USING SIMULATIONS VS OVERHEADS: A COMPARATIVE CASE STUDY OF QUESTIONING STRATEGIES IN THREE SCIENCE TEACHERS

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Author's Note

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Abstract

This 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 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. Previous studies have identified some important sets of teaching strategies for leading whole class discussions, but not specifically for visual displays such as overheads and simulations. We first used open coding to identify a set of teaching strategies teachers were using with visual displays. Video and transcripts of large group discussions from 12 lessons were then 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. In addition, data on teacher use of discussion modes such as presentation, IRE, and IRF (Initiation Response Feedback) suggest that teachers had different preferences. When teachers moved 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 discussion modes we observed suggest that fully accessing the affordances of an image involves moving beyond using the image as a "tool-for-telling" to using the image as a "tool-for-asking" .

Purpose And Research Questions For The Study

In this study I attempted to build on the work of a number of authors who have analyzed whole class discussions (Clement, 2008; Scott, Mortimer, &Aguiar, 2006: McNeill & Pimentel, 2010;Van Zee & Minstrell, 1997, Alozie, Moje, & Krajcik, 2010) including some who have identified specific strategies for leading discussions (Hogan & Pressley, 1997; Chin, 2006; and Chin, 2007). 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. It is hoped that this study will add to the literature by describing how teachers orchestrate discussions using images for engaging active thinking and responding to student ideas in lessons with conceptual goals.

Research Questions

The study 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 5second - 5 minute) 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?

Method

A. Study Design

The data collected in this study was part of a larger NSF study of visual modeling strategies in science teaching. An important goal of my study is to examine how different image modes are used by teachers to teach the same content. More specifically, how was planning and teaching affected when an overhead in a lesson is replaced by a computer simulation? To pursue this research objective, 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, we controlled for time on task by using 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 teacher use two different image modes, static overheads and dynamic simulations, I was able to explore how teachers used images in a quasi-experimental comparison.

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 Molecule* 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 1).

Table 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 answer research question 3.

Teacher	Compressed Air in Tire Lesson				Air Pressure in Syringe Lesson				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												

B. Participants, Context & 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 our research group.

C. Data Collection Methods

1. 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 post-test.

2. 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 classroom activity were videotaped and later transcribed and analyzed using Transana video software (Woods & Fassnacht, 2007). Our research team videotaped each teacher during a series of overhead lessons and a series of simulation lessons.

D. Quantitative Data Analysis

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 administered 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?

E. Qualitative Data Analysis

1. 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 at different levels (Chin, 2006; Glaser and 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. The 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 refinement 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, which took 4 years to complete, I consulted with members of our research team to check the plausibility of my findings.

2. Specific Methods

a. Microanalysis of image based discussion strategies.

Below is summary of a detailed narrative micro analysis of one teacher's use of the image and has as its main purpose to identify and describe image based discussion strategies used by the teacher as he employed the image (Price, 2013).

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 we 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 5-90 second 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 transcript was prepared and used to develop more formal names and descriptions of observed image based teaching strategies. This analysis lead to an in-depth case study of a pair of lessons taught by the author (Mr. T) designed to reach the same content goals (Price, 2013). 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. We consulted frequently with other members of our research team to gain an outside perspective during our 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 our 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 section of the 12 lessons.

Below is a condensed summary of the strategies codes used in this microanalysis of a simulation lesson (Table 7) and a description of how they helped to address Research Question 2: <u>What whole class discussion strategies were used with image displays by teachers to scaffold the development of a visualizable particulate model of a gas?</u>

<u>b. Lesson Comparison Case Studies of an Overhead Lesson and Simulation Lesson taught by 2 different teachers (2x2)</u>

Below is summary of results from a 2x2 comparative case study (Price, 2013). The purpose of the 2x2 comparative case study was to compare how the image based strategies were used with different image modes (How often are strategies and which are most common?) and how did different teachers enact the same lesson plans (How did they use strategies differently?).

For the purposes of this study, 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 20-50 minutes. Each 2 x 2 comparative case study examined a total of 4 lessons. 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 lab or 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 second level of coding focused on the effect of image 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. 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 used the code definitions of Image Based Discussion moves to understand and characterize how teachers used images. A condensed version of these strategies is provided in Table 7. For full code definitions see Price, 2013.

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 2) in both non-image based and image based discussion.

