Collaborating to transform and reproduce science education
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Abstract The adoption of new theoretical lenses sheds fresh light on the ways in which persons experience social life and make sense of participation in their lifeworlds. I consider possibilities for a refreshing new era of research and scholarship in science education –especially in regards to the interfaces between research, policy and professional practice. For almost 40 years I pursued two parallel lines of research: science learning and teaching, and learning to teach science. I continuously evolved theoretical frameworks to improve the quality of my research, changing foci and research methods, and affording concomitant changes in issues identified as salient. For example, teaching and learning were theorized as culture and associated dialectical theory, models that previously emphasized human agency included passivity, and emotions were framed as ever-present parts of science education.

I present a review of research on cogenerative dialogue (cogen) as an example of a collaborative approach to science education that holds the promise of overcoming many persistent problems. Participants in cogen expanded their agency and learned how to collaborate with others who differed from them socially and culturally. Research on cogen highlights the potential of building schooling around collaboration, rejecting the hegemonic axiom that effective science education necessitates conformity to metaphors such as competition, individualism, and control over others.

Keywords sociocultural theory • dialectical perspectives • emotions • science education • difference

Theory illuminates experience

Theory has a special role in social life, providing the lights that illuminate what we do. For the most part, we are unaware of the theoretical schemas that guide our interactions and transactions with others and it is only when something goes awry that we step back, think about what happened, and try to figure out what to do differently. Thinking back allows us to re-create and objectify the past and consider what happened; thereby producing objects for review and possible change. The changes we decide to enact become schemas to guide future actions, part of a theoretical array that unfolds as changed practices are enacted.

The theories that frame my research on teaching and learning are objects for change, recognizing the vital connection between their appropriateness and the caliber of research (Tobin, & Gallagher 2007a). My transition from using psychological to sociocultural theories of learning was gradual, grounded in continuous studies of teaching and learning science (Tobin 2009). From my first study in the mid-1970s I was concerned that quasi-experimental designs did not adequately consider learners' attributes. Accordingly, I designed a measure of formal reasoning ability based on Piaget's theory of learning (Piaget 1964) to take account of students' aptitudes for learning science (Tobin 1980).

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For the next decade more variables were added to the empirical model I was developing to make it possible for teacher educators and policymakers to engineer improvements in science education. The added variables focused on what students were doing in science classrooms and psychosocial factors related to student cognition (Tobin, & Capie 1982), perceptions of the learning environment (Fraser, Rennie, & Tobin 1987), and preferences for particular modes of participation e.g., roles, interaction patterns (Tobin, Kahle, & Fraser 1990).

A sociocultural turn

As my theoretical and empirical models expanded the research methodology changed too, affording investigations of overarching issues. Although I had not completely theorized social forces, I was concerned about ways in which tradition seemed to reproduce patterns of teaching and learning and macro policies such as statewide achievement tests tended to focus enacted science curricula (Tobin, & Gallagher 1987b). I began to employ interpretive research, using methods supported by hermeneutics and phenomenology (Tobin, Espinet, Byrd, & Adams 1988). In a helical process, the use of different theoretical lenses afforded new methods being employed, different issues being regarded as salient, and challenging outcomes and priorities for practice, research, and policy. New forms of data and novel experiences with participant observation research illuminated events, patterns, and contradictions that increasingly benefited from the interpretive lenses of sociocultural theory (Tobin, Seiler, & Walls 1999).

Sandra Harding (1998) referred to an individual's schemas as comprising a standpoint –a theoretical framework to support particular social actions. Everyone has a standpoint but most of it has not been articulated as thoughts or spoken and written as words. Reflexivity involves becoming aware of practices about which an actor previously was unaware. Accordingly, reflexivity is a social practice that can have the outcome of objectifying a standpoint. Research is an important activity in which it is useful to identify participants' standpoints. Historically, the approach to research has privileged researchers' standpoints over those of the researched. I reject the binary of researcher and researched to the extent possible, affording all participants opportunities to undertake research to improve their own practices and facilitate institutional motives (Tobin, & LaMaster 1995). Accordingly, it is potentially useful for all participants to learn about and from others' ontologies while being reflexive about their own. An appropriate starting point is for individuals to identify what they do and postulate reasons for their actions. As part of a reflexive methodology, autoethnography based on such starting points can catalyze important improvements in the quality of social encounters and institutional outcomes (Tobin 2000). Stories about what happens and why it happens can reflect different ways in which individuals are positioned in social space. We[1] do not assume that different individuals will tell the same stories about what happened when social life is enacted. This is because what happens is historically constituted, as are the meaning systems used to make sense of social practices. For example, as culture is enacted power differences mediate what happens, and social experiences are related to

[1] From this point on I use plural pronouns rather than singular because my research was undertaken in groups rather than as an individual researcher doing independent studies.

social categories such as teacher, school administrator, student, and parent. Other social categories such as sex, race, ethnicity, and English proficiency also mediate ways in which individuals experience social life.

It is important to learn from what is happening presently in science education. There are many ways to access accounts of what is happening from the perspectives of participants who are stakeholders, that is, those with a stake in the quality of science education in the institutions in which they participate. Accordingly, we can learn from listening attentively to the voices of students and teachers as they relate their experience with science education, describing what happens and explaining why it happens (Tobin, & Llena 2010). Other stakeholders, such as school-based leaders, have different roles in relation to science education and it is to be expected that teachers and students would have different stories about what is happening and why it is happening. Similarly, different stakeholders are likely to have different experiences with science education and there is an opportunity for researchers to learn from their different stories, not just those that cohere i.e., are considered the same. This would also be the case within each stakeholder group, i.e., differences within a stakeholder group and similarities are resources for learning about what is happening and why it is happening.

