Understanding Engagement: Science Demonstrations and Emotional Energy

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ABSTRACT: Although beloved of some chemists and physicists, science demonstrations have been criticized for stifling inquiry and assisting teachers to maintain a power differential between themselves and students in the classroom. This interpretive study reports the unexpected positive learning outcomes for urban science students in two chemistry classes that resulted from the use of science demonstrations during a unit on gas laws. Beginning with an examination of science demonstrations as sites of interactions, researchers observed greater student engagement and positive emotional energy, more sophisticated use by students of symbol systems associated with chemistry, and a greater willingness of students to move between description of the phenomena and submicroscopic explanations. Applying sociology of emotions to analysis of classroom conversations and actions, we examine the nature of engagement and propose explanations for the positive effect of science demonstrations on the engagement, emotional energy, and learning of students. © 2007 Wiley Periodicals, Inc. *Sci Ed* 1–31, 2007

INTRODUCTION

I arrived at Tracey's Lesson 5 chemistry class, as students were getting ready to complete a quiz based on the demonstrations that had been part of their study of the Gas Laws over the past three weeks. As I sat at the back of the room with Decimus I expected the usual challenge of encouraging him to focus and write, especially in a quiz. But as Tracey distributed the quizzes I was very surprised to observe how everybody (!) immediately

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> started to work on the quiz questions. Rather than the usual complaints about the difficulty of questions on the quiz or questions from students attempting to garner some assistance from Tracey or Angie or me for answering quiz questions, all I could hear was the scraping of pens on paper! There were no other sounds coming from the classroom. It was almost surreal. I have never observed the class so involved in an activity. I wouldn't have believed it if I hadn't seen it myself.
>
> Field Notes, 2002

The behaviors Catherine experienced that day suggested that the students valued the opportunity afforded by the quiz to communicate their learning as it related to the gas laws. By working so diligently on their responses to the quiz questions, each student was communicating her engagement in this task to the other members of the class, which Catherine interpreted as a positive working environment. This level of student engagement in Tracey's two chemistry classes was a pleasant surprise, but we had begun to observe increased student engagement more than 3 weeks earlier with the introduction of the first of three science demonstrations designed to support learning of the gas laws. As the gas laws demonstrations were introduced, we sensed a more positive learning environment, but it was not until we began to examine videotapes of the science demonstrations and discuss our experiences in the research team that we became conscious of the extent of the change in student behavior. In Tracey's classes, these science demonstrations constituted a new strategy for both her and the students she taught. As has been noted in previous studies of urban classrooms, many urban students belonging to marginalized groups do not find science engaging because it often seems irrelevant to their lives and remains inaccessible because its very structures embody ways of being that are associated with being White, middle class, and male (Elmesky, 2005). Lee and Anderson (1993) argued for the need to understand how interactions between cognitive, motivational, and affective factors affect students' willingness to participate in science and the importance of support to overcome barriers that restrict access to science understanding for traditionally underrepresented groups. Seiler (2002, 2005) claimed that when science is based on students' interests, there is potential for high levels of student engagement in science. Although there was nothing immediately obvious about science demonstrations that explained their positive effect on the learning environment of Tracey's classroom, we wondered whether structures associated with the enactment of these demonstrations created a supporting environment for students in their search for relevance in the chemistry content they were expected to learn.

UNDERSTANDING ENGAGEMENT

From an extensive review of the current research literature on school engagement, Fredricks, Blumenfeld, and Paris (2004) proposed a multidimensional model that included *behavioral*, *emotional*, and *cognitive engagement*. They identified behavioral engagement as that associated with actions that range from students' classroom actions to participation in extracurricular activities. Emotional engagement was associated with reactions to peers, teachers, the curriculum content, and school that influenced students' willingness to be involved in activities inside and outside of the classroom. Cognitive engagement was associated with whether students were willing to "exert the effort" that is required to understand "complex ideas and master difficult skills" (Fredricks et al., 2004, p. 60). The authors argued for the importance of thinking of engagement as a megaconstruct that was composed of interrelated aspects of behavior, emotion, and cognition and for understanding engagement in each construct as existing on a continuum. Thus, engagement could be thought of as a resource that "once established, builds on itself, thereby contributing to increased improvements in more distal outcomes of interest" (p. 61). Based on this argument, student willingness to complete the gas laws quiz could be understood as an outcome of interest associated with student engagement that was generated during the gas laws demonstrations. Also, they argued that engagement was open to fashioning depending on context suggesting the possibility that a change in the structure of the classroom, such as a change due to the introduction of science demonstrations, might have positive implications for student engagement in one or more of the three aspects of engagement they identified. We believe that both cognition and emotion must be present for learning to take place, and therefore positive emotion is necessary for student engagement and learning.

Skinner and Belmont (1993) in their study of suburban and rural elementary students identified teacher actions with respect to structure, autonomy support (agency), and involvement as central to the development of student engagement. Student behaviors that were indicative of behavioral engagement included persistence, concentration, asking questions, and contributing to class discussions. They claimed that engagement was part of an iterative relationship between positive student and positive teacher behaviors suggesting to us a need to study classroom interactions associated with the enactment of the gas law demonstrations that seemed to have such a positive effect emotionally and cognitively on Tracey's chemistry classes.

Historically, emotional engagement has been measured using survey or self-report instruments and has been mainly associated with interest. For example, Connell, Halpern-Felsher, Clifford, Crichlow, and Usinger (1995) used self-reports to identify self-perceptions of perceived competence, autonomy, and relatedness that were hypothesized to affect student engagement. We were interested in learning whether detailed analysis of classroom interactions would help in identification of the role of specific structures, science demonstrations, in the emergence of positive emotional energy and student engagement. Blumenfeld (1992) acknowledged the importance of systematic studies that examined what was happening in classrooms in specific content areas over time, areas of engagement research that have tended to be less studied than individual students. Blumenfeld, Puro, and Mergendoller (1992) also noted that often research on motivation or cognitive engagement tended to focus on one element of the classroom in order to learn how that element affected students' engagement rather than taking a more holistic research approach such as that associated with case studies of classrooms that might provide a richer understanding of the role of interactions in student engagement. Marshall (1992) echoed this claim arguing for the value of case studies that focus on the interaction between teacher and students. In order to examine these interactions, we focused on actions and conversations associated with the gas laws demonstrations.

Engagement, Interactions, and Conversations

A focus on the interactions that take place in a classroom acknowledges our acceptance of the importance of the social in student engagement and learning and the importance of context in understanding engagement. Drawing from the sociology of everyday life, we use a concept of context that acknowledges the role of both the preceding activity and the larger environment in which this activity is located in shaping utterances and actions such as those associated with actions before and after the enactment of the science demonstrations. At the same time, these utterances or actions are *context renewing* because they provide "the immediate context for some next action in a sequence. . . [and] inevitably contribute to the contextual framework in terms of which the next action will be understood" (Drew & Heritage, 1992, p. 18). A question that needs to be considered when we cite the context of the chemistry classroom and, more specifically, science demonstrations as an important context is whether we can show that the context, the classroom, and more specifically the science demonstration, is *procedurally consequential* to the talk that emerges (Schegloff, 1992). Schegloff asks whether the fact that the conversation is taking place in a classroom has a consequence for the trajectory, structure, or content of the interactions that are the focus of this study leading us to ask how the setting can help us to understand the role of conversation to student engagement. As sites of institutional talk classroom conversations consist of three major features that make them different from everyday social conversations: at least one of the participants is oriented to a core goal, task, or identity associated with the institution; there are usually constraints on what participants will treat as allowable contributions; and allowable talk may be associated with procedures and inferential procedures that are specific to that context (Drew & Heritage, 1992).

Interactions and Engagement

Our interest in examining the everyday life of science classrooms for engagement and emotions led us to the research of Goffman (1972) and Collins (1987, 2004). Goffman was one of the early proponents of everyday life as a subject for empirical research. He was influenced by the writings of Schutz (1964) who argued that it was important to examine face-to-face interactions in order to understand social relations because through our own experiences we expect people to behave in specific ways even though each person is selective in the specific focus they give to an interaction. As a sociologist, Collins' notion of agency and emotion is very different from that proposed by psychology-based research on engagement, which puts the individual in the center, but one that we found helpful when analyzing classroom interactions. He argues:

> [W]e would get much further if we avoid reifying the individual, that we should see individuals as transient fluxes charged up by situations. Agency, which I would prefer to describe as the energy appearing in human bodies and emotions and as the intensity and focus of human consciousness, arises in interactions in local, face-to-face situations, or as precipitates of chains of situations. (Collins, 2004, p. 6)

Collins developed the concept of interaction ritual chains from the research of Goffman and Durkheim (Collins, 1987). He describes interactions as momentarily shared conversational realities. The extent to which this reality is created depends on the motivations and resources that come to the encounter. In this context, engagement can be understood as entrainment in these conversational realities. Depending on how much people want to speak with one another in a specific way, the prior experiences and memories they bring have implications for the emergent conversation. Motivation and resources that create and maintain interactions come from previous encounters, "hence the notion of a *chain* of interactions" (Collins, 1987, p. 198). This argument forms the basis of Collins' (2004) interaction ritual theory. He describes ritual as "a mechanism of mutually focused emotion and attention, producing a momentarily shared reality, which thereby generates solidarity and symbols of group membership" (2004, p. 7). Symbols become imbued with positive emotional energy and significance. When these symbols become the focus of group attention, they become *sacred objects*. According to Collins, even the most ordinary things can become sacred and the process by which participants develop mutual focus and become in synchrony with others' microrhythms and emotions lies at the center of an interaction ritual. The capacity of interaction ritual chains to produce focused emotion and attention indicated that science demonstrations could foster objects and processes as sacred objects providing further argument for examining the interactions associated with the gas laws demonstrations.

