foster student engagement with the simulation and to encourage active reasoning. Among the moves identified was situating students in an overlay simulation. This involved encouraging student to imagine themselves as part of a complex overlay simulation. In an overlay simulation, a simulation of the particle model was projected on top of a representation of the students embedded in the macroscopic phenomenon they were trying to explain. This microanalysis of a simulation lesson addresses Research Question 2: What image-based discussion moves (small time scale strategies spanning 4seconds to 4 minutes) were used by teachers to navigate image-based discussions?

## Introduction

Middle school students struggle to understand many aspects of the particulate nature of matter. This study explores and describes whole class discussion strategies used to incorporate a computer simulation into a lesson with content goals about this subject.

## The Lesson: *Matter and Molecules*

In this study, I examine one teacher as he led his class through a lesson in Matter and Molecules (Lee, Eichinger, Anderson, Berkheimer, & Blakesee, 1993).

### Initial Student Model at the Start of this Lesson

Since this lesson goal is to develop a student model, it is useful to describe briefly the hypothesized student initial model at the start of this lesson. This study begins at a point about two weeks into the Matter and Molecules curriculum. At this point in the

curriculum, the students had been presented with a model of air, described as a gas composed of N2, CO2, O2, and H2O molecules, which are spread apart and bouncing around. This model of air had been presented through readings, teacher presentation, and static images, but students had not seen any animations of molecules up to this point in the unit.

### The Computer Simulation: *Atomic Microscope*

In the current case study, the target concept of molecular motion is inaccessible for direct manipulation or observation. In order to provide students with an opportunity to observe what happens, on a microscopic level, when a scent travels across a room, the teachers in the study decided to add a simulation from Atomic Microscope (Stark Design, 2003) to the lesson. Since these animations contain controls for manipulating variables, they are referred to here as simulations. Though it provided a rich set of static visuals, the Matter and Molecule curriculum was written before simulations of this sort were widely available, and thus, there was no guidance about how a simulation might be used to enhance this lesson.

### Challenges of Using Dynamic Visuals

In their work with multimedia, Mayer and Moreno (2002) describe how using words and pictures together, rather than either alone, can produce better gains in retention and understanding. In this lesson, the simulation acts only as a picture, since it does not contain any text or narration. The class discussion surrounding the animation acts as the supporting text. In his work, Lowe (2003) describes how dynamic visuals, like simulations, make greater processing demands on students than static images and that

students need help determining which parts of a simulation's complex visual displays are most important (useful for understanding the information it presents). Since there is more to using a simulation then simply showing it, there is a need to examine how discussion and simulation function together in minute to minute interactions in a naturalistic class setting.

## Whole Class Discussion

### The Importance and Complexity of Discussions

The importance and complexity of discussions has been cited by many other authors interested in science instruction (Lump & Staver, 1995; McNeill & Krajcik, 2008; Shulman, 2000; van Zee & Minstrell, 1997). Some studies have described general strategies teachers can use to encourage active student participation. Engle and Contant (2002), for example, describe how teachers can encourage discussions by fostering "productive disciplinary engagement" (p _) in the classroom. In classes that encourage productive disciplinary engagement, students are expected to problematize the concepts they are learning—to ask questions, test out hypotheses and generally grapple with the material they are learning— rather than serve as passive recipients of knowledge. In these classes, the students are taught that their contributions are a valid and important part of the process of learning. Similarly, in their paper on questioning in the classroom, van Zee and Minstrell note that in "inquiry teaching," (p_) teachers must be prepared to shift their agenda and ask different questions in response to student contributions throughout the lesson. During these lessons, the authors note, teachers can also shift the role of evaluating student responses to the class as a whole.

## The Need for Cognitive Strategies for Discussion

While these studies provide an important framework for how to encourage student participation in science classes more generally, they often do not explicitly address how to use cognitive strategies in discussions to reach content goals. I have found two perspectives in the literature that do attempt to address explicitly how to reach content goals using whole class discussion and that can help to explore the complexity of a discussion that develops around a complex dynamic visual, like a simulation. Both of these approaches were developed by studying student-teacher talk in naturalistic settings in secondary science classrooms and have been used to support teachers as they develop the skills needed to manage complex discussions.

## The Communicative Approach Perspective

For my analysis in this and subsequent chapters, I will be using the concepts of authoritative and dialogic communicative approaches as defined by Mortimer and Scott (2003) in their work Meaning Making in Secondary Classrooms. It is important to note that while their work draws on concepts of authoritative/dialogic discourse developed by Bakhtin (1981), these concepts have been adapted and modified for the particular purpose of understanding and encouraging different forms of student and teacher talk in secondary science classrooms. Scott, Mortimer, and Aguiar (2006) characterize talk between teachers and students in classrooms along two axes: authoritative/dialogic and interactive/non-interactive (see Figure 5-1). The authoritative communicative approach, they argue, takes place when teachers are interested in communicating one concept or perspective to their students (typically the “expert” perspective). Dialogic communicative approach, in contrast, occurs when the teacher encourages or is open to a variety of

different perspectives or ideas. Mortimer et al. contend that many teachers rely too heavily on authoritative approaches, when students can most effectively explore scientific ideas through a dialogic, highly interanimated, interactive approach. Interanimation refers to the degree to which a class is encouraged to engage with these different perspectives, comparing and contrasting different ideas to further explore the targeted scientific concept. The authors argue that having open periods of discussion, when students are encouraged to interact with each other around the material without being evaluated against the expert model, is critical to making meaningful conceptual gains.

Table 5-1
The Two Dimensions of Classroom Discussion (Scott et al., 2006)

| | **Interactive** | **Non-interactive** |
|---|---|---|
| **Dialogic** | Interactive /Dialogic | Non-interactive /Dialogic |
| **Authoritative** | Interactive /Authoritative | Non-interactive /Authoritative |

Importantly, however, Scott et al. (2006) do not believe that teachers need to use a dialogic, highly interanimated, interactive approach at all times during their lessons. Rather, they argue that "any sequence of science lessons, which has as its learning goal the meaningful understanding of scientific conceptual knowledge, must entail both authoritative and dialogic passages of interaction" (p. 606). Thus, over the course of a lesson, the teacher can constantly be moving the discussion up and down the axes of these two dimensions depending on "the teaching purpose," (p.xx) or the learning goals, for that part of the lesson.

## Model-based Co-construction

In his work on model evolution via co-construction, Clement (2008) offers a framework for how to use student ideas to reach content goals. Model-based learning refers to the process by which people acquire and assimilate knowledge into explanatory mental models. Research shows that expert scientists use mental models to reason through scientific problems and make predictions in novel cases (Clement 2003, 2004). Studies conducted on science classes have shown that supporting students in the construction of mental models can also enhance their understanding of difficult scientific concepts (Johnson & Stewart, 1990; Krajcik et al., 2006; Nunez-Oviedo, 2005; Reiser et al., 2003; White & Frederiksen, 2000; Williams & Clement, 2007). In her research on scientific reasoning among students, Hegarty argues that once students have constructed a dynamic mental model, they can manipulate it to reason about different cases (Hegarty, Kriz, & Cate, 2003; Narayanan & Hegarty, 2002).

During model based co-constructed lessons, both students and teacher share responsibility for producing and analyzing ideas as they work together to build a consensus model of the target concept. Clement (2008) notes that in a co-constructed lesson, it is important that the "knowledge developed is largely student generated but at the same time, the agenda is largely teacher directed" (p.27). Importantly, students are not expected to understand the model right away. Rather, over the course of the lesson, the teacher scaffolds the students learning process as the students build an increasingly sophisticated mental model of the target concept. This often happens in stages, as the teacher presents students with activities, demonstrations, or new information designed to prompt students to evaluate and revise their initial models (Figure 5-1).

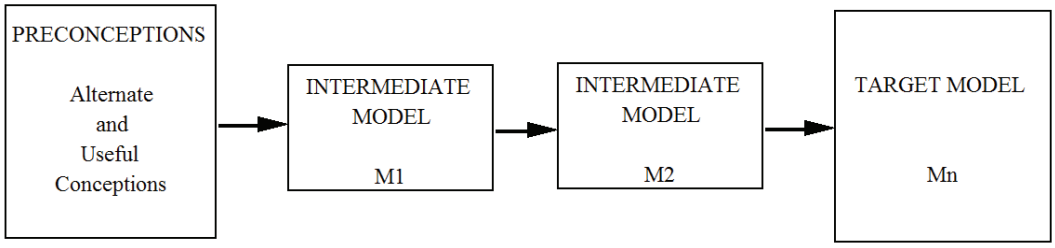



Figure 5-1
Diagram of the Model Evolution Process
(Instruction is directed at helping a student move from model Mn to model Mn+1 and toward a target model [Clement, 2000])

There are a number of studies that identify teaching strategies that can be used during model-based instruction. Many of these studies highlight cognitive strategies that teachers might use to engage students in reasoning or to encourage visualization. For example, teachers can engage their class in the co-construction of a target model by scaffolding student movement through the different phases of the GEM (Generation, Evaluation, Modification) cycle (Nunez-Oviedo, 2005, Williams & Clement, 2007). A GEM cycle is the process of "generation, evaluation and modification" (p.xx) that scientists use to construct conceptual models (Clement, 1989). Hegarty et al. (2002) found that asking students to make predictions or answer "what if" questions can encourage them to engage in mental animations. This can also serve to support model generation. Other studies have identified dissonance-producing strategies that teachers can use to inspire independent student evaluation of model components (Clement & Rea-Ramirez, 1998). For example, opportunities for model competition, and presenting students with discrepant events, are dissonance creating strategies (Clement & Rea-Ramirez, 1998; Nunez-Oviedo, 2005; Rea-Ramirez & Nunez-Oviedo, 2008).

## Theoretical Framework for the Analysis of Lesson

### Two Lenses

In this study, the communicative approach perspective and model-based co-construction are used to examine the complexity of the discussion that develops around a complex dynamic visual in a lesson about the particulate nature of matter. These two theoretical frameworks taken together provide a way to explore how whole-class discussions can be used by teachers to engage active student thinking while efficiently meeting content goals. The communicative approach describes the importance of alternating between teacher and student points of view, and exploring student sense-making during a discussion. However, little has been written, from the communicative approach perspective, on how teachers can generate agendas for using the specific student ideas during a lesson to encourage conceptual change. Research on model co-construction provides cognitive strategies for using student ideas to support conceptual change, via model evolution. The model co-construction literature offers a framework for setting an agenda to navigate the complex discussions which unfold when teachers attempt to explore and respond to complex student ideas in co-constructed lessons.

Both frameworks offer useful theoretical perspectives for exploring the structure of a simulation-based lesson and describing how a teacher attempts to surround a simulation with a productive (content +) and engaging (thinking +) discussion. In this chapter, I examine one lesson from the Matter and Molecules curriculum that was modified to incorporate a simulation. I describe the smaller scale moves that the teacher used to navigate the complex discussion that unfolded as the teacher and students interacted with the dynamic visual. I use both frameworks to examine how the lesson

strategies and discussion moves may have functioned in the lesson. Some of the strategies and moves I describe will apply specifically to the use of a simulation, while other strategies and moves could be generalized for use in other contexts.

## Lesson Analysis

### Overview of the Lesson

The lesson began with a demonstration of releasing perfume in the air. During this lab demonstration section of the lesson, the teacher presented a common sensory experience as an anchoring observation case. Then the teacher discussed the concept of the lesson but no image was displayed. In this non-image discussion section of the lesson, students were asked to construct molecular explanations of how they smelled the perfume. Then a simulation (Stark Design, 2003) representing air and cookie molecules was projected and a focused discussion of the image was used to attempt to develop the students' mental model for scent. During this image-based discussion section of the lesson, the students were asked to imagine a smell from a cookie baking and use their molecular model of air to explain how and why they could smell the cookies.

### Lab Demonstration Section of the Lesson

In the first part of the lesson, the teacher presented a common sensory experience as an anchoring observation case. The teacher placed a drop of lavender perfume on a glass slide and walked around the room with the slide until all the students had smelled the perfume. The perfume served to provide a common macroscopic phenomenon for all students in the class to explain and, thus, provide a foundation for the discussion. In this

section of the lesson, many students were speaking at once as they made efforts to smell the perfume and share their identification with their neighbors.

**Analysis of Lab Demonstration**

By offering a moment for students to engage and share these memories with their peers, the teacher offered students a low risk way to engage in the discussion about their everyday lives. These low risk participation opportunities may contribute to class norms which communicate the expectation that student will share their ideas.

## Non-image Discussion Section of the Lesson

After student had observed the perfume, the teacher discussed the concept of the lesson but no image was displayed. I refer to this as the non-image discussion. During this section of this lesson, the teacher asked students to observe a demonstration of perfume being released in the air, and then invited students to explain how smell works in terms of molecules.

## Narrative Description of Non-image Discussion

Students were then asked to use molecules to explain how the perfume traveled from where it was released to their nose. Responding to this question, they were given the opportunity to articulate their model. The intended goal of this prompt was to encourage students to revise their model of air to include perfume molecules and to show how the molecules moved from the perfume slide to their nose. Students exchanged papers and noted the presence of key words provided by the teacher (perfume, slide, molecule, movement). The goal of this activity was to engage students in the articulation and sharing of student models and emphasize the need for both macroscopic and microscope

elements of the model in their explanation. Students were asked to share their answers to this prompt during a large group discussion, but the responses were not formally evaluated by the teacher.

**Student Initial Models from the Non-image Discussion**

Asking student to share their models provided the teacher with information about the state of some of the student's initial model. In whole class discussions of their written answers, it was clear that students had a misconception described by Lee et al. (1993). For example, students still were using the macroscopic idea that still air could carry the smell, versus using the explanation in terms of perfume molecules bouncing into the nose.

Transcript 1

Steven: The molecules the lavender's made of each had a scent, and when combined with air molecules that we breathe it creates a certain scent which our nose can identify.

More importantly, students expressed uncertainty about this microscopic model and appeared to lack conviction that these explanations made sense.

Transcript 2

Teacher: OK, so you're breathing in air all the time, and so as you breath in air there's some perfume molecules in that mix and they're going in your nose too.

James: I guess, I don't' know how.

This uncertainty could be evidence of lack of a robust visualizable mental model of the microscopic events needed to explain the phenomena. Students had not yet experienced any computer simulation of this model in this unit.

## Analysis of Non-image Discussion

This non-image part of the discussion can be analyzed using both the communicative approach and model co-construction frameworks. Interpreted from the communicative approach framework, the fact that students are listening to and refining language used by peers in their answers, suggests this segment can be considered an example of interanimated discussion. Most of this occurred in small groups so transcripts of this section are not available. However, scoring activity was used to focus student attention on other student ideas and prompt students to ask for clarification about the language that students used to describe their models. Interpreted from the model construction framework, generation of possible model components is a key phase in the GEM cycles that takes place during model construction. In addition to having students generate models, the teacher also had them share what they wrote. By doing this, he was encouraging the students to compare the models presented by their peers and emphasized the need for students to use molecular model of a gas. In this framework then, this is an important step in the process of co-constructing a model for the target concept of molecular motion.

## Image-based Discussion Section of the Lesson

In the second part of the lesson, the teacher discussed the concept using a displayed image. In this lesson the image-based discussion used a simulation (Stark Design, 2003) representing air and cookie molecules that was projected onto a white board drawing, representing macroscopic elements of the phenomena (cookie and nose). I call this an overlay simulation (Figure 5-2). The purpose of an overlay simulation is to align microscopic elements of the simulation with macroscopic elements of the

phenomenon. In this case, the students were asked to imagine a smell from a cookie baking and use their model of air made of particles to explain how and why they could smell the cookies. A focused discussion of the overlay simulation was used by the teacher to attempt to engage students in the evaluation and modification of the student's initial mental model. In the Figure 5-2, the oval drawn at the right side of the simulation represents a cookie baking, and the triangle shapes to the left represents noses of students. The molecules are moving rapidly.

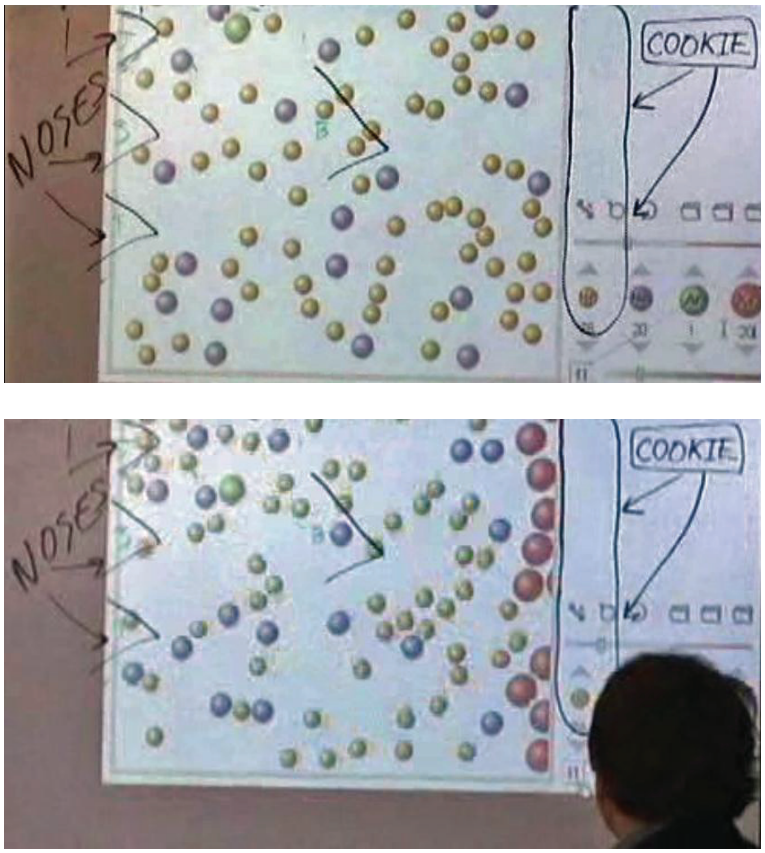



Figure 5-2
The Cookie/Nose Overlay Simulation
(shown before and after releasing the cookie molecules)

After students discussed their models about how perfume traveled to their noses, students were asked to use their model to explain how cookie smell would travel to their noses. To help them develop their molecular model of scent, a simulation representing air

and cookie molecules was projected onto a white board drawing, representing macroscopic elements of the phenomena, the cookie and the nose. The goal of this overlay simulation was to align microscopic elements of the simulation with macroscopic elements of the phenomena. In this case, the students were asked to imagine a smell from a cookie baking and use their model of air as made of particles to explain how and why they would smell the cookies. A focused discussion of the overlay simulation was used to attempt to scaffold the evaluation and modification of a robust visualizable mental model.

## Overview of Image-based Discussion Moves

The transcribed discussion associated with employing the simulation was complex. To develop a vocabulary to describe and analyze this discussion, codes for eight different discussion moves were described and defined.

### Image-based Moves Defined

The choice of how a teacher decides to navigate image-based discussions is referred to here as a "teacher move". These moves occurred on a 4 seconds to 4 minutes time scale. Since my main goal is to understand how the image is used in this lesson, this chapter will describe teacher moves that were used during the large group discussion of the image. My analysis of teacher moves will focus on how the teacher uses the projected image, in this case a simulation, to foster and orchestrate large group discussion. I refer to the moves the teacher used while discussing the image as Image-based Discussion Moves. These Image-based Discussion Moves, based on my analysis of the transcripts, appeared intended to use the image to engage students in reasoning about the model. Table 5-2 defines the Image-based Discussion Moves used within image-based

discussion episodes. These move definitions are the end result of a four year process of video analysis and coding of the 6 Overhead and 6 Simulation lessons in my data base. These Image-based Discussion Moves definitions can be applied to discussion of either type of image (dynamic simulations or static overheads).

Table 5-2
Image-based Discussion Moves that were Used in Simulation and Overhead Lessons

| Moves | Goal of Move: Small time scale (4 seconds to 4 minutes)<br>Moves can be done by teacher or student.<br>Moves can be asked as a question or presented. |
|---|---|
| ORIENT<br><br>What OBJECTS are we looking at? | Motive: Students can see an image but not know what it represents. This move involves making sure that students understand what parts of the simulation or static image are supposed to represent.<br><br>Observables: When introducing or reviewing an image the teacher or a student helps other students to identify objects in the image and map them to the situation or idea under discussion. ORIENTING focuses on the large, often static, OBJECTS or structures in the image. |
| HIGHLIGHT<br><br>What ACTIONS are happening? | Motive: Students may not know where to focus their attention or know how to interpret actions or action symbols. Many elements can change in a simulation and many actions can be implied in a complex static image. Highlighting moves expose important features of a cause OR an effect, which might be overlooked by the students.<br><br>Observables: The teacher or a student helps students focus on conceptually important ACTIONS in the mage. In these lessons, highlighting focuses on what is happening during the actions in the image to EITHER the MACRO or the MICRO elements of the image. This strategy focuses on the basic behavior of an element of the image such as how far it moved or which direction. It does not emphasize the link between cause and effect but instead attempts to clarify one side of the causal chain. |
| LINK<br><br>What is causes this effect? | Motive: A complex dynamic model often contains multiple cause and effect chains. Linking cause and effect, and then linking multiple cause and effect chains is a complex task for students.<br><br>Observables: The teacher or a student helps students focus on the link between CAUSE AND EFFECT between elements of a complex visual. In these lessons this often took the form of explaining a visible phenomenon (MACRO) in terms of how it could be explained by underlying molecular model (MICRO). |

| | |
|---|---|
| PREDICT<br><br>What will happen if...? Why? | Motive: Predicting can encourage students to reason with their explanatory model. Asking students why they made their predictions provides information about this reasoning process.<br><br>Observables: The teacher or a student asks students to predict how an image will look (structures) or behave (dynamic/function) in subsequent states or future situations. |
| CRITIQUE<br><br>What is wrong with this image? | Motive: Critiquing reminds student that the image, no matter how complex, is just an approximation of reality and one representation of the model.<br><br>Observables: The teacher or a student encourages discussion of the limitations of the image as representation of the model. |
| SITUATE<br><br>What if you were in the image? | Motive: Situating can help students to engage kinesthetic imagery and reasoning.<br><br>Observables: The teacher or a student suggests that students imagine themselves in the image or as interacting with parts of it |
| FRAME<br><br>Why look at this image? | Motive: Framing can help students connect the image to larger lesson or modeling goals.<br><br>Observables: The teacher or the student identifies the key question(s) which the image will address before showing the image or composing a wrap up or "take home message" before removing the projected image. |
| EXTEND<br><br>Where else would I see this? | Motive: Extending can encourage student to overlay the image of the explanatory model on other experiences of the phenomena in their lives. Making time for this form of transfer can help connect the model to prior knowledge.<br><br>Observables: The teacher or a student discusses applications of the model beyond the situation represented by the projected image. |

An important dimension that emerged was that the simulation can be used to present the model, (to tell), or to generate questions about the model, (to ask). When applicable, I will note how the teacher chooses between asking and telling about the simulation. The following sections will discuss these moves in greater detail as they were used in the simulation lesson. I did an analysis of the Overhead lesson but did not find different kind of moves there so I will not include examples from that class in this

chapter. I will provide examples of how these moves were used during the Overhead and Simulation lessons in the comparative case study found in Chapter 8.

## Narrative Description of Image-based Discussion Moves

In this section I will describe, define, and provide protocol examples of the image-based discussion moves shown in Table 5-2. A transcript section is included to illustrate how a teacher used a move navigated the class discussion. I then analyze these transcripts using the frameworks of model co-construction (Clement, 2008) and the communicative approach (Scott et al., 2006) to better understand how these moves may have functioned in the discussion. These moves were intended to be used by the teacher to engage the student in evaluating and modifying their model by helping the students comprehend the simulation and encourage them to use the simulation to reason about the model. In the examples below, one can see how the teacher employed a variety of moves to navigate the tension between asking and telling about the simulation and found ways to use it probe student thinking.

### Orienting Move: "What objects are we looking at?"

Table 5-3
Orienting Move Definition

| Orienting Move: "What objects are we looking at?" |
| --- |
| Motive: Students can see an image but not know what it represents. This move involves making sure that students understand what parts of the simulation or static image are supposed to represent.<br><br>Observables: When introducing or reviewing an image the teacher or a student helps other students to identify objects in the image and map them to the situation or idea under discussion. ORIENTING focuses on the large, often static, OBJECTS or structures in the image. |

**Transcript Example of the Orienting Move**

This part of class occurs directly after the non-image-based discussion of students' explanation of the perfume demonstration. The teacher has just projected the simulation on to the white board. In transcript segment 3, the teacher starts with the static simulation projected on the nose and cookie drawing and asks students to identify the yellow, green, and blue spheres projected by the simulation. Though they are not labeled, the teacher is using these spheres to represent different types of molecules in air. (See Figure 5-2)

Transcript 3: Example of orienting move

| | | |
|---|---|---|
| 164 | Teacher: | I've got a little simulation...you've seen this simulation before, so it should be familiar to you. Now this has to do with these little pictures on the board. Who can tell me what they think those pictures represent? What are those pictures? Peter, what are you thinking? |
| 165 | Peter: | Cookie molecules. |
| 166 | Teacher: | What? |
| 167 | Peter: | Cookie molecules |
| 168 | Teacher: | Could be cookie molecules, yep...could be cookies. Yes? |
| 169 | Nancy: | Um, so it's like air, and then, the yellow one's are like the air and the blue ones are like the cookie smell. |
| 170 | Teacher: | Okay. Good, good. So now we're onto- the big thing is they're molecules, right? We're showing the molecules. So both of you were right in that way. Now in terms of what colors represent-that's another thing. I haven't released, I haven't shown you any cookies yet, any cookie molecules yet. |
| 171 | Nancy: | Oh. |
| 172 | Teacher: | So if that's true, there are no cookies here. You wouldn't know that going in. |
| 173 | Nancy: | Then that's air. |

**Analysis of the orienting move**. The orienting move can be analyzed using the model co-construction framework, since the teacher is using the simulation to evaluate the state of student models. In this segment of transcript, the teacher checks the student

understanding of what the macro and micro elements of simulation represent. In this example, the teacher uses the orienting move to ask a question.

In turn 164, students are asked to interpret the static simulation and reveal how they assign meaning to its parts. The teacher's subject matter expertise and experience with the simulation often makes the meaning of simulation very clear to him, and this can lead to assumptions that students share this understanding. The teacher opens up the conversation to find out if this is the case. At this critical point between asking or telling students what the parts of simulation represents, the teacher chooses to ask them before explicitly labeling each part.

In turns 165 and 169, students reveal that they have misattributed molecules of air as cookie molecules. In a co-construction framework, this misattribution could be considered a negative model element. By asking all students to assign meaning to the simulation, this subtle misattribution, or negative model element, was brought to light. If this subtle difference between teacher and student mapping of the simulation goes undetected, it could compromise the effectiveness of the simulation in addressing a key student misconception, namely how perfume and molecules in still air interact as gases.

In turns 170 and 172, we can examine how the evaluation of the student idea was managed and see an important idea of model co-construction at work— the idea of locating and building on positive model elements. Hidden within the misattribution discussed in turn 165 and 169, students have very important positive model elements: they can distinguish between the macroscopic (nose) and microscopic (molecules) parts of the overlay simulation. By referring to the balls in the simulation as molecules, not actual cookies, students are correctly interpreting the different size scales used in the

macro and micro representations in the simulation. The teacher positively evaluates the molecule idea.

In the last sentence of turn 172, the teacher says, “There are no cookies here. You wouldn't know that going in.” By pointing out that those students did not have enough information to answer this question going in, the teacher is trying to prevent his correction of their misattribution from closing down further reasoning and participation. He wants them to understand that their misattribution was caused by a lack of information, and not by faulty reasoning. A modeling perspective helped the teacher not to expect students to reach the target model all at once. Instead, the teacher praised students for engaging in the reasoning process and focused instruction on making small changes in student models over time.

The co-construction perspective helps teachers find and comprehend positive model elements in the ideas students have shared in discussion, and then build on these ideas to navigate toward the lesson’s content goals. Finding positive model elements in student ideas also helps to foster generative classroom discussion norms. It encourages students to continue reasoning and continue risking participating during whole class discussion.

**Discussing the overlay simulation before it is set in motion: Situating, predicting, critiquing**. In this section of the lesson, the teacher uses a series of moves to encourage active engagement with the simulation; in this case a number of moves are made right before the simulation is set in motion. Some researchers have noted that students can take a passive, “couch potato” stance when watching simulations (Jones et

al., 2001; Stephens, 2013). In this example, the following moves were intended to build anticipation about what will happen when the simulation runs.

**Situating Move: "What if you were in the image?"**

Table 5-4
Situating Move Definition

| Situating Move: "What if you were in the image?" |
|---|
| Motive: Situating can help students to engage kinesthetic imagery and reasoning.<br><br>Observables: The teacher or a student suggests that students imagine themselves in the image or as interacting with parts of it. |

**Transcript Example of Situating Move**

In this example, students are invited to "be noses" the teacher drew on the overlay simulation a simulation and were encouraged to speak out when the simulation "interacts" with them.

Transcript 4: Example of Situating Move

| | | |
|---|---|---|
| 180 | Teacher: | Now, what I'm going to do is I'm going to put a lot of cookie molecules in; the red ones are gonna be our cookie molecules. And what we are going to try and figure out is which of these noses are gonna smell the cookie first. Now Alison might have a good idea about this. So what I thought I'd do is- Alison would you mind being one of the noses? You don't have to actually stand up, you just- can I just put you here? This is Alison's nose. And let's get Ben. Do you want to be a nose? |
| 181 | Students: | I want be a nose! I want to be a nose! |
| 182 | Teacher: | Nicole, we'll get you to be a nose. |
| 183 | Jane: | Me! |
| 184 | Teacher: | And what about way back there, let's get Dustin. Dustin's nose. And so your job is when you think you smell the cookie, you want to say something like you're smelling the cookie, so it could be like "mmmm" or "ahhh" or-- |
| 185 | Ellen: | "I smell a cookie." |
| 186 | Teacher: | I smell the cookie could be another one. |
| 187 | Students: | (students practice what they will say when hit by a molecule) |

**Predicting Move: "What will happen if…? Why? "**

Table 5-5
Predicting Move Definition

| Predicting Move: "What will happen if...? Why?" |
| --- |
| Motive: Predicting can encourage students to reason with their explanatory model. Asking students why they made their predictions provides information about this reasoning process.<br><br>Observables: The teacher or a student asks students to predict how an image will look (structures) or behave (dynamic/function) in subsequent states or future situations. |

**Transcript Example of Predicting**

In this example, students are asked to predict which nose would smell the cookie smell first. Mr. T does not give students a chance to share their answers in large group and thus he does not follow-up with a request for an explanation.

Transcript 5: Example of Predicting Move

| | | |
| --- | --- | --- |
| 188 | Teacher: | Everyone make a guess here. Which one- who is going to smell the cookie first? Make a guess. Make yourself a guess. |
| 189 | Students: | [talking at their in small groups for 20 seconds] |

**Critiquing Move: What is wrong with this image?"**

Table 5-6
Critiquing Move Definition

| Critiquing Move: "What is wrong with this image?" |
| --- |
| Motive: Critiquing reminds student that the image, no matter how complex, is just an approximation of reality and one representation of the model.<br><br>Observables: The teacher or a student encourages discussion of the limitations of the image as representation of the model. |

**Transcript Example of Critiquing**

Students are asked to look for a ways the simulation does not accurately represent the target model. In this case the teacher asks a student to identify that the lack of motion of molecule is making is inaccurate representation of the model.

Transcript 7: Example of critiquing move done by teacher

| | | |
|---|---|---|
| 192 | Teacher: | Now the other little piece we have to realize is that this simulation isn't accurate right now… because why? Why doesn't air look like this? What are problems with it right now? Go ahead, Carly. |
| 193 | Carly: | Well, those ones are not moving. |
| 194 | Teacher: | They're not moving, right? That's the key part. Right now this thing is frozen. Air is not like this- it's not. So we have to make it moving, and that's what we're going to do next. |

It is important to note that the Image-based discussion moves can be initiated by the teacher or the student. While comparative case studies in Chapter 6, 7 and 8 will provide examples from different teachers and image mode lessons, it is relevant here to bring in one example from another class to underscore the point that students can initiate a move. In Mr. R's class, a student critiqued the overlay simulation herself when she explained that the vertical cookie orientation (see Figure 5-2) might affect how the scent traveled.

Transcript 8: Example of critiquing move done by student

| | |
|---|---|
| Eliza: | Yeah but it can kind of go over the first nose but depending on which way the cookie is, that cookie is more like not a cookie. |
| Teacher: | Yes it is a weird direction usually you don't hold cookies this way right. |

**Analysis of Situating, Predicting, and Critiquing Moves**

This set of moves above repeatedly focused active attention on the simulation right before it was run. When viewed through the lens of model co-construction, the moment when the teacher starts the simulation moving is an important teacher contribution to the construction of the student model; it is intended to scaffold the modification of the student model to include dynamic visual elements. The three moves above were intended to set up and cue the focused active student attention on the dynamic and visual model of the cookie molecules diffusing through air, as follows.

The Situating move was intended to encourage students to engage a kinesthetic awareness of what it would be like to be hit in the nose by cookie molecules. By encouraging them to call out when a nose "smelled" a molecule, students should have another way of interacting with the simulation and should have a social motivation for attending to the behavior of the particle model.

The Predicting move was intended to encourage students to run their internal model in order to reason who would smell the perfume first. By not taking time to have students share their answers, the Mr. T missed an opportunity to learn about student models by failing to prompt students articulate their model reasoning that lead to their predictions. When Mr. R used the "Why?" follow-up to the prediction question, student were observed reasoning and gesturing about the movement of the scent. Mr. R could gain information about student models from this exchange by noticing that none of the student were referred to molecules and were instead seemed to be imaging the scent to moving as part of convection current.

The Critiquing move was intended to cue students to the key limitations in how the target model was being represented by the simulation. These limitations may impact how students are reasoning with it. Mr. T's focused students on the lack of motion of the molecules, and reminded students that the simulation manipulates these features. In Mr. R's class, a student critiqued the drawing of the cookie which the teacher had drawn on the simulation and pointed out the orientation of the cookie was impacting her prediction. In both Mr. R and Mr. T's lesson, these three moves were intended to act together to cue and direct as much student attention as possible on the key elements on the simulation, at the moment when the dynamic elements were turned on.

**Evidence Suggesting Engagement with the Simulation as was Set in Motion**

**Transcripts of student engagement**. This set of moves appeared to have built anticipation and, thus, focused attention on the actual running of the simulation. The students displayed an excited level of participation by spontaneously calling out and narrating the actions of the molecules (hitting noses) and what this means to the model (smelling) when the simulation was set in motion.

Transcript 9: Student engagement with the simulation.

| | | |
|---|---|---|
| 195 | Teacher: | So here it is. Ahh, I'm just baking that cookie. |
| 196 | Dexter: | Oh that looks tasty. |
| 197 | Landon: | That's a swarm! |
| 198 | Teacher: | Now, when it goes and it touches the nose...Katie? |
| 199 | Katie: | What? |
| 200 | Landon: | Katie smells the cookie. |
| 201 | Pam: | Go, go go! |
| 202 | Pam: | It almost did. |
| 203 | Leonard: | I smelled the cookie. |
| 204 | Justin: | Touch my nose! |
| 205 | Justin: | I smell the cookie; it's in my nose! |
| 206 | Justin: | I smell it again! |
| 207 | Ss: | [all talking at once about smelling the cookie] |

| | | |
|---|---|---|
| 208 | Molly: | Wait, Jim's smelling the same one. |
| 209 | Teacher: | Alright, yeah you are smelling the same molecule over and over. |

**Transcript example of critiquing of dynamic mode of simulation done by student**. This degree of attention may have stimulated a student critique of the simulation (turn 209), by noticing that the simulation was showing that the same molecule was being smelled over and over. In Transcript 9, a student question follows up on this idea and notices another limitation of the simulation while it is running. This student pursued this critique by asking if "the smell would go away and then … come back" as individual molecules move in and out of the nose. .

Transcript 10

| | | |
|---|---|---|
| 283 | Molly: | Well like, if you look at Adam (referencing the drawing of his nose on the screen) right now, there are like no molecules. Oh well, not anymore- but there are no molecules touching his nose. Then does that means that in real life when you're, like, saying or explaining something-also the smell will just go away and then it will come back? |
| 284 | Teacher: | Yeah, now if you think about it, we talked about how small these are and it's a question of how sensitive your nose is because obviously here this is way out of scale right? Because "one" molecules is hitting "Tim's" nose. It's only one molecule can fit in there at a time and in real life, you know, you'd be breathing trillions of them at a time so it's unlikely that if the smell is permeating the room that you wouldn't actually smell. So smell works because there's like nerves in there and the molecules actually hits those nerves, and they send that nerve firing and that firing goes in your brain and you sense it, so the molecules actually hits that nerve cell in your nose. Yeah? |

### Using Student Models to Alter the Simulation

In this part of the lesson, questions about extreme cases, the imagined really small and really big cookie, were used to prompt students to use their models to make modifications to the simulation. One of the affordances of a simulation is that variables can be changed to run various states of the model. The goal of this strategy was to prompt students to run their mental model and predict how variables of the simulation would have to be modified to represent a very small or very large cookie.

Navigating the discussion surrounding this extreme case/prediction strategy was complex, because it elicited many fruitful but unanticipated student ideas and questions. The teacher employed a variety of moves to capitalize on these student contributions, and use them to reach the content goals of the lesson.

### Linking Move: "What is causing this?"

Table 5-7
Linking Move Definition

| Linking Move: "What is causing this?" |
|---|
| Motive: A complex dynamic model often contains multiple cause and effect chains. Linking cause and effect, and then linking multiple cause and effect chains is a complex task for students.<br><br>Observables: The teacher or a student helps students focus on the link between CAUSE AND EFFECT between elements of a complex visual. In these lessons this often took the form of explaining or a visible phenomenon (MACRO) in terms of how it could be explained by underlying molecular model (MICRO). |

### Transcript Example of Linking: Making Connections between Macroscopic Phenomena and Microscopic Explanations

The teacher asked how a very big cookie could be modeled by the simulation. He modified the simulation based on student suggestions, and, while the simulation was

frozen, prompted the students to predict, “How is [the modification] going to change the smell of this thing?” This question turned out to be productively vague in that it prompted fruitful student interpretations that the teacher didn’t anticipate. He then ran the simulation to test student predictions.

Linking transcript segment 11

| | | |
|---|---|---|
| 230 | Teacher: | How about if you have a super huge cookie? How would you represent that? |
| 231 | Students: | A lot of them! |
| 232 | Teacher: | A giant one, Haley what would I do? |
| 233 | Haley: | You increase the number of cookie molecules? |
| 234 | Teacher: | Yeah, so- |
| 235 | Sebastian: | If it took you longer to bake it, would you smell it as fast? |
| 236 | Larry: | Put in two hundred and fifty |
| 237 | Chris: | Put in sixty-nine. |
| 238 | Stan: | As many as possible. |
| 239 | Teacher: | I think the most I can do before I smash my computer is fifty. |
| 240 | Larry: | No, you can do two fifty. |
| 241 | Chris: | Sixty-nine. |
| 242 | Teacher: | Now, how is this going to change how this thing is smelled? How is it going to change the smell of this thing? |
| 243 | Linda: | A bit stronger. |
| 244 | Chrissy: | You'll smell it a lot faster. |
| 245 | Teacher: | We would smell it faster. |
| 246 | Gary: | Stronger. |
| 247 | Teacher: | Maybe we would smell it more frequently therefore maybe the smell is going to be stronger. Anything else you can think of? Sebastian? |
| 248 | Sebastian: | With more molecules wouldn't the longer it would take to bake it so you'd smell it later? |
| 249 | Teacher: | Right, so we're assuming as soon as I hit this that all those things are...you're right, so the baking time would get affected because of the size, there's no question- like how hot it would have to be. We're assuming it's hot enough so it starts to release the cookie molecules, but that's a good point absolutely. Let's see what happens here... (the teacher turns on the dynamic features of the simulation) |
| 250 | Liz: | Invasion! Cookie invasion! |
| 251 | Leonard: | Invasion of the cookies molecules!!! |

**Analysis of linking move.** When viewed through the lens of the communicative approach, this segment can be seen as an example of a dialogic interaction, because the teacher explores an unexpected student point of view. Students easily modified the simulation variable needed to represent the larger cookie (turns 231-241) by suggesting an increase in the number of cookie molecules. However, asking students to predict how this would change how the cookie was smelled uncovered an unexpected student point of view and presented a greater challenge to the teacher. The communicative approach encourages teachers to explore student points of view but does not offer cognitive strategies for deciding what to say next to navigate this challenging situation.

The model co-construction framework offers cognitive strategies which can help the teacher decide what to say next. In order to understand how the teacher capitalized on the unexpected student ideas, it is helpful to view this segment through the model co-construction lens. The teacher was expecting students would apply their model and reason that the "student noses" in the overlay would smell the cookie faster since there were more cookie molecules present (turn 245). Asking a prediction question (turn 242) opened up the discussion to two more complex student ideas, specifically strength of smell (turns 243 and 246) and increasing cooking time (turns 248-249). Both of these student answers were unexpected, and the teacher stumbled a bit as he attempted to comprehend them (turn 247 and 249). Once comprehended, he sees these student ideas as useful applications of correct elements of student models. Instead of pushing students to see his point of view, or his pre-conceived answer, "faster" (which can be a tempting option), the modeling framework helps the teacher to comprehend these student ideas and see them as promising model elements which can be built upon with microscopic model

based elaborations: 1) strength of smell due to frequency of hits (turn 243-247) and 2) larger number of molecules increasing cooking time (turns 248-249).

These elaborations served as a linking move since they were intended help build a link between macroscopic phenomena and microscopic explanations: strong smell (macro) is due to increased frequency of collisions between molecule and nose (micro), and longer cooking time (macro) is due to more molecules being heated (micro). By elaborating on student predictions while the simulation was static, students were encouraged to animate mentally their microscopic model and link them to the macroscopic phenomena of strong smell and longer cooking time. These moves may contribute to forming class norms that support student dialogic discussion and model based reasoning; by choosing to probe and elaborate on student ideas, the teacher may encourage student reasoning by positively acknowledging these complex student ideas as useful contributions to the evolving student models.

**Highlighting Move: "What actions are happening?"**

Table 5-8
Highlighting Definition

| **Highlighting Move: "What ACTIONS are happening?"** |
|---|
| Motive: Students may not know where to focus their attention or know how to interpret actions or action symbols. Many elements can change in a simulation and many actions can be implied in a complex static image. Highlighting moves expose important features of a cause OR an effect, which might be overlooked by the students.<br><br>Observables: The teacher or a student helps students focus on conceptually important ACTIONS in the mage. In these lessons, Highlighting focuses on what is happening during the actions in the image to EITHER the MACRO or the MICRO elements of the image. This strategy focuses on the basic behavior of an element of the image such as how far it moved or which direction. It does not emphasize the link between cause and effect but instead attempts to clarify one side of the causal chain. |

**Transcript Example of Highlighting**

In this next segment, the teacher emphasizes one side of a causal chain: random movement of molecules lead to molecules entering the nose. Here the teaching intends to use the dynamic simulation to target a particular and common misconception, namely that the perfume is carried through the air solely by air currents (Lee et al., 1993).

Transcript 12

| | | |
|---|---|---|
| 258 | Teacher: | Now the thing I noticed when I was going around, are the cookie molecules- are they actually sticking to the air molecules? |
| 259 | Students: | No. |
| 260 | Teacher: | No, so they're not really carrying it on they're back. They are just separate molecules in the mix. |
| 261 | Jillian: | You can make them stick. |
| 262 | Teacher: | So they're not clinging together, they're just bouncing around separately. That's kind of an important point because the air is not really carrying it. As much as they're gas molecules, they're bouncing around too, and that's um, how it's getting around. Just the same way the air goes around. |

**Analysis of highlighting move**. When viewed through the lens of model co-construction, the simulation is an important teacher contribution to the construction of the student model; it is intended to scaffold the modification of the student model to include dynamic visual elements. These moves were intended to help to set up and cue focused active student attention on the subtle features of the dynamic simulation which can be used to confront a common student misconception found in mental student models.

Students learn more from complex simulations if they are directed to attend to subtle but salient parts (Hegarty et al., 2003). This finding is applied here by asking students to notice a fine subtle point of the simulation which helps confront a common misconception that air currents alone are carrying the perfume. It is difficult to address

this misconception with a static image. This Highlighting uses a simulation feature to confront a particular misconception by focusing on one side of the cause and effect chain the random movement of the molecules. It uses an affordance of the dynamic simulation to show the molecules of the air and the cookie molecules moving simultaneously but independently. Unless students are directed to attend to the interaction between air and cookie molecules, the nature of their independent motions can be overlooked.

**Framing Move: "Why look at this image?"**

Table 5-9
Definition of Framing

| **Framing Move: "Why look at this image?"** |
|---|
| Motive: Framing can help students connect the image to larger lesson or modeling goals.<br><br>Observables: The teacher or the student identifies the key question(s) which the image will address before showing the image or composing a wrap up or "take home message" before removing the projected image. |

**Transcript Example of Highlighting: Scaffolding Student Composition of a Take Home Message**

Prompting students to generate a concise phrase or "take home message" describing the main point of the lesson gives the teacher a chance to scaffold the composition of a clear and un-ambiguous statement of the lesson's content goal, namely explaining a macroscopic event using a microscopic model. In this part of the lesson, framing was first done orally and nothing was written down.