This method can be clarified with an example. Figure 1 is a sample representation of how 2 teachers used time 2 of 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. 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. I coded this as non-image 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. I coded this as image-based discussion. I used the IRE/IRF coding over the non-image (shown in yellow) and image-based (show in green) sections of the lessons. I used the image based discussion codes only over the image based discussion (shown in green).

Figure 1: Diagram of difference in the classes

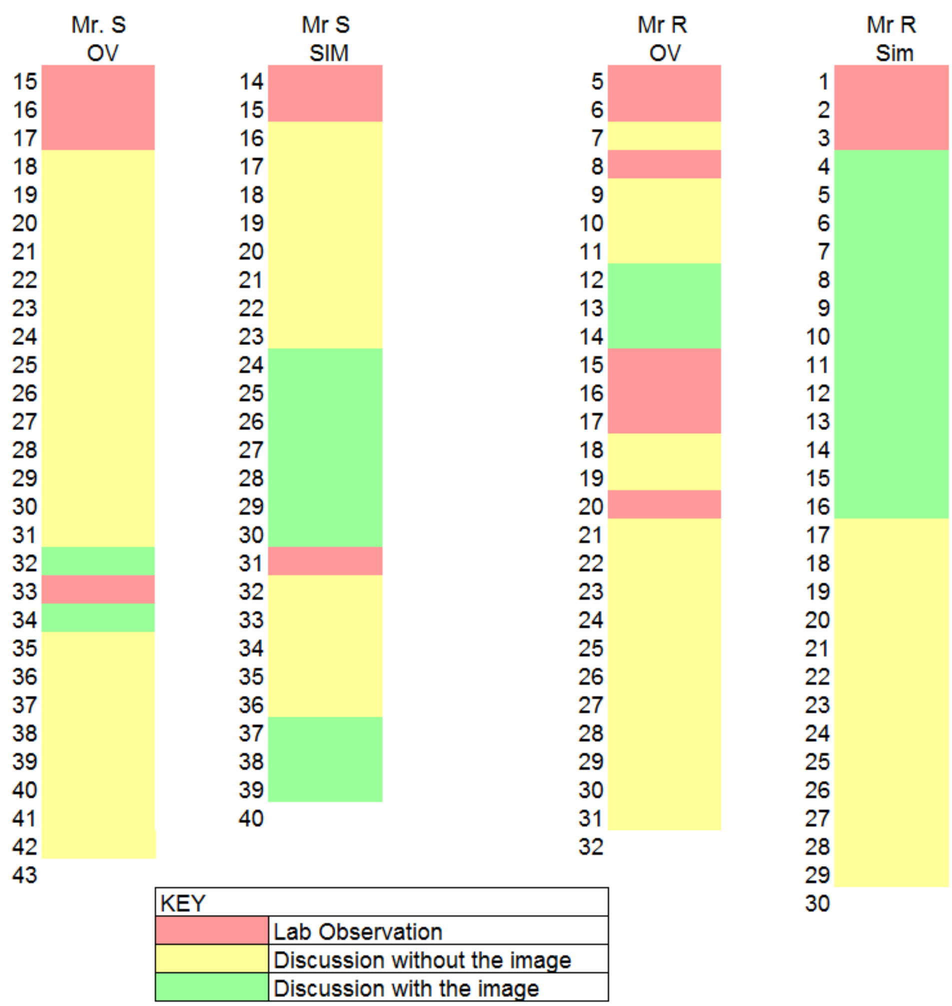
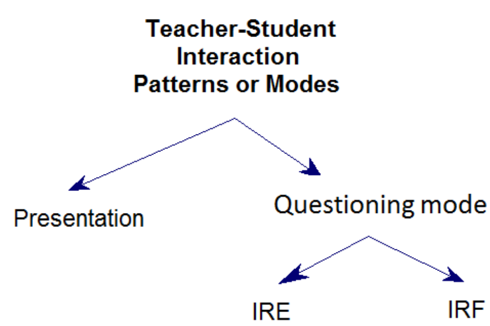


Table 2 Interaction pattern codes

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 Response Evaluation	The teacher asks a question and then evaluates student responses.
IRF	Initiation Response Follow up question	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.