Every conversation adds to the cultural capital of those who participate and this cultural capital can be invested in further interactions (Collins, 1987). Each conversation is invested with various levels of inclusion and exclusion for each individual influencing negotiation of social relationships and networks of power. When people enter into a conversation, they have expectations about who will be responsive and the further social ties that can be enacted, especially if they know something about the others involved. Collins (1987) argues that the common denominator amongst different types of conversational choice is emotional rather than cognitive based on “the inability of individuals to weigh complex decisions consciously” (p. 199). Classrooms provide a structure for whole class interactions to offer opportunities for inclusion of members of the class while excluding those outside. From these interactions, students have the chance to gain resources for further conversations and an increase or decrease in emotional energy. Interactions provide resources for building community and the establishment of student engagement both emotionally and cognitively. Students who participate in conversations acquire more energy, self-confidence, and a tendency to initiate subsequent conversations. But Collins argues that one does not need to dominate conversations to gain emotional energy. One only needs to be accepted into the group. Positive emotional energy builds from successful interactions (Collins, 2004). Emotional energy is pivotal because it “determines what each person will *feel* about the conversation he or she is getting into; how much one wants to talk to the other person, whether it is a high or low priority in comparison to what else each might do, and how successful each will be bringing off the kind of conversation he or she would like to enact” (p. 200). However, sustaining positive emotional energy depends on whatever is mutually focused upon becoming a symbol of the group, through this process these symbols becoming imbued with positive emotional energy.

Acknowledgement of the relevance of positive emotional energy comes from Skinner and Belmont (1993): “*Engagement* includes both behavioral and emotional components. Children who are engaged show sustained behavioral involvement in learning activities accompanied by positive emotional tone” (p. 572). We prefer the term positive emotional energy because it captures the sense that this energy is available to all participants. It does not reside in individuals but in the successful interactions that occur in classrooms. Interactions in which positive emotional energy is produced are more likely also to show evidence of student engagement in actions such as eye gaze, overlapping speech, entrainment in conversation, and shared actions. A collective sense of engagement can affect other students and bring them into the interaction. Cognitive aspects of interactions that are indicative of engagement could include participation in the use of language associated with chemistry knowledge, a willingness to focus on observation as well as explanation, and a desire to work together to construct chemistry knowledge. Emotions are experienced internally and exhibited so that they are available to others. For example, one of the four emotions that are thought to be universal, happiness, is associated with high-emotional energy and when someone is happy others are aware of their happiness through bodily actions, facial movements, and the structure of their speech or prosody suggesting that overlapping and excited speech are indicative of positive emotional energy. Prosodic features include the rate of speech, intensity, and pitch (Gumperz, 1992). By their structure, the gas laws demonstrations afforded students access to interactions that structure the emerging learning environment and support their achievement of conscious and unconscious goals. Science demonstrations are focused whole class interactions constitutive of a fluid type of ritual that exists on a continuum between social situations and formal rituals. They are structured by some ritual elements such as mutual focus, group assembly, barriers to outsiders, and shared mood, but the application of these elements depends very much on the context and on the actions of agents such as specific students and Tracey.

UNDERSTANDING ENGAGEMENT AND EMOTION

Collins (2004) maintained that group assembly, barrier to outsiders, and mutual focus of attention were necessary ingredients for successful interactions and positive emotional energy that was indicative of a high level of engagement. Interaction ritual theory has been used in science education research to examine the relationship between synchronous and asynchronous interactions involving a female teacher and two female students and learning (Smardon, 2004) and the types of classroom structures associated with specific types of interactions and student engagement (Olitsky, 2007). Olitsky argued that some classroom structures were more conducive than others to the development of successful interaction rituals (IRs) supporting our sense of the role of gas laws demonstrations in the development of a ritual chain. Olitsky accepted that while science objects or experiences might not be thought of as exciting as sporting or religious events it was possible for science ideas, symbols, objects, and language to become invested with emotional energy through successful interactions to become the equivalent of "sacred objects." She argued:

> Students may not consider these symbols or cognitions to be "sacred objects," yet successful IRs in science classrooms may still foster group membership surrounding them. Whether students "talk science" is therefore related to whether they are drawn emotionally to re-invoking membership in the associated membership group, which is contingent upon past IRs surrounding science in classrooms and in other settings. (Olitsky, p. 36)

Olitsky's analysis supported our argument that science demonstrations could foster the emergence of sacred objects drawing students to trains of interactions in which the demonstrations were the focal point. Using Collins' categories of ingredients needed to establish rituals, we examined transcripts of the interactions associated with the presentation of the three demonstrations. The identification of ritual ingredients was the necessary first step for the formation of ritual outcomes including sacred objects and positive emotional energy. Our analysis was also guided by Tobin's (2005) analysis in which he argued that head nodding, humor, eye contact, body orientation, overlapping speech, and the completion of each other's sentences were behaviors associated with synchrony that supported the emergence of positive emotional and evidence of student engagement. While acknowledging the cultural nature of some of these behaviors, our classroom experience indicated the veracity of Tobin's general argument. Consequently, with respect to the interactions associated with the gas laws demonstrations, we looked for these behaviors as evidence of engagement. These gas laws demonstrations will not "work" unless the students and the Tracey are engaged in the task of renewing the context of the interaction chain associated with each demonstration. If an interaction or the series of interactions does not seem to be achieving academic goals, Tracey has a pedagogical responsibility for refocusing the ongoing interactions needed to assist the generation of positive emotional energy. Otherwise Tracey would have recognized the interactions were not effective and would have moved to another pedagogical strategy.

SCIENCE DEMONSTRATIONS AND LEARNING

In many science classrooms, especially chemistry classrooms, science demonstrations are popular instructional strategies. Historically science demonstrations have been understood as a method, usually initiated by a teacher, for presenting and focusing student attention on natural phenomena for the purposes of stimulating inquiry on an application of a principle or as a visual aid to add reality to a concept (Eccles, 1963). A demonstration usually consists of a teacher or student doing an activity with the rest of the class observing what happens. Sometimes the demonstration is of a discrepant event such as adding 50 ml of water to 50 ml of alcohol and getting a total volume of 97 ml rather than the 100 ml that students expect. Sometimes the demonstration involves the use of expensive equipment that needs careful attention, such as a vacuum pump, or involves the use of potentially dangerous materials, such as the reaction between potassium permanganate and glycerol. Most descriptions of science demonstrations focus on technical aspects of implementing a specific science demonstration rather than on their more general role as an educational structure.

Certainly, science demonstrations were not a major feature of Tracey Otieno's chemistry pedagogy when we began an ethnographic study of Tracey's chemistry classes. Our desire was to examine classroom interactions and then explain what we observed using theory from sociology of emotions. In interactions, humans mutually constitute each other so that it is only by observing interactions that we can identify outcomes for each participant. Our decision to examine the relationship between science demonstrations and subsequent interactions involving the demonstrations, the students, and the teacher was based on our observations of the enacted science demonstrations, our discussions following the enacting of the science demonstrations, and our ability, through the use of videotape, to look back at past interactions. We were left two overarching questions: Why did science demonstrations have such catalytic effects on classroom interactions and the engagement and learning of students? What specific features of the enactment of these science demonstrations served to establish an environment in which it was "all right" for the students of Tracey's classes to be engaged in understanding the science of these demonstrations? A subquestion that emerged as we considered these questions was the question of what we understood by "engagement" in terms of practice and emotion and what might constitute evidence of engagement in classroom interactions. These questions framed our analysis of the interactions that were part of the shared experience of the classroom.

Understanding Demonstrations

A search of the literature on science demonstrations indicates that many of the previously published papers were technical rather than research based, designed to describe how teachers might construct specific demonstrations. These papers were of limited use as we sought to learn how studies of science demonstrations had informed research of student learning. Of the available research papers, many used science demonstrations as tools for examining learners' understanding of specific science content rather than making the structure or purpose of science demonstrations the focus of the research. For example, Champagne, Klopfer, and Anderson (1980) used the strategy "demonstrate, observe, explain (DOE)" to assess students' understanding of classical mechanics and "predict-observe-explain (POE)" strategies that commonly begin with a demonstration are used to examine students' understandings of specific science concepts.

A small number of studies involving science demonstrations have examined their effect on specific behaviors and ways of knowing, such as increased pupil attention and task involvement (Beasley, 1982); encouraging inclusivity (Buncick, Betts, & Horgan, 2001); developing conceptual and critical thinking (Bowen & Phelps, 1997); writing predictions, observations, and explanations (Shepardson, Moje, & Kennard-McClelland, 1994); and engendering better performance on tests (Chia, 1995). At least three of the nine studies that evaluated the relationship between science learning and science demonstrations either argued that science demonstrations needed a specific structure if they were to achieve the outcomes identified (e.g., Shepardson et al., 1994) or were critical of the pedagogy of science demonstrations (e.g., Roth, McRobbie, Lucas, & Boutonné, 1997). Researchers have been critical of demonstrations arguing that demonstrations were not "hands on" and limited student inquiry (e.g., Lynch & Zenchak, 2002) or because the instructor used complex equipment and the demonstrations were so poorly integrated into the overall purpose of the course that, rather than assisting student learning, they became a hindrance to learning (Roth et al., 1997).