Transcript 13

| | | |
|---|---|---|
| 263 | Teacher: | Okay, so um, what I'd like you to do if you would is to see if you can answer these questions for me...What does all this tell about cookie smell? What's the take home message for this? Sue? |
| 264 | Joe: | Smells good. |

| | | |
|---|---|---|
| 265 | Sue: | That a hard substances- wait, that solids make gases that we can smell. |
| 266 | Teacher: | Nice, anybody else? Yeah, Bill? |
| 267 | Bill: | The cookie smell is a gas and it comes through the air, and bounces around randomly like air. |
| 268 | Teacher: | Okay, and when you talk about cookie smell, who can tell me what cookie smell actually is? How about, what is the cookie smell? Go ahead, Gus? |
| 269 | Gus: | Molecules from the cookie. |
| 270 | Teacher: | Molecules from the cookie. |
| 271 | Teacher: | So when we smell anything at all, what does it mean when we smell something? What does that, Kara what's happening when we smell something? |
| 272 | Kara: | The molecules are going into your nose. |
| 273 | Teacher: | The molecules of the substance. So there is actually-in this case there's actually molecules from that cookie that got into the air, that traveled through the air, and went into the person's nose. So when you smell something, that's what's going on. No matter whether it's a good smell or a bad smell, when you smell something it is traveling...a little piece of that, a little molecule of that, turns into a gas travels through the air and hits you in the nose. Okay? |

Next Framing is done in writing. After students write down their “take home message”, the one that is shared (turn 279) shows greater evidence of thinking with a microscopic model.

Transcript segment 14

| | | |
|---|---|---|
| 278 | Teacher: | Okay, who wants to take a second and read what they have for that? Claire, would you do that? |
| 279 | Claire: | Um, wait what is it- scent is molecules from a substance that spread out into the air and go into someone’s nose. |
| 280 | Teacher: | Nice, so scent is a molecule, right? From the object- it's actually a molecule... When you smell something it's because a molecule hit us in the nose. |

**Analysis of framing move**. Previously, Sue gives a correct description to sum up the lesson but its macroscopic (turn 265). Lee et al. (1993) found that students often reverted to using the macroscopic explanation instead of microscopic explanations even after instruction. To move beyond this, the teacher asks for competing and increasingly

more sophisticated responses which explicitly use the language of the microscopic model (molecules in motion) to explain how we smell a scent (turns 266-274). At the end of this exchange (turn 275), the teacher offers an example wrap up statement that describes the microscopic model and attempts to generalize it to explain any scent, good or bad. When viewed through the lens of the communicative approach, this segment could be considered an interactive authoritative episode in which the teacher is scaffolding students attempt to use the authoritative language of the microscopic model. In turn 279, Claire succeeds in explaining smell in terms of the microscopic model.

**Extending Move: "Where else would I see this?"**

Table 5-10
Extending Definition of Extending

| **Extending Move: "Where else would I see this?"** |
|---|
| Motive: Extending can encourage student to overlay the image of the explanatory model on other experiences of the phenomena in their lives. Making time for this form of transfer can help connect the model to prior knowledge.<br><br>Observables: The teacher or the student discusses applications of the model beyond the situation represented by the projected image. |

**Transcript Example of Extending: Discussing Applications of the Model Beyond the Simulation**

In the following segment, the discussion erupted into a series of student questions and appeared to generate thought experiments to help students apply their mental model to everyday events. By encouraging questions which critiqued the simulation and extended the domain of application of the model, students appeared to free their mental model from the constraints presented by the simulation.

Student question linking model to general model of states of matter:
Transcript 15

| | | |
|---|---|---|
| 281 | Melanie: | Does that mean it's going from a solid to a gas? |
| 282 | Teacher: | Sometimes, yeah. Like in the case of cookies, you know, it's this chemical combination that's happening in the cookies, so some of those were solids, and when they combine they make a unique molecule that hits you-that forms and then turns into a gas, right? So that's the other piece of it; state of a smell has got to be a gas, doesn't it? Cause we can't see it, we can't see the gas molecules, therefore, it's got to be a gas. Yeah? |

Student question extending model to smells in everyday life:
Transcript 16

| | | |
|---|---|---|
| 285 | Samantha: | But even if there's not like a distinct smell, aren't you always like smelling something? Like, right now the room smells like-- |
| 286 | Teacher: | Right |
| 287 | Samantha: | And it's like different from if you walked outside. |
| 288 | Teacher: | Yeah, that's true. |
| 289 | Samantha: | Even people's houses smell different. |
| 290 | Teacher: | Yeah, a lot of times to me it's related to their laundry detergent they use. Seriously, don't you ever notice that- you go to someone's house and it's like "boy this smells different." It's because often they use different laundry detergent or they cook different foods. Right? A lot of times it's the food smell. |
| 291 | Sara: | Or they don't clean-they just spray… |
| 292 | Students: | (some students laugh) |
| 293 | Teacher: | See that's good point, it's background noise for us all the time Sort of like the fan is always background noise in this room or just you know, the computer humming or something is background noise, we sort of tune it out. But when we change to a new location, all of a sudden that "newness" makes us pay attention to it a little bit for a short time, until we're outside then we sort of forget that we're smelling. |

Student question about a thought experiment:
Transcript 17

| | | |
|---|---|---|
| 294 | Lynn: | Is there anywhere in the world where there's no smell always...like pure air and that's all. |
| 295 | Jill: | But then you are smelling it, because it's different. |

| | | |
|---|---|---|
| 296 | Lyla: | You start to smell yourself! |
| 297 | Teacher: | That's true, yeah, |
| 298 | Lindsay: | You are always smelling air |
| 299 | Teacher: | Little molecules of yourself are always popping off and going into the air. |
| 300 | Students: | (many student talk at once) |

**Analysis of extending**. This section is characterized by a burst of student generated questions that extended the discussion beyond the boundaries and constraints of the simulation. These questions linked discussion to previous model elements (turns 281-282), critiqued the simulation (283-284), extended the domain of model application to everyday events (turns 285-293), and generated and ran thought experiments (294-300).

When viewed through the lens of the communicative approach, this burst of student questions could be considered an interactive dialogic episode in which the teacher is open to a wide range of student points of view. Extending moves can be seen in this framework as encouraging the dialogic episode by opening up room in the discussion to considering student questions. It is interesting to note that this dialogic episode follows the authoritative episode found in the previous section on wrapping. The communicative approach suggests this sort of oscillation can occur because authoritative episodes set up the conditions needed to foster a dialogic episode in which students attempt to apply the scientific point of view to their everyday experiences.

When viewed through the lens of model co-construction, this sequence of spontaneous student questions can be seen as evidence that these students are beginning to reason with their microscopic models without the help of the computer simulation.

Extending moves in this framework can be seen as how the teacher's answers scaffold the students as they run their mental model independent of the simulation.

The transcripts provide an example of how model co-construction and the communicative approach can illuminate the conditions that support student reasoning. A modeling perspective invites a cognitive description of what preconditions might be 'set-up" during authoritative episodes. One possibility is that the external simulation contributed to dynamic and visualizable elements to student mental models, and this mental model was the condition needed to generate the rich collection of student questions we find in the dialogic episode. The communicative approach perspective invites a context description of what kinds of norms or questions can encourage students to reason with their models. One possibility is that teachers can use a dialogic approach to invite student points of view, and teachers can modify their agenda to explore these points of view. By being open to these student points of view, teachers can give room to student reasoning that develops spontaneously as it did here.

## Conclusion

In this chapter I have attempted to address the following research question: What image-based discussion moves (small time scale strategies spanning 4seconds to 4 minutes) were used by teachers to navigate image-based discussions?

Middle school students struggle to understand many aspects of the particulate nature of matter even after exposure to instruction. The lessons in the Matter and Molecules curriculum have been shown to foster growth in student understanding of the particulate nature of matter. I sought to add a description of whole class image-based discussion moves that incorporate a computer simulation and that were intended to

scaffold students in the process of constructing a mental model of molecular motion; and I also used the frameworks of model co-construction (Clement, 2008) and the communicative approach (Scott et al., 2006) to characterize how these image-based discussion moves were used during class discussions to attempt to elicit student, participation, reasoning and model construction.

Table 5-2 provides a comprehensive overview of the moves identified within this lesson. However, it may be useful to highlight some examples of moves that function to scaffold the larger-scale strategies cited in model based co-construction approaches. For example, by asking students to project themselves into the simulation and to call out when the simulated molecules "hit" their noses, the teacher successfully (a) elicited participation through the situating move. Similarly, (b) the predicting move prompted students to engage in active reasoning by asking them to run their internal model to reason who would smell the perfume first. Finally, in (c) the highlighting move the teacher drew student attention to a feature of the simulation in order to confront a particular misconception. I can hypothesize that 1) by doing (a) and (b), the teacher was promoting active learning on the part of the students; 2) by doing a, b, and c, the teacher was scaffolding the construction of the student's dynamic visualizable explanatory model of molecular motion.

In this chapter, I have attempted to introduce and define new descriptors for image-based discussion moves and I will apply these codes to the case studies in the chapters 6, 7, and 8 in which I will compare simulation based lessons with static overhead based lessons and compare how different teachers used these image modes.

## Discussion

Telling students the meaning of the simulation produces the impression of clarity, since the expert model is essentially projected before the student's eyes. However "telling" may increase the chance that students will take a passive "couch potato" stance toward the simulation, or that their misunderstanding about simulation will go unnoticed. Asking students to interpret the simulation can be more engaging and can provide useful information about the state of student models, but it takes more time and potentially introduces more noise in the signal, since its often easy for students to misunderstand the simulation or overlook a key element of it. By asking questions about the simulation, it becomes more than a presentation tool—it becomes a tool for probing student thinking. In the next chapters I will attempt to examine how an image can be used as a "tool for telling" or a "tool for asking" by looking at how teachers use of discussion modes such as presentation, IRE, and IRF (Initiation Response Feedback).

Theoretical perspectives were used to describe how the teacher managed the tension between converging on target concepts and diverging to explore student points of view. The transcripts used to define and describe the image-based discussion moves were analyzed using the frameworks of model co-construction (Clement, 2008) and the communicative approach (Scott et al., 2006) to understand how they may have functioned to in the discussion to promote productive convergence or divergence.

Previous studies have indicated that words and pictures are more effective instructional messages than words or pictures alone (Mayer & Moreno, 2002) and that students need help interpreting dynamic visuals (Lowe, 2003). There is a partially analogous situation in this lesson: the simulation functions somewhat like the pictures

and the discussion functions something like the words. Thus, how a student understands a complex image like a computer simulation may be affected by how teachers orchestrate the large group discussion which surrounds its use. For this reason, the model construction and communicative approaches could be important for successful use of complex images for concept development. Both frameworks offer conceptual approaches for generating active reasoning and productive discussions about concepts and for managing the issues of convergence and divergence that arise if teachers want to encourage and explore student's points of view through whole class discussion.

# CHAPTER 6

# COMPARATIVE CASE STUDIES OF DISCUSSION STRATEGIES USED IN A LESSON EXPLAINING AIR PRESSURE IN A TIRE

## Chapter Overview

This chapter analyzes teacher behavior in a lesson using visual media about the particulate nature of matter that was taught by two experienced middle school teachers (Mr. S and Mr. R). The lesson in this study attempted to help students construct a visualizable particulate model explaining the behavior of air as it is pumped into and released from a tire. Each teacher taught a lesson to one half of his students using static overheads and taught the other half of his students using a dynamic simulation. The two types of lessons had similar content goals, lab activities, and handouts but differed in the type of image mode used during large group discussion. Video and transcripts of large group discussions were analyzed to identify a set of image-based discussion strategies. Results suggest that the simulation mode offered greater affordances than the overhead mode for planning and enacting discussions. Differences in teacher use of discussion modes, such as presentation, IRE, and IRF, suggest that teacher preferences for discussion modes may have been affected by the use of an image. When teachers moved during a lesson from using no image to using either image mode, one teachers was observed asking more questions when the image was displayed while the other asked many fewer questions.

## Objectives of the Case Study

A goal of this study is to examine how different image modes are used by different teachers to teach the same content.

### Part One: Difference between Image Modes

Part one of this chapter reports on a comparative case study that examined the ways that the discussion of images was managed in matched sets of a simulation lesson and overhead lesson taught by the two teachers. Part one addresses the questions:

- What strategies were observed being used for leading whole class discussion in each image mode?
- How were lessons with similar lesson plans enacted differently when using different image modes?

### Part Two: Difference between Teachers

Part two of the chapter reports on a comparative case study that examined differences between teachers enacting the same lesson and image mode. This part of the chapter examines patterns of teacher-student interactions used by each teacher during the entire lesson. Part two addresses the questions:

- Did the teachers use different patterns of interactions (e.g., presentation vs. IRF vs. IRE, see Table 6-10)?
- If so, did the image use impact the patterns of interaction used by the teacher in the lesson?
- Did teacher interaction pattern choices change after an image mode started?

## Methodology

To pursue this research objective, a lesson was selected from an exemplary curriculum on the particulate nature of matter, which uses static images to help students construct explanatory models. This lesson had a particular content goal and student handout and was designed to run for most of a class period (45-50 minutes). The

overhead lesson employed an overhead as described by the curriculum and was taught using the overhead only. The simulation lesson used the same lesson structure and handout but adapted the lesson to replace the overhead part of the lesson with a computer simulation. Each teacher taught a class using an overhead lesson and a class using a simulation lesson. The lesson had the same content goal, student worksheet, and non-image-based parts. The teachers collaborated with the researchers to develop the specific overhead and simulation lesson plan.

A primary focus of this study is on the large group discussions that occur during this lesson was adapted from Matter and Molecules (Lee et al., 1993). Matter and Molecules was selected because it has been shown to foster meaningful growth in science understanding, and it addressed the content goals relevant to the school's curriculum standards. The curriculum provides detailed readings, activities, overheads, and worksheets to accompany the lessons, each designed to address a specific misconception or set of misconceptions. However, the authors of the curriculum provide little specific guidance on how to run or manage the classroom discussions that surround the activities and explicate the concepts of the lessons. The curriculum employs complex static overhead images as a key element of the instruction but was developed at a time when computer simulations were not widely available. In this study, a simulation lesson was created by substituting a computer simulation for the overhead provided in the Matter and Molecule curriculum.

## Participants, Context, and Setting

This study explores an image-based lesson about the particulate nature of matter taught by two experienced middle school teachers. Each teacher taught one half of his

students with lessons using static overheads, and taught the other half of his students with lessons using a dynamic simulation. Each simulation/overhead lesson pair had similar content goals, lab activities, and handouts but differed in the type of image mode used during large group discussion. The lesson in this study attempted to help students construct a visualizable particulate model explaining the behavior of air as it is pumped into and released from a tire. (Table 6-1). The written plan used for this lesson was developed by the teachers in conjunction with researchers at the University of Massachusetts Amherst.

The two teachers involved with the study taught 4 classes of heterogeneously grouped students. The lesson analyzed in this chapter was taught by Mr. R and Mr. S. The teachers were selected for this study because they have experience teaching this age group (each has between 8 -15 years of middle school teaching experience), they are familiar with this science content, and each teacher has demonstrated interest in participating in the planning and enacting of these complex lessons. The writing of the lesson plans and the selection of simulations to be used in these lessons was completed jointly by the teachers in consultation with my research group. To display the images, each teacher used a single PC computer projected onto white board in front of the class or an overhead projector with transparencies. Each teacher guided a whole class discussion as students worked through the lab activities and handouts provided by the curriculum.

## Data Collection Methods

Data collected included open observations in class, videotapes, and student work samples. Over the course of the 4 weeks of study in the Matter and Molecules unit (Lee et al., 1993), approximately 20 hours of classroom activity were videotaped and later

transcribed and analyzed using Transana video software (Woods & Fassnacht, 2007). The data from this study comes from this data set. In this study, I will be examining video data comes from video of four lessons, from teacher Mr. S and Mr. R, each using an overhead lesson and a matched simulation lesson. I refer to the latter as the Overhead condition and the former as the Simulation condition.

## Qualitative Data Analysis

As an exploratory study in an understudied area, analysis focuses mostly on open coding of video episodes, using constant comparison techniques, in order to differentiate and refine new constructs describing teaching strategies at different levels (Chin, 2006; Glaser & Strauss, 1967). The purpose in general of such an exploratory case study is to provide existence demonstrations of newly observed behavior patterns that promote the generation of hypotheses about whole class teaching strategies. The constant comparison method will be used to develop descriptions and categories of teacher discussion practices and strategies that were believed to engage student reasoning and construction of a particulate model of air. This will involve the interpretive analysis cycle of segmenting the data; making observations from each segment; formulating a hypothesized model that can explain the observations; returning to the data to look for more confirming or disconfirming observations; and criticizing and modifying, or extending the interpretation (Clement, 2000a). Members of the research team took field notes while videotaping the lessons, so their experience and observation of the lesson provided an important outside perspective for my analysis of the lessons. I consulted regularly with members of my research team during the analysis to check the plausibility

and validity of my findings. At each step of the analysis, I consulted with members of my research team to check the consistency of my procedures.

## Description of the Lesson

This chapter describes and analyzes the large group discussion that occurred in each of the teachers' classes as they enacted a common lesson plan. The lesson description to follow (Table 6.1) provides a basic overview of the structure of the lesson. The variety of ways this lesson plan was enacted will be described later in the chapter.

Table 6-1
Key Features in the Lesson Used in the Study

| | | |
|---|---|---|
| Title of the lesson | Explaining Bicycle Tire Lesson (4.4) from the Matter and Molecules curriculum (Lee et al., 1993) | |
| Topic of the lesson | How does the particulate model of matter explain the behavior of air as it is pumped into and released from a tire? | |
| Mode of interaction | The teacher facilitated a large group discussion of the image which was projected in front of the class.<br>The same handout was used to guide the lesson regardless of image mode used. | |
| Image mode | The "Overhead" or OV version of the lesson was taught as suggested using two static overheads provided by the curriculum. | The Simulation or "SIM" version of the lesson was taught as suggested but here Atomic Microscope (Stark Design Inc, 2005) computer simulation was used in place of the overheads. |
| Video data | 40 minutes of Mr. R teaching the OV class | 40 minutes of Mr. R teaching the SIM class |
| | 40 minutes of Mr. S teaching the OV class | 40 minutes of Mr. S teaching the SIM class |

The lesson began with a demonstration of students pumping air into a bike tire. Students were asked to construct molecular explanations of this observable phenomenon by responding to the first two prompts on the lesson activity sheet (Table 6-2). The students used their model of a gas, which had been developed in previous lessons, and

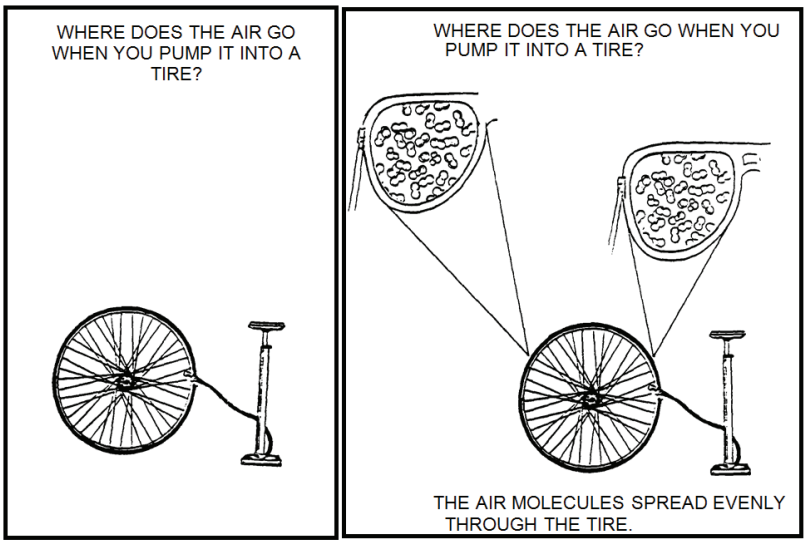
predicted what this model suggested about how a gas behaved as it was pumped into a tire.

Table 6-2
Questions from the Explaining Bicycle Tire Activity Sheet

| |
|---|
| 1. What is happening to the air as it is being pumped into a bike tire? Is it expanding or being compressed? _____ Explain in terms of molecules. |
| 2. My friend says there is more air near the valve of the bike tire where the air was pumped in. Do you agree with him? Explain why or why not. |
| 3. What is happening to the air as it is released from a bike tire? Is the air expanding or being compressed? _____ Explain in terms of molecules. |
| 4. Briefly state the two parts of a good explanation. |

The main content goal of the lesson was for students to explain a bike tire by describing the air as being compressed in the tire and that the molecules in a gas are being pushed closer together. The lesson used the discussion of external images to develop the internal mental imagery of molecules moving closer together or farther apart and to link that imagery to the compression and expansion of air as it's pumped and released from a tire. To achieve this goal students were asked to explain the event at the substance or macro-level and at the molecule or micro-level. A macro-level explanation identifies the substance responsible for the observable phenomena and describes the macroscopic changes the substance is going through. In the case of the pumped up tire, a macro-level explanation would identify the air as the substance and the change is that air is being compressed. At the micro-level students need to describe how molecules are being pushed closer together while they are bouncing around randomly and spreading evenly throughout the tire.

The overhead lesson used paired set of overheads to show a tire being pumped up and then a view of the molecules being spread out equally in all parts of the tire (Figure 6-1 from Lee et al., 1993).




TRANSPARENCY 8: WHERE DOES THE AIR GO WHEN YOU PUMP IT INTO A TIRE?

Figure 6-1
Transparencies Used in the Overhead Lessons

The simulation lesson replaced this overhead with a computer simulation called Diffusion (Stark Design, 2003). The simulation on the left side represents the inflated tire and the right side represents air outside the tire.

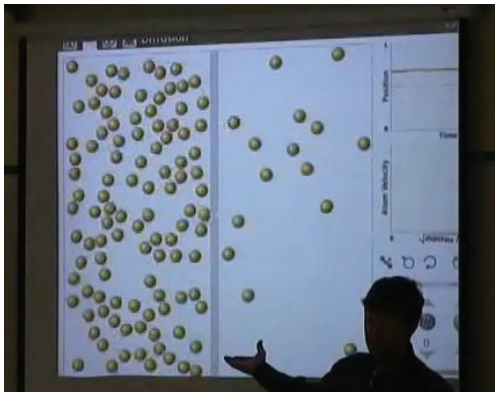


Figure 6-2
Screen Shot of the Diffusion Simulation Found in Atomic Microscope

## Analysis and Findings

This case study examines the large group discussion that occurred during this lesson. I describe how the teacher and students discussed the projected images and how they were used to foster model construction and develop a visualizable particulate model explaining the behavior of air as it is pumped into and released from a tire. I also describe patterns of teacher-student interaction, specifically how the teacher used presentation, questioning, and follow-up to help students develop and reason with their model.

### Part One: Examining the Effects of Image Mode on Discussion

In this case study, the constant comparison method was used to develop and refine descriptions and coding categories of discussion strategies that helped me to describe possible effects of image mode (simulation vs. overhead).

#### Description of Image-based Discussion Moves Coding Categories

The first level of coding involved looking at the entire lesson and determining when the lesson was focused on 1) managing logistics, as when students were finding papers and homework or talking about other assignments, 2) carrying out experiments, as when students were pumping up the tire and making observations, 3) engaging in discussion, as when the teacher and student were thinking and talking together about the explanatory model and using it to address the questions included in the lesson plan. The data for this level 1 coding are shown below in Table 6-3.

Table 6-3
Time Spent on Different Parts of the Lesson

| OVERHEAD Lesson | | |
|---|---|---|
| | Mr. R | Mr. S |
| Time spent on Logistics | 5:38 | 15:34 |
| Time spent on the Laboratory Activity | 7:04 | 3:07 |
| Length of Non-Overhead Discussion (Non-image-based) | 15:45 | 20:41 |
| Length of Overhead Discussion (Image-based ) | 3:08 | 3:16 |

| SIMULATION Lesson | | |
|---|---|---|
| | Mr. R | Mr. S |
| Time spent on Logistics | 0:00 | 13:56 |
| Time spent on the Laboratory Activity | 2:57 | 2:35 |
| Length of Non-Simulation Discussion (Non-image-based) | 12:36 | 15:42 |
| Length of Simulation Discussion (Image-based ) | 14:27 | 7:56 |

The second level of coding focused on the effect of image type on the discussion portion of the class. To do this, I identified when the overhead or simulation was used with large group discussion to develop the content goal of the lesson (Table 6-3). This "image-based" discussion code was applied to the portion of the lesson when the teacher focused student attention on the image projected in front of the class and discussed the information it contained. Once these image-based discussion episodes of class were identified, I attempted to describe and categorize small time scale teaching strategies that seemed intended to engage students in observing and reasoning with the image as the class discussed how the particulate model of a gas can be used to explain macroscopic events in the tire demonstration.

These small scale lesson strategies, called image-based teacher discussion moves, were described in Chapter 5 (Table 5-2). In this chapter, these image-based discussion strategies, or moves, are grouped into two sets based on frequency of use in these lessons. Moves used frequently include: orienting students to what the image represents by

mapping the image to the situation under discussion, predicting how the model will look or behave in subsequent states or future situations, highlighting conceptually important parts or actions in the image, and linking cause and effect relationships between parts of the image. Moves used infrequently include: critiquing the limitations of the image as model, situating students in the image by asking them to imagine themselves as part of it, framing the image by discussing the purpose of the image in the lesson, and extending discussion to applications of the image beyond the situation presented in the image. These moves were rare but in previous lessons they seemed be associated with high student engagement with the image such as unsolicited, and often loud, student contributions.

Each of these moves shown in can be asked or presented. Figure 6-3a and 6-3b shows an example from the Tire Pressure Lesson of the Orienting move being asked as a question. Figure 6-3 shows an example of the Orienting move being presented.

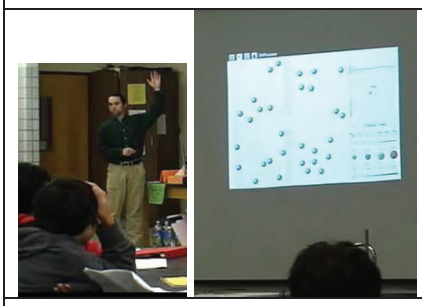
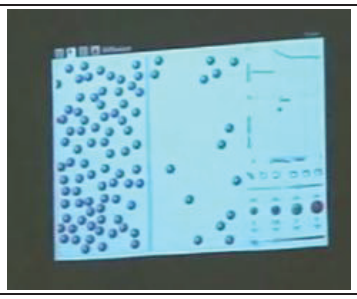
| a) T: Decide for yourself which side represents the tire." | b) T: (adds molecules) "Now which side represents the tire? " |
|---|---|
|  |  |
| Transcript from Mr. R's Simulation Image-based Discussion<br>T: Decide for yourself which side do you think represents the tire, which side represents the air. How many people think this side represents the tire? | |

Figure 6-3
Orientating Move Being Asked as a Question

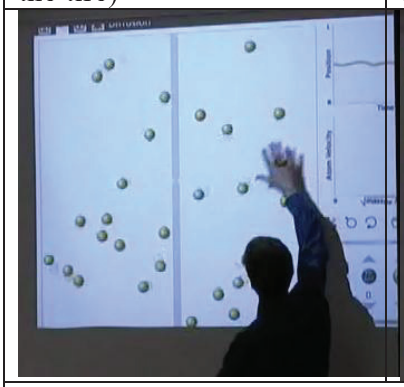
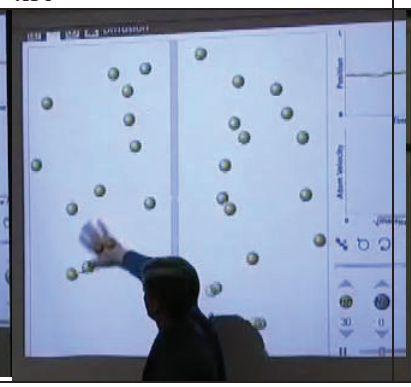
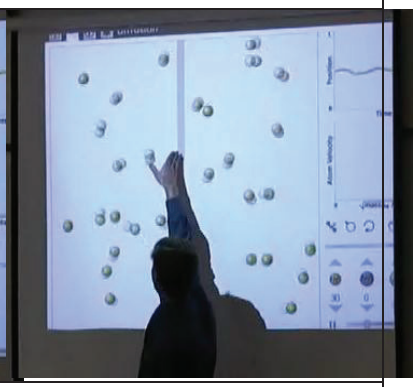
| Figure 6-4a ("air outside the tire) | Figure 6-4b "air inside the tire" | Figure 6-4c. "this is tire" |
|---|---|---|
|  |  |  |
| Transcript from Mr. S's SIM Image-based Discussion<br>T: So this is the air outside of a tire (Fig 6-4a). This is the air inside the tire (Fig 6-4b). This is the tire itself. (Figure 6-4c) And then this is the valve, with the big opening if you look at it in molecule size. | | |

Figure 6-4
Orientating Move Being Presented

**Description of Differences between Simulation and Overhead Conditions**

I found that both teachers spent more time and employed a larger number of discussion moves to integrate the dynamic simulation into the model construction process as compared to a static overhead. Mr. R used 25 moves in the simulation lesson and only 8 moves in the overhead lesson, and Mr. S used 22 moves in the simulation lesion and only 2 moves in the overhead lesson. There was a slight indication that more variety of moves were used the simulation lesson when looking at both teachers. During the simulation lesson, 5 different types of moves were used compared to 4 different types of moves used during the overhead lesson.

Table 6-4
Comparison of Image Mode Indicating More Time was Spent Discussing Dynamic Image than the Static Image

| Teacher | Time spent discussing the dynamic image Atomic Microscope (Stark Design, 2003) (min:sec) | Time spent discussing the static image (2 static overheads) (min:sec) |
|---|---|---|
| Mr. R | 14:27 | 3:08 |
| Mr. S | 7:56 | 3:16 |

Table 6-5
Comparison of Image Mode Indicating that a Greater Number of Instances of Image-based Discussion Moves were Observed During the Dynamic Image

| | Teacher | Orient | Predict | Highlight | Link | | Critique | Situate | Frame | Extend | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Instances of moves in SIM Lesson | Mr. R | 8 | 0 | 6 | 10 | | 0 | 0 | 1 | 0 | 25 |
| | Mr. S | 2 | 0 | 12 | 6 | | 2 | 0 | 0 | 0 | 22 |
| Instances of moves in OV Lesson | Mr. R | 2 | 2 | 1 | 0 | | 3 | 0 | 0 | 0 | 8 |
| | Mr. S | 0 | 0 | 2 | 0 | | 0 | 0 | 0 | 0 | 2 |

Shading is used here to indicate which moves were observed. A darker color indicates that the move was observed more than once.

## Possible Causes for Differences between the Simulation and Overhead Lessons

When comparing different image modes, some of the differences I observed between conditions (time, number of moves) could be attributed to the differences in the overhead and simulation lesson plans, and some could be attributed to spontaneous and unplanned actions by the teachers.

**Effects on Lesson Plan: The Simulation May Provide Affordances for Planning Large Group Discussion**

My intention in designing this study was to substitute a simulation for the overheads provided by the curriculum. The teachers and researchers in this study planned this lesson jointly. The group chose to use the overheads provided by the Matter and Molecule curriculum as directed by the authors of this curriculum since those authors had found these images and lesson plans to be effective at promoting learning as measured by instruments used in their study (Lee et al., 1993). In the course of considering how to use the simulation, the team felt it natural to use the affordances we could see in the simulation to depict the difficult to comprehend dynamic elements of a model. Due to the flexibility of the simulation, it was easy to obtain images of different states of the model, and each image gave the teacher an opportunity to discuss the crowdedness and motion of particles in and out of the tire. This analysis suggests that one advantage of the simulation is that it can be easily modified. The simulation lesson plan, in fact, called for the simulation to be modified a total of seven times, whereas the overhead lesson only called for four image changes, two change for each of the two overheads provided by the lesson and two for teacher drawings (Table 6-6).

Table 6-6
Number of Times the Lesson Plan Requested a Change in the Image by the Simulation and the Overhead Lesson Plans

| | **Simulation Lesson Plan** | **Overhead Lesson Plan** |
|---|---|---|
| Requested changes to the image | 7 | 4 |

Each time the simulation is modified, it provides a new image; in this way, the simulation is a reservoir of images. Each image provided by the simulation afforded the

teachers an opportunity to plan small episodes of the discussion. Though the move codes were not described when we wrote the plans, it is possible to use them to code the lesson plan for request for various moves. The result of coding the lesson plan (Table 6-7) reveals that the simulation lesson plan did, in fact, call for a larger number and variety of moves than did the overhead lesson plan.

Table 6-7
Number of Times a Move was Requested by Simulation and Overhead Lesson Plans

| **Move requested by the lesson plan** | **Simulation Lesson Plan** | **Overhead Lesson Plan** |
|---|---|---|
| Orient | 1 | 0 |
| Predict | 2 | 1 |
| Highlight | 5 | 3 |
| Link | 1 | 3 |
| | | |
| Extend | 0 | 0 |
| Critique | 0 | 0 |
| Situate | 0 | 0 |
| Frame | 0 | 0 |
| Total Moves | 9 | 7 |

**Explaining the findings above**. I hypothesize that the greater number of moves requested in the lesson plan was affected during planning, in part, by the ability of the simulation to be modified to present different states of the model. Since each new state was imagistic, it could be imagined by the lesson planner and used to trigger questions and discussion points to be raised during this episode of discussion when this image was to be projected. I also hypothesize that the simulation provided a greater affordance for planning a discussion than did the overhead. The set of information rich images provided by the simulation may have facilitated the mental rehearsal of small episodes of

discussion and triggered prompts for these discussions that could then be written into the lesson plan. This same sort of planning was possible in the overhead lesson plan but since there were fewer images, fewer episodes may have been imagined, rehearsed, and written into the plan. In this way, the simulation seemed to trigger more discussion moves in the simulation lesson plan than in the overhead lesson plan. These scripted moves contributed to the greater time spent and the greater variety of moves seen in the simulation lesson.

**Effects on Spontaneous and Unplanned Actions by the Teachers**

The difference in lesson plan is only part of the story, however. The simulation also appeared to provide an affordance for the spontaneous strategic application of discussion moves. While the lesson plan called for certain modifications of the simulation and suggested a set of discussion moves, neither teacher in the study enacted the lesson exactly as it was written. For example, Mr. S made four times as many modifications (33 spontaneous vs. 7 planned) to the simulation and twice as many discussion moves (22 spontaneous vs. 9 planned) than were called for in the simulation lesson plan (Table 6-8a and 6-8b).

Table 6-8a
Comparison of Simulation Lesson Plan and Simulation Lesson Enactment by Mr. S

| **Mr.S's Simulation Lesson** | **Planned Actions (PA) suggested by the Simulation Lesson Plan** | **Teacher Actions (TA) made by Mr. S during the teaching of the Simulation Lesson** | **Spontaneous Actions (SA= TA- PA): Difference between the lesson plan and the enactment** |
|---|---|---|---|
| | Instances | instances | Instances |
| Orient | 1 | 2 | +1 |
| Predict | 2 | 0 | -2 |
| Highlight | 5 | 12 | +7 |
| Link | 1 | 6 | +5 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 0 | 2 | 0 |
| Situate | 0 | 0 | 0 |
| Frame | 0 | 0 | +1 |
| Total Moves | 9 | 22 | +13 |
| Modifications to the Simulation | 7 | 33 | +24 |

Table 6-8b
Comparison of Overhead Lesson Plan and Overhead Lesson Enactment by Mr. S

| **Mr.S's Over-head Lesson** | **Planned Actions (PA) suggested by the Overhead Lesson Plan** | **Teacher Actions (TA) made by Mr. S during the teaching of the Overhead Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the enactment and the lesson plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 0 | 1 | 0 |
| Predict | 1 | 0 | -1 |
| Highlight | 3 | 2 | -1 |
| Link | 3 | 0 | -3 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 0 | 0 | 0 |
| Frame | 0 | 0 | 0 |
| Situate | 0 | 0 | 0 |
| Total Moves | 7 | 3 | -4 |
| Modifications to the Overhead | 4 | 2 | -2 |

A similar pattern was found in Mr. R's class. Mr. S made more modifications to the simulation (11 spontaneous vs. 7 planned) and more than twice as many discussion moves (25 spontaneous vs. 9 planned) than were called for in the simulation lesson plan (Table 6-9a and 6-9b).

Table 6-9a
Comparison of Simulation Lesson Plan and Simulation Lesson Enactment by Mr. R

| **Mr. R's Simulation Lesson** | **Planned Actions (PA) suggested by the Simulation Lesson Plan** | **Teacher Actions (TA) made by Mr. R during the teaching of the Simulation Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the enactment and the lesson plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 1 | 8 | +7 |
| Predict | 2 | 0 | -2 |
| Highlight | 5 | 6 | +1 |
| Link | 1 | 10 | +9 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 0 | 0 | 0 |
| Situate | 0 | 0 | 0 |
| Frame | 0 | 1 | +1 |
| Total Moves | 9 | 25 | +16 |
| Modifications to the Simulation | 7 | 11 | +4 |

Table 6-9b
Comparison of Overhead Lesson Plan and Overhead Lesson Enactment by Mr. R

| **Mr. R's Overhead Lesson** | **Planned Actions (PA) suggested by the Overhead Lesson Plan** | **Teacher Actions (TA) made by Mr. R during the teaching of the Overhead Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the enactment and the lesson plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 0 | 3 | +3 |
| Predict | 1 | 2 | +1 |
| Highlight | 3 | 1 | -2 |
| Link | 3 | 0 | -3 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 0 | 3 | +3 |
| Situate | 0 | 0 | 0 |
| Frame | 0 | 1 | +1 |
| Total Moves | 7 | 10 | +3 |
| Modifications to the Overhead | 4 | 6 | +2 |

These data provide evidence that these teachers generated more spontaneous moves during the discussions of the simulation than they did during the discussion of the overhead. The lesson plan can serve as a guide for the lesson, but it is not simple, nor always desirable, for a teacher to follow a lesson exactly. Often opportunities for encouraging student reasoning develop in the moment and these opportunities are difficult to anticipate in the lesson planning process. Teachers improvise responses to the thinking needs of the students and the flow of ideas that unfolds in a large group discussion. A simulation can be manipulated in response to student questions and comments and provide clear and accurate images of the model. This capability may allow the simulation to support teachers as they improvise the orchestration of discussion.

For example, both Mr. S. and Mr. R did more highlighting and linking moves than were suggested by the simulation lesson plan (shown in yellow on Figure 6-8a and 6-9a). Since highlighting and linking can be used to focus student attention on the causal chains of the model, both teachers may have noticed more opportunities or needs than anticipated by the lesson plan and used the simulation to explicate dynamic examples of causal chains found in the simulation.

In this way, the simulation condition appeared to foster a variety of unscripted discussion moves. These unscripted, spontaneous moves contributed to the time spent discussing the simulation. Based on these findings, I hypothesize that the simulation provided these teachers a greater affordance for managing a discussion than did the overhead.

**Part Two: Examining Differences in the Behavior of the Two Teachers**

This part of the chapter reports on a comparative case study that examined differences between teachers enacting the same lesson and image mode. This part of the chapter examines patterns of teacher-student interactions used by each teacher during the entire lesson and will address the question: 1) Did teachers use different patterns of interactions? 2) If so, did the image use impact the patterns of interaction used by the teacher in the lesson? 3) Did teacher interaction pattern choices change after an image mode started?

In this case study, prior descriptions of interaction modes in the literature (Nassaji & Wells, 2000), along with the constant comparison method, were used to refine descriptions and coding categories of interaction patterns that helped me to describe different patterns of teacher behaviors during discussion. Note that in the remainder of

the chapter, interaction pattern will be used when referring to teacher-student interaction pattern. Interaction pattern does not refer to a statistical interaction between variables, but rather to one of the modes in Table 6-10.

## Description of Interaction Patterns and Coding Categories

This analysis makes use of the first level of coding described above to isolate the section of the lessons devoted to discussion.

### Introduction of Class Diagram

Figure 6-5 is a representation of how the teachers used time in their lessons. The numbers along the side represent the time codes in minutes from the video of the classes. In this diagram, red represents the time devoted to observation of the phenomena, which in this case is the tire being inflated or deflated. The yellow sections represent the part of the lesson where no image was projected. During this time students were discussing the concepts but the image was not projected and, thus, was not incorporated into the discussion. The green sections represent when the concepts were being discussed while the image was being projected. This is coded as the image-based discussion because the image was used as part of the discussion.

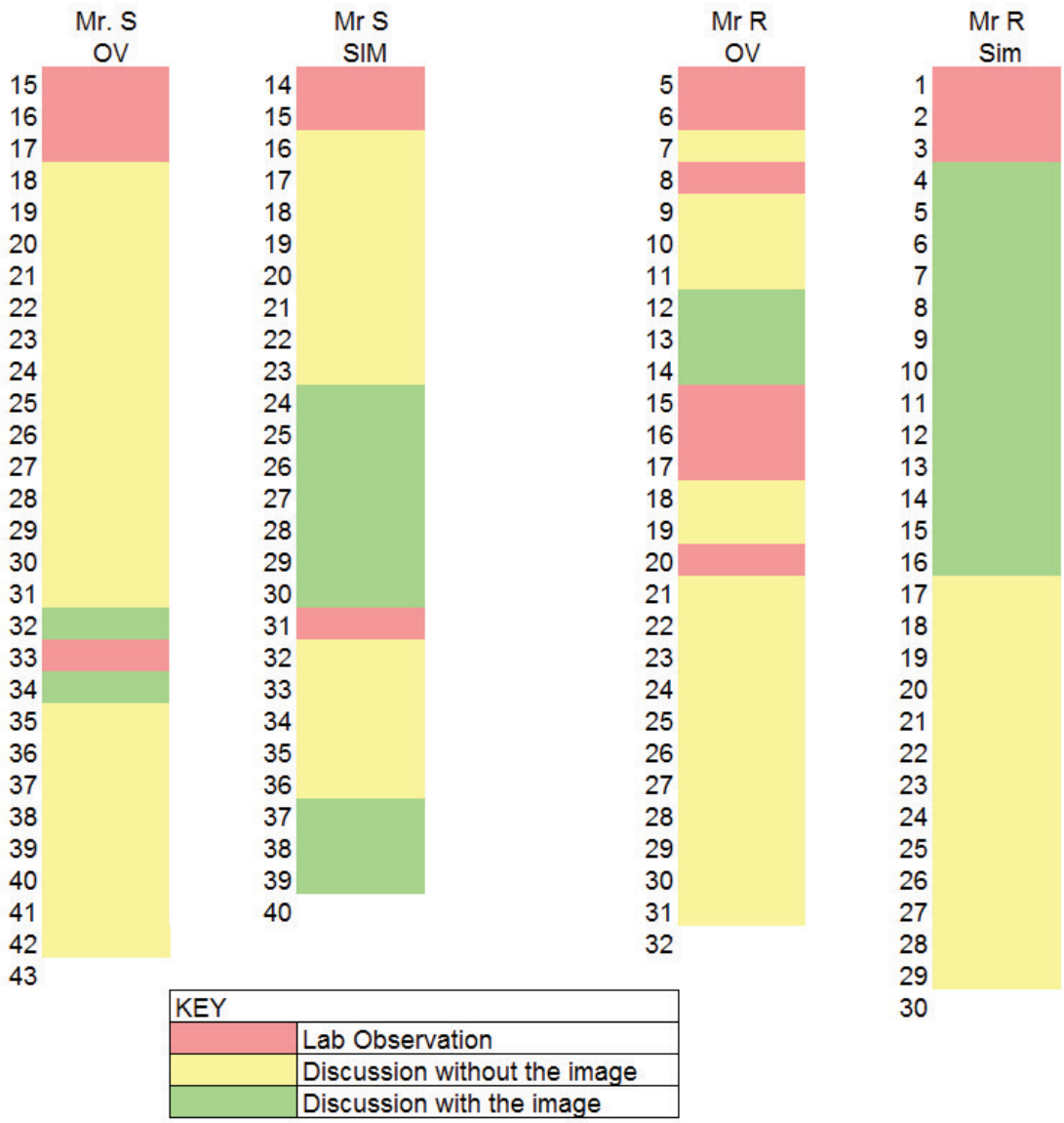


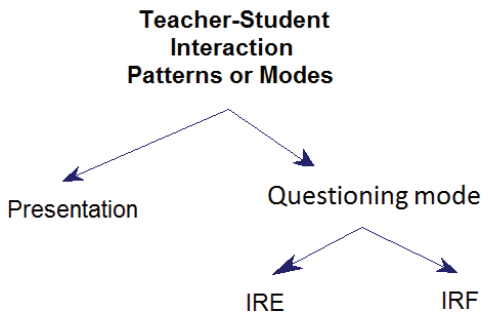

Figure 6-5
Diagram of Difference in the Classes

## Coding for Teacher-Student Interaction Patterns: Presentation, IRE, IRF

Even though teachers were following the lesson plan, there were some important differences in how they enacted it. To better understand how the difference in teachers may have affected discussion, I coded for four patterns of interaction: presentation, IRE, IRF, and other (Table 6-10).