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. This narrative and counting code analysis was used to generate inferences and 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 enactment was made. 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 was completed. Thus this comparative case study examines a total of 4 lessons.

c. <u>Lesson Comparisons for 6 Pairs of Overhead-Simulation Lessons taught by 3 different teachers (2x2x3 design as shown in Table 1)</u>

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 1 in terms of coded teacher behaviors. That is each set compared two teachers on a single lesson, and teacher behaviors in each condition were coded and compared. Differences in behaviors across teachers are summarized below described. Analysis in b) and c above will address Research Question 3: <u>How were lessons with common content goals planned and enacted differently when using different image modes</u>?

F. Limitations and Generalizability

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. Consistent with this, findings will primarily take the form of hypotheses suggested by the data rather than attempting to make statistical generalizations to a population. Common patterns as well as differences across these comparisons will be noted in the conclusions.

The fact that we are strongly hedging any claims to statistical generalizability from our sample to a population does not mean that we are giving up what Clement (2000) calls theoretical generalizability and Yin (2003) calls analytical generalizability. New strategies or principles identified in 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 our study does is to focus us on a finding within our sample that begs explanation; thereby motivating the qualitative case studies. Theoretical findings and constructs from the qualitative study should generalize analytically where readers find that they can explain some of their own observation patterns using the constructs.

Quantitative Results

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 3) and for each teacher's classes (Table 4abc)]. 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 5). It is important to note that the quantitative gain scores are not being used to attempt to project to finding to a population *outside* the study. I am using them to as part of a mixed method approach to provide quantitative descriptions of differences in learning between groups *inside* the study.

Table 3 ANOVA Results which examined changes in student scores in short and long answer pre-test to post-test for each condition (Combines results each teachers 2 SIM classes and 2 OV classes (N=117)

SIM	N= 107	Pre-test	Post-test	PrePost Gain	Percent Gain	df	F	Sig.
LONG	Mean	8.1	13.5	5.4	21.5	1	201.432	.000
SHORT	Mean	3.6	4.2	0.6	11.2	1	25.180	.000
OV	N=117	Pre-test	Post-test	PrePost Gain	Percent Gain	df	F	Sig.
LONG	Mean	9.0	12.7	3.7	15.8	1	115.055	.000
SHORT	Mean	3.6	4.2	0.6	11.2	1	8.177	.005

Table 4abc ANOVA Results which examined changes in student scores in short and long answer pre-test to post-test for each teacher. (Combines results each teacher's 2 SIM classes and 2 OV classes)

Table 4a Four classes taught by Mr. S (N= 63)								
		Pre-test	Post-test	PrePost Gain	Percent Gain	df	F	Sig.
LONG	Mean	7.65	11.86	4.206	16.83	1	92.232	.000
SHORT	Mean	3.90	4.00	.0952	1.90	1	.771	.384

Table 4b Four classes taught by Mr. R (N= 78)								
		Pre-test	Post-test	PrePost Gain	Percent Gain	df	F	Sig.
LONG	Mean	8.29	10.51	2.2179	8.8718	1	24.532	.000
SHORT	Mean	3.72	4.13	.4103	8.2051	1	13.430	.000

Table 4c Four classes taught by Mr. T (N= 83)								
		Pre-test	Post-test	PrePost Gain	Percent Gain	df	F	Sig.
LONG	Mean	9.51	16.36	6.8554	27.4217	1	305.568	.000
SHORT	Mean	3.73	4.37	.6386	12.7711	1	35.834	.000

Table 5 ANOVA Results which examined changes in student scores in short and long answer pre-test to post-test for each condition. (Combines results from 3 teachers' 6 SIM classes (N=107) and 6 OV classes (N=117)

N=224	SIM Percent Gain	OV Percent Gain	df	F	Sig
SHORT	11.2	5.3	1, 212	4.826	.029
LONG	21.5	14.8	1,212	12.9	0.000

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 6). These gain difference suggests 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 will be investigated further in the following case study sections.