Observing unsuccessful physics demonstrations, Roth and his colleagues (1997) argued that successful demonstrations depended very much on the extant knowledge of the observer. Very often students do not have the prior experience, or a demonstration is so far removed from their prior experiences, that students do not "see" what the demonstration is supposed to show. Their analysis aligns very well with Roth's (2005) classification system of *gazing* versus *observing* versus *seeing as*. Similar to what we do everyday as we walk through city streets, when students *gaze* at a science demonstration they are not engaged in a structuring activity and they are not creating patterns or forming categories. *Observing* is a more conscious process and involves students in active structuring of the world into objects characterized by specific properties. Observing involves students relating current experience to previous experiences and using new language to make connections between the two. *Seeing as* involves students in constructing an observed event such as a science demonstration, as indicative of a specific model or theory and therefore part of a culturally shared world. In science education, this culturally shared world consists of the capacity to identify variables that need to be attended to and those that can be ignored, that is, being able to separate the message from the noise (Roth & Lucas, 1997). This is a highly advanced capacity more likely to be observed with participants who have deep experience of science but a capacity that students might be expected to develop as they learn science. Roth's categorization helped us to understand that a purpose of science demonstrations was to provide a materially uncomplicated *structure*, identified by Skinner and Belmont (1993) as central to supporting student engagement, in which students could begin to move from gazers to observers and possibly seers.

Science Demonstrations As Interactions

In order to understand the structure of interactions in science demonstrations, we needed to understand more about the face-to-face behaviors associated with organizing, establishing, and maintaining conversations. Science demonstrations are examples of *focused interactions* (Goffman, 1963) that occur "whenever two or more people explicitly acknowledge a jointly maintained focus of attention" (Kendon, 1973, p. 33). A collection of individuals engaged in a focused interaction is called a *focused gathering* (Kendon, 1973). Visible behaviors, those that someone else can see, such as posture, bodily movements, and gestures/facial expressions, assist people to create and maintain positions where they can say something and are indicative of engagement. The features of a focused interaction include organization of time and space. Some focused interactions such as those associated with institutions also possess characteristics of institutional talk (Drew & Heritage, 1992). Usually such interactions begin with an opening gambit (e.g., "Good morning") and are located in a physical space such as a classroom. In a focused gathering, participants are a narrow distance range from one another and orient their bodies in relation to each other so that head rotation of less than 90 degrees to facing is possible (Kendon, 1973). The arrangement of participants in the interaction space also communicates the participation rights of members. For example, a circular arrangement helps to communicate equal opportunity for participation whereas at the other end of the continuum a triangular structure with one person at the apex, commonly seen in classrooms, communicates the right of sustained speech to that person while those parallel to the triangle's base have the right to listen. In classrooms, because of the distances between participants, talk and gross movement are the forms of communication most readily available to those present and at these distances language patterns tend to become more formal (Hall, 1966).

When participants in a focused gathering are oriented parallel to one another, the interaction is sustained between each individual and some common focus. In the case of science demonstrations, the demonstration itself provides the common focus for the interaction. According to Kendon (1990), body positioning is more important for communicating engagement than eye gaze because it requires more effort to align the body and it is more likely for eyes and head to shift because they are highly mobile. It is common for people in focused gatherings to show similarity of posture. Interactional synchrony between participants associated with matching movements at the beginning and end of an interaction constitutes "attention signals." McHoul (1978, 1990) combined Kendon's analytical framework with aspects of conversation analysis to conduct an early analysis of the structure of formal talk in classrooms especially with respect to turn taking in conversation, that is, how are decisions made about who should talk (Sacks, Schegloff, & Jefferson, 1974). He argued that there were major differences between classroom talk and natural conversation that were based on the differential participation rights and obligations of teachers and students. These studies indicated the value of conversation and nonverbal behavior analysis for revealing behaviors indicative of engagement during interactions associated with the gas laws demonstrations.

RESEARCH METHOD

In order to understand the relationship between student engagement and science demonstrations, we needed to examine the phenomenon of "talk-in-interaction" (Schegloff, 1987a). This type of conversation analysis takes as its focus the enactment of interactions and by its very focus supports a highly empirical approach to research. Ordinary conversation, the primordial site of social life, is considered to be the wild type, and focused interactions associated with classrooms and science demonstrations are considered to be transformations of this type (Sacks et al., 1974). Traditionally, conversation analysis uses "fragments of talk (or other conduct) which instantiate the phenomenon and its variants, or which exemplify the range of phenomena composing the domain. A *set of fragments,* then, to explicate a single phenomenon or a single domain of phenomena" (Schegloff, 1987a, p. 101).

Thus, vignettes of classroom conversation constitute fragments of phenomena and provide a rationale for examinations of the institutional conversation associated with teaching and learning in classroom settings to look for evidence of positive emotional energy. Conversation analysis provided a framework that allowed us to examine how social order was produced with the use of science demonstrations. Conversation analysis is underpinned by three basic ideas:

1. Interaction is structurally organized.
2. Contributions of interaction are both context shaped and context renewing.
3. These two properties of conversations mean that no order of detail in a conversation can be dismissed from the analysis as accidental or irrelevant (Heritage & Greatbatch, 1991).

However, as Levinson (1992) acknowledges institutional talk and everyday talk are different:

1. Institutional talk is goal oriented in institutionally relevant ways.
2. Institutional interaction may possess specific constraints on what one or more of the participants might treat as allowable contributions.
3. Institutional talk is associated with *inferential frameworks* and procedures that are particular to specific institutional contexts.

As we mentioned earlier, institutional interactions also differ in form from everyday conversations because the patterns of turn taking tend to be different resulting also in a reduction of the allowable range of actions.

A classroom is an obvious example of a context, where a teacher controls the patterns of turn taking associated with classroom interactions. However, our interest was in using some of the strategies of conversation analysis to see if we could identify actions and talk that could be considered to be indicative of positive emotional energy and student engagement. Schegloff (1987b) acknowledges that conversation, which is a group action involving talkers and listeners, depends as much on context as it does on the people who are present. This has implications for understanding the role of the gas law demonstrations in the emergence of student engagement because context is not transparent and "science demonstration" does not transparently communicate the structure of the context or how that context affects what is said and done. Even though a classroom is a multiperson situation, it consists of a two-party speech exchange system consisting of the teacher as one part and the students as the other. Traditionally, teacher and students alternate turns that constitute particular types of utterances or actions, such as questioning, usually the teacher, and answering, usually the students. This interaction is directional, and sometimes the teacher uses devices such as hand raising to determine who should talk and the duration of the answer as the teacher also makes an assessment about when the answer is complete.

Collins (2004) argues that successful conversational turn taking can support deeply synchronized social interaction generating collective effervescence and solidarity. Such talk is characterized by no gaps or overlaps, no embarrassing pauses, and minimal struggle about who gets the floor to speak. Successful tempos are coordinated to tenths of a second, and pauses of more than 1.5 seconds signal a breakdown in solidarity. Of course, not all conversations are successful but sites where rhythm and synchrony break down can provide useful information for understanding the role of emotions in interactions. Head nodding, eye blinking, body movements, and voice characteristics such as pitch register, and range, loudness, tempo, and duration of syllables can all be indicative of synchrony and solidarity (Collins, 2004). In high-solidarity interactions, gaps in turn taking are less than 0.1 of a second (Collins, 2004). However, for solidarity and positive emotion to last, it must be stored in symbols that allow students to recall events and experiences that are positive. Collins argues for a continuum from crowds that are focused by acting as an audience, much like the students in a science demonstration context, where "the momentary sense of solidarity may become quite strong" (2004, p. 82) and where symbols can prolong the sense of experience, to individualized encounters where personal ties are generated and there is a momentary sense of intersubjectivity: each participant understands other's behavior and assumes the others understand her (Turner, 2002).

A somewhat higher level of solidarity becomes possible in crowds that are focused by acting as an audience, as they do in a science demonstration, and where the teacher and students become involved in a collective action and goals associated with the demonstration. Importantly, because students and teacher are working on a common activity, in this case using gas laws demonstrations to understand about gases, they experience each other as others, influencing them, and in turn being influenced by them. Expressions, such as “huh?” and “what?,” alert people that there has been a breach in the conversation. These differences need to be considered when trying to make sense of institutional talk.

Research Questions

The research was not initiated by a priori research questions. Instead, questions emerged from our initial observations. The generation of data was an active process focusing on sites of interaction especially the science demonstration and discursive interactions before and after each demonstration was enacted. Data were generated from multiple perspectives that provided warrants for our assertions made in relation to the initial questions about science demonstrations. Peer review and member checking were used to ensure that both the researchers and the researched had a voice in the generation of data from vignettes and other data sources and in the claims we made about engagement and science demonstrations. This study emerged from the deep engagement of all researchers in the class. By studying the use of demonstrations, we were able to gain a better understanding of the nature of engagement, the interaction between science demonstrations and student engagement and between engagement and learning. Studying the interactions within these chemistry classes provided the data we needed to identify the role of demonstrations in the learning of chemistry and to propose a model for the use of science demonstrations in science classrooms that we believe supports the generation of positive emotional energy, student engagement, and the building of community. In the search for explanatory frameworks, we were drawn to sociology of emotions and interaction ritual theory (Collins, 2004) that helped us to understand engagement in terms of the degree to which science demonstrations became a central resource for the development of successful rituals that sustained engagement to other fields.