Table 6-10
Interaction Pattern Codes

| **Interaction patterns observed during the Image-based and Non-image-based discussion, and diagram of taxonomies used in this study.** | | |
|---|---|---|
| P | Presentation | The teacher describes or states the school science perspective of the model or concept |
| IRE | Initiation<br>Response<br>Evaluation | The teacher asks a question and then evaluates student responses. |
| IRF | Initiation<br>Response<br>Follow-up | Teacher asks a question and then probes students answer with a series of follow-up questions. That is, the teacher follows up on the student response with an invitation for students to say more and students do say more. |
| O | Other | This category included times when the teacher was manipulating the simulation, reading from the handout, or the students were working in small groups. |




## Narrative Transcript Analysis for Interaction Patterns and the Use of Images

In this section, I will use transcript excerpts from the 4 lessons in this study (Table 6-11) to attempt to identify and describe some observation patterns of how the teachers enacted the lesson that may be relevant to questions about how images are used to develop conceptual understanding. It is interesting to notice that even though the teachers were attempting to follow a common lesson plan, which they had jointly authored, they enacted the lesson in a large variety of ways.

Table 6-11
Key to Transcript Excerpts

| | **Non-image-based Discussion** | **Image-based Discussion** |
|---|---|---|
| Mr. S OV Lesson | Transcript 1 | Transcript 4 |
| Mr. S SIM Lesson | Transcript 2 | Transcript 5 |
| Mr. R OV Lesson | Transcript 3 | Transcript 6 |
| Mr. R SIM Lesson | No Example | Transcript 7 |

**Analysis of Sections of the Lesson: Lab (Red), Non-image Discussion (Yellow), Image-based Discussion (Green)**

**Lab Observations (Red Sections)**

Lab Observations: One common pattern is that both teachers began their classes by asking students to make observations of a demonstration of a tire being pumped (shown in red, Figure 6-5). During these periods of lab observation, the teachers were presenting the phenomena. Since the lab parts of lesson involved small group work and were not used for asking questions or developing explanations in these lessons, they will not be the focus my analysis.

**Non-image Discussions (Yellow)**

Teachers use time before the image is presented differently. One pattern present in the diagram in Figure 6-5 is that Mr. S spent more time discussing the concepts before showing the image than did Mr. R. This time difference is seen in both his overhead and simulation lessons.

By examining transcript examples in more detail, it is possible to form some hypotheses about why the teachers used time differently. What follows are transcripts for each teacher from the pre-image phase of the lesson. They focus on how the teachers decided to manage the discussion of a key concept in this lesson, namely, how the air

behaves when it's pumped into the tire. In their work developing this curriculum, Anderson et al. (1993) found that many students believed that air molecules stay next to the valve instead of being evenly spread throughout the tire. To address this misconception, the Matter and Molecules curriculum prompted students to answer the following "valve question."

While both teachers knew that students might share the misconception that the molecules congregate near the valve, each teacher dealt with this possibility differently.

> Valve Question:
>
> My friend says there is more air near the valve of the bike tire where the air was pumped in. Do you agree with him? Explain why or why not.

How they managed this phase of the lesson provides a way of describing the differences between the teachers.

**Transcript 1: Mr. S's OV lesson non-image discussion**. The transcript that follows provides a window into how Mr. S orchestrated this part of the lesson. Mr. S polled the class and uncovered a range of beliefs about the "valve question" and then used these different perspectives to introduce a bit of controversy into the class discussion by not evaluating student responses and allowing the valve question to remain open. This controversy seemed to motivate many students to share their ideas about this open question. In the whole class discussion of this question, Mr. S encouraged students to generate ideas about how the molecules behave near the valve by asking follow-up questions. He used an IRF exchange pattern and did not evaluate student responses but

instead encouraged them to more fully articulate their point of view and react to other students ideas.

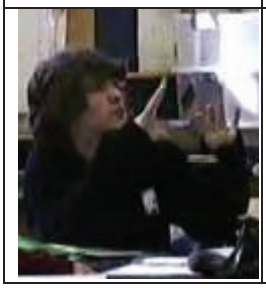
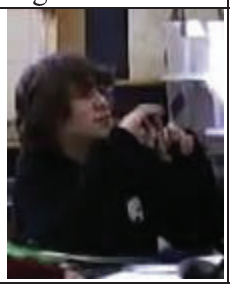
| “pushed away” | “closer together” | “spread apart” | Maria what do you think? |
|---|---|---|---|
|  |  | | |

Figure 6-6
Screen Shots from Transcript 1: Mr. S’s OV Lesson Non-image Discussion

T: When I pump air in the tire, for some time, there is gonna be more air here, for some time there's gonna be more air near the valve, what do you think Cheryl?

Cheryl: I think that there will be.

T: Let's do a quick vote. How many people think… how many people agree that for some time, there will be more air near the valve?

Students: Vote by raising hands

T: So almost half. About two people at each table. How many people think “Nope, there is not going to more anytime near the valves?”

Students: Vote by raising hands

T: About half. Good. Alright sorry "Cheryl" I cut you off, tell me about it. So you think that there will be for some period of time, there'll be more air molecules near the valve. Share your thinking.

Cheryl: There is like, when it's being pumped in, that's like where it's entering, so there would be more air molecules in that area and then afterwards it would spread out and the amount of time but probably like less than nanoseconds.

T: So you measured it in nanoseconds? Can you share it with the rest of us, everyone know how long a nanosecond is?

Cheryl: I think it's about like a millionth of second.

T: Millionth. So "Cheryl" is thinking that for some time, it's measured in the millionths of seconds there'll be more crowded in the valve. What do you think, Jose?

Jose: I think that it won't be crowded at the valve 'cause the air coming in through the valve.

T: So there'll be more air molecules, but they're gonna be everywhere, not at the valve. After you pump it? OK?

S: Nods

T: "John" what do you think?

John: When you like, pump the air in there, all of them like at the same all be pushed away so they'll be closer together everywhere, each time you pump it, there won't be like, they won't be closer together right at the valve and they'll become more spread apart everywhere else.

T: Good. So you're agreeing with Jose?

John: Ya.

T: Maria, What do you think?

**Analysis of transcript 1.** This discussion, which was sustained and encouraged by Mr. S's use of IRF interactions patterns, continued as Mr. S asked four more students to respond to other students and to articulate their own thinking about this question. Though this conversation happened before an external image is present, students may be generating their own internal images or mental models to help them think about this question. For example John's response (Figure 6-6) was accompanied by gestures figure while he is trying to describe the forces applied (Figure 6-6a) and the resulting motions of the molecules (Figure 6-6b and 6-6c). Some researchers have argued that this sort of gesturing is evidence of imagistic reasoning (Monaghan & Clement, 1999; Stephens & Clement, 2010). This transcript suggests that students are attempting to reason with their

initial mental model of how the particles would behave after being pumped in to tire. This discussion of the valve question lasted over 7 minutes and could have continued since there were many hands up in the class when Mr. S chose to begin discussion of the overhead in the image portion of the lesson.

**Transcript 2: Mr. S's SIM lesson non-image discussion**. A similar IRF set of exchanges took place in Mr. S's Simulation lesson in which he polled the students about the valve misconception and then neutrally asked student to provide reasons for their vote.

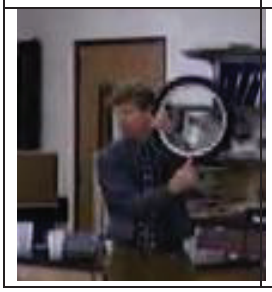
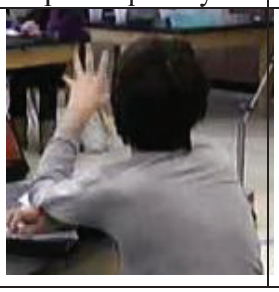
| a) T: "More air here?" | b) Voting T: "Good so it's about half" | c) Alan : "they disperse quickly" | d) Julie: "the valve, it can only fit so much air" |
|---|---|---|---|
|  | |  | |

Figure 6-7
Screen Shots from Transcript 2: Mr. S's SIM Lesson Non-image Discussion

> T: … So how many people agree with my friend, that for some time, the air near the valve is more crowded? It is, what were the exact words they used? There was more air here?
>
> S: (some students raise hand)
>
> T: Looking like third, three, half, most, maybe all that table. How many people disagree that my friend's wrong. When you pump it down, the air is not here for some time.
>
> S: (some students raise hands)
> T: Anybody else? No. Good. So it's almost half. Let's see some arguments for or against this real quick and then then I'll just show you a picture on the screen. So who could tell us, why they think, why they agree? Let's do that one first. Why do you agree? Alan?

Alan: Well, for the fraction of a second while the air is being pumped in there is a lot more air molecules in the area where it's being pumped in which is why the dial goes way up and then goes back down.

T: Did you see the dial go up and then down? Did it do any bouncing like that? We should, that would be an interesting test. We should see. If it sort of bounces a little bit, that would be some evidence. Okay, if we don't have that evidence, though, we could do that in minute, any other thoughts, any other thoughts about agreement? Why is there more air at the valve for some time? And you're saying a fraction of a second; it's not a lot of time.

Alan: They disperse really quickly.

T: Dylan?

Dylan: When they go in they kind of spread out and since you pump it in they don't just appear on the other side of the tire.

Mr. T They don't spread out instantly. It takes some time for them to get spread out. Okay. How many people think it is No? How many people disagree? Can somebody share that argument that disagrees? Julie, you got any thoughts? Why do you disagree with my friend about being more air there?

Julie: Well only because the air, like, there is also like air in the tire already so when you put the air in with the pump it's not all in the valve because there is also air in other parts of the tire. And then it spreads out.
T: Okay, so there is already air all around so you put a little more in, it's not gonna...

Julie: No, because around the valve it can only fit so much air so it has to spread out and there is already air in the other parts of the tire so.

T: All right.

**Analysis of transcript 2**. In this example Mr. S polls student and again encourages them to articulate various points of view about the valve question. This conversation is happening before an external image is present, but there is again evidence of student gesturing. This may suggest that students are generating their own internal images or mental models to help them think about this question. This transcript suggests

that students are reasoning with their initial mental model of how the particles would behave after being pumped in to tire.

This pre-SIM discussion was shorter than the pre-overhead head discussion shown above but students here are also given a chance to generate their own ideas without having them evaluated. In both the pre-overhead and pre-simulation discussion, Mr. S uses the misconception as an opportunity to get students to think and share their thinking in a whole class setting. Using Clement's (2008) model co-construction framework, the effect of Mr. S's prompts appears to be to get students to generate a model of air molecules as they are pumped into a tire. Using Mortimer and Scott's (2003) communicative approach, framework, Mr. S can be seen pursuing a dialogic communicative approach by giving students a chance to express their points of view without providing evaluation.

**Conclusion for Mr. S's non-image discussion transcripts 1 and 2**. The communicative approach (Mortimer & Scott, 2003) describes the importance of alternating between teacher and student points of view and pursuing a dialogic agenda to explore student-generated ideas and sense-making during a discussion. In these transcript excerpts from two separate classes, there is evidence that Mr. S pursued a dialogic agenda before the image was presented. This agenda was dialogic in that it encouraged students to articulate their initial model describing the behavior of air in the tire. Through his use of IRF interactions, which paired generative questions with deferred judgment on student ideas, he appeared to encourage students to attempt to reason with their initial mental model of how the particles would behave after being pumped in to tire.

**<u>Transcript 3: Mr. R's OV lesson non-image discussion</u>**. Mr. R took a different approach to the discussion he had with students before the image was presented. Instead of using the "valve question" as a prompt for student reasoning, as Mr. S did, Mr. R uses a direct instruction approach, in presentation mode to address the possible student misconception. Before the overhead was shown, Mr. R does not have students answer questions, so there is no opportunity to discuss them in whole class. Instead, Mr. R directly addresses the misconception and presents the correct conception using a set of thought experiments.

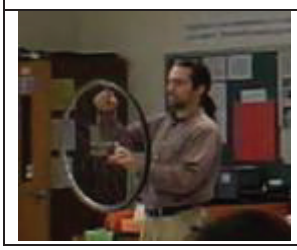
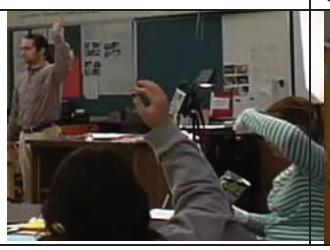
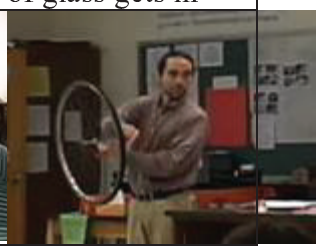
| a) Two valve thought experiment: "…put air in one valve" | b) Two valve thought experiment: "it will come out anywhere on tire. " | c) Flat tire thought experiment: "..how many have gotten a flat tire before?" | d) Flat tire thought experiment: "it doesn't matter where the piece of glass gets in" |
|---|---|---|---|
|  | |  |  |

Figure 6-8
Screen Shot of Transcript 3: Mr. R OV Lesson Non-image Discussion

> T: Where does the air go when you pump it into a tire? Here is a confusion that kids have. Some students think that when you pump up a bicycle tire, the molecules go to where the valve is. Then there is a lot of molecules right around here, but not on the other side of the tire. Here is what I want you to think about. Imagine that the bicycle tire is full again. There is more molecules inside the tire than outside the tire. And when you came up, instead of asking her to push the valve I gave her a sharp knife. And I said, "Melissa" stab the tire right here. Melissa would the sound have been much different? (as the release of air from the valve? )
>
> Melissa: ummmm....Not alot.
>
> T: Maybe let's pretend there is a second valve over on this side. Let's pretend there's a special bike tire that had two valves. We put the air on this side, and then

we pushed the valve on this side, the imaginary valve. (pause) My expectation is.. I think you're comfortable with the idea that the air would come out the same way. You have two valves here. Imagine if we put the air in this valve, and imagine an imaginary valve over here. (pause) I think you will find the idea that the air would have come out just as fine out this valve. You can put air in one valve, it will come out anywhere around the tire. (pause) How many people have gotten a flat tire before?

S: Half of the students raise hands

T: Not everyone? Well many of us have had this experience. It doesn't matter where that piece of glass gets in the tire. The air will come out just as easily. The point of that is to say that the air is distributed evenly around the bike.

**Analysis of transcript 3.** In this example, Mr. R is not asking the students to generate or evaluate any model element. The teacher is doing the generation and the evaluation. He provided thought experiments to convince students that the air molecules are evenly spread out throughout the tire. In the model co-construction framework, Mr. R could be thought of as generating the initial model of air molecules tending to stay near the valve after being pumped in the tire when he states that students can be confused and think that "molecules go to where the valve is." He then evaluates and modifies this initial model using thought experiments. In the communicative approach framework when Mr. R first articulates the student view, "Some students think...," this would be considered a short non-interactive dialogic episode. Then Mr. R switches approaches in the next sentence and pursues an authoritative communicative approach since he presents only reasoning that support the school science point of view. Mr. R does not provide students with an opportunity to write down answers to the valve question until after he has presented the model and is, in effect, treating the question as an assessment of how well they understood his presentation.

**Mr. R's SIM non-image discussion**. In his simulation lesson, Mr. R did not have any discussion with students before presenting the image. Just as in his overhead lesson, students were not given a chance to think and write about the "valve question" until after he had used the image to present the target model.

**Conclusion for Mr. R's OV and SIM non-image discussion**. Data from two classes provide evidence that Mr. R did not pursue a dialogic agenda before the image was presented. In his overhead lesson, he did not use the time before the image was projected to probe student thinking. Instead, he used this time to present the target model of how air molecules behave in a tire. The fact that Mr. R did not discuss or even have students answer the "valve question" before they discussed the image supports the hypothesis that he was pursuing a more authoritative agenda. Putting off the questions until the end would be make sense if he wanted to converge on the target model so that students could use the target model to respond to the question.

**Conclusion for non-image discussion of Mr. S and Mr. R: Transcripts 1-3.** The diagram in Figure 6-6 suggests that Mr. S spent more time before the image discussing the concepts than Mr. S. The transcript examples above suggest that this time difference is related to the type of teacher-student interactions that that teachers orchestrated. The transcripts above suggest that Mr. S spent more time on the non-image part of the lesson because he gave students a chance to answer and discuss all the lesson questions in whole class mode. Mr. R did not give student a chance to do the questions before the image, and he did not discuss their answer in whole class mode. Mr. S was observed using the discussion time to generate student ideas through a series of IRF

interactions about the model, and Mr. R was observed using this phase of the lesson to present the target model through direct instruction, using presentation and IRE interactions to evaluate student ideas.

The excerpts of transcripts from the teachers suggest the possibility that each teacher was pursuing a different agenda. In the cases presented, Mr. S used the time before the image was presented to pursue a dialogic agenda to explore student-generated ideas and sense-making during a discussion. In the pre-image part of the lesson, he appeared to use the questions and ideas they generated to motivate a discussion that encouraged students to reason with their model of a gas.

On the other hand, Mr. R used the time before the image was presented to pursue a more convergent or authoritative agenda in which he presented models and evaluated those models without input from the students. In his simulation lesson, he did not have any discussion of the questions or the key concepts of the lesson before showing the image form lesson. These different agendas would help explain some of the differences we see in diagram of difference in the classes (Figure 6-6). The yellow sections representing non-image discussion are larger in Mr. S's class before the image was presented. Mr. S's dialogic agenda may have lead him to treat the handout questions as a prompt for generating initial student models that would later be revised after discussion of the image of the target model. The discussions that generated rich and complex student ideas took more time than Mr. R's lectures about the same concept. Mr. R's authoritative agenda may have led him to treat the "valve question" as final assessment of student understanding. It would follow that his non-image discussion intervals (yellow sections)

are longer after the image was presented since he gave time for student to work on them after he has presented the target model.

**Image-based Discussions**

The green sections on Figure 6-6 represent discussions that took place while the image was projected. One pattern visible in Figure 6-6 is that Mr. R spends more time discussing the image than does Mr. S. The intervals of image-based discussion are longer in Mr. S's than Mr. R's. Below are transcripts of teachers discussing the images. They can be used to develop preliminary observation patterns that help to uncover some factors that influence each teacher's use of time.

**Transcript 4: Mr. S's OV lesson image-based discussion**. This transcript is taken from the part of class directly after the extended conversation about the "valve question" shown above. This section of class shows how Mr. S used the image to address the "valve question." He begins by noting that we ask this "valve question" because students often think that molecules stay near the valve after being pumped into the tire. He then uses a presentation mode to explain the overhead image and uses a highlighting move to describe the target model.

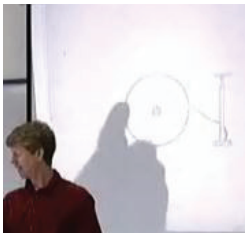
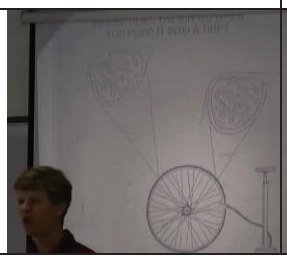
| | | | |
|---|---|---|---|
| a) T: “some kids think …. there is more air molecules hanging out here …” | b) T: “…than hanging out here” | T: “… graphic to show us, oh look, it's equally crowded everywhere. It's not more crowded at the valve” | c) T: “I can even turn it around. It’s the same crowdedness at the valve as it is someplace else in the tire. “ |
| |  |  | |

Figure 6-9
Screen Shots of Transcript 4: Mr. S’s OV Lesson Image-based Discussion

HIGHLIGHTING:
T: What the book was getting at is that some kids think that it stays that way for a while. It's not instantaneous or almost instantaneous that you pump it in there, and there is more air molecules hanging on here than hanging on here. So that was the point of their question and then they gave me this nice little graphic to show us, oh look, it's equally crowded everywhere. It's not more crowded at the valve. Okay, that's supposed to show equally crowded air in it. So it's the same. I can even turn it around. It’s the same crowdedness at the valve as it is someplace else in the tire. Okay?

**Analysis of transcript 4**. Using a model construction framework, Mr. S is using the image to evaluate and modify the model. By displaying the image and highlighting the equal crowdedness of the molecules at different locations in the tire, students can evaluate and modify the model of molecules congregating near the valve. In the communicative approach framework, when Mr. S’s stated the student view, “Some kids think...,” this could be considered a short, non-interactive, dialogic episode. Then Mr. R switched approaches and pursued an authoritative agenda since he presented only the school science point of view.

**Transcript 5: Mr. S's SIM image-based discussion**. This transcript is taken from Mr. S's simulation lesson directly after the pre-image discussion about the "valve question" shown in transcript 3. This section of class shows Mr. S orienting students to the simulation. Since the simulation does not show a tire or a pump, these features need to be imagined by the student.

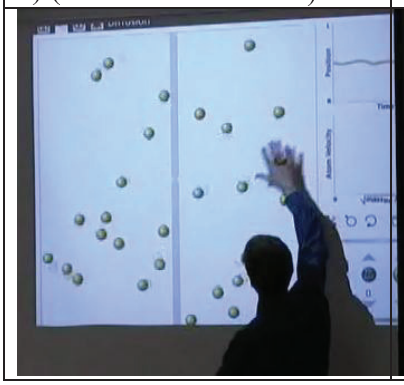
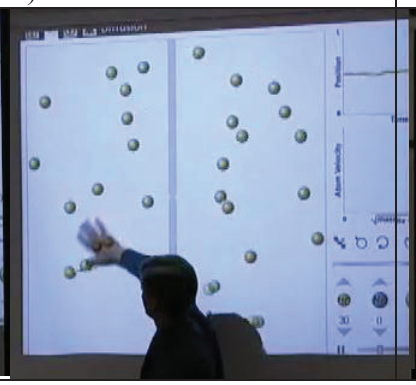
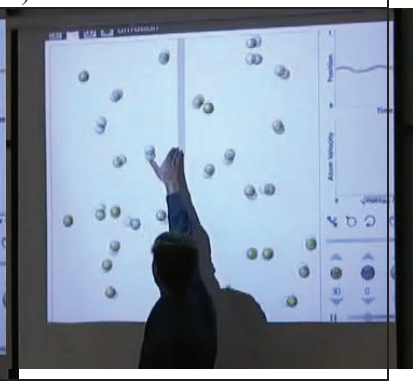
| a) ("air outside the tire) | b) "air inside the tire" | c). "this is tire" |
|---|---|---|
|  |  |  |

Figure 6-10
Screen Shots of Transcript 5: Mr. S's SIM Image-based Discussion

> T: So this is the air outside of a tire (Fig 6-10a). This is the air inside the tire (Fig 6-10b). This is the tire itself. (Figure 6-10c) And then this is the valve, with the big opening if you look at it in molecule size.

**Analysis of transcript 5**. This transcript is an example of how Mr. S switched to using presentation mode while he developed the target model using the simulation. He did not open the floor to questions or student comments. Mr. S uses an orienting move to map the parts of the simulation to the tire demonstration that students observed earlier in the class. He executes this move using a presentation mode. He tells students what parts of the simulation represent and does not ask students questions.

**Conclusion for Mr. S's image discussion transcript 4 and 5**. These transcripts from Mr. S's image-based discussions point to a preliminary observation pattern: Mr. S shifted his interaction mode from IRF to Presentation when he began discussing the

image. In transcript excerpts 1 and 2 before the image was presented, there is evidence that Mr. S pursued a dialogic agenda. However, in transcript excerpts 4 and 5, when images were displayed, Mr. S used the images to present the target model, not to ask questions about it. This presentation mode contrasts with his pre-image discussion modes when he used IRF interactions to encourage student to generate ideas about the model. During the image-based discussion his use of presentation mode suggests Ms. S pursued a more authoritative agenda and was using the image to converge on the target model.

**Transcript 6: Mr. R's OV image-based discussion**. This transcript comes from the part of the Overhead lesson immediately following his presentation of the thought experiments. In this segment he is using the overhead image to develop the model of air in the tire by asking students to predict want part of the model will look like.

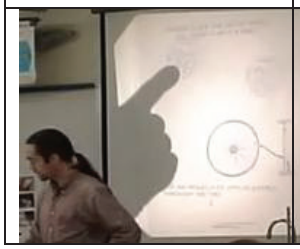
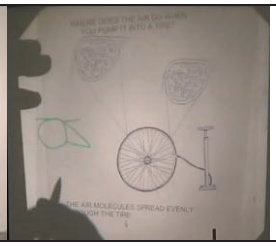
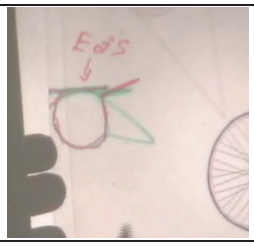
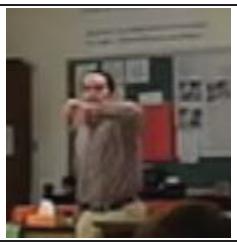
| | | | |
|---|---|---|---|
| a) T: "…any two points in the bike tire, the density of air molecules would be the same. | b) T: "There is nothing outside… I am going to draw glasses of science outside." (draws on OV) | S: "It looks like a bug…. " T: "E...of...S. Does that help? Eyeglasses of science." S: Yes. | c) T: "When the bike tire is pumped up, the outside air is less dense, same density, more density? … Vote. " |
|  |  |  |  |

Figure 6-11
Screen Shots of Transcript 6: Mr. R's OV Lesson Image-based Discussion

> T: The point of this drawing is if you look at the density of air inside, it should be the same. (Gestures over image and moves the overhead around). That would be any two points in the bike tire, the density of air molecules would be the same. The only thing I don't like about this overhead is there is nothing about outside.

Think to yourself. I'm gonna draw eyeglasses of science pointing outside. Think to yourself. What should that drawing look like?

S: Looks like an ice cream cone...

T: Yeah these are not very good eye glasses. So this is an eyeglass of science appearing outside the bike tire.

S1: Oh I see it now, yea it's got the pointy thing with the other two dudes have.

S2: I see it.

S: I still don't.

S2: It looks like a bug!

T: There are some things I am good at in life, and drawing is not one of them. I do practice though sometimes. Okay. Let's make it easy, E...of...S. Does that help? Eyeglasses of science

S: Yes. That looks a little better.

T: If you think that molecules outside the bike tire should be less dense, same density, or more dense than the bike tire, the molecules inside the bike tire. So I'm looking for less, same, or more. Comment?

S: Is this when the bike tire is pumped up?

T: This is a pumped up bike tire right now. We're assuming that the bike tire is currently pumped up. When the bike tire is pumped up, the outside air is less dense, same density, more density? Give me a vote. (Teacher shows voting gesture using up down and sideways thumb.)

S: All student vote with up, down or sideways thumbs.

T: Thank you...Thank you...Thank you. So looking around, essentially everybody had a down pointing thumb. That would be what we would expect to see. Outside we would expect to see lower density, less air molecules outside than inside. (Draws molecules on the OV showing them less dense outside tire)

**Analysis of transcript 6**. This transcript shows Mr. R is doing something he did not do before the image was present. He is asking students to make a prediction based on their model of air. Mr. R drew diagrams to set up a question, asking students, "What

would air outside the tire would look like?" This can be viewed as an attempt to have students reason with their model. This contrasts with the presentation approach that he took in the non-image sections of this lesson in which he directly presents ideas to student.

**Conclusion of transcript 6**. This example does not suggest the same generative agenda that Mr. S pursued with multiple IRF interactions in Transcript 1 but does show Mr. R taking a step away from presentation. Mr. R made room in the lesson for student follow-up questions as he oriented them to his drawings. Even though students had trouble interpreting his diagrams, Mr. R did use the overhead image to set up this question. While this is not an open-ended or generative question since students eventually only respond to a multiple choice question with a thumb vote, it could indicate a small shift that occurred in Mr. S's use of discussion once the image was present.

**Transcript 7: Mr. R's simulation image-based discussion**. In his simulation lesson, Mr. R does not have a non-image discussion segment because he does not discuss the model before displaying the simulation. Immediately following the lab, he displays the simulation and uses it to discuss the model. In this segment he is using the simulation to develop the model of air in the tire by asking students to map the simulation to the lab demonstration. Since the simulation does not show a tire or a pump, these features need to be imagined by the student. Mr. R is executing the orientating move by asking students to decide which part of the simulation represents the inside of the tire. In Transcript 2, Mr. S executed a similar orientation move but used a presentation mode. In this example,

Mr. R asks what appears to be a simple question but must respond when he finds that students do not have enough information to answer it.

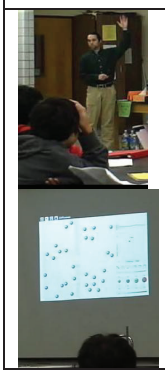
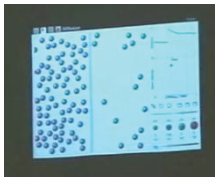
| a) T: Decide for yourself which side represents the tire.” | b) T: (adds molecules) “Now which side represents the tire? “ | c) T: “How many people think there is the same density of air in the (Flat) tire as outside?” | d) T: (Holding flat tire) “Right now, the air inside is just as dense as the air outside.” |
|---|---|---|---|
|  |  | | |

Figure 6-12
Screen Shots of Transcript 7: Mr. R’s SIM Image-based Discussion

T: Decide for yourself which side do you think represents the tire, which side represents the air. How many people think this side represents the tire?

S: (A few students vote by raising their hand.)

T: How many people think this side represents the tire?

S: (Only a few people vote by raising their hands.)

T: I'm guessing people didn't take a stand and put up their hand, and were like,

Mr. R, I don't have any information right now. Talk to your table about what represents the valve. What represents the bicycle tire valve? Talk at your table real quick.

S: Students talk at their tables.

T: OK what represents the valve? Mavis what represent the valve?

Mavis: The hole in the wall?

T: The hole in the wall. Thank you. Let's try to point it out (Teacher points to the spot on the SIM). This hole in the wall here represents the valve. Now, think for yourself. I'm going to do something (T: “pumps” in air by adding molecules to the

SIM). Now which side represents the tire? Which represents the air outside the tire? Please talk to your table right now.

S: (Students talk at their tables.)

S1: Is the tire flat? Is it flat?

S2: Mr. R, did you pump the air in the tire?

T: Okay, I was checking with some people, and one question was, "Is there air pumped into the tire?", and you should be able to answer this one. Because when you let the air out of the tire, you listen, you're pushing the valve but you can't hear air coming out. So is there the same or different density air in the tire right now? How many people think there is the same density of air in the tire as outside?

S: A few people raise their hands

T: Different density of air?

S: A few people raise their hands

T: So, not clear? Right now, the air inside is just as dense as the air outside. It's no more packed, no less packed. So you had a chance to check with people. Which do you think represents the tire up here? So, if you think the tire, when we vote, if you think this side (right) is the tire, you point towards the windows. If you think this one (left) represents the inside of the tire, you point towards the door. Three, Two, One. Which one is the tire?

S: Most students point toward the door (left)

T: Most of what I saw was people pointing towards the door, meaning that this side of the animation (left) represents the tire, which is correct.

**Analysis of transcript 7**. In transcript 7, Mr. R asks students to orient the tire to the simulation by polling the class (Figure 6-12a). When only a few students answer, he gives them time to discuss a simpler question in small groups at their tables. (What represents the valve?) More students are able to answer this orienting question, but they also inform Mr. R that they do not know whether the tire is flat or not. This critical piece of information is needed if students are going to map the real tire on to the simulation (a

flat tire would have equal molecules on each side, and a pumped up tire would not). He tries to provide this information by altering the simulation to make the side of the simulation representing the tire to have more molecules (Figure 6-12b). He encourages students to persist in their attempts to reason ("You should be able to answer this one.") and asks them to provide more information ("How many people think there is the same density of air in the tire as outside?") (Figure 6-12c). He provides the answer when students do not (Figure 6-12d), and then repeats the question with which he started ("Which do you think represents the tire up here?") and now finds that students appear to understand how the simulation maps to the tire demonstration.

**Conclusion from transcript 7**. This transcript provides an example of how Mr. R reacted when he asked questions that revealed limitations in students' understandings. Mr. R took a step away from presentation when discussion was supported by images. Asking questions that are tractable to student reasoning is a skill that takes time for teachers to develop. In this example, we see how Mr. R struggles to find questions about the simulation that are tractable to student reasoning and struggles to provide information that is needed for students to do productive thinking.

This attempt to engage student reasoning is an example of the trial and error process this teacher used as he worked on developing the questioning skills needed to manage a discussion. In transcript 7, we see evidence of this teacher's struggle to find what ideas student have and what they need to reason.

**Conclusion for image-based discussion transcripts 4-7**. In transcripts 4 and 5, Mr. S is observed using the discussion of the images to converge on the target model and

pursue an authoritative agenda. Instead of asking students to articulate their point of view, as he did before the image was displayed, Mr. S uses the projected images (OV and SIM) as a "tools for telling" by using them to support descriptions of the target model.

Mr. R is observed opening up more space in the class for student thinking than he did before the image was projected. He asks students to interpret the image and make inferences about what the image represents. These efforts to hear more from students are not always easy, even when these discussions are supported by images, since it takes time to discover what questions are tractable to student reasoning. We see evidence of this struggle to find what ideas students have and what they need to reason. He uses the image as a "tool for asking" by prompting students to interpret the information provided by the image.

**Summary of Preliminary Patterns Observed in Transcripts Excerpts 1-7**

These transcripts excerpts (1-7) suggest that the different uses of time observed in Figure 6-6 may be related to the type of teacher-student interactions that the teachers orchestrated during the non-image and image-based discussion sections of the lesson. During non-image discussion, Mr. S spent a longer interval discussing the concepts than Mr. R. Before the image, Mr. S was observed using discussion to generate student ideas through a series of IRF interactions about the model. On the other hand, Mr. R was observed using the non-image parts of discussion to present the target model through direct instruction and was not observed asking questions or encouraging students to generating student ideas.

Mr. R spent a longer time discussing the image than Mr. S. When the image was projected, teachers were observed using different interaction patterns. In the excerpts

above, Mr. R was observed using questions to ask students to interpret the image. Mr. S was observed using a presentation mode to explain the image. This preliminary pattern, summarized in Table 6-12, suggests that each teacher's pattern of interaction may have shifted when the image mode changed but that this shift was not in the same direction for each teacher. For one teacher (Mr. S), it was toward presentation, and for the other teacher (Mr. R), it was away from presentation.

Table 6-12
Summary of Preliminary Patterns observed in Transcripts Excerpts 1-7

| **Tire Pressure Lesson** | **Non-image-based Discussion** | **Image-based Discussion** |
|---|---|---|
| Mr. S<br>OV<br>Lesson | **Transcript 1**<br>Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 4**<br>Used presentation mode to explain image as target model |
| Mr. S<br>SIM<br>Lesson | **Transcript 2**<br>Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 5**<br>Used presentation mode to explain image as target model. |
| Mr. R<br>OV<br>Lesson | **Transcript 3**<br>Presented target model | **Transcript 6**<br>Used questions to prompt students to interpret the image. |
| Mr. R<br>SIM<br>Lesson | **No Transcript**:<br>Model discussion only occurred with the image present. | **Transcript 7**<br>Used questions to prompt students to interpret the image. |

## Counted Code Transcript Analysis for Interaction Patterns and the Use of Images

In this section, I use a counting code mode of analysis to determine if the preliminary observation patterns observed in the transcript excerpts are supported by analysis of the full transcript. When the full discussion transcript is considered, is there evidence that the teachers use of questioning changed when presented images were used?

To answer this question, I focused on the non-image-based discussion and image-based discussion sections previously identified (Table 6-3 and Table 6-13a and 6-13b). Codes for teacher-student interaction (Table 6-10) were used to locate instances where teachers presented or used IRE or IRF exchanges. I then counted these instances and tallied the time intervals teachers spent involved with each teacher-student interaction pattern (Figures 6-14a through 6-14d).

**Data on Interaction Patterns and the Use of Images in Full Transcripts**

Table 6-13a
Times Spent on Discussion in the Overhead Lesson

| **Overhead Lesson Discussion Times (in minutes: seconds)** | | |
|---|---|---|
| | Mr. R | Mr. S |
| Length of Discussion Section of the Lesson | 18:53 | 23:57 |
| Length of Non-Overhead Discussion | 15:45 | 20:41 |
| Length of Overhead Discussion (Image-based ) | 3:08 | 3:16 |

Table 6-13b
Times Spent on Discussion in the Simulation Lesson

| **Simulation Lesson Discussion Times (in minutes: seconds)** | | |
|---|---|---|
| | Mr. R | Mr. S |
| Length of Discussion Section of the Lesson | 27:03 | 23:38 |
| Length of Non-Simulation Discussion | 12:36 | 15:42 |
| Length of Simulation Discussion(Image-based ) | 14:27 | 7:56 |

Table 6-14a
Mr. R Count and Time of Interaction Pattern in the Simulation Condition

| **Mr. R's Simulation Lesson** | | **P** | | **IRE** | | **IRF** | | **Other** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-Image Discussion | 12:36 | 3 | 4:21 | 0 | 0:00 | 0 | 0:00 | 8:15 |
| Image Discussion | 14:27 | 13 | 6:26 | 8 | 2:38 | 4 | 4:14 | 1:09 |
| Total Discussion | 27:03 | 16 | 10:46 | 8 | 2:38 | 4 | 4:14 | 9:46 |

Table 6-14b
Mr. S Count and Time of Interaction Pattern in the Simulation Condition

| **Mr. S's Simulation Lesson** | | **P** | | **IRE** | | **IRF** | | **OTHER** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-image Discussion | 15:42 | 1 | 0:15 | 3 | 0:31 | 6 | 6:54 | 8:02 |
| Image Discussion | 7:56 | 16 | 5:10 | 4 | 1:40 | 2 | 1:06 | 0:00 |
| Total Discussion | 23:38 | 17 | 5:25 | 7 | 2:11 | 8 | 8:00 | 8:02 |

Table 6-14c
Mr. R Count and Time of Interaction Pattern in the Overhead Condition

| **Mr. R's Overhead Lesson** | | **P** | | **IRE** | | **IRF** | | **Other** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non image Discussion | 15:45 | 10 | 4:51 | 9 | 3:33 | 1 | 0:49 | 6:32 |
| Image Discussion | 3:08 | 9 | 1:51 | 0 | 0:00 | 1 | 1:17 | 0:00 |
| Total Discussion | 18:53 | 19 | 6:42 | 9 | 3:33 | 2 | 2:06 | 6:32 |

Table 6-14d
Mr. S Count and Time of Interaction Pattern in the Overhead Condition

| **Mr. S's Overhead Lesson** | | **P** | | **IRE** | | **IRF** | | **OTHER** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-image Discussion | 20:41 | 4 | 2:56 | 2 | 0:38 | 12 | 10:43 | 6:24 |
| Image Discussion | 3:16 | 3 | 0:54 | 0 | 0:00 | 1 | 0:31 | 1:51 |
| Total Discussion | 23:57 | 17 | 3:50 | 2 | 0:38 | 13 | 11:14 | 8:15 |

**Examining Patterns of Teacher Questioning during the Full Discussion**

Before focusing on non-image or image-based discussion, I report here on the discussion period as a whole. This analysis will focus on describing teacher differences observed in the whole or full discussion. The full discussion includes both the non-image and the image-based discussion sections. The summary table below (Table 6-15) contains the data from the whole discussion. These data show that teachers differed in how they managed class discussion through the use of presentation and questioning (IRE and IRF). In both the simulation and overhead classes, Mr. R used a presentation mode for almost twice long as Mr. S. On the other hand, Mr. S spent almost twice as much time using an IRF interaction mode then Mr. R in the simulation lessons and almost five times as much time using this interaction in the overhead lessons (See Table 6-15 and Figure 6-13).

**Data on Teacher Difference in Full Discussion**

Table 6-15
Summary Table of Full Discussion Analysis

| Teacher and Lesson | P | IRE | IRF | Other | Total Lesson |
|---|---|---|---|---|---|
| Mr R's SIM lesson | 10:46 | 2:38 | 4:14 | 9:46 | 27:03 |
| Mr S's SIM lesson | 5:25 | 2:11 | 8:00 | 8:02 | 23:38 |
| Mr R's OV lesson | 6:42 | 3:33 | 2:06 | 6:32 | 18:53 |
| Mr S's OV lesson | 3:50 | 0:38 | 11:14 | 8:15 | 23:57 |

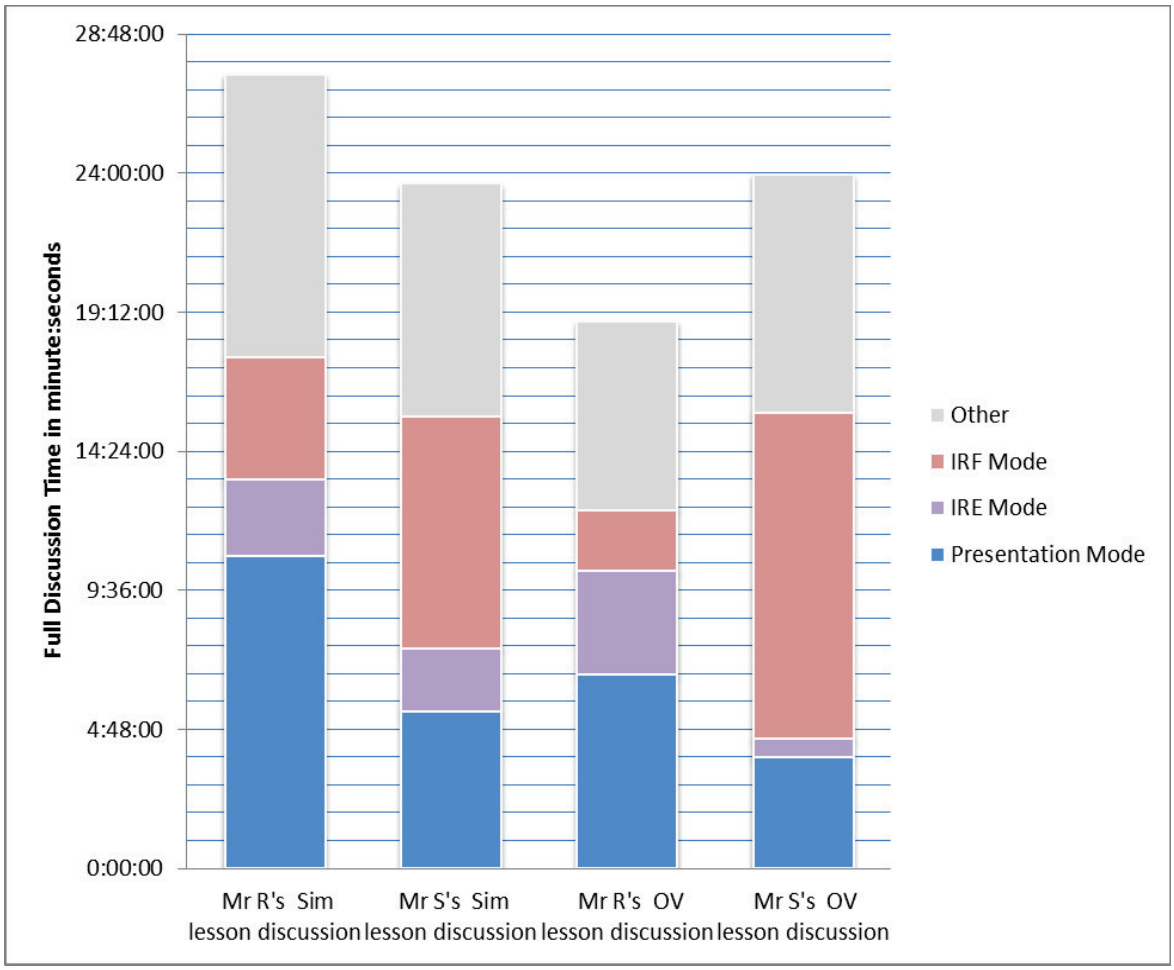



Figure 6-13
Graph of Data in Table 15 Showing Total Intervals of P, IRE, IRF Interactions

### Evidence from Unstructured Conversations with the Instructors

During the course of doing this study, I had a number of informal conversations with the participants. During one of these informal conversations, Mr. R mentioned his concern that pursuing divergent student thinking could introduce too much "noise in the signal," or introduce misconceptions that would compete with a clear statement of the target model. In his opinion, a clear statement of the target model and a clear evaluation of student answers promoted the best learning of the target concept. During a similar conversation, Mr. S mentioned his belief that giving students a chance to think about concepts before they were explained by the teacher made students more curious and increased what they remembered. Though these statements of beliefs were "off the cuff," and are not systematic data produced in a formal interview, they do provide a glimpse of the complex belief systems of practicing teachers. However, these sorts of teacher beliefs may be a factor influencing the number and type of questions the teachers asked. These informal comments are consistent with the patterns of teacher difference that are emerging from transcript data.

### Visualizing Teacher Differences on a Spectrum

Teacher preferences for asking questions may be related to their beliefs about how to manage the tensions between divergence and convergence that occur in a discussion. Asking a question requires teachers to negotiate potentially competing agendas: a divergent lesson agenda that prioritizes exploring student ideas and reasoning, and a convergent lesson agenda that prioritizes moving toward a clear statement and understanding of scientifically accepted model.

The data for the full discussion suggests that Mr. S spent more discussion intervals pursuing a divergent agenda through his use of follow-up questioning to develop the model. Mr. R spent more of the discussion intervals pursuing a convergent agenda through his use of presentation and IREs to develop the model.

Applying Scott's Communicative Approach framework, we visualize this teacher difference by placing the teachers along a Dialogic-Authoritative spectrum. On one end of this spectrum is a fully authoritative mode where only the school science point of view is considered. On the other end of the spectrum is a fully dialogic mode in which the teacher only pursues the students' points of view. In the transcript excerpts from of Mr. S's class, he was observed using IRF interactions to pursue the students' point of view. For the purposes of this visualization of teacher differences, I will map IRF interactions to dialogic side of the spectrum. This is a simplification since IRF interaction patterns can have many uses in a discussion but in these transcripts IRF is the mode used to encourage students to share their thinking.