Table 6 Results for ANOVA **Tests of Between-Subjects Effects** which showed significant difference between teacher in the short answer percent gain and the long answer percent gain

N=224	Source	df	F	Sig.
SHORT	Teacher	2. 212	4.848	.009
LONG	Teacher	2. 212	31.555	.000

Qualitative and Countable Code Results

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?*

a. *What image based discussion moves (small time scale strategies spanning 5second - 5 minute) were used by teachers to navigate image based discussions?*
b. *To what extent did teachers employ these strategies in overhead and simulation lessons?*

2a) I used the phrase "Image based Discussion move" to describe individual strategies during the discussion of an image. The descriptions of the moves were refined over time and their existence was confirmed in the case studies of 12 lessons. Table 7 below provides a condensed overview of the move descriptions. More detailed descriptions appear in Price, N. Leibovitch, and Clement (2011), Price and Clement (2011), and Price (2013)

Table 7: 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) which 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 do an extended analysis of counts 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

2b) To what extent did teachers employ these strategies in overhead and simulation lessons?

Some moves were used more frequently than others. Table 8 summarizes the instances of use of these moves in the six Overhead and six Simulation lessons analyzed in the 12 lessons. The Orienting, Highlighting and Linking moves were the three most frequently observed moves in both the simulation and the overheads lessons. More detailed descriptions of the methods used in this case study appear in in Price and Clement (2011) and Price (2013).

Table 8: Summary of instance of moves observed in the classes 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 some 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 student 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 simulations that were "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.

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?*

Findings:

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, 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: Summary Comparison the Overhead and Simulation Classes in the Case Studies

		Totals from the 6 Simulation Classes	Totals from the 6 Overhead Classes
a)	Total time discussing the image in minutes: seconds	71:17	19:32
b)	Total number of instances of image-based discussion moves were 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

Hypotheses:

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 9e). 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 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 allow the simulation to support teachers as they improvise the orchestration of discussion. In this way, the simulation condition may have fostered a variety of unscripted discussion moves for these teachers. These unscripted, spontaneous moves 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.

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. The 12 lesson transcripts were also coded for these interaction patterns (4 lessons for each of the three teachers). Here I will focus on the use of IRFs. Tables 10a, 11a, and 12a below summarize data from the three comparative case studies that each compared two teachers on the use of IRFs. In this table, 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 10b, 11b, and 12b that an IRF 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* which 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 pattern used in *Image-based* discussion can be used 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 suggests that the teacher may be using the Image as “tool for asking” vs. as a “tool for telling.” I don’t 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 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 Table 10b, 11b, 12b I refer to this pattern as "Using the Image as a Tool for Asking (as opposed to Telling)".

Tables 10ab: Findings and Hypotheses about Teacher differences in the Tire lesson Comparative Case Study

Table 10a: Percent of time spent using IRF interactions in Non-Image and Image Based Discussion in the 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**

Table 10b: Hypotheses about Teacher differences from the 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	Presented target model	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 11 ab: Findings and Hypotheses about Teacher differences in the Syringe lesson Comparative Case Study

Table 11a: Percent of time spent using IRF interactions in Non-Image and Image Based Discussion in the 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

Table 11b: Hypotheses about Teacher differences in the 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 12 ab Findings and Hypotheses about Teacher differences from the Scent lesson Comparative Case Study

Table 12a: Percent of time spent using IRF interactions in Non-Image and Image Based Discussion in the 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**

Table 12b: Hypotheses about Teacher differences in the 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 hypothetical 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, 4 to Question 1: Why did the Simulation Classes have Significantly Larger Gains?

Generating A Hypothetical 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 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 2A 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 prepost or countable coded data (D). Figure 7B diagrams a first order model that relates SIM use with increased use of Image-based discussion moves (> MOVES), based on count 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 2 A and B: Generating a hypothetical model