Making Transcripts

Since the conversation and actions associated with the enactment of the science demonstrations is important to our study, we used some of the conventions for transcribing vignettes. Transcription represents the graphic visualization of selected aspects of the behavior of individuals engaged in a conversation (Kowal & O’Connel, 2004). Thus transcripts are selective reconstructions of what occurred in the classroom. We used primary data from videotape of classroom interactions to produce the transcripts presented for analysis. We tended to use literary transcription, where deviations from Standard English are taken into account but, where relevant, tried to represent colloquial language in terms of sound. Prosodic features, such as pauses, emphasis, intonation, lengthening and volume, were included.

04 Tracey: *In* science class
[when we are not sure about something what do we do?
05 Jason: [°Experiment°.
06 Sm: =Experiment
07 Tracey: Experiment. Right. ((Tracey points to Jason acknowledging his answer))
08 Tracey: So *Sherez* (0.4) do you want to come up and do this demo?

The other conventions we used for transcribing include the following:

[	indicates the site of simultaneous or overlapping speech
()	indicate a pause of less than 0.1 of a second (0.4) indicate longer pause, in this case four-tenths of a second long
:	indicates that the sound is prolonged
=	signals latching conversation where as soon as one person stops talking the next one starts
(())	signal an action that has relevance to the talk that is taking place
In	indicates emphasis
○	indicates a word that was said more quietly than the rest of the conversation

Research Contexts

Southeast High was built as a middle school in 1909 but had been a high school since the early 1990s. It was an imposing structure rising five stories high and dominating the surrounding row homes and small businesses. Perhaps the age of the building helped to explain the lack of electrical power outlets in the classroom. The classroom consisted of a demonstration bench with water but no gas and a mix of tables—six rectangular and two round—scattered around the room at which students worked in groups. Although we collected data from two chemistry classes, the major focus of our interest was the period 5 chemistry class because the class size was larger. Each class was scheduled for one 50-minute lesson per day. The students in Tracey's classes came from a diverse range of racial, ethnic, and socioeconomic backgrounds reflecting the diversity of the school population with significant proportions of African American (almost 50%), Caucasian American (about 20%), and Asian American (about 25%) students. Scheduling resulted in more male than female students in the period 5 chemistry class.

The Teaching and Learning Context. Our experience with students in Tracey's chemistry classes was that they came to high school chemistry with very variable extant stocks of knowledge that had implications for the sense of chemistry that students were able to construct from their chemical experiences in her classroom. Prior to the use of the gas laws demonstrations, students interpreted their involvement based on their norms of what it meant to be a student acting variably by completing set tasks and answering questions or not. In each class, a number of students, such as Jason and Qoran, high-achieving African American students, were very active in class tasks, a majority such as Sherez, an African American female student, Tanya, a White student, and Lionel, an African American male student, completed minimum course requirements without demonstrating a high level of engagement, and a few, such as Markist, an African American male student explicitly refused to participate seeing little relevance for chemistry in his lifeworld.

As other researchers have demonstrated (Tobin, 2006), much teaching practice in urban schools is associated with maintaining control and often students like Markist see science as irrelevant to their lifeworlds. Tobin argues that when the teacher and students come from different racial and socioeconomic backgrounds, as was the case with Tracey and many of her students, there is potential for miscommunication and issues of disrespect to emerge. In Tobin's (2006) examination of the interactions between Alex, a chemistry teacher, and his students' positive emotional energy and a positive learning environment were associated with pace, energy, and rhythm initiated by Alex and supported by the actions of the students as they responded. However, that was not Tracey's way of being in the classroom. As a

White middle class teacher with a very different trajectory to many of the students she taught, Tracey believed that if she tried to behave differently with a high-energy style students would interpret her as acting "fake" and she would "come across" to the students as insincere and the students would feel disrespected as a result. Those reflections led her to use pedagogical interventions that she hoped would make chemistry more interesting and relevant to her students. Tracey often expressed concerns about the learning of the students who arrived from middle school with very variable science experiences and what she could do to make a difference to their chemistry learning.

Structuring the Investigation

When this study began, Tracey was in her fourth year of teaching. Catherine visited Tracey's two chemistry classes three times a week for an academic year. Our goal was to work as participant-observers to describe what happened in the chemistry classes and to make interpretations of our observations based on the sociocultural lens that we brought to the study. The initial 2-week period of the gas laws unit presented the richest resources for this study, but our prior experiences with these students provided a context against which we compared student responses to these science demonstrations. Videotape and cogenerative dialogues provided the richest sources of data, but we also used participant observations, interviews, responsive writing, reflective journals, and other research papers as data sources. As we examined videotape and field notes, we looked for salient patterns in the interactions.

We met regularly after class to review the videotapes of classes selecting sections of tape for more careful examination. Videotape allowed us to follow specific interactions and associated practices, and these data formed the basis of our assertions. The collected evidence provided opportunities to examine "taken-for-granted" aspects of demonstrations and led us to a greater appreciation for the impact of demonstrations on a range of classroom contexts. The patterns we observed formed the basis for changing some of the teaching and learning structures in this classroom and led us to propose a model for science demonstrations that has the potential to mediate the way teachers use science demonstrations as sources of stocks of knowledge especially in contexts where students' prior experiences of science have been variable or rare.

In order to present different levels of analysis, we used a number of tools including iMovie that allowed us to make vignettes needed for the initial analysis of emotion and cognition in interactions associated with the gas laws demonstrations and PRAAT, a voice analysis program, that allowed us, at the level of microanalysis, to examine conversation for features of ritual production including speech cues and overlapping speech.

Gas Laws Science Demonstrations

The three demonstrations that Tracey used are familiar to many science teachers. As we collaboratively reviewed videotapes of a number of chemistry lessons, Jason, the student-researcher who worked with us on the project, selected a specific demonstration as a site of chemistry learning for him. He referred to the demonstration as "the can crushing demonstration," and we adopted this name. For simplicity, the other science demonstrations that were our focus for this study have been named, "the inverted cup demonstration" and the "the egg in a flask demonstration." The demonstrations, described below, are sequenced in the order in which they were presented to the chemistry classes.

Inverted Cup Demonstration. The purpose of this demonstration was to illustrate that gases are made up of particles that occupy space. Tracey began this demonstration by asking the students to predict what would happen to a piece of crumpled paper that was pushed to the bottom of a plastic cup when the cup was inverted in a large container of water. In the process of asking students to make this prediction, she crumpled the paper and pushed it to the bottom of the cup in full view of the students. Students could see the paper was wedged in the base of the cup and could not fall out under the effect of gravity. Tracey then vertically inverted the cup containing the paper and pushed it under the water in a large container.

Consistent with the protocol, students were expected to complete a worksheet containing the following questions: What happened to the paper inside the cup? Can two things take up the same space? What would happen if there was a hole in the cup?

Crushing Can Demonstration. The can crushing demonstration required an empty soda can with a small quantity of water in it. The can was heated until steam could be seen escaping from the can, and then it was inverted into a tray of ice-cold water. Inverting the can in the water prevented gas from re-entering the can and the temperature of the ice-cold water caused the remaining water vapor molecules inside the can to condense into liquid water resulting in a lowering of pressure inside relative to the atmospheric pressure surrounding the can so that it spectacularly collapses. This demonstration was used to illustrate physical properties of gases and the kinetic molecular theory of gases.

Egg in a Flask Demonstration. Students were asked to suggest how it might be possible to get a hard-boiled egg into a large 1-liter Erlenmeyer flask without cutting up the egg. Tracey used a lighted paper taper to heat the air inside the flask and then placed the egg over the neck of the flask. The egg slowly moved down the neck of the flask into the body of the flask. This demonstration was used to reinforce the relationship between temperature, volume, and internal and external pressure.

RESULTS: IDENTIFYING ENGAGEMENT IN THE STRUCTURE OF A GAS LAWS DEMONSTRATION

For this analysis, we selected vignettes associated with the inverted cup demonstration because this allowed us to provide a temporal record of interactions beginning with the setting up of the first demonstration conducted by a student, Sherez. Our decision to focus more specifically on one of the demonstrations was associated with our desire to provide evidence of the emergence of shared mood and attention associated with the chronology of the inverted cup demonstration and the ensuing interactions but, where appropriate, this will be supplemented with data from the other gas laws demonstrations. All the transcripts presented use transcription conventions (see earlier section) and are presented in moves consistent with Goffman's (1976) description of a move as "a distinctive unitary bearing on some set or other of the circumstances in which participants find themselves (p. 272).

The Role of Context in Developing Conversations and Student Involvement

Tracey conducted the first "inverted cup" demonstration. She began by walking around the classroom showing students the cup with paper toweling pushed to the bottom and asking them to touch the paper to confirm that it was dry. She repeated this action with the class once she had completed the initial "inverted cup" demonstration encouraging students to touch the paper and confirm that it had remained dry. She then asked students what would happen if the bottom of the cup had a hole in it.

01 Tracey: We asked the question about (0.6) um (0.2) if there's a *hole* in the bottom of the cupwhat's going to happen? (1.0) ((Holds up plastic cup, which has been used for the previous demonstration. Students are looking at Tracey except for Fiona, a white student, looking down at work on the desk.))
02 Tracey: [This is a science class
03 Ss: [See bubbles coming up. (0.3)
04 Tracey: In science class [when we are not sure about something what do we do?
05 Jason: [° Experiment° .
06 Sm: =Experiment
07 Tracey: Experiment. Right. ((Tracey points to Jason acknowledging his answer))
08 Tracey: So *Sherez*(0.4) do you want to come up and do this demo? ((Students look towards Sherez who is at the back of the classroom. Sheraz moves towards the demonstration bench. She plays with her gum as she reaches the bench. It takes her 6.1s to reach the bench. As Sherez makes her way to front snatches of student conversation can be heard including ''air bubbles''))
09 Sm: Look for air bubbles.
10 Tracey: Ok. S::::o I don't know if you can see this but there's a little hole in the bottom of the cup. ((Holds up cup even higher with base facing towards students and points to the bottom of the cup.)) (3.0)
11 ((Tracey hands the cup to Sherez who looks at the bottom.))