In the transcript excerpts from of Mr. R's class, he was observed using a presentation mode to present the school science point of view and for this visualization I will map the presentation mode to the authoritative side of the spectrum. This is a simplification since presentation modes can be used by the teacher to present the student point of view, however in these transcripts most often it is the teacher point of view that is presented. While IRE interactions are by definition evaluative, and thus, authoritative, they do represent a step away from presentation because teachers are asking students to share their thinking. In the transcript excerpt we observed Mr. R's considering the student's point of view which in this case was the student's need for more information

about the image. IREs can uncover important student thinking that can be considered and change the flow discussion in a lesson. For the purpose of this visualization I will put IRE in the middle of the spectrum, since in this context IRE represents a step away from presentation since it can be an opening up of discussion to student ideas. The taxonomies uses in this study are represented in Figure 6-14.

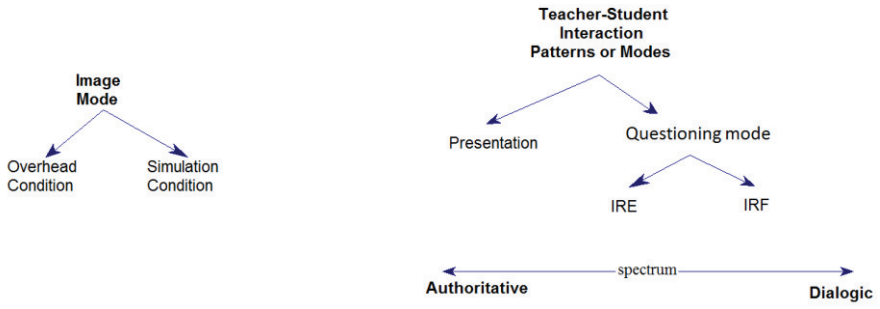



Figure 6-14
Taxonomies Used in this Study

When this taxonomy is to analyze the time interval spent on P, IRE, and IRF (Tables 6-14abcd and Figure 6-13), we notice that both teachers used both Dialogic (IRF) and Authoritative (Presentation) modes. However, Mr. S spent more time pursuing a dialogic mode of discussion. As a result Mr. S spent more time probing student ideas with follow-up questions before the simulation. Mr. R spent more time pursuing an authoritative mode of discussion and less time probing student ideas. Teachers' questioning behavior can be used to place Mr. S and Mr. R on the Authoritative -Dialogic spectrum (Figure 6-15). While this is not a strict mathematical mapping it does create a visualization that is useful for describing overall questioning strategies observed in full discussion section of these lessons.

Mr. R Mr. S

Authoritative ---------- Dialogic

Figure 6-15
Placing the Two Teachers on the Authoritative-Dialogic Spectrum

## Examining Patterns of Teacher Questioning during the Non-image and Image-based Discussion

This section will address how teacher interaction pattern choices changed after an image mode started. This analysis will focus on describing teacher difference observed in the non-image and the image-based discussion sections using data from the counted code analysis.

### Data on Teacher Difference

To facilitate this analysis I converted the time intervals spent on each interaction pattern found in Tables 6-14a through 6-14d into percentages. For example, in the SIM lesson of Table 6-14a, Mr. R used IRF mode for 4 minutes and 14 seconds during the time the simulation was up and being discussed, which is 29% of the time he spent discussing the simulation (4:14/14:27 = .29).

**Data on Teacher Difference in Non-image and Image-based Discussion**

Table 6-16a
Percent of Time Mr. R spent on each interaction pattern in the SIM Lesson

| **Mr. R's Simulation Lesson** | **Time** | **Presentation (P)** | **IRE** | **IRF** | **OTHER** |
|---|---|---|---|---|---|
| Non-image Discussion | 12:36 | 35% | 0% | 0% | 65% |
| Image Discussion | 14:27 | 45% | 18% | 29% | 11% |
| Total Discussion | 27:03 | 40% | 10% | 16% | 35% |

Table 6-16b
Percent of Time Mr. S Spent on Each Interaction Pattern in the SIM Lesson

| **Mr. S's Simulation Lesson** | **Time** | **Presentation (P)** | **IRE** | **IRF** | **OTHER** |
|---|---|---|---|---|---|
| Non-image Discussion | 15:42 | 2% | 3% | 44% | 51% |
| Image Discussion | 7:56 | 65% | 4% | 14% | 0% |
| Total Discussion | 23:38 | 23% | 9% | 34% | 34% |

Table 6-16c
Percent of Time Mr. R Spent on Each Interaction Pattern in the OV Lesson

| **Mr. R's OV Lesson** | **Time** | **Presentation (P)** | **IRE** | **IRF** | **OTHER** |
|---|---|---|---|---|---|
| Non-image Discussion | 15:45 | 31% | 23% | 5% | 41% |
| Image Discussion | 3:08 | 59% | 0% | 41% | 0% |
| Total Discussion | 27:03 | 35% | 19% | 11% | 35% |

Table 6-16d
Percent of Time Mr. S Spent on Each Interaction Pattern in the OV Lesson

| **Mr. S's OV Lesson** | **Time** | **Presentation (P)** | **IRE** | **IRF** | **OTHER** |
|---|---|---|---|---|---|
| Non -image Discussion | 20:41 | 14% | 3% | 52% | 31% |
| Image Discussion | 3:16 | 28% | 0% | 16% | 57% |
| Total Discussion | 23:57 | 16% | 3% | 47% | 34% |

## Changes in Interaction Patterns when the Image was Displayed

### Data of Shift in Interaction Patterns with Image

The data in Figures 6-16a through 6-16d provide evidence that teacher-student interaction patterns changed when the image was displayed. When the image was displayed, Mr. R increased his use of IRF interactions. On the other hand, when the image was displayed, Mr. S decreased his use of IRF interactions (Table 6-17). The addition of these images seems to be to be related to the shifts in the teacher interaction mode profile.

Table 6-17
Changes in Interaction Patterns when the Image was Displayed

| | | |
|---|---|---|
| Mr. S used IRF more during Non-imaged discussion than during image-based discussion. | **IRFs before the Image**<br><br>SIM Lesson 6:54/15:42= 44%<br>OV Lesson 10:43/20:41 = 52% | **IRFs during the Image**<br><br>SIM Lesson 1:06/7:56 =14%<br>OV Lesson 0:31/3:16 = 16% |
| Mr. R used IRF more during Image-based discussion than he did during Non-image-based discussion. | **IRFs before the Image**<br><br>SIM Lesson 0/12:36 = 0%<br>OV Lesson 0:49/15:45 = 5% | **IRFs during the Image**<br><br>SIM Lesson 4:14/14:27 = 29%<br>OV Lesson 1:17/3:08 = 41% |

**Visualizing the Interaction Mode Shift**

Applying Scott's Communicative Approach framework, we can place the teachers along an Authoritative-Dialogic spectrum and diagram a possible effect of image mode on discussion mode. Without the simulation, Mr. S spent more time pursuing a dialogic mode of discussion through his use of IRFs. With the image, Mr. S spent more time pursuing an authoritative mode through his use of Presentation and IREs. Mr. R's pattern shift was in the opposite direction. Without the image, Mr. R spent more time pursuing an authoritative mode of discussion through his use of Presentation and IREs. With the image, Mr. R moved more toward a dialogic mode through his use of IRFs. However, this increased use of IRF does not suggest a dramatic shift by Mr. R to dialogic end of the authoritative-dialogic spectrum.

In the transcript excerpt of Mr. R discussing the image, he was observed generating questions interpreting the image. These questions were framed by the goal of using the image to present the target model. The increased use of presentation mode by all teachers when they started to use the image as part of discussion suggest that teachers were focused on converging on the target model during the discussion of the image.

An overall effect was that the image appeared to bring these two teachers closer together on the left of Dialogic/Authoritative spectrum, as shown in Figure 6-16. Both teachers are on the authoritative side of the spectrum since there is evidence that they are using the image to converge on the target the model. However, since Mr. R is using more questions in his efforts to use the image to converge on the model, he has been placed to the right of Mr. S. This signifies that Mr. R is taking steps away presentation modes by to asking students interpret the images and to reason with their models.

**Non-Simulation discussion (before the image was projected)**

Mr. R Mr. S

Authoritative ---------- Dialogic

**Simulation discussion (while the image was projected)**

Mr. S Mr. R

Authoritative ---------- Dialogic

Figure 6-16
Comparing Teachers' Placement on the Dialogic-Authoritative Spectrum during Different Image Modes

I offer a speculative hypothesis that the image may be supporting the teachers as they transition between dialogic and authoritative discussion modes. As a strong statement of the model, the image might limit, constrain, or bound student divergence and reduce the potential for conceptual divergence in student responses. The image's ability to restrict divergence of student response may be supporting Mr. R's willingness to ask potentially divergent questions and allow students to have a larger role in articulating the model. As a complex image, the simulation can be difficult to interpret. The need to interpret a complex image opens a space for generating a line of questioning that converges on the target model. These convergent question episodes (IREs) allow students to articulate how their internal model is being used to interpret and reason with the external representation of the model (the image). In transcript 7, Mr. R was observed using the image-based discussion move Orientation as a question. ("What side of the simulation represents the tire?") When the image was used as a "tool for asking," the image-based moves are constructed as questions about the image.

On the other hand, the image may be assisting Mr. S's attempt to divide the lesson into a dialogic phase and an authoritative phase. There is evidence that Mr. S used the non-image part of class as an opportunity to follow a dialogic agenda and pursue divergent student thinking. This can be seen in his polling of class to uncover student's diverse ideas about air molecule around a valve and his willingness to pursue these different points of view through the use of IRF interaction. There is evidence that he then used the image as a turning point in the discussion, and began to use the presentation of the image-based discussion moves to follow an authoritative agenda. The image helped him follow this agenda since it provides a strong statement of the target model. In transcript 5, Mr. S was observed executing the image-based discussion move "Orientation" in a presentation mode. ("So this is the air outside of a tire. This is the air inside the tire. This is the tire itself.") When the image is used as a "tool for telling," the image-based discussion moves were used to organize and logically sequence a thorough presentation of the model using the image.

## Summary of Conclusions

### Part One: Summary of Effect of Image Mode on Discussion

I have identified strategies that these teachers used to navigate image-based discussion in this lesson. These image-based discussion moves are summarized in Table 6-18.

Table 6-18
Image-based Discussion Moves

| Moves | Central question of the move |
|---|---|
| ORIENT | What are we looking at? |
| PREDICT | What will happen if...? Why? |
| HIGHLIGHT | What is happening? |
| LINK | What is causing this? |
| CRITIQUE | What is wrong with this image? |
| SITUATE | What if you were in the image? |
| FRAME | Why are we looking at this image? |
| EXTEND | Where else would this image apply? |

Compared to the Overhead condition, the Simulation condition produced a) more time discussing the image, b) more moves, and c) more scripted moves in the lesson plans, and d) more spontaneously generated moves in the discussion. Although not all of these patterns were strong, we can see if these trends hold up in the additional case studies.

**Part Two: Summary of Differences in the Behavior of the Two Teachers**

Even though the teachers were attempting to follow a common lesson plan, which they had jointly authored, they enacted the lesson in a wide variety of ways. These varieties of enactments time intervals from both overhead and simulation conditions were used for the comparisons listed below. To summarize, Mr. S spent more time than Mr. R discussing the model when the image wasn't projected. (36:23 minutes compared to 28:21 minutes). Mr. S spent more time engaging in IRF interactions than Mr. R (19:14 minutes compared to 6:20 minutes). Mr. R spent more time than Mr. S discussing the model when the image was projected. (17:45 minutes compared to 11:12 minutes) Mr. R

was observed presenting the school science point of view almost twice as much time as Mr. S. (17:32 minute compared to 9:15)

These data lead me to hypothesize a possible cause for the different pattern of enactments (Table 6-6). In these lessons, Mr. R and Mr. S managed the tensions between a dialogic agenda and an authoritative agenda differently. Mr. S's overall approach was more dialogic, since he used time to pursue divergent student ideas. Mr. R's overall approach was more authoritative, since he did not pursue divergent student ideas and spent more time presenting the target model.

The data in Table 6-17 indicate that Mr. S used more IRF interactions before the image was projected then while the image was projected. Mr. R used more IRF interactions while the image as being discussed than before. I hypothesize that the use of an image may have facilitated a shift in the interaction mode profile for each teacher. In Mr. S's case, he may have used the image as "tool for telling" to develop the target model and to help him transition between a dialogic agenda and an authoritative agenda. He used IRFs to pursue divergent student thinking unconstrained by an image of the target model, and then he shifted to an authoritative agenda in which he used image-based discussion moves to present the image as target model. Mr. R was observed mostly following an authoritative agenda in which he mostly presented the target model with or without an image present. However, when the image was present, Mr. R moved a few steps toward a dialogic agenda by asking questions about the image. He may have been using the image as "tool for asking" and used the fact that the image needing interpretation to generate questions that prompted student to reason with their model. It appears that the image was useful to these teachers in two different ways. The image's

strong statement of the model may have helped Mr. S have a discussion that converged on a target model, while the image's complexity may have left leave room for Mr. R ask for student interpretation and reasoning. These two features of an image may have helped Mr. S shift between authoritative and dialogic agendas and it may have helped Mr. R provide a space for discussions that keep students in a "reasoning zone" while he ultimately converge on the target models.

Mr. S was observed presenting the image-based discussion moves, and Mr. R was observed executing the image-based discussion moves as questions. Whether the image-based discussion move are presented or asked as questions may be an indicator if the image is viewed as "tool for telling," or as a "tool for asking." In addition, there is evidence that the simulation afforded more use of discussion moves than the overheads. Since each discussion move could be asked as a question, it then follows that the simulation could generate more questions. In fact, Mr. R was observed generating more questions about the simulation than about the overhead (12 SIM questions: 1 OV questions). Since questions play such a large role in how teachers manage the divergent and convergent forces in a discussion, a simulation may attain added value in a discussion because the teacher may be able to use it to generate more questions than a static image.

# CHAPTER 7

# COMPARATIVE CASE STUDIES OF DISCUSSION STRATEGIES USED IN A LESSON EXPLAINING COMPRESSABLITY OF GASES IN A SYRINGE

## Chapter Overview

Using the same methodology as the previous case study in Chapter 6, this study analyzes teacher behavior in a lesson using visual media about the particulate nature of matter that was taught by two experienced middle school teachers (Mr. T, the author, and Mr. R). The lesson in this study attempted to help students construct a visualizable particulate model explaining how a gas can push back on a plunger when compressed. Each teacher taught a lesson to one half of his students using static overheads and taught the other half of his students using a dynamic simulation. The two types of lessons had similar content goals, lab activities, and handouts but differed in the type of image mode used during large group discussion. Video and transcripts of large group discussions from four lessons were analyzed using codes for a set of image-based discussion strategies and codes for teacher student interaction patterns. Results suggest that the simulation mode offered greater affordances than the overhead mode for planning and enacting discussions. Differences in teacher use of discussion modes, such as presentation, IRE, and IRF suggest that teacher preferences for discussion modes may have interacted with the simulation or overhead condition.

## Objectives of Comparative Case Study of the Syringe Lesson

A goal of this study is to examine how different image modes are used by teachers to teach the same content.

### Part One: Difference between Image Modes

Part one of the chapter reports on a comparative case study that examined the ways that the discussion of images was managed in matched sets of a simulation lesson and overhead lesson taught by the two teachers. Part one addresses the questions:

1. What strategies were observed being used for leading whole class discussion in each image mode?
2. How were lessons with similar lesson plans enacted differently when using different image modes?

### Part Two: Difference between Teachers

Part two of the chapter reports on a comparative case study that examined differences between teachers enacting the same lesson and image mode. This part of the chapter examines patterns of teacher student interactions used by each teacher during the entire lesson. Part two addresses the questions:

1. Did the teachers use different patterns of interactions (e.g., presentation vs. IRF, see Table 6-10)?
2. If so, did the image use impact the patterns of interaction used by the teacher in the lesson?

### Part Three: Differences due to Teachers and Image Modes

Part three of the chapter reports on a cross comparative study where effects due to teacher differences and image mode are considered. Part three addresses the questions:

1. Was an image discussion strategy linked with particular interaction patterns?
2. Did teacher interaction pattern choices change after an image mode started?

## Description of the Lesson

In this section, I examine two teachers as they led their class through the Compression of Air and Water Lesson in Matter and Molecules (Lee et al., 1993). This chapter describes and analyzes the large group discussion that occurred in each of the teachers' classes as they enacted a common lesson plan.

Table 7-1
Key Features in the Lesson Used in the Study

| | | |
|---|---|---|
| Title of the lesson | Compression of Air and Water Lesson (4.2) from the Matter and Molecules curriculum (Lee et al., 1993) | |
| Topic of the lesson | How does the particulate model of matter explain the behavior of water or air when attempts are made to compress a liquid or a gas in a closed syringe? | |
| Mode of interaction | The teacher facilitated a large group discussion of the image that was projected in front of the class.<br>The same handout was used to guide the lesson regardless of image mode used. | |
| Image mode | The "Overhead" or OV version of the lesson was taught as suggested using two static overheads provided by the curriculum. | The Simulation or "SIM" version of the lesson was taught as suggested but here PhET computer simulation was used in place of the overheads. |
| Video data | 50 minutes of Mr. T teaching the OV class | 50 minutes of Mr. T teaching the SIM class |
| | 50 minutes of Mr. R teaching the OV class | 50 minutes of Mr. R teaching the SIM class |

The lesson began with students drawing their model of a liquid and a gas, which had been developed in previous lessons (Figure 7-1) and predict what this model suggested about the compressibility of a liquid and a gas.

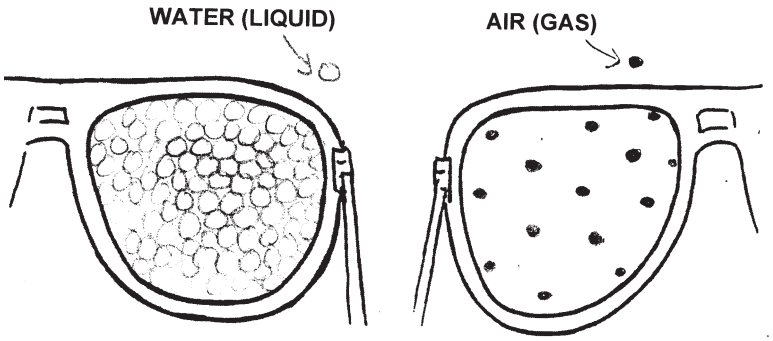



Figure 7-1
Student Drawing of Molecular Model in the "Eyeglasses of Science" from the Activity Sheet

Students were then given a clear 100 ml open syringe filled with air and asked to draw how molecules of air were distributed inside and outside of the syringe (Figure 7-2).

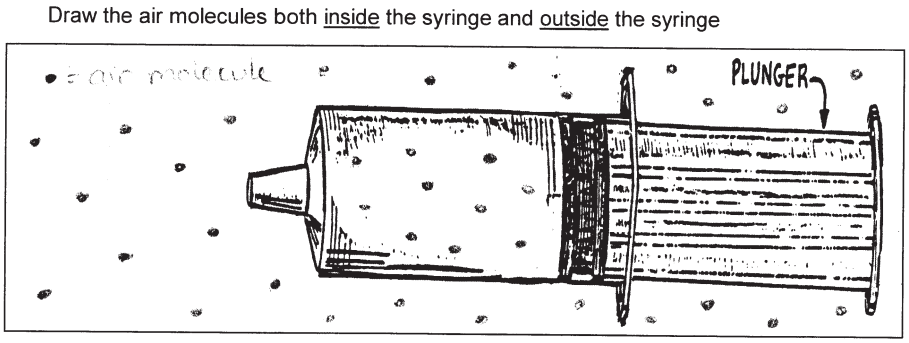



Figure 7-2
Student Drawing of Molecules Inside and Outside of the Syringe

Students then used the syringe to observe the degrees of compressibility found in liquids and gasses. Students filled their syringes with water, put their finger over the end so nothing could escape, and attempted to push the plunger in. They repeated this experiment with air.

After observing the syringe, students were asked to use their molecular model of a liquid and a gas to explain why a water-filled syringe did not compress but an air-filled syringe did. When students pushed on an air-filled syringe, they were able to squeeze

about 60 ml of air down to about 15 ml. A series of images were then discussed to encourage students to evaluate and modify their molecular model of a gas to explain their observations. Why did the liquid feel like a solid? How did the gas prevent them from pushing the plunger all the way in? (A few students were surprised when they pushed enough to blow out the side of the syringe!) How can invisible air molecules feel like a solid object when compressed?

To explain the behavior of a compressed gas, students needed to understand how molecules in a gas can generate a force that can resist the force of the plunger. The main content goal of the lesson was to have students explain the observable force of resistance as caused by the invisible action of trillions of molecules of gas bouncing against the wall of the plunger. The lesson used the discussion of external images to attempt to develop the internal mental imagery of bouncing molecules and link that imagery to the force produced by a compressed gas.

The overhead lesson used paired set of overheads to show the non-compressed and the compressed state of the gas (Figure 7-3) from Lee et al. (1993). After viewing and discussing the images students were asked to evaluate and modify their written descriptions of the molecular model of a gas that they had used to explain their observations on their activity sheet.

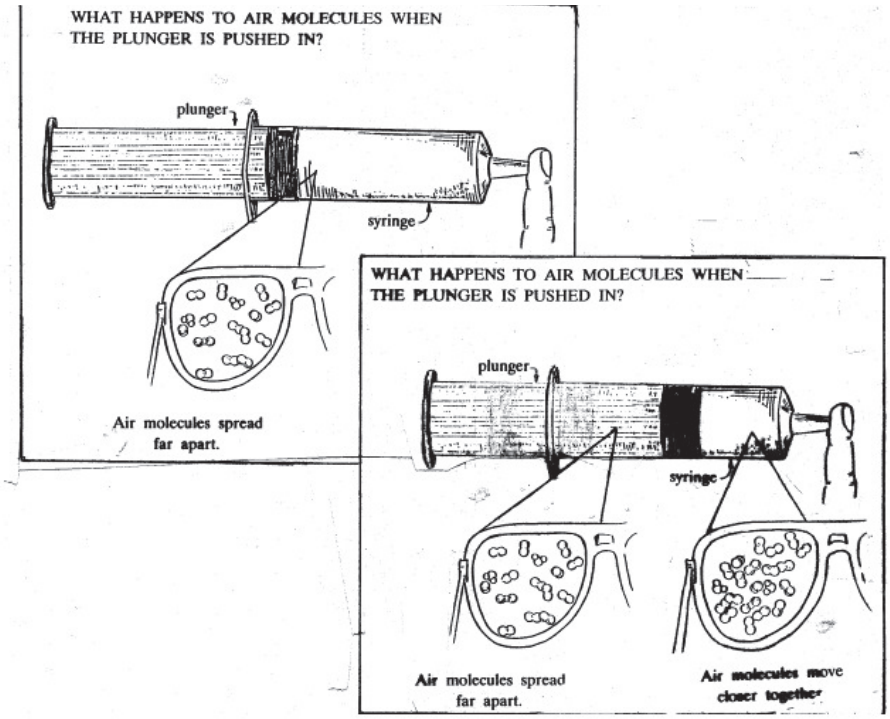



Figure 7-3
Transparencies Used in the Overhead Lessons

The simulation lesson replaced this overhead with a computer simulation called Gas Properties (version 3.08.07 (28795) Feb 19, 2009) (Reid et al., 2009).

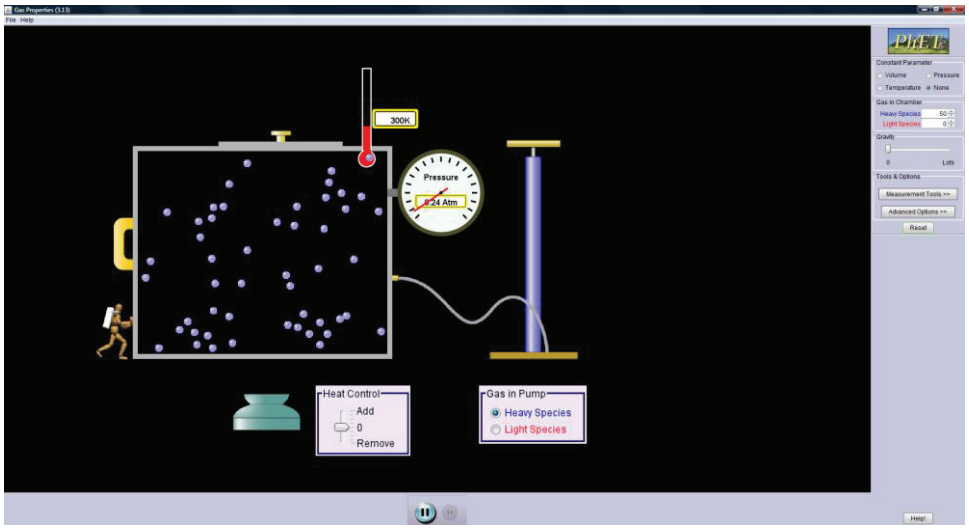



Figure 7-4
Screen Shot of the Gas Properties Simulation by PhET
(http://phet.colorado.edu/en/simulation/gas-properties)

## Analysis and Findings

This case study examines the large group discussion that occurred during this lesson. I describe how the teacher and students discussed the projected images and how they were used to foster model construction and develop a visualizable particulate model explaining how a gas can push back on a plunger when compressed. I also describe patterns of teacher-student interaction, specifically how the teacher used presentation, questioning, and follow-up to help students develop and reason with their model.

### Part One: Examining the Effects of Image Mode on Discussion

In this case study, the constant comparison method was used to develop and refine descriptions and coding categories of discussion strategies that helped me to describe possible effects of image mode (simulation vs. overhead). Part one addresses the questions: What strategies were observed being used for leading whole class discussion in each image mode? How were lessons with similar lesson plans enacted differently when using different image modes?

### Description of Image-based Discussion Moves Coding Categories

The first level of coding involved looking at the entire lesson and determining when the lesson was focused on 1) managing logistics, as when students were finding papers and homework, 2) carrying out experiments, as when students were using the syringe to make observations, and 3) engaging in discussion, as when the teacher and student were thinking and talking together about the explanatory model and using it to address the questions included in the lesson plan. The data for this level 1 coding are show below in Table 7-2.

Table 7-2
Time Spent on Different Parts of the Lesson

| SIMULATION Lesson | | |
|---|---|---|
| | Mr. R | Mr. T |
| Time spent on Logistics | 7:40 | 7:53 |
| Time spent on the Laboratory Activity | 9:46 | 7:43 |
| Length of Non-Simulation Discussion (Non-image- based) | 17:48 | 30:18 |
| Length of Simulation Discussion (Image-based ) | 17:11 | 5:41 |
| **OVERHEAD Lesson** | | |
| | Mr. R | Mr. T |
| Time spent on Logistics | 6:51 | 1:38 |
| Time spent on the Laboratory Activity | 7:43 | 10:55 |
| Length of Non-Overhead Discussion (Non-image-based) | 31:46 | 32:34 |
| Length of Overhead Discussion (Image-based ) | 1:57 | 2:05 |

I then identified when the overhead or simulation was used with large group discussion to develop the content goal of the lesson. Once these image-based discussion episodes of class were identified (Table 7-2), I attempted to code for small time scale teaching strategies that seemed intended to engage students in observing and reasoning with the image as the class discussed how the particulate model of a gas can be used to explain macroscopic events in the syringe experiments. The coding for this section was based on the image-based discussion strategies rubric previously presented in Chapter 5 (Table 5-2).

**Example of Three Important Moves**

I want to focus for a moment on the strategies that were observed being used the most during the discussion of the image and illustrate them with transcripts and images from the syringe lesson. With these example, I hope that the differences between and functions of Orienting, Highlighting, and Linking in this lesson become clear.

**Example of the Orienting Move**

The teacher displays the Gas Law PhET simulation but before he can use it to help students build an explanation of the behavior compressed gasses in a closed syringe, he checks to see if students have made the connection between the projected visual and the syringe.

He uses an orienting strategy and asks each student to hold up their syringe and overlay it visually on top of the image projected of the simulation. This oriented students to the visible and macroscopic parts of the model, namely the syringe, wall, and plunger.

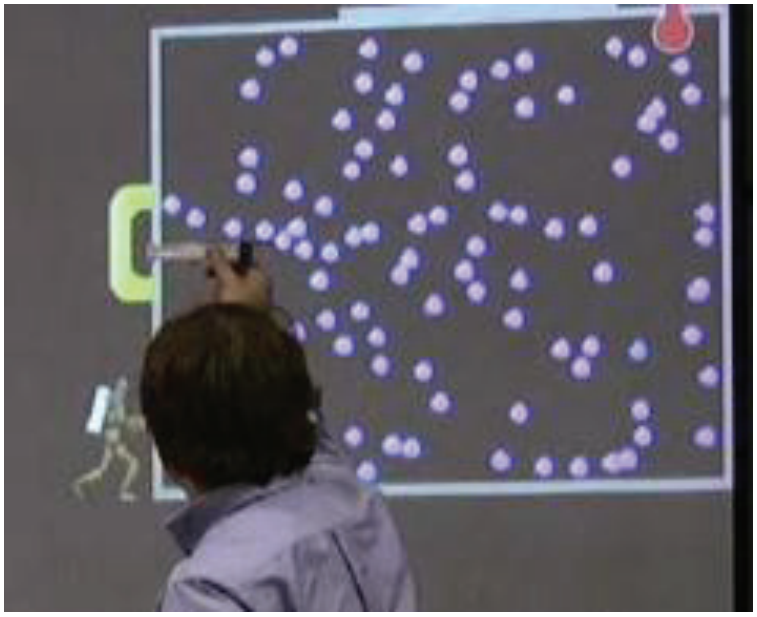


Figure 7-5
Using the Orienting Move to Map the Actual Syringe on to the Projected Image Representing the Syringe

> Teacher: So do you see how this simulation is like the syringe? So where's the plunger in this syringe?
>
> Student: The little guy next to the wall.
>
> Teacher: That little guy is the plunger right? And so I hold the syringe up like this, and the little guy in the simulation push against this handled wall just like I can push against the plunger.

Next, the teacher uses another orienting move to clarify micro elements of the model. In this case the teacher checks in to see if students understand that the dots on the screen represent the invisible air molecules in the syringe.

> Teacher: Now what is inside the syringe? What are we able to see in side this syringe in the simulation now? Jenna?
>
> Student: Air.

**Example of the Highlighting Move**

In this example, the teacher displays the simulation and asks students to focus on an effect caused by compressing gas. The teacher HIGHLIGHTS the changes in body posture in the figure pushing on the wall of the chamber filled with a gas. Before students can think about what this increased leaning posture might be caused by, students need to make the observation that the figure is leaning more and infer he is pushing harder on the chamber wall as he moves toward the right.

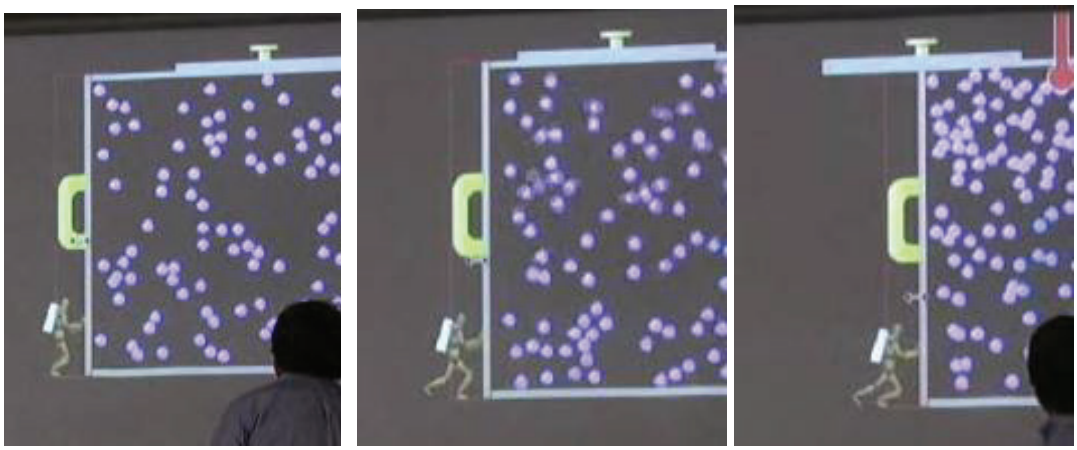


Figure 7-6
Highlighting One Side of a Cause and Effect Chain

> Teacher: Now let's watch what happens as I push this plunger in...
>
> Student: He's walking.
>
> Teacher: He's walking, what do you notice he's doing?

Student: Pushing.

Teacher: He's still pushing, right...

Teacher: Do you notice anything different about him now?

Student: He's just leaning and shaking.

Teacher: He is pushing harder.

At this point the teacher HIGHLIGHTS the action of the MICRO elements of the model, the behavior of the molecules, by modifying a variable on the simulation so only a few molecules are present. This makes it easier to count the collisions of the molecules against wall of the container. He gestures over the image to focus attention on the collisions of the molecule with the wall and then asks students to count the collisions before and after the wall is moved to the right.

T: So the question becomes: "What is happening? What do you notice about that wall? What do you notice about the way molecules are interacting with the plunger?"

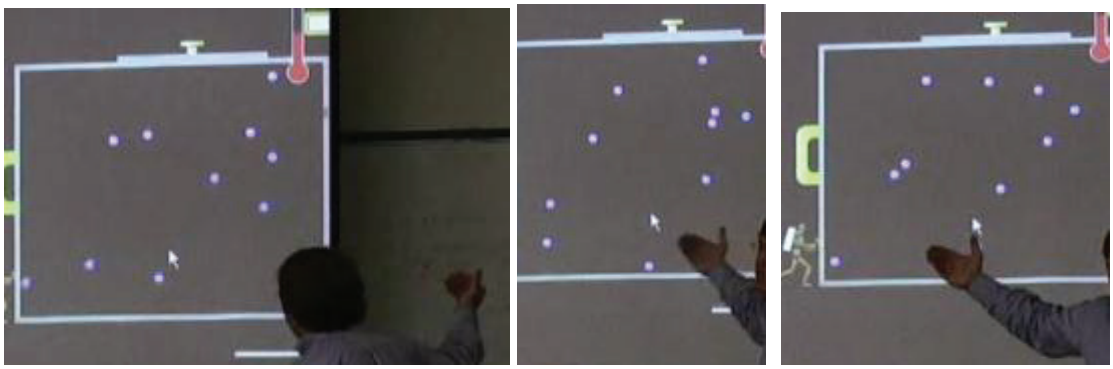


Figure 7-7
Highlighting by Counting Molecular Collisions with the Plunger out

Teacher: It's actually easier if we take a minute and we look at this… we could almost count how many are hitting the plunger. One...Count with me how many are hitting the plunger.

Student and Teacher: One... two.... three..... four....five....six

Teacher: Do you see how slowly they hit the plunger now?

Teacher: Now when I push this thing in, try to count it now.

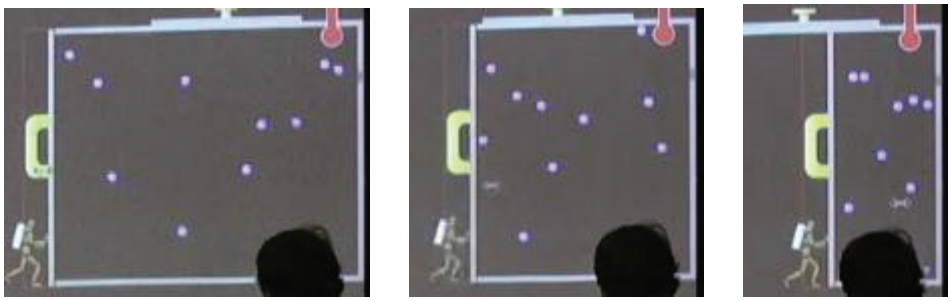


Figure 7-8
Highlighting by Counting Molecular Collisions with the Plunger Out

Student: 1,2,3,4, 5, 6 --- It's too fast to count!

Teacher: It is too fast to count. So there are more hitting the plunger here when I have it compressed in like this.

**Example of Linking**

Now that the cause (molecules hitting the plunger) and the effect (having to push hard to keep the gas compressed) have been carefully observed and described, the teacher then asks students to put these observations together and articulate the link between the cause and effect.

Teacher: So what did I just do to the syringe "Angelica"?

Student: Moved it closer moved it closer so all the air molecules could produce pressure.

Teacher: Ok, but give me your explanation second, just what did I do to the plunger first?

Student: Pushed it in.

Teacher: I just pushed the plunger in to the right. And what happened to those molecules then?

Student: They moved faster.

Teacher: They moved faster. And what did they do to the face of the plunger that they weren't doing as much before?

Teacher: They are pushing it? So we were able to see these things hitting, and you can see this person straining, right? And did you notice that you were straining when you were pushing in your syringe. You were like working really hard to get this thing in!

Teacher: Why isn't he pushing as hard now (when the plunger is out), "Tyler"?

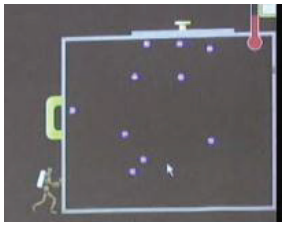


Figure 7-9
Simulation Representing an Extreme Case with Few Atoms

Student: Well because they're not really hitting the side.

Teacher: Yeah, what forces him to push in is when the molecules hit that plunger… Here with the plunger out) the guy doesn't have to put in any work at all. And that is what is causing the plunger to resist our movement. (Teacher takes out syringe and starts to strain to push it in). The more we push it in, the more molecules that are hitting that plunger. Ok? And the more molecules that are hitting that plunger the harder it is to push.

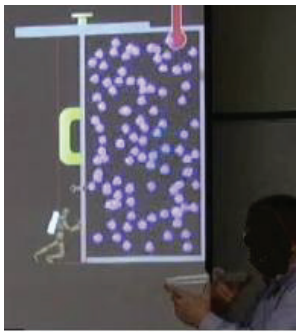


Figure 7-10
Simulation Representing an Extreme Case with Many Atoms

## Description of Differences between Simulation and Overhead Conditions

I found that both teachers spent more time and employed a larger number and larger variety of discussion moves to integrate the dynamic simulation into the model construction process as compared to a static overhead.

Table 7-3
Comparison of Image Mode Showing More Time was Spent Discussing Dynamic Image than the Static Image

| Teacher | Time spent discussing the dynamic image (PhET computer simulation) (min:sec) | Time spent discussing the static image (2 static overheads) (min:sec) |
|---|---|---|
| Mr. T | 5:41 | 2:05 |
| Mr. R | 17:11 | 1:57 |

Table 7-4
Comparison of Image Mode Showing that A Greater Variety of Image-based Discussion Moves was Used during the Dynamic Image

| | Teacher | Orient | Predict | Highlight | Link | | Critique | Situate | Frame | Extend | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Instances of moves in SIM Lesson | Mr. T | 5 | 0 | 8 | 4 | | 1 | 0 | 1 | 0 | 19 |
| | Mr. R | 6 | 5 | 11 | 12 | | 5 | 1 | 2 | 1 | 43 |
| Instances of moves in OV Lesson | Mr. T | 2 | 0 | 1 | 0 | | 0 | 0 | 0 | 0 | 3 |
| | Mr. R | 0 | 0 | 2 | 4 | | 0 | 0 | 0 | 0 | 6 |

Shading is used here to indicate which moves were observed. A darker color indicates that the move was observed more than once.

## Possible Causes for the Difference between the Simulation and Overhead Conditions

As in the previous case study (Chapter 6), when comparing different image modes, some of the differences I observed between conditions (time, number of moves,

variety of moves) could be attributed to the differences in the overhead and simulation lesson plans, and some could be attributed to spontaneous and unplanned actions by the teachers.

## Effects on Lesson Plan: The Simulation May Provide Affordances for Planning Large Group Discussion

This study was designed to examine what occurs when these teachers substituted a simulation for the overheads provided by the curriculum. In the course of considering how to use the simulation, the team felt it natural to use the affordances we could see in the simulation to depict the difficult to comprehend dynamic elements of the particulate model of gas in a syringe. For example, the simulation allowed the teachers to manipulate the number of gas molecules in the chamber, and this triggered them to set up extreme cases of the syringe, one with only a few molecules and one packed full of molecules (Figure 7- 11).

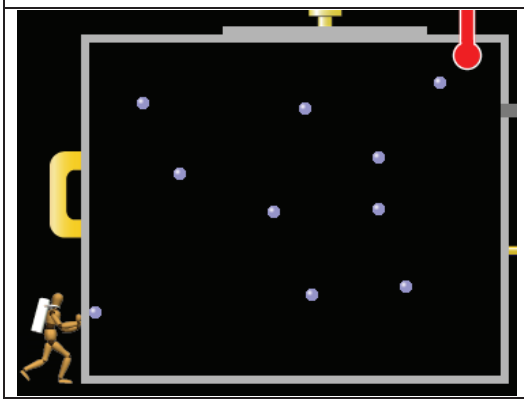
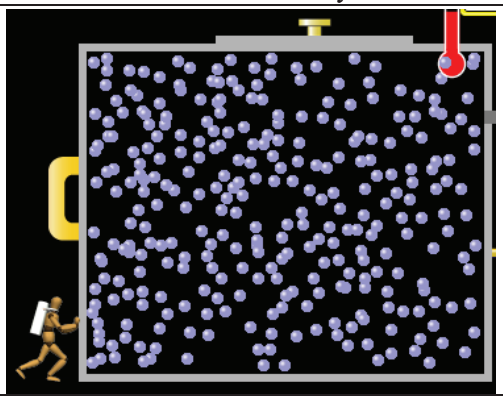
| Extreme Case: Few Molecules | Extreme case: Many Molecules |
|---|---|
|  |  |

Figure 7-11
Simulation Modified to Represent Two Extreme Cases

Due to the flexibility of the simulation, it was easy to obtain images of different states of the model, and each image gave the teacher an opportunity to discuss how the rate at which molecules collide with the plunger affects the forces on the plunger. This

analysis suggests that one advantage of the simulation is that it can be easily modified. The simulation lesson plan, in fact, called for the simulation to be modified a total of 10 times, whereas the overhead lesson only called for 2 image changes, one change for each of the two overheads provided by the lesson (Table 7-5). Each time the simulation is modified, it provides a new image. In this way, the simulation served as a reservoir of easily generated and accurate images, each representing different states of the model.

Table 7-5
Number of Times the Lesson Plan Requested a Change in the Image by the Simulation and the Overhead Lesson Plans

| | **Simulation Lesson Plan** | **Overhead Lesson Plan** |
|---|---|---|
| Requested changes to the image | 10 | 2 |

The ability to generate multiple images may have made the simulation useful for planning. Each image provided by the simulation afforded the teachers with an opportunity to plan small episodes of the discussion. Though the move codes were not described when they wrote the plans, it is possible to use them to code the lesson plan for request for various moves. The result of coding the lesson plan (Table 7-6) reveals that the simulation lesson plan did, in fact, call for a larger number and variety of moves than did the overhead lesson plan.

Table 7-6
Number of Times a Move was Requested by Simulation and Overhead Lesson Plans

| Move requested by the lesson plan | Simulation Lesson Plan | Overhead Lesson Plan |
|---|---|---|
| Orient | 8 | 2 |
| Predict | 4 | 0 |
| Highlight | 5 | 0 |
| Link | 5 | 2 |
| | | |
| Extend | 0 | 0 |
| Critique | 1 | 0 |
| Situate | 0 | 0 |
| Frame | 1 | 0 |
| Total Moves | 24 | 4 |

**Part One: Explaining the Findings Above**

I hypothesize that the greater number of moves was caused, in part, by the ability of the simulation to be modified to present different states of the model. Since each new state was imagistic, it could be visualized by the lesson planner, and used to trigger questions and discussion points to be raised. Lesson planning for a large group discussion can overwhelm working memory due to its complexity and the multiple paths a discussion can take. Here, the simulation may have allowed the lesson planner to isolate and imagine separate images to be discussed. These images are an efficient way to represent a great deal of information about the model. A list of text about the model, for example, would quickly become too dense to be useful in a lesson plan.

The set of images provided by the simulation may have facilitated the mental rehearsal of small episodes of discussion and triggered prompts for these discussions that could then be written into the lesson plan. This same sort of planning was possible in the

overhead lesson plan, but since there were fewer images, fewer episodes may have been imagined, rehearsed, and written into the plan. In this way, the simulation seemed to trigger more discussion moves in the simulation lesson plan (24 moves) than the overhead did in the overhead lesson plan (4 moves). (Table 7-6) These scripted moves contributed to the greater time spent and the greater variety of moves seen in the simulation lesson. I hypothesize that the simulation provided a greater affordance for planning a discussion than did the overhead.

**Effects on Spontaneous and Unplanned Actions by the Teachers**

The difference in lesson plan is only part of the story, however. The simulation also appeared to provide an affordance for the spontaneous strategic application of discussion moves. While the lesson plan called for certain modifications of the PhET simulation and suggested a set of discussion moves, neither teacher in the study enacted the lesson exactly as it was written. For example, while Mr. R did all of the steps in the lesson plan, he made twice as many modifications to the simulation and almost twice as many discussion moves than were called for in the simulation lesson plan (Table 7-7a and 7-7b).