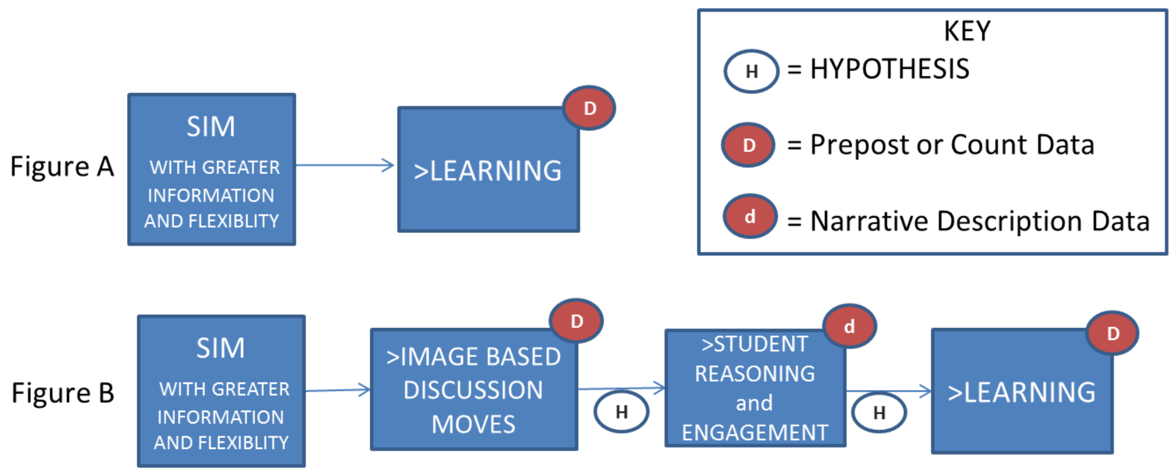
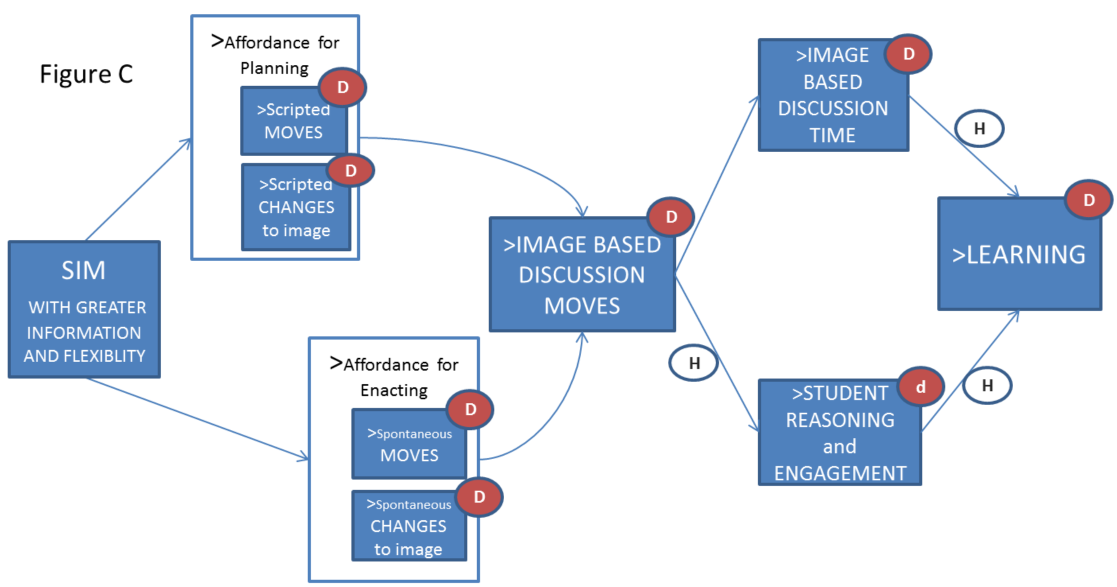


Figure C presents a more complex set of associated model elements. In this model, the simulation's affordance for planning and enacting is related to data from counts of scripted and spontaneous moves and image changes data. These provide reasons for the greater number of moves in the simulation classes. 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 2 C: Generating a hypothetical model



Limitations of the Study

First, there are a number of factors which 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 along these lines but the present findings from pre-post testing cannot be projected to a larger population *outside* the study in a rigorous way.

However, I instead focused on using the quantitative testing results in describing differences between groups [gains for the SIM and OV conditions] *inside* this study and this is more in 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. So what was their purpose here?

Purposes of Pre-Post Gain studies:

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 pretest 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 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**.**

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 prepost 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 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 we 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, M., Kriz, S. & Cate, C., 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 number of options available in 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 diagramed model above (Figure 7C) 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 the simulation condition (including activated teaching strategies) was “better” 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.

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) **Highlight** how the it represents sides of a causal chain,
4) **Predict** a future state of the simulation,

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 (Price, N., Leibovitch, A., and Clement, J., 2011) 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 13: Summary Table 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 for Asking” approach rather than presenting material within these moves, the sequence of moves above could help teachers generate questions (Table 13) 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.

In terms of interaction style approaches, it is hoped that this study’s descriptions of approaches to the image (Asking/Telling) 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.

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