This introductory vignette provides a preface to the structure of the interactions that are associated with the use of the gas law demonstrations. Tracey's first statement, move 01, contains a filled pause containing the nonverbal expression, "um," sandwiched between two unfilled silent pauses. As a macrostructure, these pauses communicate Tracey's signal that she wants to "hold the floor" and that any other conversations should cease (Stenström, 1990). At a microlevel, these pauses, especially the filled pause, provide evidence of Tracey's search for the specific words she wants to use while concurrently providing a resource for students sensitizing them to the likelihood of important linguistic information in Tracey's following statement and to a change of focus in the interaction to a cup with a hole in the bottom rather than one without. Students enact their agency based on their goals by either accepting this offer and listening to her statement or persisting in other actions.

The square brackets signal sites of overlapping speech that illustrate both synchrony and asynchrony in the initial interactions. An example of asynchrony occurs at move 03 as students respond to the question Tracey presented in move 01. However, by move 02, Tracey had already moved on to articulate a norm that she was to emphasize throughout these gas laws interactions: the importance of experimentation for differentiating between competing hypotheses. By moves 04, 05, and 06, Jason and one other student use overlapping speech to respond with "experiment" to Tracey's question of what one did in science when one was not sure about something indicating a level of synchrony has been achieved in the interaction.

When we discussed this interaction later, Tracey admitted that even though her use of pauses served to help her plan the interaction and decide which words she would give greater intensity, such as "hole" in move 01, she was not conscious of doing this until we began a microanalysis of these interactions. Her use of intensity and pausing served as a resource for students assisting them to understand the aspects of the context in which they should focus including "hole" and "cup." Emotionally, these linguistic cues served to introduce the focus of the interactions and cognitively they assisted students to recognize the significance of the hole in the cup to understanding this area of chemistry. Even this early vignette, focused as it is on the inverted cup demonstration, communicates the importance of the context of the demonstration for ongoing classroom conversation and indicates that it is procedurally consequential to the talk (Schelgoff, 1992). As the demonstration becomes a resource for conversation, participants are reminded of the importance of observing the demonstration if they wish to be involved in ongoing conversations.

For this second demonstration in the "inverted cup" sequence, in move 08 Tracey asked Sherez if she was interested in conducting a demonstration, choosing her because she was part of a group that commonly was not very involved in class activities. Although framed as a question, there was an expectation that Sherez would agree to her request but the question structure provided space for both Sherez and Tracey to enact their agency without the other necessarily losing face and introducing negative emotional energy into the interaction. Applying Collins' (2004) description of agency by her actions of standing and beginning to move to the front of the room, Sherez brought a positive energy to the interaction that was available to her peers indicating that it was appropriate to be involved and that some of her goals for chemistry were aligned with Tracey's goals. Nevertheless, Sherez needed 6.1 seconds to walk to the front of the class and the demonstration bench where all the demonstrations were conducted. You might expect that during the time Sherez took to walk to the demonstration bench students would lose focus, but examination of eye gazes and body movements in the vignette shows students following her movement as she stands to come to the front and then readjusting their focus to Tracey as she uses the time as a resource to emphasize to the rest of the class that there is a hole in the bottom of the cup. It could be argued that Sherez's walk to the demonstration bench actually contributes to entraining other students to the actions associated with the inverted cup demonstration.

11 Tracey: *We* 'll give (0.8) we'll give (0.2) Sherez a piece of paper. ((Sherez is still looking at the bottom of the cup.))
12 Tracey: She can stuff the paper inside the cup. ((Tracey moves to the side.)) (2.5)
13 Tracey: ((To Sherez)) You can stuff (0.2) the paper into the bottom of the cup. ((Tracey hands the paper and cup to Sheraz who proceeds to stuff the paper in the cup.))
14 Lionel: I can't see anything.

15 Tracey: Move round this side Sheraz so they can see.
((Sherez moves to the side of the equipment.))
16 Tracey: Ok? (0.4) Is everybody close enough so they can
see?
17 Ss: ((As Sherez begins to push the inverted cup
under the water)) *Yo!*
18 Tracey: Ok, (.) everybody's got a view?
19 Ss: *Yoh!*
20 Sm/f: Bubbles coming off!

Tracey's use of the repetition, "we'll give," in move 11 serves a dual purpose as a bid for focus from the students and as a signal to students of a change in the direction of the interaction, from establishing the conditions for the demonstration to Sherez's setting up of the demonstration. Note that Tracey uses Lionel's comment in move 14 as a pedagogical resource emphasizing the importance of observation at this stage and reinforces this importance by asking Sherez to move so that students can see the demonstration. The norm embedded in this set of interactions is that observing is important at this stage of the demonstration. Lionel's comment is also available to the students who are copresent helping to support their focus on the demonstration and possibly signaling both emotional value, "I want to see what happens" and cognitive value, "observing this demonstration will assist my understanding." Tracey uses "ok" in moves 16 and 18 not to signal that a situation is satisfactory but that something significant is about to take place that students should be able to observe because of its potential as a resource for them. Schleef (2004) has shown that in the college setting female natural science instructors commonly use "okay" as a transition and/or a progression check question marker especially in lectures although men tended to use it more as a progression marker than women did. Progression checks are used by the powerful to maintain the power dynamic in the classroom because they are used to check that students are following the presentation of information but there is no expectation that students will respond verbally. Tracey mainly uses okay as a transition marker in her interactions with the students suggesting her desire for more symmetrical classroom interactions, where students have the capacity to enact their agency if their goals align with her academic goals. Students confirm their focus in moves 17 and 19 by exclaiming "Yoh!" a comment which becomes a resource for the rest of the class to communicate an acknowledgement that they have observed something of significance as air bubbles rise from the hole in the cup that others should have noted also and a sense of satisfaction at the observation they have just made.

Building Mutual Focus and Shared Mood

These series of interactions contain the steps necessary for building mutual focus on the demonstration, an ingredient necessary for the establishment of ritual in interactions associated with the demonstrations. The intensity of the focus might be different for different students, but overall the level of engagement stands in stark contrast to the classroom interactions that we had come to expect from students in these classes. Structurally these interactions afforded students' access to resources associated with observations of gas behavior. Questions and responses associated with being able to observe the demonstration created a structure that constituted a step toward establishing bodily copresence in which students' sense of their mutual participation was heightened by their increasing awareness of each other's consciousness. The establishment of bodily copresence creates a barrier to outsiders and a sense of belonging to the group and was initiated by a focus on the demonstrations conducted by Sherez, a condition necessary for the establishment of interaction ritual chains associated with positive emotional energy (Collins, 2004). In later gas laws demonstrations, such as the can crushing demonstration, having students gather around the demonstration bench provided a more obvious structure for group assembly and for establishing mutual focus and shared mood.

Once the demonstration of the inverted cup with hole in the bottom was completed, Tracey asked students what they had observed during the demonstration.

32 Tracey: Ok, ok, so *what* so what happened? (1.0) What
did you see coming off the top?
33 Sfs: =Air bubbles.
34 Ss: =Air bubbles
35 Tracey: Right. Anna and Tanya saw air bubbles. (1.5)
Shhh! ((There are a number of conversations
going on around the room as groups discuss what
they saw)) (0.8)
36 Tracey: What's that? ((A student at the back of the
room has made a comment.))
37 Sf: ((Repeating her inaudible observation.)) The
air's got a place to go so it doesn't stay in
the cup.
38 Tracey: =Ok, the air's got a place to go it doesn't
stay in the cup *so* that means (0.6) *what* can get
into the cup?
39 Ss: ((In unison))=Water. (1.3)
40 Tracey: *Water*, (0.6) right. So the water (0.8) gets in
to the cup as the air escapes. (0.6) *So* what
was it that prevented the (1.5) Shhh!!
41 Sf: Air.
42 Tracey: Yolanda said air. Air prevented the water (2s)
Ok, why is this happening? (3s)

Once again Tracey uses repetitions in the form of "ok, ok" to signal a transition to discussing the observations associated with the demonstration conducted by Sherez, and she reinforces this by emphasizing "what" in the same sentence. Student choruses of "air bubbles" in moves 33 and 34 happen so quickly that there is no pause between her question in move 32 and their responses providing evidence of synchrony. Tracey's use of "Shhh!" on two occasions during this interaction provides evidence of her attempts to ensure that students remain focused on the specific observations and chemistry laws that provide the rationale for these demonstrations. In each case, Tracey uses shhh as a nonlexical interjection into ongoing student conversations. As participants in this ongoing conversation, students infer the expected behaviors associated with the use of this interjection (Wharton, 2003). A video still of some students from the classroom taken during this interaction (see Figure 1) show students of different ethnicities looking toward the site of the demonstration. Their eye gaze and body orientation toward the site of the demonstration communicate their continuing engagement with the conversation that followed the demonstration (Kendon, 1973, 1990). The synchrony of these actions with latching, where one person's statement directly follows another (shown in the transcript by =), indicates chains of interactions. Together with the responses in unison, such as the shared response in move 39, they

Figure 1. Evidence of mutual focus from eye gaze and body orientation toward the demonstration and ensuing conversation. Note the apparent synchrony of eye gaze and body positioning of each person toward each other as they focus on the inverted cup demonstration. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

suggest a verve and energy in the classroom conversation that was lacking when this series of interactions began. Such synchrony in responses reinforces our argument that these interactions are supporting an emerging mutual focus and shared mood, ingredients necessary for the development of interaction ritual chains and positive emotional energy, a precursor for student engagement.