Table 7-7a
Comparison of Simulation Lesson Plan and Simulation Lesson Enactment by Mr. R

| **Mr. R's Simulation Lesson** | **Planned Actions (PA) suggested by the Simulation Lesson Plan** | **Teacher Actions (TA) made by Mr. R during the teaching of the Simulation Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the enactment and the lesson plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 8 | 6 | -2 |
| Predict | 4 | 5 | +1 |
| Highlight | 5 | 11 | +6 |
| Link | 5 | 12 | +7 |
| | | | |
| Extend | 0 | 1 | +1 |
| Critique | 1 | 5 | +4 |
| Situate | 0 | 1 | +1 |
| Frame | 1 | 2 | +1 |
| Total Moves | 24 | 43 | +19 |
| Modifications to the Simulation | 10 | 22 | +12 |

Table 7-7b
Comparison of Overhead Lesson Plan and Overhead Lesson Enactment by Mr. R

| **Mr. R's Overhead Lesson** | **Planned Actions (PA) suggested by the Overhead Lesson Plan** | **Teacher Actions (TA) made by Mr. R during the teaching of the Overhead Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the enactment and the lesson plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 2 | 0 | -2 |
| Predict | 0 | 0 | 0 |
| Highlight | 0 | 2 | +2 |
| Link | 2 | 4 | +2 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 0 | 0 | 0 |
| Situate | 0 | 0 | 0 |
| Frame | 0 | 0 | 0 |
| Total Moves | 4 | 6 | +2 |
| Modifications to the Overhead | 2 | 4 | +2 |

Mr. T did not complete all the steps of the simulation lesson plan, but he did six more moves than were suggested by the parts of the lesson plan that he did complete (Table7- 8a and 7- 8b).

Table 7-8a
Comparison of Simulation Lesson Plan and Simulation Lesson Enactment by Mr. T

| **Mr. T's Simulation Lesson** | **Planned Actions (PA) suggested by the Simulation Lesson Plan** | **Teacher Actions (TA) made by Mr. T during the teaching of the Simulation Lesson** | **Spontaneous Actions (SA= TA- PA): Difference between the lesson plan and the enactment** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 8 | 5 | -3 |
| Predict | 2 | 0 | -2 |
| Highlight | 2 | 8 | +6 |
| Link | 1 | 4 | +3 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 0 | 1 | +1 |
| Situate | 0 | 0 | 0 |
| Wrap | 0 | 1 | +1 |
| Total Moves | 13 | 19 | +6 |
| Modifications to the Simulation | 7 | 7 | 0 |

Table 7-8b
Comparison of Overhead Lesson Plan and Overhead Lesson Enactment by Mr. T

| **Mr. T's Overhead Lesson** | **Planned Actions (PA) suggested by the Overhead Lesson Plan** | **Teacher Actions (TA) made by Mr. T during the teaching of the Overhead Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the enactment and the lesson plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 2 | 2 | 0 |
| Predict | 0 | 0 | 0 |
| Highlight | 0 | 1 | +1 |
| Link | 2 | 0 | -2 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 0 | 0 | 0 |
| Situate | 0 | 0 | 0 |
| Frame | 0 | 0 | 0 |
| Total Moves | 4 | 3 | -1 |
| Modifications to the Overhead | 2 | 2 | 0 |

These data provide evidence that these teachers generated more spontaneous moves during the discussions of the simulation than they did during the discussion of the overhead. In these lessons the teachers were able to manipulate the simulation and improvise discussion moves that responded to student questions or comments. For example, this lesson plan did not call for any situating or extending, yet Mr. R was observed using these moves in response to student comments. In addition, both Mr. R and Mr. T did more highlighting and linking moves than were suggested by the simulation lesson plan (shown in yellow on Tables 7- 8a and 7-7a). Since highlighting and linking focus student attention on the dynamic elements of the model, both teachers may have noticed more opportunities or needs than anticipated by the lesson plan and used the simulation to explicate theses dynamic elements.

In this way, the simulation condition appeared to foster a variety of unscripted discussion moves for these teachers. These unscripted, spontaneous moves contributed to the time spent discussing the simulation. I hypothesize that the PhETsimulation provided a greater affordance for managing a discussion for these teachers than did the overhead.

**Part Two: Examining Differences in the Behavior of the Two Teachers**

This part of the chapter reports on a comparative case study that examined differences between teachers enacting the same lesson and image mode. This part of the chapter examines patterns of teacher-student interactions used by each teacher during the entire lesson and will address the questions: 1) Did teachers use different patterns of interactions? 2) If so, did the image use impact the patterns of interaction used by the teacher in the lesson? As in the previous case study (Chapter 6), prior descriptions of interaction modes in the literature (Nassaji & Wells, 2000), along with the constant comparison method, were used to refine descriptions and coding categories of interaction patterns that helped me to describe different patterns of teacher behaviors during discussion.

## Description of Interaction Patterns and Coding Categories

This analysis makes use of the coding described in Chapter 6 to isolate the section of the lessons devoted to discussion.

**Syringe Lesson Class Diagram**

Figure 7-12 is a representation of how the teachers used time in their lessons. The numbers along the side represent the time codes in minutes from the video of the classes. In this diagram, red represents the time devoted to observation of the phenomena, which in this case is air being compressed in a syringe. The yellow sections represent the part of the lesson where no image was projected. During this time students were discussing the concepts, but the image was not projected. The green sections represent when the concepts were being discussed while the image was being projected. This is coded as the image-based discussion because the image was used as part of the discussion.

Figure 7-12
Differences in Time Intervals of Non-Image and Image-based Discussion in the 4 Classes

## Coding for Pattern of Teacher-Student Interactions: Presentation, IRE, IRF

Even though teachers were following the lesson plan, there were some important differences in how they enacted it. To better understand how the difference in teachers may have affected discussion, I coded for four patterns of interaction: presentation, IRE, IRF, and other (Chapter 6, Table 6-10).

## Narrative Transcript Analysis for Interaction Patterns and the Use of Images

In this section I identify and describe some preliminary observation patterns of how the teachers used discussion to engage reasoning and develop conceptual understanding. Teachers enacted the lesson plan in a variety of ways even though they were using a common lesson plan. As in the previous chapter, the focus of the analysis is on the non-image discussion and image-based discussion episodes. By examining transcript examples in more detail, it is possible to form some hypotheses about why the teachers used the questions differently.

Table 7-9
Correspondence between Transcripts Excerpts and Lessons

| | **Non-image-based Discussion** | **Image-based Discussion** |
|---|---|---|
| Mr. T OV Lesson | Transcript 1 | Transcript 5 |
| Mr. T SIM Lesson | Transcript 2 | Transcript 6 |
| Mr. R OV Lesson | Transcript 3 | Transcript 7 |
| Mr. R SIM Lesson | Transcript 4 | Transcript 8 |

### Analysis of Sections of the Lesson: Non-Image (Yellow) and Image-Based Discussion (Green)

**Difference in the non-image discussions (yellow sections)**. These teachers used the time before the image was presented differently. One pattern present in Figure 7-12 is that Mr. T spent more time discussing the concepts before showing the image than did Mr. R. This time difference is seen in both his overhead and simulation lessons.

What follows are transcripts for each teacher from the non-image phase of the lesson. They focus on how the teachers decided to manage the discussion of two key concepts in this lesson, namely, how the air molecules behave in a compressed and non-compressed syringe. In their work developing this curriculum, Lee et al.(1993) found that

many students believe that gas molecules become unevenly distributed when they are compressed or expanded. To uncover this misconception, the Matter and Molecules curriculum prompted students to answer what I call the open syringe and compressed syringe questions.

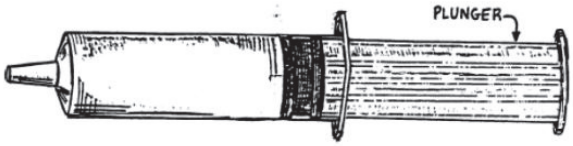
| |
|---|
| Common Student Misconception:<br>"When air is compressed in a syringe, air stays around the opening of the syringe because air is pushed forward. In contrast, when air expands in the syringe, air stays around the plunger because air is pushed backward." |
| Target Model:<br>"The constant motion of molecules and their freedom to move anywhere in the gaseous state assures that they will generally be distributed evenly (actually randomly) throughout the space occupied by a gas." |
| Open Syringe question:<br>"Below is a drawing of a syringe. How would molecules of air be arranged in the open syringe when the plunger is all the way out? Draw the air molecules in and out of the syringe." |
| Compressed syringe question:<br>"Why can't you push the plunger all the way in with air in it?" |
|  |

Figure 7-13
The Open and Compressed Syringe Questions
(Excerpted from Matter and Molecules Lesson 4, Anderson et al., 1993)

Both teachers knew that students might have misconceptions about how molecules are distributed in open and compressed syringes. How they managed this phase of the lesson provides a way of describing the differences between the teachers.

**<u>Transcript 1: Mr. T's OV lesson non-image discussion</u>**. The transcript that follows provides a window into how Mr. T orchestrated the part of the lesson discussing the "open syringe question."

> T: Ok, but you think when I do this (Teacher puts plunger in the syringe) , that somehow compresses that (pointing to the air in the tube of the syringe) ?
>
> Kanya: No, but if you go like this (S pushing the syringe in), then it does.

The next student who speaks has been convinced by John and Kanya and has changed his view of how the molecules would be distributed.

> David: Well, well, at first, I said it was evenly distributed, but a lot of what John and Kanya said made sense, and I also wanted to add that when you suck in more, air is coming out of the little airway right here less fast because it's such like a small opening and if it was like this (points to syringe with no plunger in it.), it would just be able to freely move out and in.

Later in the discussion students began presenting the reasoning for the molecules being evenly distributed in and out using model elements from previous lessons. For example Oscar brings in the concept of diffusion.

> Oscar: Um, I think, it's actually equally distributed um, because the hole is so small, but molecules are like tiny, they're like, really small, so I don't think they would have trouble going through a small hole.
>
> T: So you think, even if you did the thing that Kanya was talking about, if you pulled it like that, and you suck the air in, there is still an equal number here than there is out?
>
> Oscar: Yeah. And also like, diffusion, wouldn't they like, wouldn't they like, when you do like, so basically they're evenly spread 'cause they're going to low concentration.
>
> And a little further on in the conversation another student, Simon brings in the speed of the molecules.
>
> Simon: Well, I'm thinking, I kind of agree with what they were saying, even if you pulled this out, and, for some reason, like, it wasn't evenly spaced, in the beginning, you said before that like gas molecules move six hundred miles an

> hour, so, if they were moving that fast, they would like immediately even themselves out even though the hole is really little, they could get out there.

But these reasons do not seem to change Kanya's model and she persists and presents the idea that the geometry of the syringe traps the randomly moving molecules.

> Kanya: The whole thing with the hole is yeah, molecules could get through it, but like the whole point of molecules is they're moving randomly, so the smaller the hole, it like cuts down on the chance of the molecule randomly bouncing out of the hole. And so the molecule, with the smaller hole, the molecules are more likely just to like bounce off the wall of the thing-a-majiggy.
>
> T: They won't be able to get out. So they're sort of trapped in there?
>
> Kanya: Yea, 'cause it's, it's random, so the smaller the hole, it cuts back on the chance for them to get out.

This "hole traps molecules in the syringe" idea encourages four more students to explain their reasoning for the evenly distributed model. The full large group discussion of this open syringe question took ten minutes included 24 responses by students, many of them gesturing as they describe what is happening to molecules inside the syringe. There were still students raising their hands to speak when the discussion ended. Mr. T was not observed evaluating or expressing the target model, the equal distribution of molecules inside and outside the open syringe.

Figure 7-14
Screen Shots from Transcript 1: Mr. T's OV Lesson (Non-image Discussion)

**Analysis of transcript 1.** In this example Mr. T polls students and then neutrally gives the few students with the misconception an opportunity to share their reasoning first. During the course of the discussion both sides (even distribution / uneven distribution) get a chance to articulate their points of view about the "open syringe question". This conversation occurs before an external image is present, but students were observed reasoning with model elements like random motion, diffusion, and high speeds of molecules and gesturing over the syringe as they describe the behavior of molecules. This suggests that students are generating their own internal images or mental models to help them think about this question. This transcript suggests that the IRF

interaction pattern used by Mr. T encouraged students to reason with their initial mental model of how the molecules of a gas would behave in this new container, a syringe. The curriculum had not described a misconception in which the shape of the container would trap molecules and cause them to become more crowded inside an open syringe than in the outside air, but several students expressed this idea. While Mr. T did not evaluate this misconception directly, students' were observed doing this evaluation. There is evidence that the student who started with this misconception, held on to it, and was not convinced by some students' reasoning

Mr. T did not discuss the "Compressed Syringe" question. This may be because the "open syringe" discussion took longer than expected to pursue the different lines of student reasoning.

**Conclusion for transcript 1**. An extended exploration of student thinking was prompted by Mr. T's use of IRF interactions patterns. Students were observed reasoning with their model and evaluating each other's models. The teacher did not evaluate student models. This section took longer than anticipated by the lesson plan and time ran out before Mr. T could finish the lesson plan.

**Transcript 2: Mr. T's SIM lesson non-image discussion**. A more limited IRF exchange took place in the non-image discussion of Mr. T's Simulation lesson. He polled the students about their ideas about the "open syringe" question and then prompted one student with a misconception to explain his reasoning.

Open Syringe Question

T: what's true of the spacing of the molecules inside and outside that plunger? Let’s do a hand. If I were drawing the molecules inside and outside, the molecules are spaced, that is they're some distance away from each other, and if you looked at that space in between them what's true of the molecules inside and the molecules outside? "Theo?"

Theo: They're the same distance apart.

T: How many people think they should be the same? They should be drawn with the same spacing inside and out? Do you agree with that? Molecules spacing inside and out are the same?

S: (6 hands up out of 20)

T: Do you agree with that? Molecules inside and outside are the same?

S: (student shakes head)

T: No? Why not "Josh"?

Josh: Because well the outside air has more space.

T: OK, so...

Josh: They should be drawn the same but not be the same distance away from each other.

T: Because there's more space outside?

Josh: Ya.

T But if you think about it...so you're saying just naturally they're more crowded inside here than outside? Why would they be more crowded in here?

Josh: Because there's less space.

T: What if I take the plunger out like this? (takes plunger out leaving an empty syringe)

Josh: Well then you just broke it(Laughter)

T: What if I put this back in? In other words, if this is just normal everyday air inside here, I guess what I'm arguing is if it's normal everyday air inside and normal everyday outside air there is nothing different, we're not doing anything to

the air because this is open, then if you haven't changed the air inside. It should be the same as the air outside. Right? We haven't done anything to the air, the air outside is the inside air, but the same spacing should be true, I'm agreeing with those folks that have them evenly spaced.

This transcript begins with Mr. T asking students to respond to the 'compressed syringe' question: "Why can't you push the plunger all the way in with air in it?"

S There still needs to be room for the air.

T: OK, still has to be room for the air, so there's still something there, so there has to be room for it. Anyone else? Got something "Dylan"?

Dylan: Well, once you compress it fully it's gonna be as densely packed as liquid or a solid because the molecules are closer together.

T: So when I push that all the way I'm suddenly turning that into a solid?

S: Not a solid, the molecules are just closer together, they're clustered more.

T: OK, it's closer but is it as close as a liquid?

S: No, almost but not as close. if we had enough power we could compress it into a liquid.

T: Right, but if we had enough power we could compress it maybe into a liquid, but it's still into what state of matter when we do that?

S: Gas.

T: Still a gas. So that's important right? Because they're still far apart, so the question becomes: "They're not touching, they're still just a gas, so why can't we push it in?" , they're not like a liquid because we can still see it, there's no liquid in there, so why can't we push it in anymore? What do you think "Mavis?"

S: It's because most of the air molecules are already trying to escape to the free spaces that are open, and all the other molecules can't occupy the same space, so they're all fighting for the same empty space.

T:OK, so why does that prevent us from pushing it in all the way?

S:(long pause, student speaks softer ) because, it's like...harder...all the empty space is kinda like being taken up by the molecules going around.

S: OK, so you're sort of siding with Dylan on that, that is, there's no more room for them. But if there were no more room, and you turned that into a liquid, then we'd have a liquid in there, there wouldn't be a gas, it's still a gas, there's still alot of room in there.

Teacher switches on the simulation

**Analysis of transcript 2**. In this transcript excerpt of the open syringe question, Mr. T polls students and again encourages a student to explain his belief that air molecules are more densely packed inside of the syringe. This line of questioning brings out a student's misconception but comes to a close when Mr. T provides an explanation of the target model. Mr. T uses a similar pattern while discussing the compressed syringe question. He is observed using an IRF pattern to encourage students to reason with their model before presenting the target model. Students appear to be struggling with the concept that multiple molecular collisions can create a force and may be attempting to generate a viable visual model.

**Conclusion for Mr. T's non-image discussion transcripts 1 and 2**. In these transcript excerpts from two separate classes, there is evidence that Mr. T pursued a generative agenda before the image was presented. His use of IRF interactions appeared to encourage students to attempt to reason with their initial mental model of how the molecules behaved in side of a syringe.

**Transcript 3: Mr. R's OV lesson non-image discussion**. Mr. R took a different questions.

T: Also, with the drawing for number three, with the syringe, you approach to the discussion of the open syringe and compressed syringe should show that when the syringe is just sitting here, there is a density of airs inside is the same as the

density of airs outside. So they're no squished or further apart inside right now than the airs are in the air around you right now.

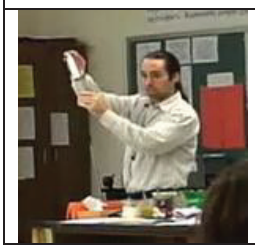
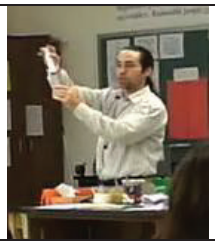
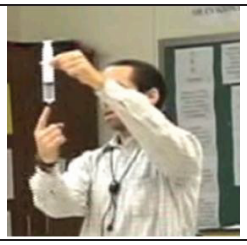
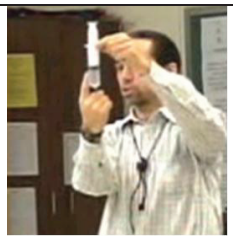
| a) The reason you can't push it down ” | b) the more you squish it | c) the more it can push up | d) in the same amount of time. |
|---|---|---|---|
|  |  |  |  |

Figure 7-15
Screen Shot from Transcript 3: Compressed Syringe Question

T: So the reason you can't push it down is not because the molecules are touching. The reason you can't push it down is the more you squish it the more it can push up against you in that same amount of time. If I keep my finger over the end, and I increase the density of the air inside, instead of being pushed millions of times a second, it's getting pushed up say billions of times a second. So I've got to work harder to resist those more molecules pushing up. So what I want you to do is when I'm done talking is to put your finger over the end, push it down a little bit. Feel your muscles. Feel how hard your muscles are working, squish it a little more another 10 and feel how hard your muscles are working and think of it as not your muscles working to hold it down, think of it as the molecules pushing up against you. You think oh they're working pretty hard, man a lot of them are working now, and then I get to the maximum point and I'm like WOW there's billions and billions of things slamming up against my hand.

**Analysis of transcript 3.** In discussion of both syringe questions, Mr. R is presenting the target model to students. He is not perusing student points of view. He is observed using a jabbing gesture while trying to explain the reason the plunger of a closed syringe filled with air could not be pushed in all the way. Mr. R gestured as he was describing the dynamic action of the molecule in the model.

**Transcript 4: Mr. R's SIM lesson non-image discussion**. Mr. R took a different approach to the discussion he had with student before the image was presented.

Open syringe Question: Done before the simulation

T: We looked at waters as compared to airs, of course we know that air is oxygen, nitrogen, and carbon dioxide, but you drew waters, so they're closer together, and the airs are much further apart, and based on the bottom drawing, everybody has drawn it right now, there should be the same number of air inside or the same density of airs inside as the density of airs outside.

Compressed syringe Question: Done after the simulation.

T: So, with the plunger, you can think of it as a "push-a-war" right now, who's winning, right now I'm pushing in, I'm winning. I'm winning; I'm stronger than those molecules. And then it gets to the point where when I'm holding it this way, the molecules are pushing back against the plunger, harder than I can resist my fingers. You can't push it anymore. What you need to do to understand this is imagine, billions of little molecules in there, slamming against the plunger. If you're imagining billions of little molecules slamming against the plunger, it will make sense, at some point, as they confined to a smaller space more of them are pushing.

**Analysis of transcript 4**. In the non-image sections of Mr. R SIM lesson, he was observed presenting the target model as he explained the answers to the open and compressed syringe questions. He presented his answer to the compressed syringe question after the image was displayed.

**Conclusion for Mr. R's OV and SIM non-image discussion.** In both his SIM and OV lessons, Mr. R was observed presenting the model. He did not pursue a generative agenda using IRF before the image was displayed.

**Conclusion for non-image discussion of Mr. T and Mr. R's transcripts 1-4**

The sets of transcripts from the teachers suggest the possibility that each teacher was pursuing a different agenda. In the cases presented, Mr. T used the time before the image was presented to pursue a divergent or generative agenda. In the pre-image part of the

lesson in he appeared to use the questions and ideas they generated to motivate a discussion which encouraged students to reason with their model of a gas.

On the other hand, in the segments from Mr. R, he used the time before the image was presented to pursue a more convergent or authoritative agenda in which he presented models and evaluated those models without input from the students. These results are summarized in Table 7-10.

Table 7-10
Preliminary Summary of Teacher Use of Interaction Patterns in Non-image-based Discussion

| | **OV Non-image** | **SIM Non-image** |
|---|---|---|
| Mr. T | IRF | IRF |
| Mr. R | Presentation | Presentation |

**Image-based discussions.** The green sections on Figure 7-12 represent discussions which took place while the image was projected. One pattern visible in Figure 7-12 is that Mr. R spends more time discussing the simulation than does Mr. T. They both discussed the Overhead for about 2 minutes. Below are transcript excerpts of the teachers discussing the images and they can be used to develop preliminary observation patterns that help to uncover some factors which influence each teacher's use of time.

**Transcript 5: Mr. T's OV lesson image-based discussion**. This discussion was in response to a question about why air can be compressed but water cannot.

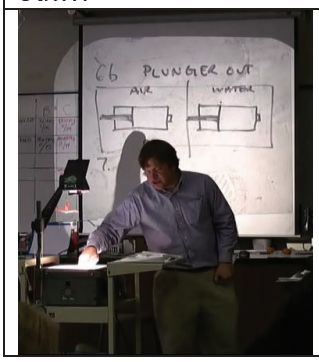
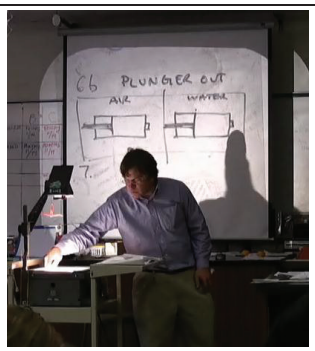
| a) T: “Why can you compress air but… | b) T: “but not water?” |
|---|---|
|   |   |

Figure 7-16
Screen Shots of Transcript 5: Mr. T’s OV Lesson Image-based Discussion

T: Why can we compress air but not water?

Lisa: Because there's more space between the air molecules.

T: OK, people like that?

S: Yeah, (Many students nodding and agreeing.)

T: That's the basic idea, right? So did you hear what she said? Can you say it again "Lisa"? Can you say it in a sentence?

Lisa: OK, you can compress the air because there's more space between the air molecules than with water.

T: OK, And what about the water Gloria? Why can't you compress water?

Gloria: They're already compressed without alot of room in between.

T: OK Good. They're already compressed. They're already basically touching each other, and when they're touching each other like that, it's gonna to be impossible to push them any closer together.

**Analysis of transcript 5.** The teacher is using an IRE patter to develop the molecular explanation of why air can be compressed but water cannot. The lesson ends before he can discuss the compressed syringe question. He is not observed using the OV to discuss the dynamic elements of the model.

**<u>Transcript 6: Mr. T's SIM image-based discussion</u>**. This transcript is taken from Mr. T's Simulation lesson after the pre-image discussion about the Open syringe question shown in transcript 2. This section of class shows Mr. T linking the behavior of molecules to the force felt when trying to compress air.

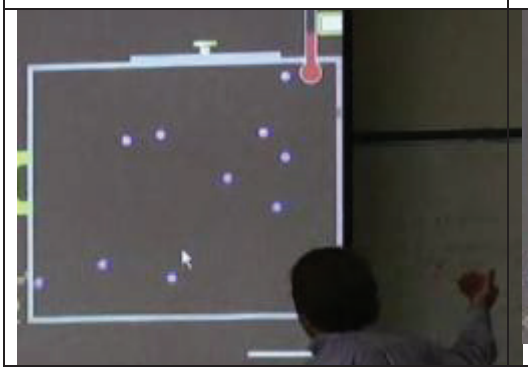
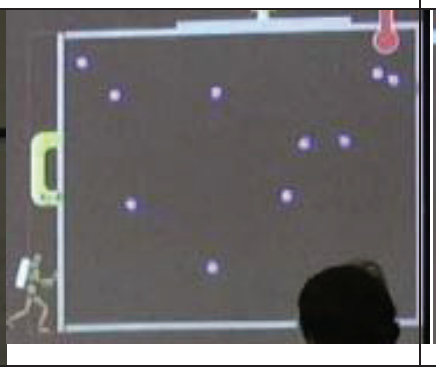
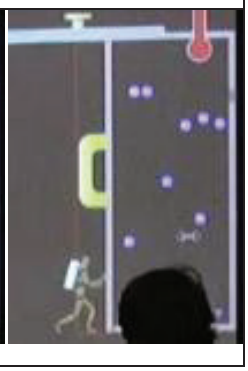
| a) T: "Count with me how many are hitting the plunger." | b) T:"Now when I push this thing in, try to count it now." | c) T: When I push this thing in, try to count it now |
|---|---|---|
|  |  |  |

Figure 7-17
Screen Shots of Transcript 6: Mr. T's SIM Image-based Discussion

T: It's actually easier if we take a minute and we look at this; so here's one with obviously just a very few number here right? So this guy isn't really pushing hard. Why isn't he pushing as hard Thomas?

S: Well because they're not really hitting the side.

T: Yeah. What forces him to push in is when the molecule hit that plunger. We could almost count how many are hitting the plunger. One...Count with me how many are hitting the plunger. One... two.... three..... four....five....Six. Do you see how slowly they hit the plunger now? The guy doesn't have to put in any work at all. Now when I push this thing in, try to count it now.

S: 1,2,3,

S: It's too fast to count.

T: It is too fast to count. So there is more hitting the plunger here when we have it compressed in like this. And that is what is causing the plunger to resist our movement. The more we push it in, the more that are hitting that plunger. Okay? The more that are hitting that plunger the harder it is to push.

**Analysis of transcript 6**. Mr. T uses a series of highlighting and linking moves to develop the cause and effect relationship between the behavior of the molecules and the behavior of the macroscopic model. He executes these moves using an IRE pattern. He asks a student to describe the cause and effect relationship and then evaluates and elaborates on his response. This transcript is an example of how Mr. T switched to using an IRE questioning mode while he develops the target model using the simulation. He did not follow-up student responses with request for more reasoning. This transcript hints at a change in an interaction pattern when he began discussing the image.

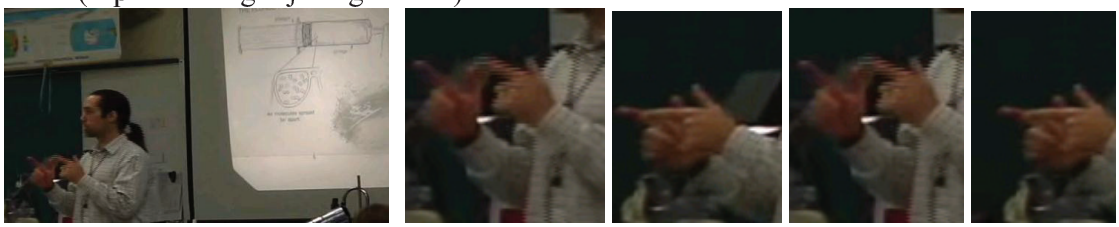
**Conclusion for Mr. T's Image Discussion Transcripts 5 and 6**. These transcripts from Mr. T, both of image-based discussions, point to a preliminary observation pattern: Mr. T shifted his interaction mode from IRF to IRE and Presentation when he began discussing the image. Mr. T used the images to present the target model, not to ask follow-up questions about it. This presentation or IRE interaction mode contrasts with his pre-image discussion modes when he used IRF interactions to encourage student to generate ideas about the model. During the image-based discussion, his presentation mode suggests that Mr. T pursued a more convergent agenda and was using the image to evaluate and modify student models.

**Transcript 7: Mr. R's OV image-based discussion.** This transcript comes from the part of the Overhead lesson after Mr. R's discussion of the compressed syringe question. In this segment, he is observed using the overhead image to further develop the model that he presented before the overhead was displayed.

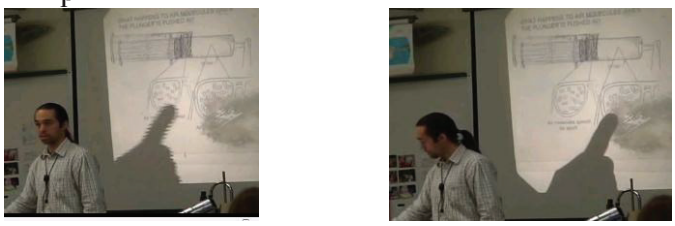
> T: So, here is an overhead describing what was going on. When the molecules are far apart, as you thought by feeling your muscles, they are not pushing back against you that hard. But as the syringe gets more compressed the molecules are getting more compressed which means that they are bouncing against you harder; as well as all sides of the syringe but the only side you can feel is the plunger side.. If they bounce harder meaning you need to work harder and you can feel that.

**Analysis of transcript 7.** This transcript shows Mr. R continuing the presentation mode image he was using before the image was displayed. He is observed using jabbing and pumping gestures while attempting to link the behavior of the gasses to the forces required to compress a gas. Mr. R gestured as he was describing the dynamic action of the molecule in the model and the forces they conveyed. (Figure 7-18)

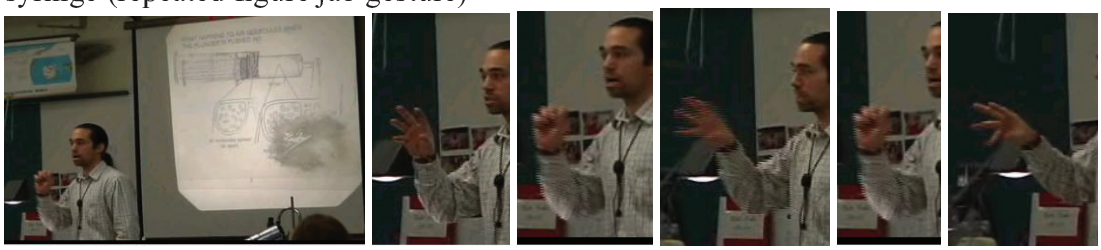
a) T: So, here is an overhead describing what was going on. When the molecules are far apart, as you thought by feeling your muscles, they are not pushing back against you that hard. (repeated finger jabs gestures)



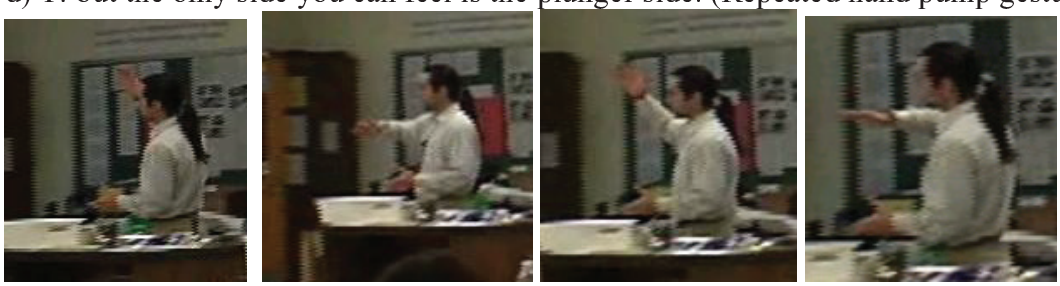
b) T: But as the syringe gets more compressed the molecules are getting more compressed



c) T: which means that they are bouncing against you harder; as well as all sides of the syringe (repeated figure jab gesture)



d) T: but the only side you can feel is the plunger side. (Repeated hand pump gesture)



e) T: If they bounce harder (finger jab) meaning you need to work harder (hand pump) and you can feel that.

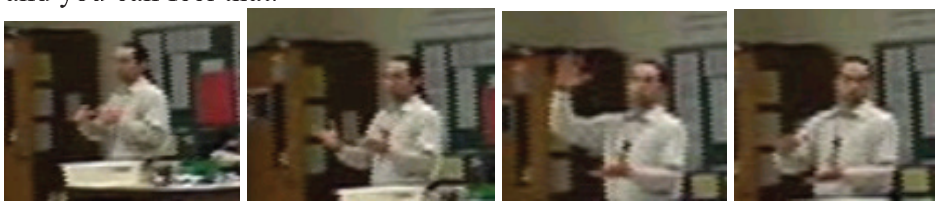


Figure 7-18
Screen Shots of Transcript 7: Mr. R Gesturing in OV Image-based Discussion

**<u>Transcript 8: Mr. R's SIM image-based discussion</u>**. In his simulation lesson, Mr. R does not discuss the concepts in the compressed syringe questions before starting the simulation. In this segment, he is using the simulation to develop the model of air in a syringe by asking students to link the behavior of molecules to the force needed to compress a syringe full of air.

| a) T: "Ok notice how he's leaning more now." | b) S7: ( gestures by flicking a pen) "molecules hit the wall so that makes more pressure" | c) T: "because when he is pushing, on the other side |
|---|---|---|
| | | |

Figure 7-19
Screen Shots Transcript 8: Mr. R's SIM Image-based Discussion

T: I'm gonna move it a little bit and see if what you said still makes sense. (Mr. R moves the wall of the container in the simulation to the right.) We will wait until he's pushing a little bit harder. Ok notice how he's leaning more now.

S: Oh he is.

T: He is resisting harder. Is he resisting the thing you said? Quick check at your table. What is he resisting? What is he working against there?

(Students talk at their tables of 4).

T: What is he working against there?

S1: He pushing against the air right?

T: Eliza, What is he working against? What is he resisting?

S2: Like the air pressure

T: Air pressure. Natalia, what is he pushing against?

S3: The air molecules

T: The air molecules.

T: "Casey" what's he working against? What's he resisting against?

S4: The pressurized air molecules?

T: The pressurized air molecules and "Issac" what is he working against?

S5: The air molecules?

T: The air molecules. Yeah! When I bring it in a little bit further... Woops too hard.
(Mr. R compresses the air in the simulation and blows the top off the container)

S1: Oh it popped.

S2: I was right!

S3: Oh my god they just went flying!

S4: Oh my god, they went crazy!

S5: Just like when she popped the syringe!

S6: Can you do it again?

T: I'll show you that in a little bit. There's a level you can take it to where just like the syringes -you can break the syringes. Oh I am too close.

(Teacher makes other adjustments to simulation to prevent it from “popping” again)

T: People gave answers of what is he resisting, see if you can continue with your thinking with why is this needle bouncing back and forth? If he is resisting the pressure of the air molecules, why is the needle bouncing back and forth? So talk at your table, if he is resisting air why is the needle bouncing?

Small Group for 30 seconds.

T: Ok welcome back? So why is that needle bouncing around? Let’s get some volunteers. Why is the needle bouncing around? Yeah?

S7: Because like there's like more randomness when the molecules hit the wall so

that makes more pressure like against it so it changes to become more hard. Yes so it's not steady

T: Random amounts different ones hit the wall at different times. Changes something?

S7: When you are pushing him and moving the wall and the molecules are pushing on the other side, but there are more of them pushing on the wall because when he is pushing, on the other side. They are not always going to be right there. (She gestures with pen flicking it many time as she talks about the molecules hitting the wall and as she is alternating between talking about the "man pushing" side of the plunger and the "molecule hitting" side of the plunger.)

T: The idea is that they're not always right there and sometimes if you watch, you can see there are not so many in one area, sometimes they're more over here. Angelo. Other ideas? Why is that needle jiggling?

S: I don't have any.

T: "Lee"? You don't have to I am just prompting in case you do. I sometimes won't volunteer an answer unless I am asked.

S: Student shakes head.

T: To summarize, what is the guy resisting? He is resisting the molecules hitting the other side of the wall. He has got to resist those. Why does the needle jiggle? Just as the people who volunteered said, it's not the same number of molecules hitting all the time, it's slightly random. It changes up and down, so the pressure changes a little bit but not very much.

**Analysis of transcript 8.** In this transcript Mr. R asks students to link the molecules to force felt in a compressed syringe. In this example, Mr. R asks for multiple student responses to the same question and he does not evaluate the student responses initially. One student was observed using gestures as she described the link between the action of molecules and the force felt when compressing a syringe (Figure 7-19). He uses questions to analyze the simulation before student have had a chance to think about or discuss the "compressed syringe question"

**Conclusion for transcript 8**. In this transcript, Mr. R is observed prompting responses from multiple students before evaluating. This can be viewed as Mr. R taking a step away from presentation when discussion was supported by images. Asking questions and comprehending responses from multiple students is a skill that takes time for teachers to develop.

**Conclusion for image-based discussion: Transcripts 5-8.** Mr. T is observed using the discussion of the images to evaluate student models and, thus, his interaction patterns are more authoritative and evaluative. He presents the target model and uses presentation and an IRE interaction pattern instead of an IRF interaction pattern. Mr. T leaves less room for students to articulate their point of view than before the image. These observations support the hypothesis that he is using the image as a "tool for telling."

When using the simulation, Mr. R is observed opening up more space in the class for student thinking than he did before the image was projected. He asks students to interpret the image and make inferences about what the image represents. Mr. T opened up space for student thinking by generating questions that were tractable to student reasoning and manageable for him to negotiate. He asked multiple groups a similar question and then listened and attempted to comprehend multiple student responses. These observations support the hypothesis that he is using the simulation as a "tool for asking." These preliminary patterns are summarized in Table 7-11.

Table 7-11
Preliminary Summary of Teacher Use of Interaction Patterns in Image-based Discussion

| | **OV Image Discussion** | **SIM Image Discussion** |
|---|---|---|
| Mr. T | Presentation | IRE |
| Mr. R | Presentation | IRF |

**Summary of Preliminary Patterns Observed in Transcript Excerpts 1-8**

These transcript excerpts suggest that the different uses of time observed in Figure 7-12 may be related to the type of teacher-student interactions that the teachers orchestrated during the non-image and image-based discussion sections of the lesson. Before the image, Mr. T was observed using discussion to generate student ideas through a series of IRF interactions about the model. On the other hand, Mr. R was observed using the non-image parts of discussion to present the target model through direct instruction and was not observed asking questions or encouraging students to generating student ideas.

When the image was projected, teachers were observed using different interaction patterns. Mr. R spent a longer time discussing the image than Mr. T. In the excerpts above, Mr. R was observed using questions to ask students to interpret the image. Mr. T was observed using a presentation mode to explain the image. This preliminary pattern, summarized in Table 7-12, suggests that each teacher's mode of interaction may have shifted when images were projected but that this shift was not in the same direction for each teacher. For one teacher, Mr. T, it was toward presentation, and for the other teacher Mr. R, it was away from presentation.

Table 7-12
Summary of Preliminary Patterns Observed in Transcripts Excerpts 1-8

| **Syringe Lesson** | **Non-image-based Discussion** | **Image-based Discussion** |
|---|---|---|
| Mr. T OV Lesson | **Transcript 1** Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 5** Used presentation and IRE, interaction patterns to use the image as "tool for telling." |
| Mr. T SIM Lesson | **Transcript 2** Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 6** Used presentation and IRE, interaction patterns to use the image as "tool for telling." |
| Mr. R OV Lesson | **Transcript 3** Presented target model | **Transcript 7** Presented Target Model |
| Mr. R SIM Lesson | **Transcript 4** Presented Target model | **Transcript 8** Used IRF interaction patterns to use the image as a "tool for asking." |

## Counted Code Transcript Analysis for Interaction Patterns and the Use of Images

In this section, I use a counting code mode of analysis to determine if the preliminary observation patterns observed in the transcript excerpts are supported by analysis of the full transcript. When the full discussion transcript is considered, is there evidence that the teachers use of questioning changed when presented images were used?

Table 7-13a
Times Spent on Discussion in the Simulation Lesson

| **Simulation Lesson Discussion Times (in minutes: seconds)** | | |
|---|---|---|
| | Mr. R | Mr. T |
| Length of Discussion Section of the Lesson | 34:59 | 35:59 |
| Length of Non-Simulation Discussion | 17:48 | 30:18 |
| Length of Simulation Discussion(Image-based ) | 17:11 | 5:41 |

Table 7-13b
Times Spent on Discussion in the Overhead Lesson.

| **Overhead Lesson Discussion Times (in minutes: seconds)** | | |
|---|---|---|
| | Mr. R | Mr. T |
| Length of Discussion Section of the Lesson | 33:43 | 36:00 |
| Length of Non-Overhead Discussion | 31:46 | 33:55 |
| Length of Overhead Discussion (Image-based ) | 1:57 | 2:05 |

These data reveal that a major difference in teacher behavior was the difference between the time teachers spent discussing the simulation: Mr. R spent 17:11 minutes, Mr. T, 5:41 minutes. Note that Non-Simulation in Table 7-13a does not refer to the Overhead Condition but rather to the portion of the Simulation Condition classes that were spent in discussion without the simulation displayed.

Since the major teacher effect was seen in the Simulation condition, the analysis in this section will focus only on data from the simulation lesson. To better understand how the difference in teachers may have affected discussion, I coded for four patterns of interaction: presentation, IRE, IRF, and other (Chap 6, Table 6-10). I then counted instances and tallied the time each teacher spent involved with each interaction pattern (Tables 7-14a and 7-14b)

Table 7-14a
Mr. R Count and Time of Interaction Pattern in the Simulation Condition

| **Mr. R's Simulation Lesson** | | **P** | | **IRE** | | **IRF** | | **OTHER** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-SIM Discussion | 17:48 | 16 | 6:22 | 6 | 1:56 | 0 | 0:00 | 9:30 |
| Simulation Discussion | 17:11 | 25 | 6:40 | 4 | 1:41 | 6 | 4:30 | 4:20 |
| Total Discussion | 34:59 | 41 | 13:02 | 10 | 3:37 | 6 | 4:30 | 13:50 |

Table 7-14b
Mr. T Count and Time of Interaction Pattern in the Simulation Condition

| **Mr. T's Simulation Lesson** | | **P** | | **IRE** | | **IRF** | | **OTHER** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-SIM Discussion | 30:18 | 9 | 10:18 | 4 | 1:47 | 10 | 12:07 | 6:06 |
| Simulation Discussion | 5:41 | 9 | 2:27 | 7 | 1:58 | 2 | 1:04 | 0:12 |
| Total Discussion | 35:59 | 18 | 12:45 | 11 | 3:45 | 12 | 13:11 | 6:18 |

This table reveals that Mr. R was observed presenting the school science point of view more than twice as often as Mr. T (41 times compared to 18 times) in the simulation condition classes. Mr. R spent less time engaging in IRF interactions than Mr. T did (4:30 minutes compared to 13:01 minutes). Pursuing and clarifying student meanings through follow-up questions takes more time than directly presenting the model.

## Part Two Conclusions

These data lead me to hypothesize a possible cause for the teacher difference in simulation use seen in Table 7-13a. Mr. T tended to ask students to generate the model and used discussion time to pursue divergent student thinking. The time spent by Mr. T engaging in IRF interactions before the simulation left less time for Mr. T to discuss the simulation. Less time to discuss the simulation could also result in a smaller number and variety of image-based discussion moves as seen in Figure 7-4. Mr. R tended to present the target model and, thus, converge on the model without leaving much room for students to articulate their model. By presenting clear statements of the model, Mr. R was able to move quickly through the lesson and was able to spend more time discussing the simulation.

An interview with Mr. R revealed that his preferences for convergent discussions sprang from his concern that pursuing divergent student thinking could introduce too much "noise in the signal," or introduce misconceptions that would compete with a clear statement of the target model. In his opinion, a clear statement of the target model and a clear evaluation of student answers promoted the best learning of the target concept. Mr. T worried that presenting the model too quickly would leave students' misconceptions hidden and that this would interfere with learning. He believed that probing both convergent and divergent student ideas engaged student reasoning and provided him with information about the state of student thinking that he could then use to co-construct the target model using student ideas. His preference was pursuing student ideas even if it took longer than expected. He acknowledges that the pursuit of the student points of view did uncover misconceptions that were challenging to address and that addressing these misconceptions resulted in longer and more divergent episodes of discussion. These longer divergent episodes made it more time consuming to converge on the target model and reach the content goal of the lesson.

These sorts of teacher beliefs may have influenced the number and type of questions the teachers asked. When IRF and IRE instances are combined, they provide one measure of the amount of questioning done by each teacher. I converted the time spent on each interaction pattern into percentages. For example, in the third row of Table 7-14a, Mr. R used presentation mode for 6 minutes and 40 seconds during the time the simulation was up and being discussed, which is 39% of the time he spent discussing the simulation (6:40/17:11 = 39%). Tables 7-15a and 7-15b indicate that Mr. R used about

23% of the total discussion time asking questions compared to 47% of time spent on questions by Mr. T.