This vignette also illustrates the willingness of students to participate in the describing of phenomena associated with the demonstration and the presentation of explanations, but when Tracey asked students more generally explain these observations (see move 42) there was a pause of 3 seconds. It is difficult to assess from the transcript alone whether students interpret Tracey's comment, "Ok, why is this happening?," in move 42 as a criticism of something they are doing wrong or a question of the phenomenon they have just observed in the demonstration although student focus (see Figure 1) would suggest the latter. However, the silence of the students becomes a resource for Tracey who recognizes that students might need further resources to assist them to develop an explanation leading Tracey to restate the conditions surrounding the demonstrations so far: one cup had a hole in its base and the other did not, and the observed outcomes. She turns to Lionel in move 43 to invite him to describe his observations. Lionel nods his head to communicate to others, including Tracey, that he is following her description and is willing to provide a specific observation, which he does with the statement, "Bubbles come out."

43 Tracey: Ok, (0.7) S:::o let's go back (1.2s) When we didn't have a hole in the cup there's air in the cup ((Raises the cup)) (0.3) we submerge it ((Tracey mimes repeating the demonstration as though she is pushing the inverted cup under the water and looks at Lionel who has been commenting)) (1.0) and what *happens*? The paper towel stays dry. (1.7) Ok? (0.6) Once we have the hole (2s) Once we have the hole, what happens?

44 Tracey: Lionel you saw it. ((Tracey points to Lionel sitting at the front of the room)) (0.4) You were close right? You saw it? (1.0)

45 Lionel: Bubbles came out. (0.1)

46 Tracey: Bubbles came out (1.2) ((Lionel nods as Tracey runs through the observations pointing towards Lionel while facing the class)) the air escapes from the cup (0.9) and the paper towel got wet. (1.3)

47 Daniel: *We* never knew if it wasn’t wet or was. (1.4)

By presenting an observation and nodding when Tracey repeated his observation, Lionel confirmed his willingness to be involved in maintaining an interaction. At the same time, Lionel’s comment becomes a resource for the other students in the class. In response, Daniel, an African American student sitting near Lionel, challenges Tracey’s final comment that the paper towel was wet when the cup had a hole in it. This challenge becomes a further resource for structuring the interactions in the classroom because rather than responding negatively Tracey responds in a way that signals to the rest of the class the value of Daniel’s challenge: first by asking Sherez who confirms that the paper was not wet when she began the demonstration and then by inviting students to vote on two hypotheses whether the water came through the hole at the top of the cup or came in underneath the cup. First, students vote for one of the hypotheses by raising their hands and a count is taken and then Tracey asks the class how it might be possible to identify which hypothesis is supported. Voting constituted another strategy for establishing bodily copresence within the group. By the raising of their hands to vote on either of the hypotheses, these Grade 10 students signaled their copresence and willingness to continue to participate in the interactions and create a resource, vote counts, that assisted the ongoing development of interactions associated with the inverted cup demonstration. In so doing, they also reaffirmed their solidarity with other participants in these interactions. Qoran’s suggestion that it might be helpful for observing the outcome of the demonstration if the water was colored and Tracey’s support for his suggestion and search for a viable method of achieving this indicated their mutual focus and the positive character of the interaction maintained a positive shared mood.

76 Tracey: Pardon?

77 Qoran: If you color the water or something like that if you get a plastic see through cover or something like that you can see how the water comes in

78 Tracey: =Right. If we got a plastic see through cover. I like your idea of coloring the water so we might be able to see a little better. Let me see if I have something. Let’s see if I have some food coloring ((Adds grape Koolaid and then looks for a stirrer)) (2.0)

79 S: Yard stick. ((Tracey picks up the yard stick and proceeds to use it to stir the Koolaid)) (0.3)

80 S: O::::u! A ruler!

81 Lionel: =That’s so ghetto

82 ((Sheraz, moving much more quickly (1.5) than when she previously came to the front of the room to do the first demonstration, comes to the bench to repeat the demonstration with colored water and engages in some play displacing Lionel who was keen to do the demonstration. Lionel who gives in with a smile.))
83 Tracey: Ok, so what do you see?
84 Randell: =Take the paper out of the inside of the cup or we won’t be able to see.
85 Tracey: =Oh, ok. Good enough. Yeah, we’ve already established *that* so now we just need to take a look at which direction the water comes in.
86 Tracey: See if we can see this.
87 ((Sherez repeats the demonstration now with the water colored)) (3.0)
88 Students: (In unison) The bottom!!
89 Tracey: Did you see that?
90 Students: The bottom! The bottom! (5s)
91 Lionel: Man, was I wrong.

In this final demonstration sequence, Sherez’s quick movement to the demonstration bench, four times faster than the first time she conducted a demonstration, suggested a change in the environment of the classroom so that completing the demonstration had become an enjoyable activity that others shared. Students asking people to move, moving their chairs so they had a better view, and moving their bodies so that they could see Sherez conduct the inverted cup demonstration with colored water provided evidence of synchrony between the students who were observing and Sherez who was conducting the demonstration. In the photographs (see Figure 2) note that Michelle, a White student sitting at a front table close to the door, who is obscured in the first image can be observed leaning forward so that she can see the demonstration in the second image. Her bodily movement is toward the demonstration providing evidence to the rest of the class that she is entrained with the demonstration that Sherez is conducting. Similarly, by leaning forward so that she

Figure 2. Sherez completes the third demonstration in a series of demonstrations associated with the “inverted cup” demonstration. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

can see, Tracey signals her engagement (see Figure 2). The jesting interaction in moves 80 and 81 between Lionel and another student in which Tracey's instrumental use of a ruler as a stirrer became the focus of their humor established to the rest of the class that they were following Tracey's actions as she set up the demonstration and the latching between move 80 and 81 provided evidence of their synchrony. In moves 83–91, the latching speech and conversation moves with little time lapses between are further indicators of synchrony and mutual focus (Collins, 2004).

The use of humor generated more positive emotional energy from this interaction and helped to sustain the interaction ritual beyond the initial demonstration. By this stage, students were familiar with the inverted cup demonstration and were willing to make suggestions about how the actual demonstration could be improved. Such interactions were very different from the initial inverted cup demonstration that was conducted by Tracey where students were unfamiliar with the demonstration and the goals that Tracey had for the demonstration.

Synchrony and Solidarity

These vignettes signal the importance of student and teacher collaboration for the generation of interactions in which the demonstration and associated phenomena become the focus of a chain of interactions. Through this focus, the demonstration becomes ritualized so that students develop expectations about the outcomes of each demonstration. Their expectations encouraged them to make predictions and some to comment on whether their expectations were fulfilled. Evidence of engagement included student tracking of the demonstration and the resulting conversations, challenging the format of the demonstration, and making suggestions about how a demonstration could be improved.

More than one successful demonstration helps to build emotional energy because the success of the inverted cup demonstration supports the reassembly of the group for the next conversation or demonstration associated with the gas laws. As other demonstrations are enacted, the inverted cup demonstration becomes a "cognitive device for reminding ourselves of past rituals" (Collins, 2004, p. 146). This is how demonstrations become sites for interaction ritual chains. However, if Tracey continued with more gas laws demonstrations, perhaps five or more, it is quite likely that students and she would become satiated with gas laws demonstrations and the demonstrations would have less of a positive effect and might even begin to generate negative emotional energy associated with boredom. However, for science demonstrations to be effective at helping to generate positive emotional energy, strategies for achieving bodily copresence and barriers to outsiders must take participants above a threshold for shared mood and attention.

As a site for the emergence of positive emotional energy, this study also suggests that classroom interactions need to be more symmetrical where respect for each other's claims, both student and teacher, provides resources for developing a chain of interactions. If power rituals drive classroom interactions, where the dynamic is asymmetrical in favor of the teacher, positive emotional energy and engagement are less likely to emerge. Our findings are consistent with Seiler (2005) who argued that in urban science classrooms very often positive emotional energy can be associated with a rare alignment of teacher goals (e.g., student involvement and learning) and student goals (e.g., gaining respect and studying an interesting area of science). The gas laws demonstrations provided a resource for Tracey and the students to initiate and maintain a series of interactions that could become part of successful rituals, emotionally intense and cognitively focused, in which students became involved in beginning to create or reproduce a culture of chemistry for that classroom.

Although the number of students engaged in interacting with Tracey was greater as the series of interactions associated with the inverted cup were enacted, generally African American students communicated their engagement more explicitly than White or Asian American students. For example, Jason and Lionel often acted as interaction brokers willing through actions, such as nodding and eye gaze and high-intensity speech, and humor to support both Tracey and other students so that interactions were maintained. Our results are consistent with Tobin (2005) who argued that, based on Boykin's (1986) research, within African American culture there exists a disposition for communalism, "a tendency to consider participation from the perspective of the group rather than self" (p. 53). So in classrooms where African American students make up a significant number of the classroom population, as was the case in Tracey's class, the emergent ritualization of demonstrations and the associated synchrony were necessary for constructing solidarity associated with shared goals and acceptance of different students' agency. Although the Asian American students in the class were not as vocal, through the use of actions such as eye gaze and raising of hands to signify their vote, they provided evidence of their engagement and support for the ongoing interactions. As Collins (2004) reminds us, successful interactions engender positive emotional energy for all of those who are copresent.