Table 7-15a
Percent of Discussion Time Spent on Each Interaction Pattern by Mr. R in the Simulation Condition

| **Mr. R's Simulation Lesson** | **Time** | **Presentation (P)** | **IRE** | **IRF** | **OTHER** |
|---|---|---|---|---|---|
| Non-SIM Discussion | 17:48 | 36% | 11% | 0% | 53% |
| Simulation Discussion | 17:11 | 39% | 10% | 26% | 25% |
| Total Discussion | 34:59 | 37% | 10% | 13% | 40% |

Table 7-15b
Percent of Discussion Time Spent on Each Interaction Pattern by Mr. T in the Simulation Condition

| Mr. T's Simulation Lesson | Time | Presentation (P) | IRE | IRF | OTHER |
|---|---|---|---|---|---|
| Non-SIM Discussion | 30:18 | 34% | 6% | 40% | 20% |
| Simulation Discussion | 5:41 | 43% | 35% | 19% | 3% |
| Total Discussion | 35:59 | 35% | 10% | 37% | 18% |

Teacher preferences for asking questions may be related to beliefs about how to manage the tensions between divergence and convergence that occur in a discussion. Asking a question requires teachers to negotiate potentially competing agendas: a divergent lesson agenda that prioritizes exploring student ideas and reasoning, and a convergent lesson agenda that prioritizes moving toward a clear statement and understanding of scientifically accepted model. The data suggest that Mr. T spent more time pursuing a divergent agenda through his use of follow- up questioning to develop the model. Mr. R spent more of the discussion time pursuing a convergent agenda through his use of presentation and IREs to develop the model.

Applying Scott's Communicative Approach framework, I can place the teachers along a Dialogic-Authoritative spectrum. Viewing the totals in the bottom rows of Tables 7-15a and 7-15b I see that both teachers used both Dialogic and Authoritative modes. However, Mr. T spent more time pursuing a dialogic mode of discussion. As a result Mr. T spent more time probing student ideas with follow-up questions before the simulation, but this left him less time to use the simulation to converge on the target model. Mr. R spent more time pursuing an authoritative mode of discussion. Mr. R spent less time

probing student ideas but this left him more time to use the simulation to converge on the target model.

| | | |
|---|---|---|
| | Mr. R | Mr. T |
| Authoritative ---------- | | Dialogic |

Figure 7-20
Placing the Two teachers on the Dialogic- Authoritative Spectrum

Scott, Mortimer, and Aguiar (2006) argue that lessons with content goals should involve both authoritative and dialogic modes of interactions. Finding the right balance between authoritative and dialogic episodes in a lesson can be challenging, because when a teacher probes the student point of view, he can uncover significant and unexpected divergence from the target model.

For example, some students in Mr. T's class were observed drawing air molecules compressing themselves in an open syringe without the student pushing on the plunger. Mr. T asked a series of follow-up questions about this drawing and discovered that this belief was based on a misconception about the relative size of the opening in the syringe compared to the air molecules. It took time to discover this belief and then give the students and teacher a chance to respond to those who were convinced that the syringe geometry would trap the air molecules, "letting molecules come in but not let them out."

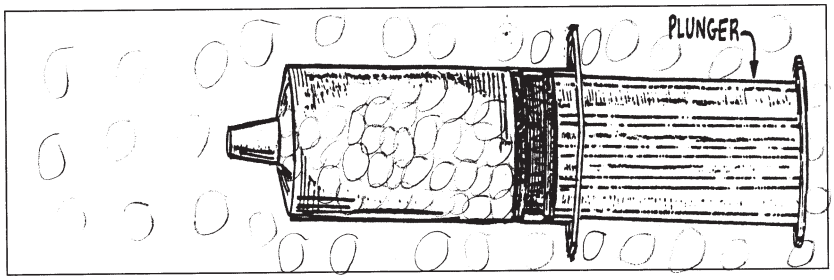



Figure 7-21
Student Drawing Air Molecule in an Open Syringe

Responding to divergent student ideas in ways that foster norms for student participation and reasoning is a complex task. Journal entries made by Mr. T revealed that he was surprised by the length of time that this part of the discussion took. He continued to pursue follow-up questions, because students were reasoning with their models, and he thought that this student reasoning might converge on the target concept: air molecules equally distributed inside and outside of the open syringe. He avoided negative evaluation of student ideas, because he was "curious to see where their ideas came from" and he did not want "to dampen the class norms that foster this kind of thinking." To maintain these norms, he felt it was important to "listen carefully to student ideas" since they had "risked stating them publicly to their peers."

Pursuing student reasoning in this way can result in lessons taking longer than planned, and these longer lessons can force subsequent lessons to be compacted or omitted in order to meet the time demand of the school curriculum. One can see this on a small scale in Mr. T's lesson in which the use of the simulation was compacted. In this lesson, Mr. R and Mr. T managed the tensions between dialogic discourse and authoritative discourse differently. Mr. T's overall approach was more dialogic, since it pursued divergent student ideas, but it left less time for the simulation. Mr. R's overall

approach was more authoritative, since it did not pursue divergent student ideas, and this left more time to discuss the simulation.

## Part Three: Examining the Effects of Teacher and Image Mode Conditions

In part three, I report on a cross comparative study where effects due to teacher differences and image mode are considered. This section will address the questions: 1) Were discussion moves associated with particular interaction patterns? and 2) Did teacher interaction pattern choices change after an image mode started?

### Moves and Interactions

By combining the data from part one and two, I was able to count the times each interaction pattern occurred during an image-based discussion move.

Table 7-16 contains combined data from these two teachers' classes, and it shows how the most common moves could be used in three different interaction patterns: presentation, IRE, and IRF. Orienting, Highlighting, and Linking moves were associated with all three interaction modes. Predicting (asking student students to predict future states of the simulation) was, of course, associated with questioning (IRE or IRF). Highlighting, which involves describing the dynamics shown in an image, was done most frequently via teacher presentation instead of questioning. The other moves were observed too infrequently to comment on any association with interaction patterns.

Table 7-16
Combined Data from These Two Teachers' Classes Showing the Interaction Patterns Associated with Each Move

| | **Presentation** | **IRE** | **IRF** |
|---|---|---|---|
| Orient | 5 | 5 | 2 |
| Predict | 0 | 1 | 3 |
| Highlight | 15 | 3 | 1 |
| Link | 12 | 2 | 2 |
| | | | |
| Extend | 0 | 0 | 0 |
| Critique | 3 | 0 | 0 |
| Situate | 1 | 0 | 0 |
| Wrap | 3 | 0 | 0 |
| Totals | 39 | 11 | 8 |

**Findings**

The image-based discussion moves Orienting, twice as often as they were accomplished by questioning (IRE or IRF).

**Interaction Patterns After an Image Mode was Started**

The data in Tables 7-17a and 7-17b show that Mr. T used more IRE interactions after the simulation mode was started and Mr. R used more IRF interactions after simulation mode was started.

Table 7-17a
Interaction Pattern Data from Mr. R's Class

| Mr. R | Time | Presentation (P) | IRE | IRF | OTHER |
|---|---|---|---|---|---|
| Non-SIM Discussion | 17:48 | 36% | 11% | 0% | 53% |
| Simulation Discussion | 17:11 | 39% | 10% | 26% | 25% |
| Total Discussion | 34:59 | 37% | 10% | 13% | 40% |

Table 7-17b
Interaction Pattern Data from Mr. T's Class

| Mr. T | Time | Presentation (P) | IRE | IRF | OTHER |
|---|---|---|---|---|---|
| Non-SIM Discussion | 30:18 | 34% | 6% | 40% | 20% |
| Simulation Discussion | 5:41 | 43% | 35% | 19% | 3% |
| Total Discussion | 35:59 | 35% | 10% | 37% | 18% |

The change in visual mode may have changed the interaction mode profile. One possible explanation for this is that simulation, as a complex imagistic statement of the model, could have an effect on teacher interaction patterns.

**Findings**

Applying Scott's Communicative Approach framework, I can place the teachers along a Dialogic-Authoritative spectrum and diagram a possible effect of image mode on discussion mode. Without the simulation, Mr. T spent more time pursuing a dialogic mode of discussion through his use of IRFs. With the simulation, he spent more time pursuing an authoritative mode through his use of IREs. Mr. R's pattern was just the opposite. Without the simulation, Mr. R spent more time pursuing an authoritative mode of discussion through his use of IREs. With the simulation, he spent time in a dialogic

mode through his use of IRFs. An overall effect was that the simulation appeared to bring these two teachers closer together in the middle of the Dialogic/Authoritative spectrum, as shown in Figure 7-22.

```
Non-Simulation discussion (before the image was projected)

                        Mr. R              Mr. T
   Authoritative ------------------------------------------------------------------ Dialogic

Simulation discussion (while the image was projected)

                        Mr. R  Mr. T
   Authoritative ------------------------------------------------------------------ Dialogic
```

Figure 7-22
Comparing Teachers' Placement on the Dialogic-Authoritative Spectrum During Different Image Modes

I offer a speculative hypothesis that the simulation may be supporting the teachers as they transition between dialogic and authoritative discussion modes. As a strong statement of the model, the simulation might limit, constrain, or bound student divergence and reduce the potential for conceptual divergence in student responses. The simulation's ability to restrict divergence of student response may be supporting Mr. R's willingness to ask potentially divergent questions and allow students to have a larger role in articulating the model.

On the other hand, the simulation may be supporting Mr. T's attempts to converge on the target model while asking questions that allow the students to articulate the target model. As a complex image, the simulation can be difficult to interpret. The need to interpret a complex image opens a space for generating a line of questioning that converges on the target model. These convergent question episodes (IREs) allow students

to articulate how their internal model is being used to interpret and reason with the external representation of the model (the simulation).

## Summary of Conclusions

### Part One: Summary of Effect of Image Mode on Discussion

Compared to the Overhead condition, the Simulation condition produced a) more time discussing the image, b) more moves, c) more variety of moves, d) more scripted moves in the lesson plans, and e) more spontaneously generated moves in the discussion. I hypothesize that simulation effects a), b), c) could be caused by an interaction of d) and e). Observations d) and e) suggest that the simulation provides an interesting affordance for planning and enacting discussions.

More speculatively, I hypothesize that this affordance may be associated with the simulation's capacity to be quickly and easily manipulated to display clear and accurate images of multiple states of the model. Also, I hypothesize, again speculatively, that this affordance may be associated with the way in which these images help the teacher think about the model while planning, and may provide a reference point that can be used for generating clear statements and productive questions about the model.

### Part Two: Summary of Differences in the Behavior of the Two Teachers

Mr. R spent more than twice the time discussing the simulation than Mr. T (17:11 minutes compared to 5:41 minutes). Mr. R was also observed presenting the school science point of view more than twice as often as Mr. T. (41 times compared to 18 times). Mr. T spent more time engaging in IRF interactions than Mr. R (13:01 minutes compared

to 4:30 minutes). Pursuing and clarifying student meanings through follow-up questions takes more time than directly presenting the model.

This data leads us to hypothesize a possible cause for the teacher effect on image use seen in Figure 7-12. In this lesson, Mr. R and Mr. T managed the tensions between dialogic discourse and authoritative discourse differently. Mr. T's overall approach was more dialogic, since it pursued divergent student ideas, but it left less time for the simulation. Mr. R's overall approach was more authoritative, since it did not pursue divergent student ideas, and this left more time to discuss the simulation.

**Part Three: Summary of the Effects of Teacher and Image Mode Conditions**

The data in Table 7-16 reveal that moves were more often accomplished through teacher presentation rather than through teacher questions. The data also show that at least three image-based discussion moves can be accomplished by questioning (Orienting, Highlighting, Linking).

The data in Figure 7-17a and 7-17b show that Mr. T used more IRE interactions after the simulation mode was started, and Mr. R used more IRF interactions after the image mode was started. I hypothesize that the visual mode may have changed each teacher's interaction mode profile. One possible explanation for this is that the simulation's strong statement of the model may constrain the discussion, while the simulation's complexity may leave room for student interpretation. These two features of a simulation may provide a space for discussions that can support teachers' attempts to keep students in a "reasoning zone" while the teachers converge on target models at the same time.

# CHAPTER 8

# COMPARATIVE CASE STUDIES OF DISCUSSION STRATEGIES USED IN A LESSON EXPLAINING SCENT IN AIR

## Chapter Overview

Using the same methodology as the two previous case studies (Chapters 6 and 7), this chapter analyzes teacher behavior in a lesson using visual media about the particulate nature of matter that was taught by two experienced middle school teachers (Mr. T, the author, and Mr. S). The lesson in this study attempted to help students construct a visualizable particulate model explaining how scent molecules travel to the nose. Each teacher taught a lesson to one half of his students using static overheads, and taught the other half of his students using a dynamic simulation. The two types of lessons had similar content goals, lab activities, and handouts but differed in the type of image mode used during large group discussion. Video and transcripts of large group discussions from four lessons were analyzed using codes for a set of image-based discussion strategies and codes for teacher student interaction patterns. Results suggest that the simulation mode offered greater affordances than the overhead mode for planning and enacting discussions. Differences in teacher use of interaction patterns, such as presentation, IRE, and IRF suggest that teacher preferences for these discussion modes may have been affected when images were discussed.

### Objectives of Comparative Case Study of the Scent in Air Lesson

A goal of this study is to examine how different image modes are used by teachers to teach the same content.

## Part One: Difference between Image Modes

Part one of the chapter reports on a comparative case study that examined the ways that the discussion of images was managed in matched sets of a simulation lesson and overhead lesson taught by the two teachers. Part one addresses the questions: What strategies were observed being used for leading whole class discussion in each image mode? How were lessons with similar lesson plans enacted differently when using different image modes?

## Part Two: Difference between Teachers

Part two of the chapter reports on a comparative case study that examined differences between teachers enacting the same lesson and image mode. This part of the chapter examines patterns of teacher student interactions used by each teacher (e.g., presentation vs. IRE vs. IRF, see Chapter 6, Table 6-10). Part two addresses the question: Did the teachers use different interaction patterns?

## Part Three: Differences due to Teachers and Image Modes

Part three of the chapter reports on a cross comparative study where effects due to teacher differences and image mode are considered. Part three will address the question: Did teacher interaction pattern choices change after an image mode started?

## Description of the Lesson

In this chapter, I examine two teachers as they led their class through a lesson in Matter Molecules (Lee et al., 1993) titled Clean Air and Smells. In their work developing this curriculum, the authors described a number of common misconceptions that this lesson was targeting. They suggest that students have difficulty understanding that gas is

matter and that smells are made of matter. They indicate that students may think that air is a continuous substance that carries things, like scents. Students with a particulate model of gas may still postulate that air molecules pick up or carry the smell or that air molecules may be still (as in still air). These misconceptions make it difficult for students to understand that smells of substances are made of molecules that mix with air molecules and that we smell because these molecules randomly move to our nose.

This lesson was based around two central questions, what I call the perfume question and the cookie question:

> **Perfume Question**
> How did the perfume travel from where it was released to your nose? Use molecules in your explanation.
>
> **Cookie Question**
> How would cookie smell travel from where it was released to your nose? Use molecules in your explanation

The perfume question was discussed before the image but after student had observed perfume being released in the room. The cookie question was discussed using either an overhead or a simulation.

This chapter describes and analyzes the large group discussion that occurred in each of the teachers' classes as they attempted to address these questions by enacting a common lesson plan. The lesson description to follow will provide a basic overview of the structure of the lesson. The variety of ways this lesson plan was enacted will be described later in the chapter.

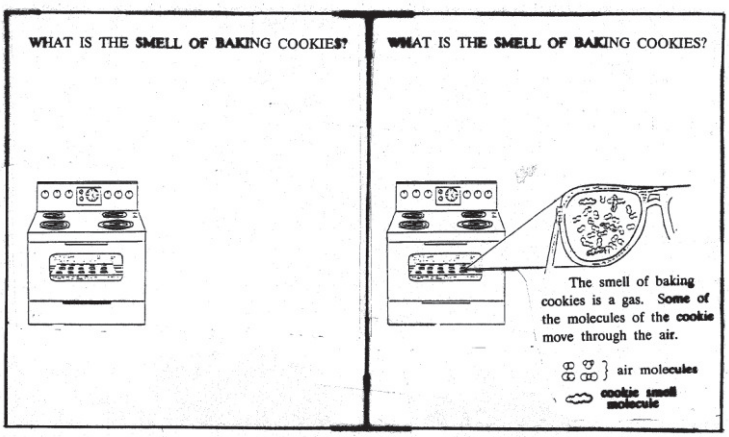
Table 8-1
Key Features of the Lesson Used in the Study

| | | |
|---|---|---|
| Title of the lesson | Clean Air and Smells (3.2) from the Matter and Molecules curriculum (Lee et al., 1993) | |
| Topic of the lesson | How does the particulate model of matter explain how a scent travels from a liquid source to our nose? | |
| Mode of interaction | The teacher facilitated a large group discussion of the image which was projected in front of the class.<br>The same handout was used to guide the lesson regardless of image mode used. | |
| Image mode | The "Overhead" or OV version of the lesson was taught as suggested using two static overheads provided by the curriculum. | The Simulation or "SIM" version of the lesson was taught as suggested but here a simulation from Atomic Microscope (Stark Design, 2003) was used in place of the overheads. |
| Video data | 50 minutes of Mr. S teaching the OV class | 50 minutes of Mr. T teaching the SIM class |
| | 50 minutes of Mr. S teaching the OV class | 50 minutes of Mr. T teaching the SIM class |

The lesson began with a demonstration that released perfume in the air. Students were asked to construct molecular explanations of this observable phenomenon by responding to the Perfume Question. Then an image, either the overhead or a simulation (Stark Design, 2003) representing air and cookie molecules was projected. During this part of the lesson, the students were asked to imagine a smell from a cookie baking and use their molecular model of air to explain how and why they could smell the cookies. A focused discussion of the image was used by the teacher to attempt to develop the students' mental model for scent.

The overhead lesson used a paired set of overheads to show cookie smell is made of molecules that mix with air molecules (Figure 8-1) from Lee et al. (1993). The

simulation lesson replaced this overhead with a computer simulation called Atomic Microscope (Figure 8-2) from Stark Design Inc. (2003).




TRANSPARENCY 6: WHAT IS THE SMELL OF BAKING COOKIES?

Figure 8-1
Transparencies Used in the Overhead Lessons

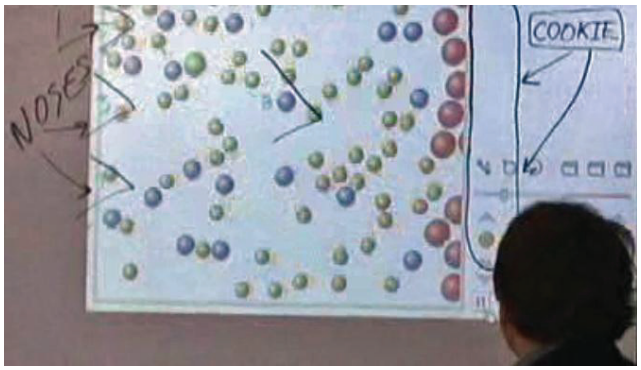



Figure 8-2
Image Used in the Simulation Lesson (Stark Design, 2003)

## Analysis and Findings

This case study examines the large group discussion that occurred during this lesson. I describe how the teacher and students discussed the projected images and how they were used to foster model construction and develop a molecular explanation of a gas. I also describe patterns of teacher-student interaction, specifically how the teacher

used presentation, questioning, and follow-up to help students develop and reason with their model.

## Part One: Examining the Effects of Image Mode on Discussion

In this case study, the constant comparison method was used to develop and refine descriptions and coding categories of discussion strategies that helped to describe possible effects of image mode (simulation vs. overhead).

### Description of Image-based Discussion Moves Coding Categories

The first level of coding involved looking at the entire lesson and determining when the lesson was focused on 1) making observations, as when students were smelling the perfume demonstration, and 2) engaging in discussion, as when the teacher and student were thinking and talking together about the explanatory model and using it to address the questions included in the lesson plan.

Table 8-2
Time Spent on Different Parts of the Lesson

| **SIMULATION Lesson** | | |
|---|---|---|
| | Mr. T | Mr. S |
| Time spent on the Laboratory Demonstration | 2:16 | 2:11 |
| Length of Non-Simulation Discussion | 9:37 | 6:02 |
| Length of Simulation Discussion (Image-based ) | 18:33 | 7:29 |
| **OVERHEAD Lesson** | | |
| | Mr. T | Mr. S |
| Time spent on the Laboratory Demonstration | 2:17 | 1:38 |
| Length of Non-Overhead Discussion | 22:29 | 14:01 |
| Length of Overhead Discussion (Image-based ) | 6:08 | 2:58 |

The second level of coding focused on the effect of image on the discussion portion of the class. I identified when the overhead or simulation was used with large group discussion to develop the content goal of the lesson. The data for this level of coding is shown below in Table 8-2. Once these image-based discussion episodes of class were identified, I coded for image-based discussion moves (Chapter 5, Table 5-2).

## Description of Differences between Simulation and Overhead Conditions

I found that both teachers spent more time and employed a larger number and variety of discussion moves to integrate the dynamic simulation into the model construction process as compared to a static overhead (Tables 8-3 and 8-4).

Table 8-3
Comparison of Time Interval Spent Discussing the Image in Each Image Mode

| Teacher | Time spent discussing the dynamic image (Stark Design, 2003) simulation, (min:sec) | Time spent discussing the static image (2 static overheads) (min:sec) |
|---|---|---|
| Mr. T | 18:33 | 6:08 |
| Mr. S | 7:29 | 2:58 |

Table 8-4
Comparison of Variety and Number of Image-based Discussion Moves in Each Image Mode

| | Teacher | Orient | Predict | Highlight | Link | Situate | Critique | Frame | Extend | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Instances of Moves in SIM Lesson | Mr. T | 4 | 2 | 3 | 4 | 4 | 3 | 5 | 1 | 26 |
| | Mr. S | 7 | 2 | 1 | 3 | 1 | 0 | 0 | 0 | 14 |
| Instances of Moves in OV Lesson | Mr. T | 5 | 1 | 0 | 9 | 0 | 0 | 0 | 0 | 15 |
| | Mr. S | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 6 |

## Possible Causes for the Difference between the Simulation and Overhead Conditions

When comparing different image modes, I found that some of the differences I observed between conditions (time, number of moves, variety of moves) could be attributed to the differences in the overhead and simulation lesson plans, and some could be attributed to spontaneous and unplanned actions by the teachers.

**Effects on Lesson Plan: The Simulation May Provide Affordances for Planning Large Group Discussion**

My intention in designing this naturalistic study was to substitute a simulation for the overheads provided by the curriculum. The teachers and researchers in this study planned this lesson jointly. The group chose to use the overheads provided by the Matter and Molecule curriculum as directed by the authors of this curriculum since those authors had found these images and lesson plans to be effective at promoting learning as measured by instruments used in their study (Lee et al., 1993). In the course of considering how to use the simulation, the team felt it natural to use the affordances we could see in the simulation to depict the difficult to comprehend dynamic elements of a model. For example, the simulation allowed the teachers to manipulate the number of gas molecules in the chamber, and this triggered us to set up extreme cases of the very large and very small cookie (Figure 8-3).

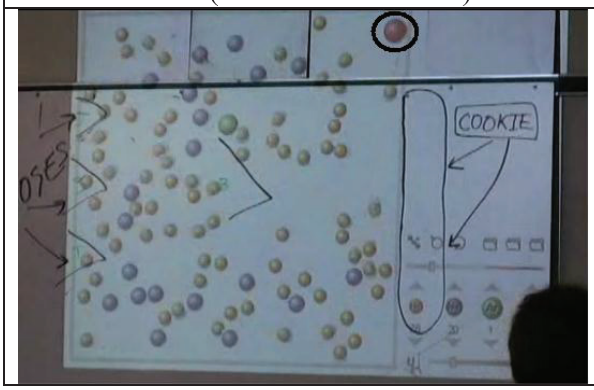
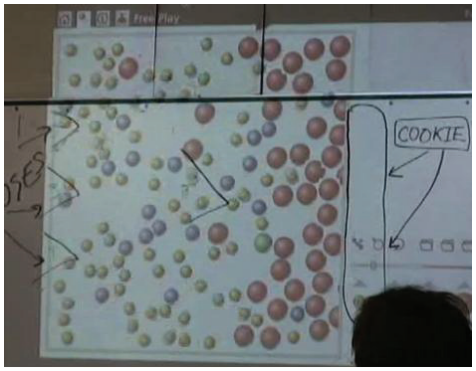
| Extreme Case: Very Small Cookie Made of One Molecule (shown in the circle) | Extreme Case: Very Large Cookie Made of Many Molecules |
|---|---|
|   |   |

Figure 8-3
Simulation Modified to Represent Two Extreme Cases

Due to the flexibility of the simulation, it was easy to obtain images of different states of the model and each image gave the teacher an opportunity to discuss how the number of molecules would affect the smell. This analysis suggests that one advantage of

the simulation is that it can be easily modified. The simulation lesson plan, in fact, called for the simulation to be modified a total of nine times, whereas the overhead lesson only called for three image changes, one change for each of the two overheads provided by the lesson and a teacher drawing (Table 8-5). Each time the simulation is modified, it provided a new image; in this way the simulation was a reservoir of images.

Table 8-5
Number of Times the Lesson Plan Requested a Change in the Image by the Simulation and the Overhead Lesson Plans

| | **Simulation Lesson Plan** | **Overhead Lesson Plan** |
|---|---|---|
| Requested changes to the image | 9 | 3 |

Each image provided by the simulation afforded the teachers with an opportunity to plan small episodes of the discussion. Though the move codes were not described when my team wrote the plans, it is possible to use them to code the lesson plan for request for various moves. The result of coding the lesson plan (Table 8-6) indicated that the simulation lesson plan did call for a larger number and variety of moves than did the overhead lesson plan.

Table 8-6
Number of Times a Move was Requested by Simulation and Overhead Lesson Plans

| **Move requested by the lesson plan** | **Simulation Lesson Plan** | **Overhead Lesson Plan** |
|---|---|---|
| Orient | 3 | 1 |
| Predict | 3 | 1 |
| Highlight | 0 | 0 |
| Link | 4 | 3 |
| Situate | 1 | 0 |
| Critique | 0 | 0 |
| Frame | 2 | 2 |
| Extend | 0 | 0 |
| Total Moves | 13 | 7 |

**Part One Conclusions**

This data again leads me to hypothesize that the greater number of moves was caused, in part, by the ability of the simulation to be modified to present different states of the model. Here, the simulation's ability to be modified to quickly alter the number of molecules may have helped the lesson planning team to imagine two extreme cases (Figure 8-3). Each information rich image provided by the simulation may have facilitated the mental rehearsal of a small episode of discussion and triggered prompts for these discussions. For example, the ability of the simulation to represent a very large cookie may have helped to stimulate the prediction question which was added to the plan: "How would a very large cookie be represented by the simulation? In this way, the simulation seemed to trigger more discussion moves in the simulation lesson plan than in the overhead lesson plan. These scripted moves contributed to the greater time spent and the greater variety of moves seen in the simulation lesson. I hypothesize that the simulation provided a greater affordance for planning a discussion than did the overhead.

**Effects on Spontaneous and Unplanned Actions by the Teachers**

The difference in lesson plan is not the only factor, however. The simulation also appeared to provide an affordance for the spontaneous strategic application of discussion moves. Just as in the case studies of the previous chapters (Chapters 6 and 7), while the lesson plan called for certain modifications of the simulation and suggested a set of discussion moves, neither teacher in the study enacted the lesson exactly as it was written.

For example, while Mr. T was enacting the lesson plans he made 13 more discussion moves than were called for in the simulation lesson plan (Table 8-7a and 8-7b) and only 8 more discussion moves than were called for in the overhead lesson plan.

Table 8-7a
Comparison of Simulation Lesson Plan and Simulation Lesson Enactment by Mr. T

| **Mr. T's Simulation Lesson** | **Planned Actions (PA) Suggested by the Simulation Lesson Plan** | **Teacher Actions (TA) made by Mr. T during the Teaching of the Simulation Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the Enactment and the Lesson Plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 3 | 4 | +1 |
| Predict | 3 | 2 | -1 |
| Highlight | 0 | 3 | +3 |
| Link | 4 | 4 | 0 |
| Situate | 1 | 4 | +3 |
| Critique | 0 | 3 | +3 |
| Frame | 2 | 5 | +3 |
| Extend | 0 | 1 | +1 |
| Total Moves | 13 | 26 | +13 |
| Modifications to the Simulation | 9 | 9 | +0 |

Table 8-7b
Comparison of Overhead Lesson Plan and Overhead Lesson Enactment by Mr. T

| **Mr. T's Overhead Lesson** | **Planned Actions (PA) Suggested by the Overhead Lesson Plan** | **Teacher Actions (TA) Made by Mr. T during the Teaching of the Overhead Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the Enactment and the Lesson Plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 1 | 5 | +4 |
| Predict | 1 | 1 | 0 |
| Highlight | 0 | 0 | 0 |
| Link | 3 | 9 | +6 |
| Situate | 0 | 0 | 0 |
| Critique | 0 | 0 | 0 |
| Frame | 2 | 0 | -2 |
| Extend | 0 | 0 | 0 |
| Total Moves | 7 | 15 | +8 |
| Modifications to the Overhead | 3 | 4 | +1 |

As Mr. S was enacting the lesson plans, he made one more discussion move than was called for in the simulation lesson plan (Table 8-8a and 8-8b) and one fewer discussion move than was called for in the overhead lesson plan.

Table 8-8a
Comparison of Simulation Lesson Plan and Simulation Lesson Enactment by Mr. S

| **Mr. S's Simulation Lesson** | **Planned Actions (PA) Suggested by the Simulation Lesson Plan** | **Teacher Actions (TA) made by Mr. S during the Teaching of the Simulation Lesson** | **Spontaneous Actions (SA= TA- PA): Difference between the Lesson Plan and the Enactment** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 3 | 7 | +4 |
| Predict | 3 | 2 | -1 |
| Highlight | 0 | 1 | +1 |
| Link | 4 | 3 | -1 |
| Situate | 1 | 1 | 0 |
| Critique | 0 | 0 | 0 |
| Frame | 2 | 0 | -2 |
| Extend | 0 | 0 | 0 |
| Total Moves | 13 | 14 | +1 |
| Modifications to the Simulation | 9 | 8 | -1 |

Table 8-8b
Comparison of Overhead Lesson Plan and Overhead Lesson Enactment by Mr. S

| **Mr. S's Overhead Lesson** | **Planned Actions (PA) Suggested by the Overhead Lesson Plan** | **Teacher Actions (TA) made by Mr. S during the Teaching of the Overhead Lesson** | **Spontaneous Actions (SA= TA - PA): Difference between the Enactment and the Lesson Plan** |
|---|---|---|---|
| | Instances | Instances | Instances |
| Orient | 1 | 2 | +1 |
| Predict | 1 | 1 | 0 |
| Highlight | 0 | 0 | 0 |
| Link | 3 | 2 | -1 |
| Situate | 0 | 0 | 0 |
| Critique | 0 | 0 | 0 |
| Frame | 2 | 0 | -2 |
| Extend | 0 | 1 | +1 |
| Total Moves | 7 | 6 | -1 |
| Modifications to the Overhead | 3 | 2 | -1 |

These data provide evidence that both teachers generated more spontaneous moves during the discussions of the simulation than they did during the discussion of the overhead. Mr. T was observed generating more spontaneous moves than Mr. S. The greater number of unscripted moves generated by Mr. T may have contributed to the greater time Mr. T spent discussing the simulation.

### Part Two: Examining Differences in the Behavior of the Two Teachers

This part of the chapter reports on a comparative case study that examined differences between teachers enacting the same lesson and image mode. This part of the chapter will examine patterns of teacher student interactions used by each teacher during the lesson and will address the question: 1) Did teachers use different patterns of interactions?

### Description of Interaction Patterns and Coding Categories

Even though teachers were following the lesson plan, there were some important differences in how they enacted it. This analysis makes use of coding described above to isolate the section of the lessons devoted to lab and discussion as I did in the other chapters. To better understand how the difference in teachers may have affected discussion, I coded for four patterns of interaction: presentation, IRE, IRF, and other (Chapter 6, Table 6-10).

## Narrative Transcript Analysis for Interaction Patterns and the Use of Images

In this section I identify and describe some preliminary observation patterns of how the teachers used discussion to engage reasoning and develop conceptual understanding. Teachers enacted the lesson plan in a variety of ways even though they were using a common lesson plan. As in the previous chapter, the focus of this analysis will be on the non-image discussion and image-based discussion episodes.

Table 8-9
Key to Transcript Excerpts

| | **Non-image-based Discussion** | **Image-based Discussion** |
|---|---|---|
| Mr. S<br>OV Lesson | Transcript 1 | Transcript 5 |
| Mr. S<br>SIM Lesson | Transcript 2 | Transcript 6 |
| Mr.T<br>OV Lesson | Transcript 3 | Transcript 7 |
| Mr. T<br>SIM Lesson | Transcript 4 | Transcript 8 |

### Analysis of Sections of the Lesson: Non-image and Image-based Discussion

What follows are transcripts for each teacher from the non-image and image phase of the lesson of both the SIM and OV lessons. The analysis focuses on how the teachers decided to manage the discussion of a key concept in this lesson, namely, how scent travels from its source to someone's nose.

### Non-image Discussions: Transcripts 1-4

What follows are transcripts for each teacher from the non-image phase of the lesson.

**Transcript 1: Mr. S's OV non-image discussion**. In this Pre-OV section of the lesson, Mr. S is observed using an IRF interaction pattern to prompt students to use their models of a gas to explain how they smelled the perfume.

> Mr. S: How did that perfume travel to your nose-- sense of smell? How did that happen? How did you smell it? How did it get from the plate to you smelling it? Marc?
>
> Marc: Well I am going to need a life line, Mr. S.
>
> Mr. S: Life line to Sara?
>
> Sara: Um… well.
>
> Mr. S: How do you smell it?
>
> Sara: My theory is that when you put it on the hot plate it partially evaporated so it mixed with the rest of the air.
>
> Mr. S: So it became vapor?
>
> Sara: Yep
>
> Mr. S: And mixed with the air? Ok and what else has to happen for you to smell it?
>
> Roberto: It has to go into your nose?
>
> T: So it's becoming a vapor and I heated the plate up so it would help it happen a little faster and go into your nose. Eva, anything to add?
>
> Eva: Well the molecules bounce around with the air molecules and it spreads through the room.

**Analysis of transcript 1**. Mr. S uses an IRF mode to ask students to use their model of a gas to explain how they smell perfume. He was observed using follow-up questions to encourage students to say more about their models. Four students share their initial models of scent and appear to be building on the previous student's idea. It's not until the end of this excerpt that a student is observed adding molecules as part of the

model. It is not clear if the initial models the students generated include a molecular explanation for scent. In these examples, the teacher did not evaluate specifics model elements but instead repeated the student's idea back as a question.

**Transcript 2: Mr. S's SIM non-image discussion**. In the pre-SIM section of the lesson, Mr. S is observed using an IRF interaction pattern to prompt students to use their models of a gas to explain how they smelled the perfume.

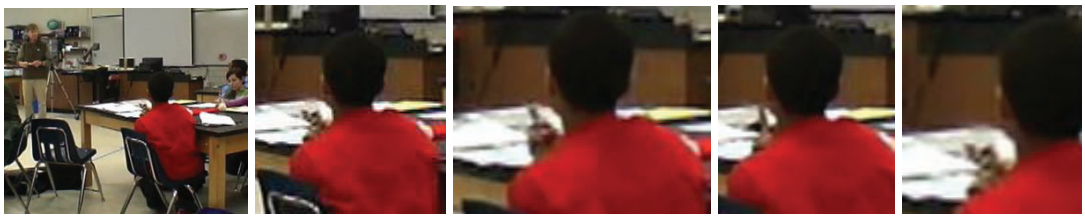


Figure 8-4
Student (Chris) Using Pointing Gestures While Explaining How Vapor Goes in to the Air

> Mr. S: How'd the smell get from those drops to your nose? What do you think Kelly?
>
> Kelly: The molecules from the....they turn into like water - like vapor somehow, then molecules raise into air then like your nose picks them up.
>
> Mr. S: The perfume molecules went from a liquid to a vapor?
>
> Kelly: Yea.
>
> Mr. S: Like we have seen water do, and then we have got your nose to smell them?
>
> Kelly: Yea.
>
> Mr. S: Mavis, anything to add?
>
> Mavis: No
>
> Mr. S: Chris?
>
> Chris: When the perfume is being heated up, like water, then its vapor, goes in the air, it travels to your mouth and it comes to your nose and you breathe it 'cause you have to.

Mr. S: Um So Chris mentioned that I heated it up how like when I heat water up it becomes a vapor that helps it become a vapor faster.

Chris: And the air picks it up and it comes to your nose as you are breathing in the air.

Mr. S: So you are breathing in air. And it's in the air and you pick it up.

**Analysis of transcript 2**. Mr. S was observed using an IRF mode as he prompted student to explain how the scent of perfume traveled to their nose. He was observed using follow-up questions to encourage three students to articulate their models but for two students, Kelly and Mavis, Mr. S's follow-up did not result in them explaining their model further. The last speaker, Chris, was observed using gestures while explaining how the perfume "vapor goes in the air," which suggests he may be generating internal visualizations (Monaghan & Clement, 1999; Stephens & Clement, 2010) but since he does not describe molecules, this may not include visualizing molecules of air and perfume moving randomly.

**Conclusion for Mr. S's non–image discussion: Transcripts 1 and 2**. In both examples, Mr. S was observed using an IRF mode to encourage students to reason with their model before a model was displayed. This suggests that he was using the pre-image part of the lesson to pursue a dialogic agenda in which students were prompted to reason with their model before the target model was developed. By asking follow-up questions and rephrasing student responses as questions, Mr. S was observed attempting to prompt students say more about their model. Though not all these attempts were successful, some students did make efforts to elaborate on their models. Students expressed a variety of student models; Kelly used molecules in her explanation of scent, and Chris did not.

**<u>Transcript 3: Mr. T's OV non-image discussion</u>**. In the following example, Mr. T began discussing the "cookie question" before an image of the molecules was presented. Here, they are reasoning with their models to describe what they imagine the area above baking cookies "looks like" using the "glasses of science." The "glasses of science" metaphor prompted students to imagine magnifying matter enough to be able to see the molecules.

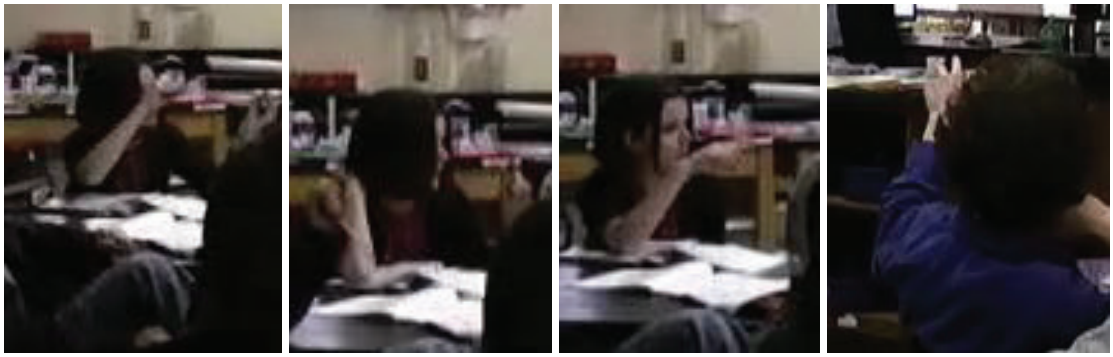


Figure 8-5
Students Gesturing in Mr. T's OV Lesson Non-Image Discussion

Sara: A bunch of molecules all bunched together.

T: Ok, So there would be a bunch of molecules out here. Robin, what else can we say?

Robin: There would be like big groups of molecules, and like little molecules, coming out.

T: Why would there be big bunches and why would there be little ones?

Robin: Because the cookies are made out of molecules so there would be a big bunch of them because they are made of them. And then little pieces after you smell it. If there wasn't any flavor it wouldn't smell.

T: So the little ones, are they cookie, or are they air?

Robin: Both?

T: Both. Ok. So, would we be able to see the big ones?

Robin: Yes.

T: There would be big chunks, maybe if you burn the cookies, though, right. Normally, when I bake cookies, I don't see anything coming out of the stove, but I smell it. So, I'm wondering how big you think those clumps are. Are they big enough to see?

Robin: No, they're not big enough to see.

T: But they're clumped because..., again, why are they clumped?

Robin: The big clumps, they're in the oven, where the cookies actually are, and then the smaller molecules are floating around the air.

T: I have got you. There are big clumps of molecules that the cookies are and then they form into molecules that get in the air.

Dan: They form the cookie molecules.

T: Right, cookie molecules. Angelo, What do you got?

Angelo: Since ovens are fairly well closed there is only a couple exits that the molecular structure could have got out of, anything turned into a gas, so it would be very concentrated violently bouncing gasses around any of the open exits but then spread out farther away out from the stove.

T: Ok so they would be…the particles, where they're leaking out, they'd be concentrated?

S: Yes.

**Analysis of transcript 3**. Mr. T was observed using an IRF mode to encourage students to reason with their models. In the exchange with Robin, Mr. T asked a number of follow-up questions before he comprehended the model she was attempting to articulate. When Robin first speaks, she appeared to have an incorrect model, but instead of evaluating the student, Mr. T used a dialogic interactive approach and pursued the student point of view (T: Why ... big bunches? Why… little bunches? ) and probed student understanding. (T: So the little ones, are they cookie, or are they air?) This set of IRF exchanges led to a fuller statement of the student model and allowed the teacher to

comprehend the complexity of it. She appeared to have a molecular model of scent which she was able to use to explain not only that scent is made of molecules ("smaller clumps of molecules") but also that cookies are "big clumps" of molecules that act as the source of the scent molecules ("little pieces of them [the cookies] after you smell it."). Robin and Angelo were both observed making gestures as they were describing the movement of molecules which suggests they may be generating internal visualizations of their model (Monaghan & Clement, 1999; Stephens & Clement, 2010).

**Transcript 4: Mr. T's SIM non-image discussion**. In the pre-SIM section of the lesson, Mr. S is observed using an IRF mode of questioning to prompt students to use their models of a gas to explain how the perfume traveled from where it was released to their nose.

> Steven: The molecules the lavender's made of, each had a scent, and when combined with air molecules that we breathe it creates a certain scent which our nose can identify.
>
> T: OK, so the molecules of the perfume mix with the air and together those things make the scent. What was the last sentence you said?
>
> Steven: That your nose can identify it as Lavender.
>
> T: OK, nice, "Juliana" You wanna say something?
>
> Juliana: Yea I said the perfume is made of different molecules, and as the molecules and gas diffuse through the air, it eventually gets to your nose and you can smell the scent.
>
> T: Say that again for me...
>
> Juliana: The perfume is made of different molecules, and these molecules and gases diffuse through the air, and eventually gets through your nose and you can smell the scent.
>
> T: What's getting to your nose?

Juliana: What'd you mean?

T: Yea, I'm asking you. What's actually getting to your nose?

Juliana: The molecules.

T: The molecules of...

Juliana: The perfume.
T: The perfume, OK so the perfume molecules are traveling and they actually go in your nose...is that what you're saying?

Juliana: I guess so.

**Analysis of transcript 4**. In this transcript excerpt, Mr. T is observed asking two students to use their models of gas to explain how perfume is smelled. Mr. T uses an IRF mode by asking student to repeat their ideas and using follow-up questioning to probe and clarify student meanings. Using this type of clarifying follow-up question suggests that Mr. T was pursuing a dialogic interaction by attempting to get students to articulate their points of view. However, since these students were observed reasoning about perfume molecules as part of their model, this dialogic interaction did not diverge far from the target model.

**Conclusion for Mr. T's use of non-image discussion: Transcripts 3 and 4**. The transcript excerpts above provide examples of the interaction modes Mr. T used during non- image-based discussion. In both OV and SIM lessons, Mr. T is observed using IRF questioning pattern and students are observed reasoning with their models. Some students are observed gesturing as they explain their model which could be evidence of reasoning with internal visualizations.

**Conclusion for Mr. S and Mr. T's use of non-image discussion: Transcripts 1-4.** The transcript excerpts above provide examples of the interaction modes Mr. T and Mr. S used during non-image-based discussion. In both OV and SIM lessons, Mr. T and Mr. S are observed using IRF questioning pattern and students are observed reasoning with their models before the image was displayed. This preliminary pattern, summarized in Table 8-10, suggests that both teachers may have pursued a dialogic agenda during the Non-image section of discussion. While there are clearly some important differences in these IRF interactions, pursuing coding that makes fine grain distinctions between types of IRF interactions is beyond the scope of this study.

Table 8-10
Summary of Teacher Use of Interaction Patterns in Non-image-based Discussion

| | OV Non-Image Discussion | Sim Non-image Discussion |
|---|---|---|
| Mr. S | IRF | IRF |
| Mr. T | IRF | IRF |

**Image-based Discussions: Transcripts 5-8**.

What follows are transcripts for each teacher from the image-based discussion phase of the lesson.

**Transcript 5: Mr. S's OV image-based discussion**. After describing their model of perfume scent students were asked to think about a similar question: "How does cookie smell travel from where it was released to your nose?" In Mr. S's lesson, students were not given time to generate or discuss their model of cookie scent before he used the overhead to present the target model. The transcript below provides an example of the how Mr. S uses the overhead to present the target molecular model of cookies smell.

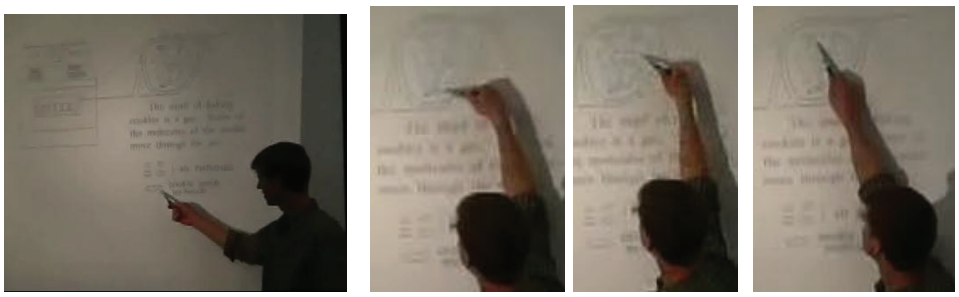


Figure 8-6
Screen Shot to Transcript 5 from Mr. S's Overhead Image-based Discussion

Mr. S: So in my oven, you can see them there, a bunch of chocolate cookies. They are almost done can you imagine you open the oven, and you peek inside hot air comes out. Can you imagine it? How does that work that you can smell the cookies? What does the air look like when you open the door and all that air comes up what does it, if we could see it with our eye glasses of science what would it look like?

S: Cookie molecules

Mr. S: Cookie molecules. That cookie went from solid some of them became vapor. Here is an eyeglasses of science looking at the air in there so they made up a shape for a cookie molecule. This is what the cookie molecule is going to look like and there some of them in the air in addition to water carbon dioxide, nitrogen and oxygen so they were all mixed together in the air. You are getting cookie molecules in your nose when you smell cookie.

Later in the lesson Mr. S extends the smelling model to tasting. He offers an analogy that "smelling is like tasting with your nose" and students respond to this with a set questions.
Mr. S: So how are you smelling those things? Its molecules becoming vapor entering into your nose. It like tasting whatever it was with your nose, the actual molecules are in the air and go in your nose.

Imani: Isn't it from, when we eat, like when you eat, alot of our taste is there because of how we smell the food? Like, when we eat something, like, they are in your taste buds but also, like, you are smelling them.

Mr. S: Nods

Bella: So What if we are eating something that is really good but there was something that smelled really bad right next to it, would you like it or not? Or eating something really bad, next to something really good?

Mr. S: Shrugs

**Analysis of transcript 5**. In this example, Mr. S asks students to predict what the glasses of science will reveal and a student provides short answer ("Cookie molecules"). Mr. S elaborates on this answer while showing students the overhead of the microscopic image. He orients students to the cookie and air molecules in the image ("This is what the cookie molecule is going to look like.") and then he links the cookie and air molecules "all mixed together" and to the idea of them going "in a your nose" to cause the smell of the cookie. Orienting and linking moves are both executed in a presentation mode. Mr. S did not add drawings to his overhead. Later in the lesson, Mr. S presents an analogy (smelling is like tasting with your nose) that extends the model beyond smelling and this leads to a set of student questions about how taste and smell interact. Mr. S does not answer these questions nor does he follow-up to probe student thinking. I coded this as an IRF exchange since his analogy appeared to prompt students to apply model reasoning to different situations.

**Transcript 6: Mr. S's SIM image-based discussion**. The transcript excerpts below provide examples of the interaction modes Mr. S uses to discuss the simulation. Mr. S begins the image-based discussion by asking IRE questions to orient students to the molecules in the simulation.

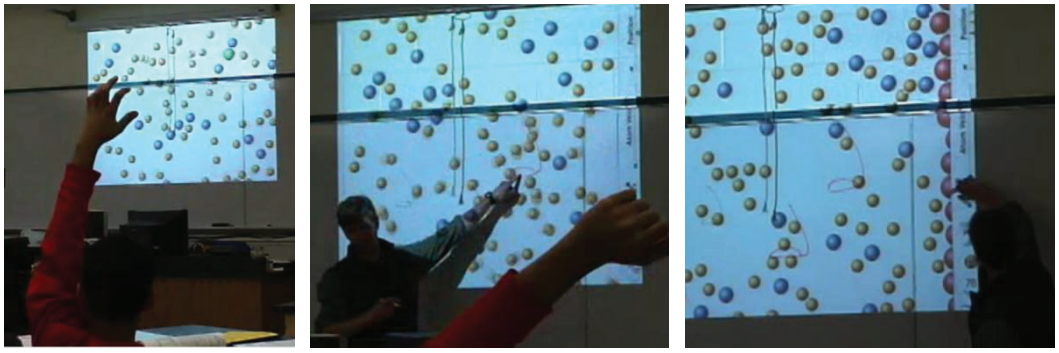


Figure 8-7
Screen Shots of Transcript 6 from Mr. S's Simulation Image-based Discussion

Mr. S: What's this supposed to be a model of?
David: One is the perfume its mixed with the air, the other one is the air, like the orange is the air, there's the water in the air, it's pushing them all around to

Student: NO! It's made of the other molecules.

Mr. S: What are the two most common things in our air from the reading? What were the two most common things in our air? Keegan?

Keegan: Oxygen and carbon dioxide.

Mr. S: Sarah?

Sarah: Nitrogen and oxygen.

Mr. S: Nitrogen and oxygen. Do you remember about how much of the air is nitrogen and about how much of the air is oxygen?

Sarah: Four fifths nitrogen and one fifth oxygen.
Mr. S: Four fifths; 80%, most of it is nitrogen, one fifth; 20% oxygen. So we are thinking this is air. What's the yellow thing supposed to represent? Dylan?
Dylan: Nitrogen.

Mr. S: Nitrogen. What's the blue representing, Chris?

Chris: Oxygen

Mr. S. Oxygen. So this is our air, mostly oxygen and nitrogen. That green one is representing carbon dioxide and water.

The teacher then uses a presentation mode to orient students to the macro elements of the simulation, to situate students in the simulation by drawing noses, and to link molecules "hitting the nose" to the act of smelling the cookie.

Mr. S: There's a big cookie all the way to the top of the wall. And that cookie just came out of the oven. And I need some volunteers to be noses. Here is Kaya's Nose, Hanna's nose. Alright need a couple of other noses. Greg. Just remember which nose is yours. This is your nostril. So we've got four noses. Now I'm gonna add a hot cookie. So imagine this is the cookie that just came out of the oven, it's hot so some of the cookie becomes a vapor. Raise your hand when your nose smells the cookie. Let's see who gets it. (Mr. S adds about 50 red cookie molecules to the simulation.)

Student: Boom, Damn, Whish. (Many students call out when molecules move)

Mr. S then ask student to make predictions about how the simulation could be used to represent two extreme cases (tiny cookie, giant cookie). He confirms those predictions by modifying and running the simulation according to student suggestions.

> Mr. S: What if we had an ity bity tiny cookie in the oven how would we make this model have an extremely small cookie cooked in the oven? How would we change this so it would be a really small cookie? Davis?
>
> Davis: There would be less of the red molecules, because less would turn into vapor, so less would go to your nose.
>
> Mr. S: So I could put in one like that! So that gets me a very small cookie.
> (Mr. S modifies the simulation and releases one cookie molecule.)
>
> Mr. S: OK, how would make a ginormous or a super batch of a dozen-dozen cookies? What would this be like?
>
> Student: (many students call out answers)
> Mr. S: Sarah thank you for raising your hand.
>
> Sarah: Put in an incredibly large amount of molecules.
>
> (Mr. S modifies the simulation and releases a 150 cookie molecules,)
>
> Student: INVASION!!
>
> Student: ohhhh! Snap! (Many student calling out as they watch the molecules.)
>
> Student: It's so painful!
>
> Mr. S: So now how quickly do you smell the cookies?
>
> Student: I am getting it.
>
> Student: I am smelling like 20 different cookies.
>
> Student: That is one tough cookie.
>
> Mr. S: Yeah, and its smells stronger doesn't it.

**Analysis of transcript 6**. Mr. S is observed using presentation and IRE questions to develop the model using the simulation. He used the very tiny/very big cookie extreme

case questions to link size of cookie to the number of molecules but he does not ask. Instead of verbally evaluating students, he endorses their ideas by modifying the simulation as they suggested (very few molecules, very many molecules).

**Conclusion for Mr. S's use of image-based discussion: Transcripts 5 and 6.** The transcript excerpts above provide examples of the interaction patterns Mr. S used during image-based discussion. In both OV and SIM examples, the image is being used to explain the molecular model and, thus, the discussion is converging on the target model. In the simulation lesson, the teacher is observed asking students to interpret and make predictions about the images as he is orchestrating this convergence. In the overhead lessons he is observed presenting the model using orienting and linking moves. However here he presents an analogy (smell is like taste) which is followed by a series of student model based questions that extend the model to consider other situations.

**Transcript 7: Mr. T's OV image-based discussion**. The transcript excerpts that follow provide examples of how Mr. T orchestrated the part of the lesson which used the overhead to discuss the "cookie smell question."

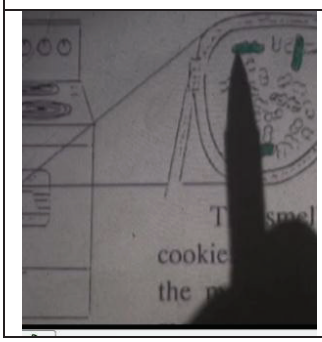
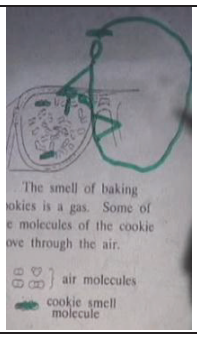
| a) T:" the green ones are the cookie smell" | b) T: "Here is their mouth. See, there is their nose." | c) T:"molecule is going to go up inside that person's nose" |
|---|---|---|
|  |  | |

Figure 8-8
Screen Shots of Transcript 7 from Mr. T's Overhead Image-Based Discussion

Mr. T adds color to the “cookie” molecule on the overhead, orients students to the diagram, and then presents the model by linking the molecules bouncing into the person’s nose. The teacher makes circular gestures with his pen over the overhead as he describes the motion of the cookie molecules.

T: You'd see these molecules, which are the molecules of what, Emily? What are these molecules?

Emily: The cookie smell.

T: The green ones, we're gonna say the green ones are the cookie smell, so what are the other ones?

Emily: Air molecules.

T: The other ones are air molecules. That's the origin of the smell, there is actually little cookie molecules that come off of the heated cookies, go into the air, bounce around, bounce around until they bump inside our nose. OK?

Then Mr. T draws a diagram of a person smelling, orients student to the drawing, and then links the motion of molecules to the person smelling by presenting the model while indicating the motion of molecules with his pen.

T: Now, we could imagine that if we put a nose right here. Here is a person's nose. Here is their eye. Here the person's face. Here is their mouth. See, there is their nose. The nose is getting close to that little cookie molecule, and the cookie molecule is gonna go up inside that person's nose and they're gonna go, Hmmm cookie molecules.

Then Mr. T executes more orienting and linking moves by asking students questions about the model shown in the overhead.

T: It's a gas, and gasses are made up of, these little green things, which are what?

Sally: Cookie smell molecules.

T: They're cookie smell molecules. Very nice. so Why do we smell stuff? Who can tell me why do we smell stuff? Christy?

Christy: Because it goes into our nose, because the air molecules, because we breathe in the air molecules.

T: The air doesn't smell.

Christy: No, but the molecules which go into your nose have a smell.

T: What molecules go?

Christy: Of whatever you are smelling.

T: Of whatever you are smelling. So give me an example, so, of cookies.

Christy: The cookie molecules mix with the air molecules, so we breathe in the air molecules and they have the molecules of the cookie as a gas.

T: Nice. Very good. All right. How does the smell get to your nose, though? How does it go from here to your nose?

S: The air pushes it.

T: The air pushes it. What do we know about molecules to begin with? Especially molecules of a gas? Jahire. What about their motion? What do we know about their motion?

Jahire: They slide and bump against each other.

T: They slide and bump, in other words, they're moving right?

Jahire: Yeah.

T: They're moving, and they're moving all the time. So even if there wasn't any air current, we could sit totally still in this room, with no air currents, turn off the vent, and that gas perfume smelled molecule would find its way to you eventually. Even if this air was totally still in terms of wind, it's because the air molecules are constantly bouncing around. Ok?

**Analysis of transcript 7**. Mr. T is observed using presentation, IRE, and IRF modes while discussing the overhead. He uses questions to orient student to the image and then uses the image to presents the model. Mr. T adds drawings to the overhead and uses these drawings to link the molecular model to the macroscopic act of smelling. He follows this with a set of orienting and linking moves which he executes using IRE and IRF questions. These questions were intended to encourage students to continue reasoning as they attempt to articulate their molecular model of scent. The IRF exchanges

end with a teacher presentation of the model. This set of transcripts is an example of the three types of teacher-student interaction patterns (P, IRE, IRF) that Mr. T was observed using when discussing the overhead.

**Transcript 8: Mr. T's SIM image-based discussion**. The transcript excerpts that follow provide examples of how Mr. T orchestrated the part of the lesson which used the simulation to discuss the "cookie smell question."

Mr. T starts, as Mr. S did, by orienting students to the simulation by asking students to map the multi -colored spheres in the simulation to the molecular model of air.

| | |
|---|---|
| Teacher: | Who can tell me what they think those pictures represent? What are those pictures? Peter, what are you thinking? |
| Peter: | Cookie molecules. |
| Teacher: | What? |
| Peter: | Cookie molecules |
| Teacher: | Could be cookie molecules, yep...could be cookies. Yes? |
| Nancy: | Um, so it's like air, and then, the yellow one's are like the air and the blue ones are like the cookie smell. |
| Teacher: | Okay. Good, good. So now we're onto- the big thing is they're molecules, right? We're showing the molecules. So both of you were right in that way. Now in terms of what colors represent- that's another thing. I haven't released, I haven't shown you any cookies yet, any cookie molecules yet. |
| Nancy: | Oh. |
| Teacher: | So if that's true, there are no cookies here. You wouldn't know that going in. |
| Nancy: | Then that's air. |

After the simulation has been run, Mr. T stops it and asks a student to explain the model that they just observed. This student gestures as he describes molecules breaking off the cookie and spreading out (Figure 8-9).

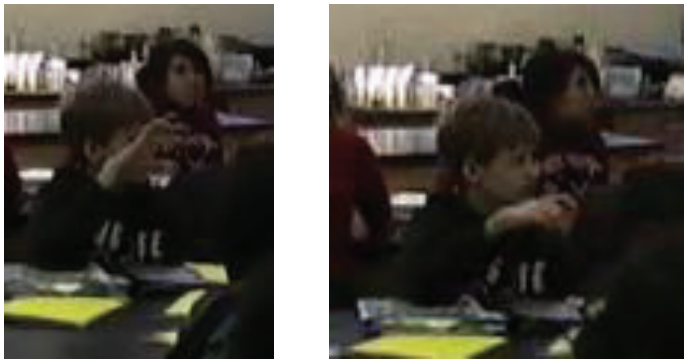


Figure 8-9
Transcript 8 Screen Shot of Steve Gesturing in Mr. T's Simulation Lesson

T: Who can explain why you can smell a cookie?

T: Steve.

Steve: Because of the airborne cookie particles in the air.

T: OK, and what happens to those cookie molecules?

Steve: Well, they break off of the cookie, and then they're in the air and they're in a gaseous form, and they make their way to your nose just by spreading out, and then you breathe them in and then you smell them.

T: Nice! So he had this important piece, what state of matter is that right there Peter?

Peter: gas

T: It's gotta be gas for us, right? For us because we don't see the cookie in the air, therefore the cookie molecules must in the state of a gas, and so we're doing this.

Later in the lesson Mr. T sets up an extreme case thought experiment. He asks students to predict how a giant cookie could be the represented by the molecules in the simulation.

Teacher: How about if you have a super huge cookie? How would represent that?

Students: A lot of them!

Teacher: A giant one, Haley what would I do?

Haley: You increase the number of cookie molecules?

Then he asks students to predict how a large number of molecules would affect the smell and tests those predictions by running the simulation.

> Teacher: Now, how is this going to change how this thing is smelled? How is it going to change the smell of this thing?
>
> Linda: A bit stronger.
>
> Chrissy: You'll smell it a lot faster.
>
> Teacher: We would smell it faster.
>
> Gary: Stronger.
>
> Teacher: Maybe we would smell it more frequently therefore maybe the smell is going to be stronger. Anything else you can think of? Sebastian?
>
> Sebastian: With more molecules wouldn't the longer it would take to bake it so you'd smell it later?
>
> Teacher: Right, so we're assuming as soon as I hit this that all those things are...you're right, so the baking time would get affected because of the size, there's no question- like how hot it would have to be. We're assuming it's hot enough so it starts to release the cookie molecules, but that's a good point absolutely. Let's see what happens here... (the teacher turns on the dynamic features of the simulation)
>
> Liz: Invasion! Cookie invasion!
>
> Leonard: Invasion of the cookies molecules!!!

**Analysis of transcript 8.** In this set of transcripts, Mr. T is observed using IRE and IRF modes while discussing the simulation. He uses IRE questions to orient student to the image and then uses an IRF exchange as he prompts a student to explain the model right after he has watched the simulation. The extreme case was used to generate two questions: 1) How would a molecular model represent a very big cookie? and then 2) How would that many molecules affect the macroscopic experience of scent?

**Conclusion for Mr. T's use of OV and SIM images: Transcripts 7 and 8.** The transcript excerpts above provide examples of the interaction modes Mr. T used during image-based discussion. In both OV and SIM examples, the image is being used to explain the molecular model and, thus, the discussion is converging on the target model. In the OV lessons, Mr. T is observed presenting the model using orienting and linking moves to converge on the target model but also asking IRE and IRF questions. In the SIM lesson, the teacher is observed asking students IRE and IRF questions to interpret and make predictions about the simulation as he is orchestrating this convergence. In both the SIM and OV lesson, Mr. T is observed asking students to articulate their model directly after observing the image.

**Conclusion for Mr. S and Mr. T's use of OV and SIM images: Transcripts 5-8.** The transcript excerpts from these four classes above provide examples of the interaction modes Mr. S and Mr. T used during image-based discussion. In both OV and SIM examples, the image is being used to explain the molecular model. Both teachers use presentation mode and IRE questions about the image to converge on the target. In the SIM lessons, Mr. S is observed presenting the model using orienting and linking moves to converge on the target model. In both the SIM and OV lesson Mr. T is observed using IRF questions to probe and refine student models. For example, Mr. T is observed asking students to explain the model right after observing the image and then using follow-up questions to push students to fully and clearly articulate their model.

Table 8-11
Summarizing the Preliminary Pattern in Teacher Use of Image-based Discussion

| | **OV Image Discussion** | **SIM Image Discussion** |
|---|---|---|
| Mr. S | P, IRE, IRF | P, IRE |
| Mr. T | P, IRE, IRF | P, IRE, IRF |

**Conclusion for Mr. T's use of OV and SIM images: Transcripts 1-8**. The transcripts of the non-image discussion from all four separate classes in this case study provide examples of how Mr. S and Mr. T pursued a generative agenda before the image presented. Their use of IRF interactions in transcripts 1-4 appeared to encourage students to attempt to reason with their model of gas and use it to generate a molecular model of scent.

The transcripts of the image-based discussions provide examples of how Mr. S and Mr. T used presentation and IRE interaction modes to converge on the target model. In both OV and SIM examples, the teachers appear to be using the image as a "tool for telling" by calling attention to the image's strong statement of the molecular model and using it to guide the discussion toward converging on the target model. In both the SIM and OV lesson, Mr. T is observed using IRF questions to probe and refine student models. For example, Mr. T was observed using the extreme case to prompt students to interpret the simulation, make predictions and then explain some of these predictions. This suggests that Mr. T was also using the image a "tool for asking."

When the image was projected, teachers were observed using different interaction patterns. In the excerpts above, Mr. T was observed using IRF questions to ask students to interpret the image. Mr. S was observed using a presentation mode and IRE questions to explain the image. This preliminary pattern, summarized in Table 8-12, suggests that

each teacher's mode of interaction may have shifted in the same direction but with different magnitudes for each teacher. For one teacher, it was “two steps” toward presentation, since Mr. S began using presentation and IRE modes instead of IRFs. For the other teacher, it was only one step toward presentation because Mr. T was still observed pursuing student points of view using IRF questions.

Table 8-12
Summary of Preliminary Patterns Observed in Scent Lesson Transcripts Excerpts 1-8

| Scent Lesson | Non-image-based Discussion | Image-based Discussion |
|---|---|---|
| Mr. S OV Lesson | **Transcript 1** Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 5** Used presentation and IRE, interaction patterns to use the image as “tool for telling.” |
| Mr. S SIM Lesson | **Transcript 2** Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 6** Used presentation and IRE, interaction patterns to use the image as a “tool for telling.” |
| Mr. T OV lesson | **Transcript 3** Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 7** Used presentation, IRE, and IRF interaction patterns to use the image as a “tool for telling.” and a “tool for asking.” |
| Mr. T SIM lesson | **Transcript 4** Used IRF interaction patterns to prompt students to reason with their initial model. | **Transcript 8** Used presentation, IRE, and IRF interaction patterns to use the image as a “tool for telling.” and a “tool for asking.” |

## Counted Code Transcript Analysis for Interaction Patterns and the Use of Images

In this section, I use a countable code mode of analysis to determine if the preliminary observation patterns observed in the transcript excerpts are supported by analysis of the full transcript. When the full discussion transcript is considered is there evidence that the teachers used different interaction patterns?

Table 8-13
Intervals Spent on Discussion in the Simulation and Overhead Lesson

| **SIMULATION Lesson** | | |
|---|---|---|
| | Mr. T | Mr. S |
| Length of Discussion Section of the Lesson | 28:10 | 13:31 |
| Length of Non-Simulation Discussion | 9:37 | 6:02 |
| Length of Simulation Discussion (Image-based ) | 18:33 | 7:29 |
| **OVERHEAD Lesson** | | |
| | Mr. T | Mr. S |
| Length of Discussion Section of the Lesson | 28:37 | 17:01 |
| Length of Non-Overhead Discussion | 22:29 | 14:01 |
| Length of Overhead Discussion (Image-based ) | 6:08 | 2:58 |

The data in Table 8-13 reveals that one difference in teacher behavior was the time spent in large group discussion in these lessons. Mr. T spent more time discussing the concepts in both the OV and SIM lessons than did Mr. S. For example, the blue shaded area in Table 8-13 shows that in the simulation lesson Mr. T spent 28:10 minutes compared to Mr. S 13:31 minutes. Mr. T spends more time on the full discussion part of the OV lesson as well (Mr. T 28:37 compared to Mr. S 17:01). This pattern is also found when the full discussion is divided into non-image and image-based discussion.

To better understand difference in how the teachers used discussion, I coded for four patterns of interaction: presentation, IRE, IRF, and other (Chapter 6, Table 6-10). I then counted instances and tallied the time each teacher spent involved with each interaction pattern (Tables 8-14a-8-14d)

Table 8-14a
Mr. T Count and Time of Interaction Pattern in the Simulation Lesson

| **Mr. T's Simulation Lesson** | | **P** | | **IRE** | | **IRF** | | **OTHER** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-image Discussion | 9:37 | 2 | 1:26 | 2 | 1:09 | 3 | 3:02 | 4:00 |
| Image Discussion | 18:33 | 9 | 3:00 | 11 | 5:55 | 6 | 8:10 | 1:28 |
| Total Discussion | 28:10 | 12 | 4:26 | 13 | 7:04 | 9 | 11:12 | 5:28 |

Table 8-14b
Mr. T's Count and Time of Interaction Pattern in the Overhead Lesson

| **Mr. T's Overhead Lesson** | | **P** | | **IRE** | | **IRF** | | **Other** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-Image discussion | 22:29 | 5 | 6:38 | 5 | 2:15 | 9 | 9:04 | 4:32 |
| Image Discussion | 6:08 | 4 | 2:19 | 4 | 1:39 | 3 | 2:10 | 0 |
| Total Discussion | 28:37 | 9 | 8:57 | 9 | 3:54 | 12 | 11:14 | 4:32 |

Table 8-14c
Mr. S Count and Time of Interaction Pattern in the Simulation Lesson

| **Mr. S's Simulation Lesson** | | **P** | | **IRE** | | **IRF** | | **Other** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non image Discussion | 6:02 | 2 | 0:51 | 2 | 0:46 | 1 | 1:42 | 2:43 |
| Image Discussion | 7:29 | 7 | 3:39 | 11 | 3:04 | 1 | 0:46 | 0 |
| Total Discussion | 13:31 | 9 | 4:30 | 13 | 3:50 | 2 | 2:28 | 2:43 |

Table 8-14d
Mr. S Count and Time of Interaction Pattern in the Overhead Lesson

| **Mr.S's Overhead Lesson** | | **P** | | **IRE** | | **IRF** | | **OTHER** |
|---|---|---|---|---|---|---|---|---|
| | Time | Count | Time | Count | Time | Count | Time | Time |
| Non-image Discussion | 14:03 | 1 | 0:49 | 3 | 1:59 | 5 | 6:03 | 5:12 |
| Image Discussion | 2:58 | 4 | 1:26 | 1 | 0:36 | 2 | 0:56 | 0 |
| Total Discussion | 17:01 | 5 | 2:15 | 4 | 2:35 | 7 | 6:59 | 5:12 |

These tables reveal that Mr. T was observed using an IRF interaction pattern more often than Mr. S (9 times compared to 2 times in the simulation condition classes and 12 time compared to 7 time in the overhead conditions classes). Mr. T spent more time engaging in IRF interactions than Mr. S (11:12 minutes compared to 2:28 minutes in the simulation condition classes and 11:14 minutes compared to 7:59 minutes in the overhead condition classes).

## Part Two Conclusions

These data lead me to hypothesize a possible factor for the teacher difference in use of discussion seen in Table 8-12. When IRF and IRE instances are combined, they provide one measure of the amount of questioning done by each teacher. Table 8-15 combines data over both image and non-image discussion from Table 8-12 to provide a metric of how much questioning occurred. For example, in Table 8-15, in Mr. S's SIM Lesson he devoted 3 minutes 50 seconds to asking 13 IRE questions, and 2 minutes 28 seconds to asking 2 IRF questions (shown highlighted). Thus in this lesson Mr. S spent a total of 6 minutes 15 seconds asking 15 questions. Using this metric, Mr. T engaged in questioning interactions more often and a longer time interval than Mr. S (Table 8-15).

Both Mr. S and Mr. T were observed using IRF interactions to ask students to reason with their models and using discussion time to pursue student thinking but Mr. T used IRF interactions more often and for a longer time interval than Mr. S. Thus one reason Mr. T may have devoted more time to discussion, as shown in Table 8-13, was that he was spent more time pursuing and clarifying student meanings through questioning. In this way the different use of questioning by these teachers may have impacted the time teachers devoted to discussing concepts with students.

Table 8-15
Use of Questions by Teachers in the Scent SIM and OV Lessons

| **Teacher and Lesson** | **IRE Instances over Time in min:sec** | **IRF Instances over Time in min:sec** | **Total Questioning IRE+IRF Instances over Time in min:sec** |
|---|---|---|---|
| Mr. T's SIM Lesson Discussion | 13<br>7:04 | 9<br>11:12 | 22<br>18:16 |
| Mr. T's OV Lesson Discussion | 9<br>3:54 | 12<br>11:14 | 21<br>15:08 |
| Mr. S's SIM Lesson Discussion | 13<br>3:50 | 2<br>2:28 | 15<br>6:18 |
| Mr. S's OV Lesson Discussion | 4<br>2:35 | 7<br>6:59 | 11<br>9:34 |

.

**Part Three: Examining the Effects of Teacher and Image Mode Conditions**

In part three, I report on a cross-comparative study where effects due to teacher differences and image mode are considered. This section addresses the question: Is there evidence that teachers use of interaction pattern changed when moving from non-image-based discussion to image-based discussion?

**Interaction Patterns After an Image Mode was Started**

I converted the time spent on each interaction pattern (Tables 8-14a through 8-14d into percentages (Table 8-16a through 8-16d). For example, in the third row of Table 8-16a, labeled Image Discussion, I use the data from Table 8-14a that Mr. T used a presentation mode for 3:00 minutes during the time the simulation was displayed (18:33 minutes) and, and determined that Mr. T spent about 16% of the image-based discussion using a presentation mode (3:00/18:33 = 16.2%).

Table 8-16a
Percent of Time Mr. T Spent on Each Interaction Pattern in the SIM Lesson

| Mr. T's Simulation Lesson | Time | Presentation (P) | IRE | IRF | OTHER |
|---|---|---|---|---|---|
| Non-image Discussion | 9:37 | 14.9% | 12.0% | 31.5% | 41.6% |
| Image Discussion | 18:33 | 16.2% | 31.9% | 44.0% | 11.9% |
| Total Discussion | 28:10 | 15.7% | 25.1% | 39.8% | 19.4% |

Table 8-16b
Percent of Time Mr. T Spent on Each Interaction Pattern in the OV Lesson

| Mr. T's Overhead Lesson | Time | Presentation (P) | IRE | IRF | OTHER |
|---|---|---|---|---|---|
| Non-image Discussion | 22:29 | 29.5% | 10.0% | 40.3% | 20.2% |
| Image Discussion | 6:08 | 37.8% | 26.9% | 35.3% | 0 |
| Total Discussion | 28.37 | 31.3% | 13.6% | 39.3% | 15.8% |

Table 8-16c
Percent of Time Mr. S Spent on Each Interaction Pattern in the SIM Lesson

| **Mr. S's Simulation Lesson** | **Time** | **Presentation (P)** | **IRE** | **IRF** | **OTHER** |
|---|---|---|---|---|---|
| Non -image Discussion | 6:02 | 14.1% | 12.7% | 28.2% | 45.0% |
| Image Discussion | 7:29 | 48.8% | 41.0% | 10.2% | 0 |
| Total Discussion | 13:31 | 33.3% | 28.4% | 18.2% | 20.1% |

Table 8-16d
Percent of Time Mr. S Spent on Each Interaction Pattern in the OV Lesson

| **Mr. S's OV Lesson** | **Time** | **Presentation (P)** | **IRE** | **IRF** | **OTHER** |
|---|---|---|---|---|---|
| Non -image Discussion | 14:03 | 5.8% | 14.1% | 43.1% | 47.0% |
| Image Discussion | 2:58 | 48.3% | 20.2% | 31.5% | 0% |
| Total Discussion | 17:01 | 13.2% | 15.2% | 41.0% | 30.6% |

The data in Tables 16a-16d and 14a-14d show that during these four non-image discussions, Mr. T and Mr. S spent a greater percentage of their time using an IRF interaction mode than a presentation mode. This data is summarized in Table 8-17.

Table 8-17
Percent Data from the Non-image Discussion Section of the Four Lessons

| **Teacher and Lesson** | Non-image Discussion Interaction Patterns Percent of time spent in each teacher-student interaction pattern during non-image discussion. |
|---|---|
| Mr. T SIM Lesson | IRF (31.5) > P (14.9) > IRE (12.0) |
| Mr. T OV Lesson | IRF (40.3) > P (29.5) > IRE (10.0) |
| Mr. S SIM lesson | IRF (28.2) > P (14.1) > IRE (12.7) |
| Mr. S OV lesson | IRF (43.1) > IRE (14.1) >P (5.8) |

The data in Tables 16a-16d and 14a-14d also show that during these four image discussions, Mr. T and Mr. S spent a greater percentage of their time using a presentation mode during image-based discussion than during non-image-based discussion. This shift was not the same for both teachers. Mr. S's use of presentation mode increased more than Mr. T's. This data is summarized in Table 8-18.

Table 8-18
Comparison of Percent Time Spent Using a Presentation Mode

| **Teacher and Lesson** | Comparison of Percent of Time Using a Presentation Mode (P) during Image-Based and Non-Image-Based Discussion |
|---|---|
| Mr. T SIM Lesson | P image 16.2% > P before image 14.9% |
| Mr. T OV Lesson | P with image 37.8% > P before image 29.5% |
| Mr. S SIM lesson | P with image 48.8% > P before image 4.1% |
| Mr. S OV lesson | P with image 48.3% > P before image 5.8% |

The data summarized in Table 8-19 suggests that the change in teacher-student interaction pattern during the image-based discussion was different for Mr. S and Mr. T. During these image discussions, Mr. T spent a greater percentage of time using IRF modes than Mr. S.

Table 8-19
Comparison of Percent Time Spent Using an IRF Interaction Pattern

| Name of the Lesson | Comparing Teachers Using Image-based Discussion<br>Comparison of percent time teacher spent using an IRF mode during image-based discussion |
|---|---|
| SIM Lesson<br>Image-based discussion | Mr. T IRF (44) > Mr. S IRF (10.2) |
| OV Lesson<br>Image-based discussion | Mr. T IRF (35.3) > Mr. S IRF (31.5) |

## Discussion: Visualizing Patterns of Teacher Questioning During the Non-image and Image-based Discussion

This section will attempt to summarize and visualize how teacher interaction pattern choices changed after an image mode started. This analysis focuses on describing teacher differences observed in the non-image and the image-based discussion sections, using data from the counted code analysis.

### Visualizing Teacher Differences on a Spectrum

The Dialogic-Authoritative spectrum (Chapter 6, Figure 6-14) can be used to roughly visualize the different questioning patterns used during non-image and image-based discussion. During the non-image discussion sections of these lessons, both teachers were observed using an IRF interaction mode more than P or IRE, and thus, both can be placed toward the dialogic side of the spectrum. Because Mr. T spent more time using IRF interactions than Mr. S, he is placed more to the dialogic side of the spectrum than Mr. S (Figure 8-10a)

The Dialogic-Authoritative spectrum can be used to diagram a possible effect of image on discussion mode. With the image, both Mr. S and Mr. T spent more time pursuing an authoritative approach through their increased use of the presentation mode (Table 8-17). This can be represented by a showing both teachers to the left on the Dialogic-Authoritative spectrum (Figure 8-10). However, in both narrative and counting transcript evidence, Mr. T was observed using more IRF interaction during image-based discussion than Mr. S. Therefore, he is not shifted as far to the left on the Dialogic-Authoritative spectrum as Mr. S. The counted code data support the preliminary pattern suggested by the narrative transcript data, that each teacher's mode of interaction may

have shifted in the same direction but with different magnitudes for each teacher. For one teacher, it was “two steps” toward presentation since Mr. S began using more presentation instead of IRFs. For Mr. T, it was only “one step” toward presentation because Mr. T was still observed pursuing student points of view using IRF questions. Figure 8-10ab compares teachers’ placement on the Dialogic-Authoritative spectrum during non-image and image-based discussion.

**Mr. S Mr. T**
**Authoritative ---------- Dialogic**

Figure 8-10a
Teachers on the Dialogic-Authoritative Spectrum during Non-image-based Discussion

**Mr. S Mr. T**
**Authoritative ---------- Dialogic**

Figure 8-10b
Teachers on the Dialogic-Authoritative Spectrum during Image-based Discussion

I offer a speculative hypothesis that the image may be supporting these teachers as they managed the transition between dialogic and authoritative discussion modes. The image may be assisting Mr. T to keep the dialogic phase of class open as the lesson shifts to using the image to evaluate student models and converge on the target concept. There is evidence that Mr. T used both the non-image and image-based discussions as opportunities to ask IRF questions. The need to interpret a complex image opens a space for generating a line of questioning that converges on the target model. These convergent question episodes may have encouraged students to articulate how their internal model is

being used to interpret and reason with the external representation of the model (the image). In transcript 8, Mr. T was observed using the image-based discussion move Linking as a questions (Who can explain why you can smell a cookie? and "How is this [extreme case] going to change how this thing is smelled?) When using the image as a "tool for asking," the teacher is focused on the space for interpretation and prediction provided by the complex image and in the case of these simulations and uses them to generate multiple states of the model to interpret. With this focus, the image-based moves can be used to suggest categories of questions to ask about the image (Chapter 6, Table 6-18).

On the other hand, the image may be assisting Mr. S's attempt to divide the lesson into a dialogic phase and an authoritative phase. There is evidence that Mr. S used the non-image part of class as an opportunity to follow a dialogic agenda and pursue divergent student thinking. This can be seen in his use of IRF questions to uncover student's molecular model of scent. There is evidence that he then used the image as a turning point in the discussion and began to use the presentation of the image-based discussion moves to follow an authoritative agenda. The image helped him follow this agenda since it provides a strong statement of the target model. In transcripts 5 and 6, Mr. S was observed executing "Linking" moves in an presentation and IRE mode (Transcript 5: "You are getting cookie molecules in your nose when you smell cookie" and Transcript 6: "How would we make this model have an extremely small cookie?). When using the image as a "tool for telling," the teacher is focused on the image's ability to provide a strong statement of the target model. With this focus, the image-based discussion moves can be used to suggest a logical sequence for the presentation of image.

One such sequence might be: orient students to the image, highlight both sides of a causal chain, and then link the sides of the causal chain together.

## Summary of Conclusions

### Part One: Summary of Effect of Image Mode on Discussion

Compared to the Overhead Lesson, the Simulation Lesson produced a) more time discussing the image, b) more moves, c) a greater variety of moves, d) more scripted moves in the lesson plans, and e) more spontaneously generated moves in the discussion. I hypothesize that simulation effects a), b), and c) could be caused by a combination of d) and e). Observations d) and e) suggest that the simulation provides an interesting affordance for planning and enacting discussions.

More speculatively, I hypothesize that this affordance may be associated with the simulation's capacity to be manipulated to display accurate images of multiple states of the model and may be associated with the way in which these images help these teachers think about the model while planning.

### Part Two: Summary of Differences in the Behavior of the Two Teachers

One way teachers differ is that they spent different amounts of time discussing the concepts in the lesson. Data in Figure 8-13 indicate that during both SIM and OV lessons, Mr. T spent more time discussing the concepts than Mr. S [SIM: (Mr. T 28:10) > (Mr. S 13:31) and OV: (Mr. T 28:37) > (Mr. S 17:01)]. Data on teacher interaction patterns lead me to hypothesize a possible factor for the teacher difference in use of discussion time. Combined data on IRF and IRE interaction patterns that occurred during the full discussion indicate that Mr. T engaged in questioning interactions more often than Mr. S

(SIM: 22 >15 and OV: 21 > 11) and for longer time intervals than Mr. S (SIM: 18:16 > 6:18 and OV 15:08 > 9:34) (Figure 8-15). In addition Mr. T used IRF interaction patterns more often (SIM: 9 > 2 and OV: 12 > 7) and for longer intervals than Mr. S (SIM: 11:12 > 2:28 and OV: 11:14 > 7:59). These data lead me to hypothesize that Mr. T spent more time on the discussion section of the SIM and OV lessons because he used more questioning interaction patterns than Mr. S.

**Part Three: Summary of the Effects of Teacher and Image Mode Conditions**

The data from the 4 lessons examined in this chapter indicates that during the Non-image discussions both teachers spent a larger percentage of their time using an IRF interaction mode than a presentation mode or an IRE mode (Table 8-17). The data also indicate that both teachers spent a greater percentage of their time using a presentation mode during image-based discussion than during non-image-based discussion (Table 8-18). However, the amount of the shift toward presentation was not the same for both teachers. During the image-based discussion, Mr. T's use of presentation mode increased less than Mr. S's (Table 8-18).This preliminary pattern suggests that during image-based discussion each teacher's interaction pattern may have shifted in the same direction but with different magnitudes for each teacher. For Mr. S, it was "two steps" toward presentation, and for the Mr. T, it was only "one step" toward presentation. I hypothesize that Mr. T used the image both as "tool for telling" and as a "tool for asking." He was observed asking students to interpret and make prediction about the complex image by phrasing the image-based discussion moves as questions. Mr. S was observed presenting the image-based discussion moves and using the image more predominately as a "tool for telling."

# CHAPTER 9

## SUMMARY OF COLLECTIVE FINDINGS AND CONCLUSIONS

In this study I attempted to build on the work of a number of authors who have analyzed whole class discussions (Alozie, Moje, & Krajcik, 2010; Clement, 2008; McNeill & Pimentel, 2010; Scott, Mortimer, &Aguiar, 2006; van Zee & Minstrell, 1997), including some who have identified specific strategies for leading discussions (Chin, 2007; Hogan & Pressley, 1997). A perceived limitation of these studies was the lack of research on strategies used with visual displays. In this study I have attempted to focus on whole class discussions using visual displays (simulations or overheads) in order to identify discussion strategies and patterns in interaction modes used in that context.

The dissertation addressed the following questions:

1. Learning Gains. Was there a difference in content learning between students who were taught with a set of simulation-based lessons and students who were taught with a set of static overhead based lessons?

2. Identifying Discussion Strategies. What whole class discussion strategies were used with image displays by teachers to scaffold the development of a visualizable particulate model of a gas?

    a) What image-based discussion moves (small time scale strategies spanning 5 seconds to 5 minutes) were used by teachers to navigate image-based discussions?

    b) To what extent did teachers employ these strategies in overhead and simulation lessons?

3. Differences between Simulation and Overhead Discussions. How were lessons with common content goals planned and enacted differently when using different image modes? What advantages and disadvantages do static overheads and dynamic simulations have for planning and enactment of these lessons, and how do teachers exploit these advantages?
4. Differences between Teachers in Discussions. Were there differences in how the different teachers provide a context for and employ the image to discuss the model? If so, how can these differences be described?

## Research Question #1: Learning Gains

Was there a difference in content learning between students who were taught with a set of simulation based lessons and students who were taught with a set of static overhead based lessons?

Using a criterion of p=.05, ANOVA tests found that there were significant learning gains from pre to post in both image conditions (Table 9-1) and for each teacher's classes (Tables 9-2a, 9-2b, and 9-2c). There was a significant gain difference in content learning in favor of the students who were taught with a set of simulation-based lessons compared to students who were taught with a set of static overhead based lessons (Table 9-3). It is important to note that because of limitations on the sample used in this study, these statistical findings must be considered exploratory, and one cannot project the findings to a population outside the study in a rigorous way. I am using them primarily as part of a mixed methods approach to provide quantitative descriptions to any differences in learning between groups inside the study. The quantitative findings provided a result to be explained that motivated the qualitative case studies. The qualitative studies provided details that contributed to an attempt to develop possible explanations for the differences found in the quantitative study.

Table 9-1
ANOVA Results that Examined Changes in Student Scores in Short and Long Answer Pretest to Posttest for Each Condition

| **SIM** | N= 107 | Pretest | Posttest | Pre-Post Gain | Percent Gain | df | F | Sig. |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 8.1 | 13.5 | 5.4 | 21.5 | 1 | 201.43 | .000 |
| SHORT | Mean | 3.6 | 4.2 | 0.6 | 11.2 | 1 | 25.18 | .000 |
| | | | | | | | | |
| **OV** | N=117 | Pre-test | Post-test | Pre-Post Gain | Percent Gain | df | F | Sig. |
| LONG | Mean | 9.0 | 12.7 | 3.7 | 14.8 | 1 | 115.05 | .000 |
| SHORT | Mean | 3.9 | 4.2 | 0.3 | 5.3 | 1 | 8.17 | .005 |

Table 9-2abc
ANOVA Results that Examined Changes in Student Scores in Short and Long Answer Pretest to Posttest for Each Teacher

**Table 9-2a** Four Classes Taught by Mr. S (N= 63)

| | | **Pre-test** | **Post-test** | **Pre-Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 7.65 | 11.86 | 4.21 | 16.83 | 1 | 92.23 | .000 |
| SHORT | Mean | 3.90 | 4.00 | .095 | 1.90 | 1 | .77 | .384 |

**Table 9-2b** Four Classes Taught by Mr. R (N= 78)

| | | **Pre-test** | **Post-test** | **Pre/Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 8.29 | 10.51 | 2.22 | 8.87 | 1 | 24.53 | .000 |
| SHORT | Mean | 3.72 | 4.13 | .41 | 8.21 | 1 | 13.43 | .000 |

**Table 9-2c** Four Classes Taught by Mr. T (N= 83)

| | | **Pre-test** | **Post-test** | **Pre/Post Gain** | **Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|---|---|---|
| LONG | Mean | 9.51 | 16.36 | 6.86 | 27.42 | 1 | 305.58 | .000 |
| SHORT | Mean | 3.73 | 4.37 | .639 | 12.77 | 1 | 35.83 | .000 |

Table 9-3
ANOVA Results that Examined Differences in Student Scores in Short and Long Answer Pretest to Posttest for Between Each Condition

| N=224 | **SIM Percent Gain** | **OV Percent Gain** | **df** | **F** | **Sig.** |
|---|---|---|---|---|---|
| LONG | 21.5 | 14.8 | 1, 212 | 12.9 | .000 |
| SHORT | 11.2 | 5.3 | 1, 212 | 4.83 | .029 |

In conclusion, in response to Research Question #1: "Was there a difference in content learning between students who were taught with a set of simulation based lessons and students who were taught with a set of static overhead based lessons?" the answer regarding the sample studied appears to be "yes." An analysis by teacher yielded a significant difference in learning gains between teachers on the long and short answer test (Table 9-4). These gain differences between teachers also suggest that the image mode is not the only variable at work here and suggest that teaching behaviors used to employ different image modes is an interesting topic to study. The specific nature of the teaching strategies and teacher behaviors employed in these lessons were investigated further in the case study chapters.

Table 9-4
Results for ANOVA Tests of Between-Teacher Effects Indicating a Significant Difference between Teachers in the Short Answer Percent Gain and the Long Answer Percent Gain

| N=224 | **Source** | **df** | **F** | **Sig.** |
|---|---|---|---|---|
| SHORT | Teacher | 2, 212 | 4.85 | .009 |
| LONG | Teacher | 2, 212 | 31.56 | .000 |

(See Chapter 4 for more detail on Question 1.)

## Research Question #2: Discussion Strategies Identified

What whole class discussion strategies were used with image displays by teachers to scaffold the development of a visualizable particulate model of a gas?

1. What image-based discussion moves (small time scale strategies spanning 5 seconds to 5 minutes) were used by teachers to navigate image-based discussions?