Pedagogically, the gas law demonstrations provided participants with opportunities to become familiar with the chemical phenomena associated with this set of demonstrations. As a resource for students, these outcomes provided students the capacity to anticipate forthcoming outcomes that served to establish a shared mood and mutual focus necessary for synchrony and the emergence of positive emotional energy. The sharing and refining of explanations initiated by Tracey as she engaged students in making a commitment for one of the hypotheses associated with the pathway of water into the cup when the cup was holed became a resource for understanding the behavior of gases. By the time, the students and Tracey participated in the third gas laws demonstration of the egg in the flask some students were finishing her sentences illustrating a level of synchrony not observed at the beginning of the gas laws unit. For example, Qoran finishes a sentence Tracey started when she says, "Once we put the egg on top we've sealed it" that he completes with, "there's no way for the egg to get out."

Tracey's use of interjections, such as *okay* and *shhh* and student use of *yoh* and in later interactions *wow,* became group resources that served to maintain an interactional flow providing an environment for the emergence of synchrony and positive emotional energy (see Figure 3). Even though these terms do not communicate propositional knowledge, they help participants to focus on the overall purpose of these demonstration-based interactions to learn about the gas laws. This indicates to us that discourse, interjections, and body movements support student engagement so that engagement is best understood as mutually constructed within interactions.

DEMONSTRATIONS AS A SHARED EXPERIENCE

We were left with the question of how science demonstrations had such a positive effect on the classroom. We noted that the gas laws demonstrations provided the class with shared experiences that students and teachers could make sense of and at a later time refer to in discussion. Tracey described it as being.

> [L]ike having watched a movie together. In lab, everyone has a similar (we hope) experience in doing the lab, but the class does not actually share the experience—and I think this makes a difference. We can all refer to the demo and not have to be too specific because we all saw it and this gives us a great starting point for learning and building scientific explanations.

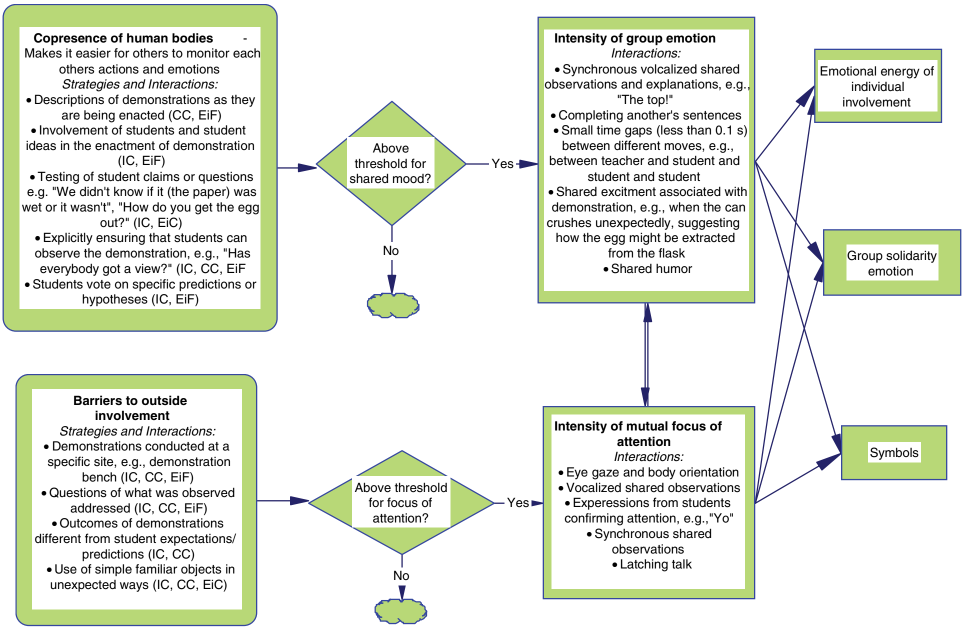


Figure 3. Interaction ritual chain and science demonstrations. Modified from Collins (2004). Note the code for specific gas law demonstrations, IC: inverted cup, CC: can crushing, EiF: egg in flask, indicates where specific strategies or interactions were observed. The positive emotional energy and symbols generated from one successful ritual provide the energy for further rituals generating an interaction ritual chain. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

With this comment, Tracey was drawing the distinction between the laboratory activities that students carried out and the gas laws demonstrations. In laboratory activities, students in small groups follow a laboratory procedure and make required observations. An implicit assumption of carrying out a laboratory activity is that each student makes the same observations and the observations mean the same to each student. Our experience of working with students reveals the invalidity of this assumption. However, with the gas laws demonstrations each student and teacher was involved in observing the same event. We recognize that what a student observes depends on what that student already knows so that each student will not make the same observations. But the demonstrations provide a basis for discussion about what happened as Tracey asked questions such as "What happened?" It is through discussion that students have the opportunity to identify shared observations and elaborate new ways of talking about gas particles based on these observations. According to Roth and Lucas (1997), these discussions become "interpretive resources" because they support students to move from gazers to observers and seers building cultural capital in the process.

Demonstrations, and the enveloping conversations, provided opportunities for teacher and students to make greater use of language and symbols associated with this area of science by providing them with a resource, their observations of each demonstration, that they could use to discuss variables associated with gases, such as volume and pressure, and make it "all right" to ask questions, propose answers, and participate in making suggestions for further tests. From this shared experience, it was possible for the members of the class to begin conversations about the observations and to develop explanations.

162 Qoran: What happened was it was hot and the **molecules** had **expanded** ((Qoran moves his fingers to show the movement of the molecules coming together)) and when you pushed it over [into the water] they sucked back together and there weren’t no air or nothin’ to go inside when they sucked back together it pulls it all in so there’s the same amount of stuff in (0.1)
163 Tracey: Right, very nice. Right that goes with//
164 Qoran: Jason ((looking to Jason further back in the room))
165 Tracey: ((Nodding in agreement)) That goes with what Jason was talking about (0.1) "matter doesn’t, (0.2) or mass doesn’t get created or destroyed. It changes form"
166 Jason: =It **transfers** into a different form.
167 Tracey: =Right it transfers into a different form (0.2) So it goes into a gas
168 Randall: =Goes from water to gas
169 Tracey: Right () from water to gas
170 Randall: =To water

In this vignette taken from the can crushing demonstration, Qoran provides an explanation for the shared observation that the hot can had collapsed inwards when it was upended in the cold water. His explanation becomes a resource for other participants as he uses both everyday and technical language in his explanation that can be heard by the class. Tracey also uses his explanation as a resource because she wants to make sure that students understand that matter is not altered when it undergoes a change of state. The latching speech and lack of pausing from moves 162 to 170 also indicates synchrony and a high-positive energy interaction.

231 Iesha: It’ll go into the bottle (0.2)
232 Tracey: Iesha what did you say?
233 Iesha: It’s going to go into the bottle because of a **vacuum** (0.2)
234 Tracey: The egg’s going to go into the bottle (0.4)
Why do you think it’ll go into the bottle?

In this vignette, Iesha, a student who rarely participated in whole class discussions prior to the introduction of the gas laws demonstrations, initiates the class discussion of predicting what will happen to the egg in the egg-in-flask demonstration with her comment, “It’s going into the bottle.” When she is asked by Tracey to repeat her claim so that it can be heard by everybody, she speaks more loudly and adds a hypothesis to her prediction. Iesha’s prediction and explanation become a resource for ongoing classroom conversation about the enactment of the egg-in-flask demonstration and development of an explanation for the phenomenon associated with the demonstration as Tracey asks all students why they think the egg will go into the flask.

In these contexts, students' sense of control over the resources available and their ability to construct observational and explanatory structures contributed to the flow of the conversation, positive emotional energy, and student engagement. In the process, students began using science language they found to be necessary to perform these practices. Thus, the use of words such as "condensed," "expanded," and "molecules" during the latter stages of the gas laws sequence illustrated their greater facility with the symbol systems of chemistry and recognition that it was possible to generate positive emotional energy from the use of such terms. However, Collins (2004) reminds us that it takes time for each participant to come to feel membership associated with these shared symbols of observation and language and to use them as a resource in further conversations, thereby reinforcing the value of multiple demonstrations associated with a specific content area.

The use that Tracey and students in the class made of these demonstrations stands in stark contrast to the study conducted by Roth et al. (1997) in which Mr. Sparks' use of complex materials, unfamiliar to students, resulted in demonstrations that were both mysterious and confusing. Using interaction ritual theory, we understand that such teacher practices can generate negative rather than positive emotional energy. Without positive emotional energy, no ritual interaction chain can emerge and therefore the outcomes for learning from demonstrations in Mr. Sparks' class would be minimal at best. In Tracey's classroom, there was a role for students in the conduct of some demonstrations and all demonstrations were constructed from simple everyday items with which students were familiar. Familiar resources afford student agency, but unfamiliar items and technical equipment truncate their agency either because students are intimidated by equipment or because they first have to learn how to use the equipment before they can attend to the science concepts that are supposed to be the focus of the demonstration. In Figure 2, note the use of everyday items for the inverted cup demonstration.