2. To what extent did teachers employ these strategies in overhead and simulation lessons?

I used the phrase "Image-based Discussion move" to describe individual strategies during the discussion of an image. Chapter 5 presented a narrative microanalysis of a simulation lesson taught by the author using the refined and final set of image-based discussion strategies. This chapter introduced the final version of image-based strategies definitions and described how these strategies unfolded during this image-based discussion. This set of Image-based Discussion moves was identified on the basis of classroom video and transcripts. The descriptions of the moves were refined over time and their existence was supported in the case studies of 12 lessons in Chapters 6, 7, and 8. Table 9-5 below provides a condensed overview of the move descriptions. More detailed descriptions appear in Chapter 5, Table 5-2.

Table 9-5
Summary Table of Image-based Discussion Moves

| |
|---|
| ORIENTING: The teacher helps students to identify objects in the image and map them to the situation or idea under discussion. |
| HIGHLIGHTING: The teacher focuses students on conceptually important features of a cause OR an effect, in the image. It does not emphasize the link between cause and effect but instead attempts to clarify one side of causal chain. |
| LINKING: The teacher or a student helps students focus on the link between CAUSE AND EFFECT between elements of a complex visual. |
| PREDICTING: The teacher or a student asks students to predict how an image will look (structures) or behave (dynamic/function) in subsequent states or future situations. |
| CRITIQUING: The teacher or a student encourages discussion of the limitations of the image as representation of the model. |
| EXTENDING: Discussing applications of the model beyond the situation represented by the projected image. |
| SITUATING: The teacher or a student suggests that students imagine themselves in the image or as interacting with parts of it. |
| FRAMING: The teacher or a student identifies the key question(s) that the image will address before showing the image or composes a wrap up or "take home message" before turning off the image. |

I hypothesized that the teachers in this study used these moves to employ the image in these lessons to promote student engagement and active reasoning. Although I did not count instances of student reasoning, the Image-based Discussion moves did appear to help teachers to focus the student's attention and reasoning in the discussion on the image's most conceptually salient features, and this can be hypothesized as an impact that these strategies can have. There are existence demonstrations in the transcript analyses that the image-based discussion moves resulted in:

- student attention and engagement
- generation of model elements
- discussion focused on specific subtle elements in the image
- successful student explanations of lab observations in terms of molecular motions as a hidden mechanism
- linked discussion to previous model elements
- critiques of the simulation

Some moves were used more frequently than others. Table 6 summarizes the instances of use of these moves in the six Overhead and six Simulation lessons analyzed in Chapters 6, 7, and 8. The Orienting, Highlighting, and Linking moves were the three most frequently observed moves in both the simulation and the overheads lessons.

Table 9-6
Summary of Instances of Moves Observed in the 12 Lessons in the Case Studies

| | **Orient** | **Predict** | **Highlight** | **Link** | **Situate** | **Critique** | **Frame** | **Extend** | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| Instances of moves in SIM Lesson | 32 | 9 | 41 | 39 | 11 | 6 | 14 | 2 | 154 |
| Instances of moves in OV Lesson | 11 | 4 | 6 | 15 | 3 | 0 | 0 | 2 | 43 |

One can also make several speculative theoretical hypotheses to explain some of the above findings:

A) I hypothesize that the Orienting move was used frequently in the simulation lessons because the simulations used were only partially analogous to lab observations they were being used to represent. Students may need more support in orienting to simulations that do not directly represent the situation being described. For example in

the Clean Air and Scent lesson, an overlay simulation was used in which the teacher drew the macroscopic elements of the situation (noses and cookie) on the white board over the more abstract and general simulation image of bouncing particles. The teacher then discussed how these drawing could be mapped to the phenomena students had observed in the lab demonstration. I would hypothesize that a simulation which more closely resembles the situation being discussed may require less orienting.

B) I hypothesize that the Highlighting and Linking moves may have been used frequently because they deal with causal chains, and the key concept in these lessons involved developing a mechanistic explanation in the form of a causal chain of how an observable macro-phenomena was caused by a collective invisible micro-action of molecules. Both the simulations and the overheads studied here were model centered in that they featured depictions of normally invisible systems of particles, and therefore were presenting representations of explanatory models. If I had studied images that represented virtual laboratories only (e.g., simply gave pressure readings for a tank without molecules moving inside the tank), I might have seen fewer Highlighting and Linking moves.

(See Chapters 6, 7, and 8 for more detail on Question 2.)

## Research Question #3: Differences between Simulation and Overhead Discussions

How were lessons with common content goals planned and enacted differently when using different image modes? What advantages and disadvantages do static overheads and dynamic simulations have for planning and enactment of these lessons, and how do teachers exploit these advantages?

The image-based discussion moves described above were coded in all 12 lesson transcripts for 6 simulation and 6 overhead classes. In addition, the numbers of changes made to the image were tallied. As shown in Table 9-7, compared to the Overhead lessons, the Simulation lessons produced:

a) more time discussing the image

b) more moves

c) more scripted moves in the lesson plans

d) more spontaneously generated moves in the discussion

I hypothesized that patterns a) and b) observed in the simulation lessons could be caused by a combination of c) and d).

Table 9-7
Summary Comparison the Overhead and Simulation Classes in the Case Studies

| | | Totals from the 6 Simulation Classes | Totals from the 6 Overhead Classes |
|---|---|---|---|
| | Total time discussing the image in minutes: seconds | 71:17 | 19:32 |
| b) | Total number of instances of image-based discussion moves observed | 154 | 43 |
| c) | Number of scripted image-based discussion moves | 76 | 30 |
| d) | Number of spontaneously generated image-based discussion moves | 68 | 13 |
| e) | Total number of changes made to the image during image-based discussion. | 90 | 21 |

## Hypothesized Affordances

Observations c) and d) suggest that the simulation provided some special affordances for planning and enacting discussions. I hypothesized that the simulation

provided a greater affordance for both planning and managing a discussion than did the overhead. First, I hypothesized that the greater number of moves was caused, in part, by the ability of the simulation to be modified to present different states of the model during the design of the lesson (Table 9-7e). The set of information rich images provided by the simulation may have facilitated the mental rehearsal of small episodes of discussion and triggered prompts for these discussions that could then be written into the lesson plan. This same sort of planning was possible in the overhead lesson plan, but since there were fewer images, fewer episodes may have been imagined, rehearsed, and written into the plan. In this way, the simulation seemed to trigger more scripted discussion moves in the simulation lesson plan than in the overhead lesson plan. These scripted moves may have contributed to the greater time spent and the greater variety of moves seen in the simulation lessons.

Second, I hypothesized that the simulation also provided a greater affordance for managing a discussion than did the overhead. In the case studies, the teachers generated more spontaneous moves during the discussions of the simulations than they did during the discussion of the overheads. A simulation can be manipulated in response to student questions and comments and provide clear and accurate images of the model. This capability may have allowed the simulation to support these teachers as they improvised the orchestration of the discussion. In this way, the simulation condition may have fostered the use of a variety of unscripted discussion moves for these teachers. These unscripted, spontaneous moves may have also contributed to the time spent discussing the simulation. So I also hypothesized that the simulation provided a greater affordance

for managing a discussion for them than did the overhead. (See Chapters 6, 7, and 8 for more detail on Question 3.)

**Research Question #4: Differences between Teachers in Discussions**

Were there differences in how the different teachers provide a context for and employ the image to discuss the model? If so, how can these differences be described?

In the case studies, teachers were observed enacting the common lesson plan differently. One way these differences in enactment can be described is by examining data on percent of time teachers spent engaging in presentation, IRE, and IRF interaction patterns used during (a) Non-Image discussions before the use of a displayed image and (b) Image-based discussion. In Chapters 6, 7, and 8 the 12 lesson transcripts were coded for these interaction patterns (4 lessons for each of the three teachers). Here I will focus on the use of IRFs. Tables 9-8a, 9-9a, and 9-10a below summarize data from the three comparative case studies that each compared two teachers on the use of IRFs. In Tables 9-8ab, 9-9ab, and 9-10ab, a shaded cell indicates that an IRF interaction pattern was used for more than 25% of that discussion time.

Using data from narrative transcript analysis, I hypothesized that some uses of the IRF interactions pattern were associated with observations of students reasoning about models and, thus, were involved with providing a context for and employing the image for student reasoning. Here I take the approach that whether teachers reach a 25% level of IRF usage can provide a means of summarizing and visualizing how the same image-based lesson plans were enacted differently by different teachers. I hypothesize that the observed differences in IRF usage in non-image discussion suggest a difference in how teachers provided a context for the image. More specifically, I am hypothesizing in

Tables 9-8b, 9-9b, and 9-10b that a pattern of using IRF's 25% of the time or more in the non-image discussion suggests that the teacher may be following a dialogic agenda that encouraged students to reason with their initial model vs. an authoritative agenda that focused more heavily on presenting the target model. Although I did not do systematic counting here, an overall pattern discernible in the transcripts analyzed is that the IRFs employed in the non-image discussion were associated with a dialogic agenda of encouraging divergent student thinking and encouraging the articulation of multiple points of view without evaluation.

I am also hypothesizing in these tables that differences in IRF patterns used in image-based discussion can serve as an indicator of differences in how the image is being employed. More specifically, I am hypothesizing that an IRF usage greater than 25% in the image-based discussion suggests that the teacher may be using the image as a “tool for asking” vs. as a “tool for telling.” I do not refer to this as a dialogic use of the image because an overall pattern discernible in the transcripts analyzed is that the IRFs employed in the image-based discussion were more associated with efforts to encourage convergent student thinking and encourage the careful articulation of the target model. Though this was a more convergent use of the IRF pattern, I hypothesized that the presence of this level of IRF usage indicated that the teacher was using the affordance of the complex visual display to generate interpretation and prediction questions to engage student reasoning about the model. In Tables 9-8b, 9-9b, 9-10b I refer to this pattern as "Using the Image as a Tool for Asking” (as opposed to Telling).

Table 9-8ab
Summary of Findings and Hypotheses about Teacher Differences from the Compressed Air in Tire Lesson Comparative Case Study

**Table 8a** Percent of Time Spent Using IRF Interactions in Non-Image and Image-based Discussion in the Compressed Air in Tire Lesson Comparative Case Study

| Lesson | Teacher | Non-image Discussion | Image-based Discussion |
|---|---|---|---|
| SIM Tire | Mr. S | 6:54 min/ 15:42 min = 0.44 | 1:06 min/ 7:56 min = 0.14 |
| SIM Tire | Mr. R | 0:00 min/ 12:36 min = 0.00 | 4:14 min/ 14:27 min = 0.29 |
| | | | |
| OV Tire | Mr. S | 10:43 min/ 20:41 min = 0.52 | 0:31 min/ 3:16 min = 0.16 |
| OV Tire | Mr. R | 0:49 min/ 15:45 min = 0.05 | 1:17 min/ 3:08 min = 0.41 |

Bolding indicates using that IRFs accounted for at least 25% of the discussion time

**Table 8b** Hypotheses about Teacher Differences from the Compressed Air in Tire Lesson Comparative Case Study

| Class | Teacher | Non-image Discussion | Image-based Discussion |
|---|---|---|---|
| SIM Tire | Mr. S | Pursued a dialogic agenda | Used Image as Tool for Telling |
| SIM Tire | Mr. R | NA | Used Image as Tool for Asking |
| | | | |
| OV Tire | Mr. S | Pursued a dialogic agenda | Used Image as Tool for Telling |
| OV Tire | Mr. R | Presented target model | Used Image as Tool for Asking |

Table 9-9ab
Findings and Hypotheses about Teacher Differences in the Air Pressure in a Syringe Lesson Comparative Case Study

**Table 9-9a** Percent of Time Spent Using IRF Interactions in Non-Image and Image-Based Discussion in the Air Pressure in a Syringe Lesson Comparative Case Study

| Lesson | Teacher | Non-image Discussion | Image-based Discussion |
|---|---|---|---|
| SIM Syringe | Mr. T | 12:08 min/ 30:18 min = 0.40 | 1:04 min/ 5:41 min = 0.19 |
| SIM Syringe | Mr. R | 0:00 min/ 17:48 min = 0.00 | 4:30 min/ 17:11 min = 0.26 |
| | | | |
| OV Syringe | Mr. T | 19:44 min/ 32:34 min = 0.60 | 0:00 min/ 2:05 min = 0.00 |
| OV Syringe | Mr. R | 3:09 min/ 31:46 min = 0.10 | 0:00 min/ 1:57 min = 0.00 |

Bolding indicates using that IRFs accounted for at least 25% of the discussion time

**Table 9-9b** Hypotheses about Teacher Differences in the Air Pressure in a Syringe Lesson Comparative Case Study

| Lesson | Teacher | Non-image Discussion | Image-based Discussion |
|---|---|---|---|
| SIM Syringe | Mr. T | Pursued a dialogic agenda | Used Image as Tool for Telling |
| SIM Syringe | Mr. R | Presented target model | Used Image as Tool for Asking |
| | | | |
| OV Syringe | Mr. T | Pursued a dialogic agenda | Used Image as Tool for Telling |
| OV Syringe | Mr. R | Presented target model | Used Image as Tool for Telling |

Table 9-10ab
Findings and Hypotheses about Teacher Differences from the Clean Air and Scent Lesson Comparative Case Study

**Table 9-10a** Percent of Time Spent Using IRF Interactions in Non-Image and Image-based Discussion in the Clean Air and Scent Lesson Comparative Case Study

| Lesson | Teacher | Non-image Discussion | Image-based Discussion |
|---|---|---|---|
| SIM Scent | Mr. S | 1:42 min/ 6:02 min = 0.28 | 0:46 min/ 7:29 min = 0.10 |
| SIM Scent | Mr. T | 3:02 min/ 9:37min = 0.32 | 8:10 min/ 18:33 min = 0.44 |
| | | | |
| OV Scent | Mr. S | 6:03 min/ 14:03 min = 0.43 | 0:56 min/ 2:58 min = 0.32 |
| OV Scent | Mr. T | 9:04 min/ 22:29 min = 0.40 | 2:10 min/ 6:08 min = 0.35 |

Bolding indicates using that IRFs accounted for at least 25% of the discussion time

**Table 9-10b** Hypotheses about Teacher Differences in the Clean Air and Scent lesson Comparative Case Study

| Lesson | Teacher | Non-image Discussion | Image-based Discussion |
|---|---|---|---|
| SIM Scent | Mr. S | Pursued a dialogic agenda | Used Image as Tool for Telling |
| SIM Scent | Mr. T | Pursued a dialogic agenda | Used Image as Tool for Asking |
| | | | |
| OV Scent | Mr. S | Pursued a dialogic agenda | Used Image as Tool for Asking |
| OV Scent | Mr. T | Pursued a dialogic agenda | Used Image as Tool for Asking |

This analysis also suggests descriptors of different ways these teachers provided a context for the image (pursuing dialogic agenda vs. presenting the target model) and different ways these teachers employed the image ("tool for telling" vs. "tool for asking") in these lessons. This mode of analysis provides evidence that there were differences in

how the different teachers provided a context for and employed the image to discuss the model.

## Relating Results from Questions 2, 3, and 4 to Question 1: Why Did the Simulation Classes Have Significantly Larger Gains?

### Generating a Hypothesized Model from These Findings and Hypotheses

It seems appropriate at this point to ask whether some of the qualitative findings and hypotheses discussed above to address research questions 2, 3, 4 might be combined to explain the quantitative pre-post results in question 1: that the simulation classes had significantly higher gains than the overhead classes. I conclude that the answer is not a simple one and that it is more appropriate to attempt to construct an initial model of what might have caused the result. This is offered as a hypothesized model, parts of which have some support in the data, but other parts of which remain speculative. Using the model, I attempt to make connections between the qualitative case study findings and the quantitative pre-post findings.

An important heuristic for model generation is diagraming the model. Figure 9-1A represents the raw finding for Question 1: that simulation lessons (SIM) were associated with greater learning gains (>LEARNING) and that the >LEARNING model result is based in pre-post (P). Figure 9-1B diagrams a first order model that relates SIM use with increased use of image-based discussion moves (> MOVES), based on countable code data (D) and shows my hypotheses (H) that >MOVES was associated with greater student active reasoning and engagement, which, I hypothesize, should be associated with greater learning. Although I did not have the time and resources to do an extended analysis of counts of student reasoning and engagement, existence demonstrations of

such effects were noted from transcripts in the case studies showing student reasoning following a teacher move. Therefore, I have attached a small "d" next to this element in the diagram to indicate this more qualitative level of evidence.

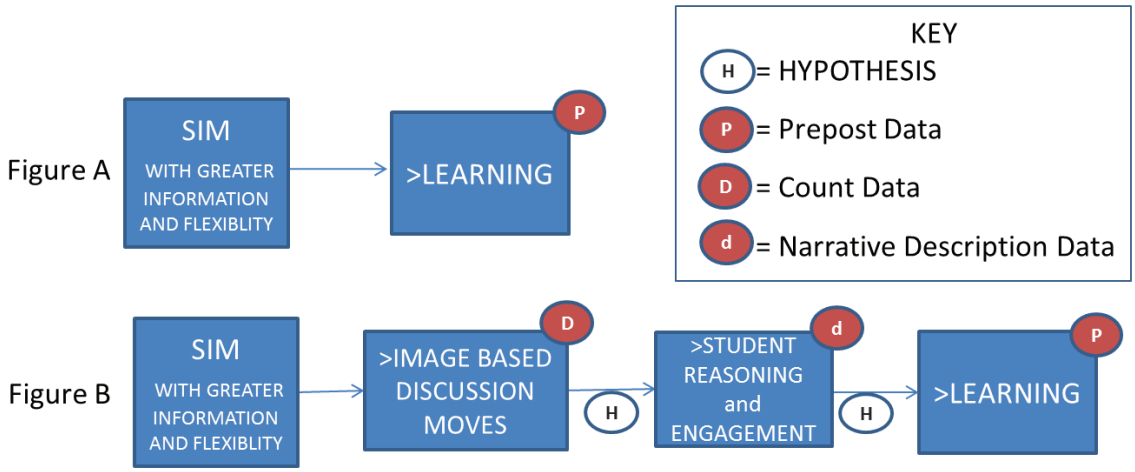



Figure 9-1A and B
Generating a Hypothesized Model

Figure 9-1C presents a more complex set of associated model elements. In this model, the simulation's affordance for planning and enacting is related to data from counts of scripted and spontaneous moves and image changes data. These provide reasons for the greater number of moves in the simulation classes. The model attempts to represent the role of greater time discussing the image, which also may in turn be associated with greater learning gains. (Note that this refers to greater Discussion Time not Time on Topic, since the SIM and OV classes were fairly well matched on total time on topic.)

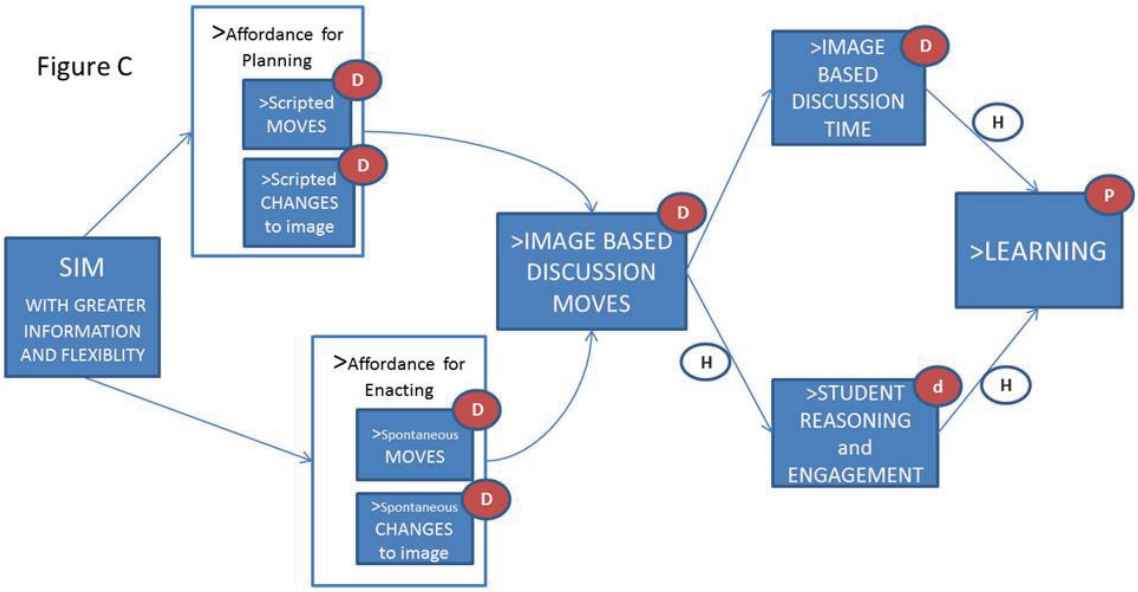



Figure 9-1C
Generating a Hypothesized Model (Complex Set of Model Elements)

## Limitations of the Study

First, there are a number of factors that limit the conclusions that can be drawn from the quantitative pre-posttest findings in this study. The most typical and traditional use of gains for two conditions is to attempt to project any significant gain differences onto a larger population. However, the condition to which a student was assigned in this study was determined by the school and not by strict randomization procedures. Also the limited sample size available meant that I could not use classes as the unit of analysis. The lack of randomization and the small sample size within a single school mean that the results of the quantitative comparisons cannot be projected rigorously to a population outside the study. They may suggest a provocative exploratory result pointing to a direction for future research.

I used the quantitative pre/post testing results for describing differences between SIM and OV conditions inside this study, and this is more fitting with the major purposes

of this study. The primary purpose of the overall study was to formulate new descriptions of teaching strategies and modes of operating used with image displays to foster conceptual learning. Pre/post test results cannot speak to this purpose. Rather, their purpose here was:

> 1. Indicate whether some learning occurred in each condition and for each teacher. Since a major part of the purpose of the case studies is to study the means used by the teachers to foster learning, it is important if we first have evidence that some learning occurred. For this purpose, we simply asked whether the post- test was significantly higher than the pre-test for each group of interest.
>
> 2. Indicate whether learning within one group (image mode or teacher) was greater than in the other group for the subjects inside this study. This provided a context that motivates the case studies that can dig into the details of what was happening in each condition.
>
> 3. Third, any gain difference findings between conditions inside the study give us a target to shoot for as a phenomenon to be explained. The case studies allowed us to construct and support a hypothesized model of teaching processes that can explain why the quantitative gain differences occurred.

Thus, I used quantitative methods for unusually narrow purposes in this study as part of a mixed methods design. In this mixed methods approach, these quantitative pre-post and gain comparisons are designed primarily to motivate interest in the qualitative case studies of classes inside the study. That is, the main purpose of the quantitative testing is to motivate, provide a context for, and enhance the qualitative case studies. This is a much more restricted purpose than that of projecting a result onto a population outside the study. As described in the methodology (Chapter 3), the fact that I am strongly hedging any claims to statistical generalizability from my sample to a population does not mean that I am giving up what Clement (2000) calls theoretical generalizability and Yin (2003) calls analytical generalizability. What the statistical portion of this study did was to focus me on findings within my sample that beg explanation; thereby

motivating the qualitative case studies. The theoretical findings and constructs from the qualitative studies may generalize analytically where readers find that they can apply these constructs to explain some of their own observation patterns.

Second, the author was a teacher in the study, and thus, a potential source of bias. However the author remained blind to both condition and teacher during the scoring of the pre-post tests, which should limit any possible effects of bias there. He could not remain blind to teacher or conditions during the transcript analysis, but he conferred regularly with an expert colleague on the interpretations made in the analysis. The primary focus of this study is the identification and description of strategies employed by teachers for using images in whole class discussion. Intuitively, bias does not seem as strong a concern for the purpose of identifying types of strategies as it does for test results.

A third limitation of this study involves the kind of images that were used. Both the simulations and the overheads studied here were model centered in that they featured depictions of normally invisible systems of particles and, therefore, focused on representations of explanatory models. If the images had been of virtual laboratories only, different moves might have been observed. Therefore, the strategies identified and information on how often they were used should not be taken as typical for all uses of images in the classroom.

Fourth, the learning gain differences between the image modes must be interpreted with caution since they may be related to difference between the affordances of these two particular image modes. I am not suggesting that all dynamic images are better than all static images. It could be argued that the overhead condition was not a

strong control group since the overhead images used were limited in multiple ways (static, fewer images, less complex graphics, one color black line drawings) as compared to the simulation images (dynamic, many images, more complex graphics, multicolor). These differences were important to the study design in order to produce a naturalistic space for teacher decision making that I could then examine qualitatively. In addition, some of these image mode differences appear larger now in retrospect than they did at the start of the study because of the work done here to articulate and characterize the difference in affordances of the image modes. For example, it did not naturally occur to these teachers to generate entirely new static diagrams to mimic the multiple states of the model. It is now possible, after the study, to recommend this as a strategy for using overheads, based on the observation of teachers using the simulation as a generator of many static images. It would be interesting to compare a simulation to a larger series of static images that would more closely mimic the choices afforded by a simulation. In addition, there are other tradeoffs that complicate the decision between using overheads and simulations. There are costs associated with using computer simulations that need to be considered, such as the time invested in finding a simulation that conceptually matches the target model with the correct level of complexity, not to mention learning how to use them. And in many cases it may be easier for a teacher to create a new overhead in response to an issue that arises with students, than it is to find or create a simulation. The analysis of the time on image factor would have been strengthened if I could have included time as a variable in the ANOVA, but because of the sampling difference between the case studies and the pre/post, I was not able to do that. Clearly, more study is needed to disentangle the complexity involved with which image mode differences are

most critical and efficient for producing learning gains. It is hoped that this study makes a contribution to this effort exposing some of this complexity. Fifth, the simulations used in this study were available alternatives chosen by teachers as part of a naturalistic study of the use of overhead and simulation images. This study is not an experiment that tried to change one small feature of the image and to narrowly control all other variables to study just the effect of that feature. The center of this study is a set of qualitative case studies that attempted to discover what teaching strategies were used in addition to the presence of the image itself in two conditions, where there were multiple differences between each condition.

For example, one might assume that the simulations provided more available information and more options than overheads did and attempt to use that simple fact to explain the quantitative results. However, more available information does not imply more learning, and I believe the case studies indicate that the explanation is more complicated. In reality, a complex simulation takes time and discussion in order for students to understand it; Lowe (2003) and Hegarty (Hegarty & Just, 1993; Hegarty, Kriz, & Cate, 2003) found that adults can have marked difficulties in interpreting animations. More options similarly do not imply more learning. In practice, more options means that teachers will face more decisions about how to employ the image. I saw wide variations in how teachers used the same simulation and found fairly large individual differences between teachers in their gain scores. These findings suggest that the image mode is not the only variable at work here. Teaching strategies and modes of discussion may play a large role in learning outcomes. The model in Figure 9-1C shows intermediate mechanisms at work that were the central focus in this study — the teaching

strategies and modes of operating through which the additional flexibility and information in the simulation could be used to foster greater learning. The quantitative results suggest that this simulation condition (including activated teaching strategies) was "better" than this overhead condition and the qualitative findings and hypotheses attempt to provide vocabulary and categories to help explain how it was "better" in terms of what teachers actually do with a simulation. While the Figure in 9-1C models some possible advantages of simulation use, it may also provide implications for how to design or use more complex static images than were used in this study.

## Instructional Implications

Here, I will speculate on how the moves identified in this study could best be organized for sharing with teachers. The Image-based Discussion moves (shown in bold) can be shared with teachers as moves that may help teachers plan and execute a strategic pathway that supports comprehension of a simulation or a complex static image by focusing the student's attention and reasoning on the image's most conceptually salient features.

One such idealized sequence of moves for using a simulation in a lesson might be:

Observe the simulation in static mode

1. **Orient** students to the image.
2. **Situate** students in the simulation.
3. **Predict** a future state of the simulation.
4. **Highlight** how it represents sides of a causal chain.

Observe the simulation running

5. **Explain** the Linkage between the sides of a causal chain.
6. **Frame** the simulation by explaining the purpose of viewing it.
7. **Critique** the limitations of the simulation.
8. **Extend** the application of the simulations to other situations.

Of course, teachers will need to adapt to student responses and vary this procedure as needed. Part or all of this sequence could be used multiple times in a lesson with a simulation that can represent multiple states of the target model. For example, two of the simulation lessons in this study made use of the simulation's affordance of changing a variable and allowed the teachers to discuss extreme cases, one with very few and one with very many molecules. Each time an extreme case was run, some part of this sequence was repeated. For example, the following sequence of moves was repeated twice in Mr. T's scent lesson (Chapter 5), once for each two extreme cases: While imagining their nose being situated in the overlay simulation, students were asked to predict how the simulation could represent a very large or very small cookie in terms of molecules, and then predict how that number of scent molecules would smell. Each time the simulation was run, students we asked to highlight when molecules hit their noses by calling out, and link that molecular collision to the marco observation of scent. This sequence was followed by student generated critiques and extensions of the image to other situations.

Table 9-11
Summary of Questions Associated with Image-based Discussion Moves

| Moves | Central question of the move |
|---|---|
| ORIENT | What are we looking at? |
| SITUATE | What if you were in the image? |
| HIGHLIGHT | What is happening? |
| PREDICT | What will happen if...? Why? |
| LINK | What is causing this? |
| FRAME | Why are we looking at this image? |
| CRITIQUE | What is wrong with this image? |
| EXTEND | Where else would this image apply? |

By using an image as a "Tool for Asking" approach rather than presenting material within these moves, the sequence of moves above could help teachers generate questions (Table 9-11) that promote student engagement and active reasoning as they make predictions and inferences about the simulation and then use it to generate, evaluate, and modify their internal mental representation of the model. It is hoped that this question sequence would support the work of teachers and teacher educators as they attempt to develop the questioning skills needed to orchestrate a discussion that engages student reasoning and converges on conceptual goals. In practice, with limited time, teachers might want to use a mixed approach in which they use the image to both ask and tell.

Previous work (Price, 2007) has suggested that the skills needed to use an IRF interaction pattern do not develop all at once but rather over a period of months or years. Each step away from lecture toward a more flexible IRF interaction pattern requires skills that are a challenge to develop. One speculative implication of my findings on teacher differences is that projected images could play a role in facilitating the shift between lecture and more dialogic patterns of interaction. In Figures 9-12 through 9-15, I have

attempted to diagram the ways teacher-student interaction patterns were observed shifting when the image mode was displayed (Table 9-8a, 9-9a, 9-10a). In these figures the curved red line represents the teacher using an IRF interaction pattern to pursue divergent student points of view. The straight red line represents the teacher using a more authoritative approach intended to present the school science point of view. By providing a strong statement of the target model, the image could provide a useful constraint on the potential divergence of student responses. This constraint could afford a teacher the opportunity to use the image-based discussion to develop the skills of using IRF interaction patterns without worrying about being taken too far off agenda by highly divergent student ideas (Figure 9-2). Once the skills needed to use IRF interactions to pursue student ideas are developed, IRF patterns could be used flexibly and strategically over other parts of the lesson (Figure 9-3, Figure 9-4).

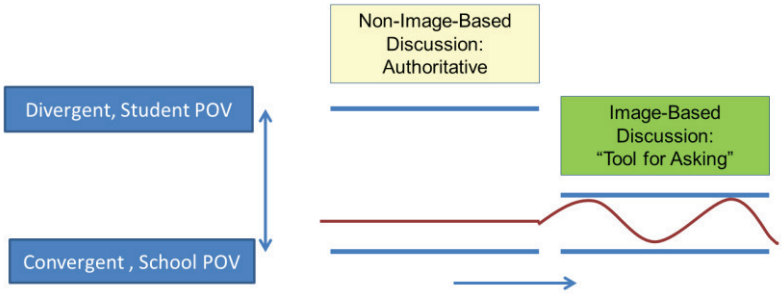



Figure 9-2
Teacher Using IRF Interaction Patterns During the Image-based Discussion

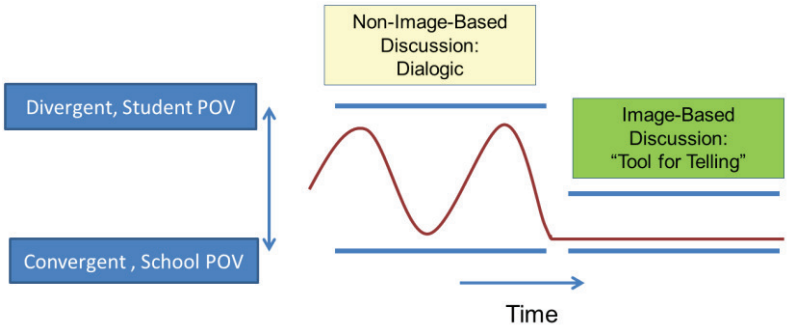



Figure 9-3
Teacher Using IRF Interaction Patterns During the Non-image-based Discussion

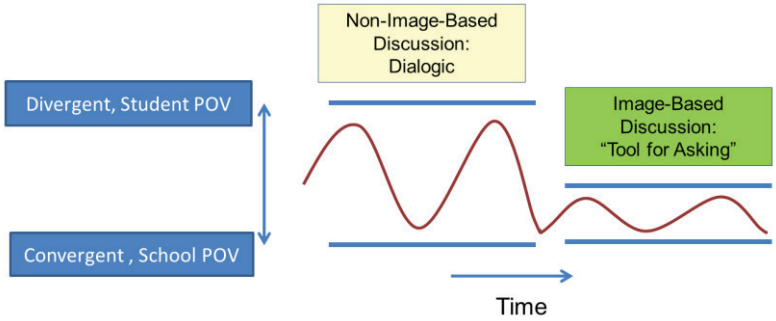



Figure 9-4
Teacher Using IRF Interaction Patterns During All Phases of the Lesson

(See Chapters 6, 7, and 8 for more detail on implications.)

This study provides new descriptions of strategies teachers use to orchestrate image-based discussions designed to promote student engagement and reasoning in lessons with conceptual goals. It is hoped that these strategies will support the work of teachers, teacher educators, and researchers as they seek to understand how images can be used in whole class discussion to develop student reasoning and conceptual understanding.

# APPENDIX A

## MATTER AND MOLECULES OV/SIM STUDY PRE-POSTTEST

M&M post-test NAME_____

DATE_____

INSTRUCTIONS

*In this survey, for questions that ask for an explanation or ask "why?" try to give the most complete explanation you can. Include molecules in your answer where reasonable.*

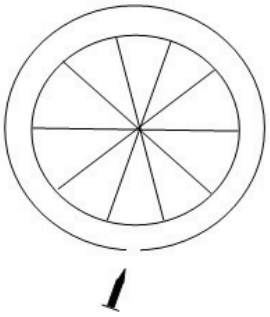
1A. Explain what happens if you run over a nail on your bicycle and the tire gets punctured and starts to leak. Include molecules in your response if you can.

1B. As the air escapes, you can hear a hiss. After one minute, you still hear the hiss. Is the air coming out as quickly it was when it was first punctured?

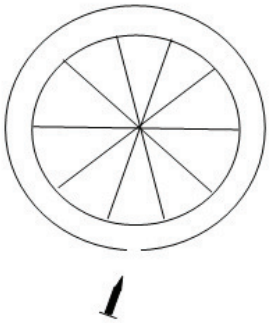
Yes_____ No_____ Why or why not?

1C. A few minutes later, you still hear a quiet hiss. Your tire does not yet look flat but now it feels soft when you touch it. Draw dots to show molecules of air inside and outside of the tire in each case. Remember that air is still escaping from the tire.

Right after the puncture



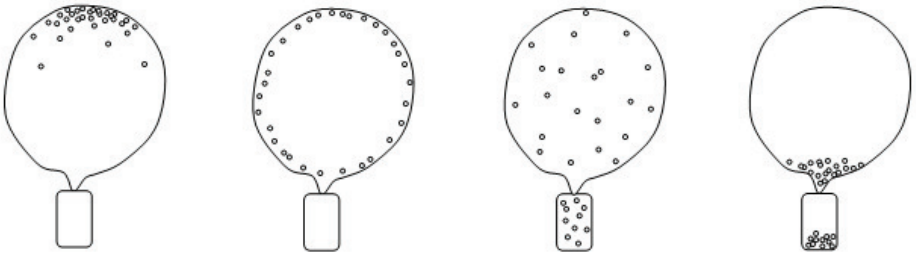
Several minutes later



2A.

*Empty balloon*

If you attached a tank of compressed air to an empty balloon and let air flow into the balloon, how would the molecules look as the balloon is expanding?



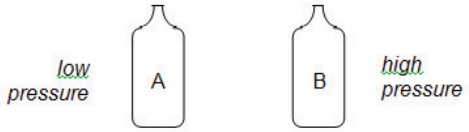
a) b) c) d)

2B. Explain why you chose your response

3. When you open a bottle of alcohol, the smell of alcohol soon reaches your nose. Compare the liquid alcohol in the bottle with the smell of alcohol that reaches your nose. How are they alike and how are they different?

4. Why is it harder to get enough air to breathe when you are high in the mountains? The air is thinner, so shouldn't it be easier to breathe it in?

5A.




Oxygen in tank A is under low pressure. The oxygen in tank B has been compressed a lot by putting more oxygen in under high pressure. Why does oxygen come out of tank B faster than it does out of tank A when the tanks are opened?

5B. By "faster," we mean that:

a) each molecule is moving faster.
b) more molecules are coming out each second.
c) Both a) and b).
d) Neither a) nor b).

6. Molecules of air inside a full, blown-up balloon are moving:

a) faster than you can run.
b) faster than you can walk but not faster than you can run.
c) faster than a turtle but not faster than you can walk.
d) faster than a caterpillar but not faster than a turtle.

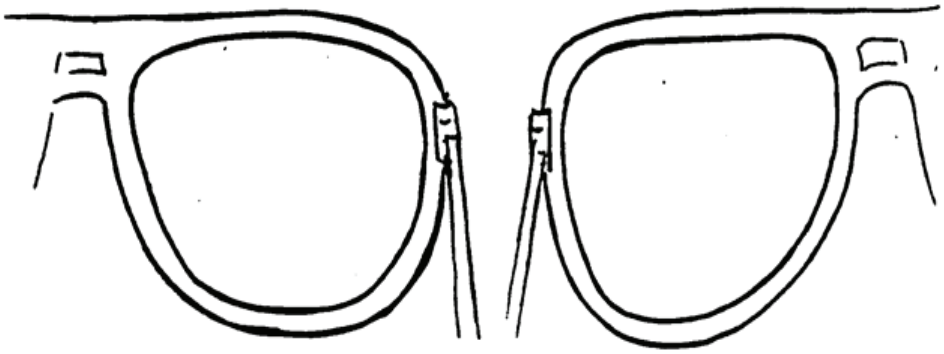
| |
|---|
| 7. Why is it easier to squeeze 5 gallons of air into a 1 gallon tank than it is to squeeze 5 gallons of water into a 1 gallon tank? |
| 8. Which do you think is bigger, a molecule or a speck of dust? (Pick only one)<br>a) They are about the same size.<br>b) The molecule is a little bigger.<br>c) The molecule is a lot bigger.<br>d) The speck of dust is a little bigger.<br>e) The speck of dust is a lot bigger.<br>f) I don't know. |
| 9. It is not easy to stretch the skin of a balloon. Why does a balloon stretch and get bigger when you blow air into it? |

## APPENDIX B

## LESSON EXPLAINING AIR PRESSURE IN A TIRE HANDOUT

Question Set Explaining the Bicycle Tire

2. In the eyeglasses of science below, draw what the molecules of air would look like in mountain air and in a scuba tank.



**MOUNTAIN AIR** **SCUBA AIR**

3. Which would have more molecules in a gallon: a gallon of air from the top of a mountain or a gallon of air from a valley? Explain your answer.

   Answer: _____

   _____

4. If the valve of a scuba tank full of air is opened, what do you think will happen? Use what you know about molecules to explain your answer.
   Answer: _____

   _____

1. What is happening to the air as it is being pumped into a bike tire? Is it expanding or being compressed? _____ Explain your thinking in terms of molecules.

_____

_____

_____

2. My friend says that for some time, there is more air near the valve of the bike tire where the air was pumped in. Do you agree with him? Explain why or why not.

_____

_____

_____

3. What is happening to the air as it is released from a bike tire? Is the air expanding or being compressed?_____ Explain your thinking in terms of molecules.

_____

_____

_____

4. Briefly state the two parts of a good explanation.

a) _____

b) _____

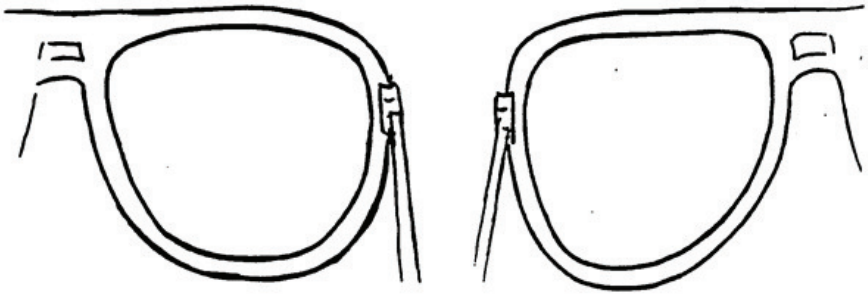
## APPENDIX C

## LESSON EXPLAINING COMPRESSABILITY OF GASSES IN A SYRINGE HANDOUT

**Activity Compressing Air and Water**

Before we begin this activity, let's review what we've learned about how molecules are arranged and how they move in liquids and gases. Draw in one of the eyeglasses of science below how molecules are arranged in a liquid like water, and in the other eyeglasses of science how molecules are arranged in a gas like air.

**WATER (LIQUID)** **AIR (GAS)**



1. How far apart are the molecules of a gas compared to a liquid?

_____

_____

2. In which of these two states of matter, liquid or gas, do you think it would be easier to push together molecules? _____

2b. Why? Explain your thinking. _____

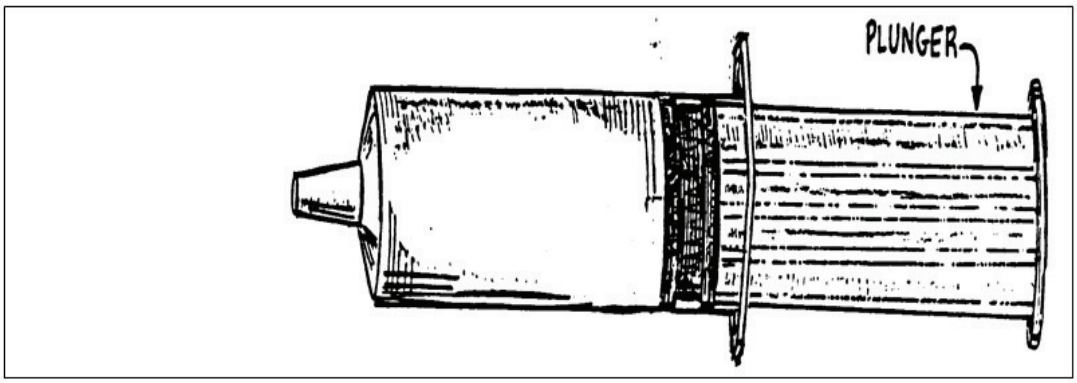
_____

The following activity will help you see if your prediction is correct.

Your teacher will give you a plastic syringe and a cup of water. Look carefully at the syringe and move the plunger in and out. Notice that the end of the plunger has a seal so that no air can get past the plunger. Air can move in and out only through the hole in the tapered end. While you are moving the plunger in and out, feel the air coming out of the syringe.

3. Below is a drawing of a syringe. How would molecules of air be arranged in the syringe when the plunger is all the way out?

Draw the air molecules both inside the syringe and outside the syringe




4. Now fill your syringe with water. Hold it over the cup. Now carefully place your thumb over the end of the syringe so that no air can escape and try to push the plunger in. Can you push the plunger in when the syringe is filled with water?

_____

5. Now try the same experiment with air instead of water and pull the plunger out as far as it will go. Place your thumb firmly over the end of the syringe. Keep your thumb on the syringe tightly so no air can escape. Try to push the plunger in. What happened?

_____

_____

_____

6.Why can you push the plunger in some when there is air in the syringe, but not at all when there is water in it?

_____

_____

_____

_____

6b. Make a drawing to show what you mean in #6.

| Syringe with air in it | Syringe with water in it. |
| --- | --- |
| | |

7. Why can't you push the plunger all the way in with air in it?

_____

_____

_____

_____

Did your explanations for Questions 6 and 7 talk about molecules? Remember that a good explanation talks about molecules. These explanations should talk about the way molecules are arranged in liquids (water) and in gases (air). Go back and write some more for Questions 6 and 7 using these ideas about how molecules are arranged in order to explain what happens in the syringe.

Now, pull the plunger out as far as it will go. Place you thumb firmly over the end of the syringe and push it in as far as it will go. Keep your thumb on the syringe. Let go of the plunger.

8. Explain why the plunger moves back out.

_____

_____

_____

## APPENDIX D

## LESSON EXPLAINING SCENT IN AIR HANDOUT

Question Set and Demonstration Clean Air and Smells

1. What is air made of? Name at least four gases. _____

   _____

2. My friend said that all molecules in the air are the same. Is my friend right? Explain why you think so. _____

   _____

3. Your teacher will release a small amount of perfume in the room. What do you think perfume is made of? _____

4. How did the perfume travel from where it was released to your nose? Use molecules in your explanation. _____

   _____

   _____

   _____

5. Ammonia is another substance that you can smell.
   a. Invent a shape for ammonia molecules and
   b. Draw a picture of what air in your kitchen might look like with eyeglasses of science shortly after you opened a bottle of ammonia.

| Just after being opened. | A few minutes after being opened. | An hour after being opened. |
|---|---|---|
| | | |

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