Apart from the symmetry of interactions and opportunities for shared observations associated with the conduct of the demonstrations, another factor supporting student engagement was that students had prior experience of these everyday items including plastic cups, paper stirrers, Koolaid, and hard-boiled eggs. However, in the context of the science demonstrations, not all of the items behaved the way students expected and this unexpected behavior, which was part of the shared experience of each demonstration, supported further conversation.

Neither science demonstrations nor balancing equations (see Olitsky, 2007) necessarily come to mind as activities that generate positive emotional energy, but both studies emphasize the importance of whole class interactions for establishing rituals and the importance of familiar materials for generating solidarity. We argue that the ritual interaction chains associated with the gas laws demonstrations supplied students access to chemical symbol systems and practices that previously had been denied them allowing them to achieve learning goals in an emotionally positive environment. The gas laws demonstrations provided conceptual boundaries to the language and symbol systems that were enacted thereby assisting student involvement. This suggests a role for demonstrations in the learning of science as a bounded structure of specific language and symbol systems that becomes a shared experience for all students and provides a basis for ongoing science conversation.

Using a model modified from Collins (2004), it is possible to represent the elements of the interaction ritual associated with the gas laws demonstrations in a flow chart (see Figure 3). Note where the strategies employed by Tracey as she set up the demonstrations served to establish copresence and barriers to outsiders, conditions that were necessary to establish the required threshold mentioned earlier. However, successful interactions involving students and teacher are necessary for both the establishment of the initial conditions and group emotion and mutual focus that produce the emotional energy that entrains ongoing interactions.

RITUALS, SCIENCE DEMONSTRATIONS, AND ENGAGEMENT: EMOTIONS AND INTERACTIONS IN LEARNING

A physical assembly of students who can collectively observe the demonstration and the use of familiar items for the demonstration were necessary resources for the establishment of a science demonstration as an initial shared experience. The publicly agreed observations provided a resource for questions associated with developing explanations that could be tested using further demonstrations or experiments, as happened with the inverted cup demonstration, thereby providing a series of structures that introduced specific norms about the nature of science. Interaction ritual chains and engagement served to maintain these structures, and the positive emotional energy generated supported movement to small group interaction where the emphasis was on writing instead of conversation.

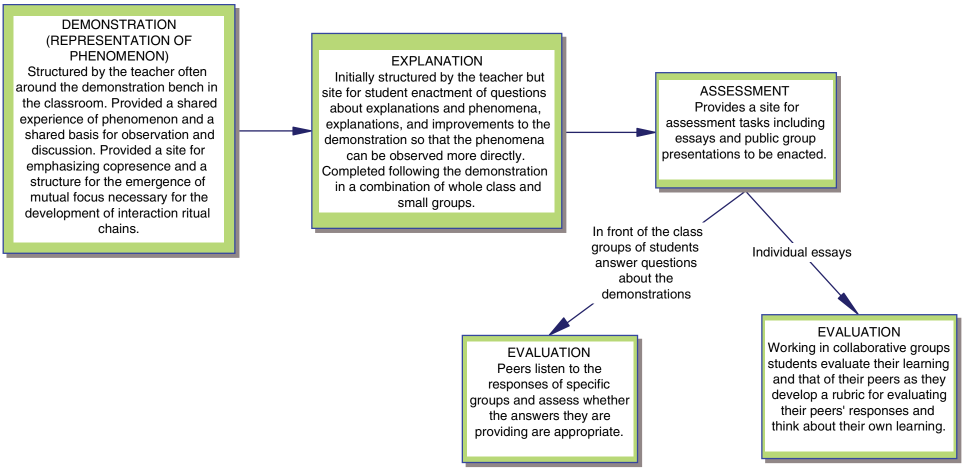
The initial demonstrations transitioned students to working in groups and then to working in assessment and evaluation, where students used practices and symbol systems appropriate to the conceptual area of gas behavior and the gas laws that was indicative of science learning. During assessment and evaluation, students created their own representations that they used to explain the behavior of the gases they observed during the demonstrations. Structuring a link to assessment reinforced for the students the value of these interactions for supporting their learning of kinetic theory and the gas laws.

As noted in the opening vignette, Catherine was surprised by the positive responses of the students to the gas laws quiz especially when all of the questions required extended written responses. Tracey estimated that on a typical chemistry test essay question, prior to this quiz, a quarter to a third of the students in her class would not attempt any extended-response question leaving the space blank. The use of the demonstrations for assessment was an idea that Tracey developed as she observed students participating in the initial demonstration and evaluated the need to develop assessment tasks that were consistent with the focus of the demonstrations and the emphasis placed on developing understanding about the kinetic theory of gases from the enactment of these demonstrations.

From the assessment task students cooperatively developed a rubric for evaluation. Using the collaboratively developed rubric, they peer evaluated responses to the assessment task and provided detailed feedback on the strengths and weaknesses of each response. Students were very positive in their responses to their learning that had ensued from this transition between demonstration, explanation, assessment, and evaluation (see Figure 4). Thus, the positive emotional energy and student engagement that emerged from the gas laws demonstrations allowed Tracey to implement new strategies in the gas laws unit including peer presentations, peer question and answer forums, development of peer rubric for quiz assessment, and peer assessment. As a result of engagement, students participated in a greater range of activities such as writing, asking questions, devising new experiments, and problem solving.

IMPLICATIONS FOR SCIENCE EDUCATION

Although this study was based on a detailed analysis of a small number of vignettes, the vignettes were presented on a continuum from the initial introduction of a science demonstration to emerging conversations that were framed by the initial inverted cup demonstration in order to provide a chronological representation of the emergence of successful interactions and their attendant positive emotional energy. As such, we draw some



DEMONSTRATION (REPRESENTATION OF PHENOMENON) Structured by the teacher often around the demonstration bench in the classroom. Provided a shared experience of phenomenon and a shared basis for observation and discussion. Provided a site for emphasizing copresence and a structure for the emergence of mutual focus necessary for the development of interaction ritual chains.

EXPLANATION Initially structured by the teacher but site for student enactment of questions about explanations and phenomena, explanations, and improvements to the demonstration so that the phenomena can be observed more directly. Completed following the demonstration in a combination of whole class and small groups.

ASSESSMENT Provides a site for assessment tasks including essays and public group presentations to be enacted.

In front of the class groups of students answer questions about the demonstrations

Individual essays

EVALUATION Peers listen to the responses of specific groups and assess whether the answers they are providing are appropriate.

EVALUATION Working in collaborative groups students evaluate their learning and that of their peers as they develop a rubric for evaluating their peers' responses and think about their own learning.

Figure 4. Maintaining the ritual, positive emotional energy, and student engagement. Assessments were developed from demonstrations. During assessment students worked individually and in small groups, and during evaluation they worked collaboratively as a whole class to develop an acceptable evaluation rubric to evaluate their learning and that of their peers. An important aspect of these sites of interaction is that they are porous so that it is possible for positive emotional energy that was generated from the gas laws demonstrations to be entrained in other activities. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

tentative general conclusions about science demonstrations and student engagement for others to consider. As a site of focused action, science demonstrations conform to the features of institutional talk including being goal focused at least for one of the participants in two-party conversations involving teacher and students. Concurrently, science demonstrations provide opportunities for teacher action that are central to student engagement including providing an initial structure that supports student autonomy and involvement in the establishment of successful interactions (Skinner & Belmont, 1993). In so doing, science demonstrations can provide a site for teaching and learning where it is possible for student and teacher schooling goals to come together.

This study indicated that science demonstrations involving the use of familiar materials are resources offering opportunities for students and teachers to coexplore physical phenomena and interactions that can support the emergence of positive emotional energy. Instead of relying on students' prior experiences, demonstrations provide a shared resource for all participants. The conduct and results of the demonstration provide a frame of reference for successful interactions associated with discussions of observations and explanations. Positive emotional energy from successful interactions associated with the demonstrations can be entrained to other tasks such as those connected with assessment and evaluation so long as these tasks are explicitly related to the demonstrations. This shared experience also provides a basis for using the language of science, a necessary step for leaning chemistry. Successful interactions provide opportunities for students to elaborate new ways of talking about gas particles based on their shared observations thus expanding student access to stocks of knowledge at hand and norms that they could use to communicate their understanding of the behavior of gases. Successful interactions also provide teachers with greater knowledge of students' facility with symbol systems associated with coming to know science.

In many respects, a focus on demonstration as a site for ritual provides an ecological model for classroom-learning environments within which we have to be cognizant of interactions involving both students and teachers and of the transitions between sites that engage both students and teachers. Such focus would force us to examine the multitude of interactions that emerge at such sites and serve to structure classroom-learning environments where cognition and emotion merge. Our argument for learning requires setting up opportunities that allow students to participate in experiences requiring observation and language use before imposing on learners symbols and explanations removed from their world experiences.

Pedagogy, informed by the primacy of the relationship between experience and language, fosters the creation of learning environments that are infused with science practice and strategies that interrogate students' experiences of the world so that students begin to learn their way around science using actions that foster student engagement. This is absolutely essential because engagement is necessary for student learning. Science demonstrations have the potential to provide a beginning point for experiencing science, talking about experiences, proposing questions, suggesting patterns, and testing those questions and patterns; structuring these into a ritual with a specific content focus provides another structure for emotionally intense and cognitively focused interactions that support student learning. Science demonstrations have the potential to establish an environment in which conversations about observations and the development of explanations can encourage students, such as those from urban schools, who have not had many chances to do so, to engage in practices associated with science such as observing, describing, talking, socially interacting, writing, problem solving, inquiring, testing, and explaining.

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