Knowledge as culture

Our sociocultural perspective views knowledge as cultural enactment i.e., science learning is regarded as the enactment of science culture. Epistemologically learning is the production of culture i.e., schemas and associated practices. Production involves agency, the appropriation of resources to afford the successful attainment of goals. As individuals act in a field with the purpose of learning science they interact with participants to produce culture that orients toward science learning. Sometimes learners are aware of the culture they enact and at other times they are unaware. What is important is that as actors appropriate structures, those structures are transformed; thereby contributing to a dynamic flux of structures that supports the activity of all participants in a field. Many of our studies emphasized the importance of the dialectical relationship between agency and structure. At the same time we studied learning to teach using coteaching, observing that coteachers learn from one another by being in a field with others. Wolff-Michael Roth (2007) afforded our use of passivity as dialectically related to agency (Lévinas 1999). Initially the idea of passivity was difficult to apply, however Michel Juffé (2003) noted that receptivity was central to understanding passivity. This was an important insight that had strong connections with our earlier work in which it was evident that participants learned from one another by *being-in* a field *with* others (Heidegger 1996). The connections to policy in science education also were strong because of the historical interest in constructivist models for learning that emphasized the agency of learners in accommodating and assimilating conceptual conflicts to produce equilibration (Tobin 1993). Also, the burgeoning interest in argument focused on agency and the production of appropriate language from which the science canon could build (Jimenez-Aleixandre, & Erduran 2008). Relatively little attention was directed toward non-agentic learning and social climates that afforded learning via passivity. Accordingly, our dynamic theory describes how culture structures fields in which it is enacted and becomes an affordance

for cultural creation and production (Tobin 2007). The distinction between creation and production is that creation does not orient toward an individual's goals whereas agency does. For example, creation can occur because individuals are receptive to learning by being with others. Continuous structural resonances create culture over which an individual does not have full control. A common example is the creation of emotions, such as frustration. If a problem is difficult to solve, or if a classroom environment is not conducive to deep thinking, a learner may become irritated even though his or her goal is to learn science.

Doing research

The purposes of research are often considered as dichotomous to produce theory or to transform practices. Adopting an ethic of responsibility, we assumed and adapted Guba and Lincoln's (1989) authenticity criteria. We wanted to learn from doing research while using what we learned to catalyze changes in the institution and improve social life for all participants, irrespective of their positioning in social space i.e., gender, ethnicity, religion, social class. In regard to learning from the research, we adopted a standpoint that all participants' ontologies should change (including our own) as a result of being involved in the research. Similarly, all stakeholder groups should learn about and from others' ontologies –not to persuade them to change, but to consider what advantages they afford.

Researching emotions

Theoretical frameworks from cultural sociology exposed us to a plethora of theories, including the sociology of emotions. Our pathway to research on emotions focused on interaction ritual chains undertaken by Randall Collins (2004). Regina Smardon (2004) and Stacy Olitsky (2006) introduced us to Collins' work. We were most interested in ways in which participants in science could work together collaboratively, building solidarity as well as identities related to science (Smardon 2004). Central to this work is that emotions act like social glue that interconnects collective and individual interests and actions. As individuals work synchronously they develop shared mood and as they achieve success after success positively valenced emotions develop, affording social inscriptions of identity. If the mood continues to build positively collective effervescence in the form of laughter, cheering, and clapping can occur (Olitsky 2006). Analogously, if there is a build up of negative emotional energy (EE), collective effervescence can reflect anger, sorrow, fear, and associated secondary emotions. Figure 1 depicts laughter as an example of collective effervescence.

Our first experience with laughter in research involved a study in which Ashraf Shady, a teacher researcher, distinguished between students laughing with and laughing at the teacher (Shady 2008). In ongoing research in urban high schools in which I was teacher, the students appeared to use laughter as a sign of their disrespect for authority. Laughter seemed to occur randomly and at times that did not warrant laughter from my standpoints as teacher and researcher (Tobin 2000). What was happening was reminiscent of Bakhtin's Carnival, in which lower-class individuals deployed satire, bawdy humor,

mime and mimicry, violence, and gross conduct to mock authority and authority figures (Bakhtin 1988). As Bakhtin pointed out, there is no way to defeat Carnival, the best recourse being to join it. I soon experienced this as a first hand reality. When someone in my class laughed I would move closer to them, an endeavor to shut down the disruption without fuss –a proximity desist. Within seconds of me moving to one part of the room someone on the other side of the room would laugh and I would go to them. The students were playing with me, and I was like the ball in their game of football. Based on Bakhtin's suggestion it might be more fruitful for teachers to permit laughter and perhaps join students in a form of collective expression. It is possible that seemingly innocuous laughter serves the purpose of positively tuning the emotional climate (EC) of the class.

Laughter is a form of collective effervescence associated with shared mood, positive EC, entrainment, and a triggering event that affords the habitus of laughing with others when events like this occur in places like this.

Figure 1. Collective laughter arises during cogen.

Jonathan Turner's (2002) theories on primary emotions allow us to examine different types of emotions in conjunction with the agency | passivity dialectic (Sewell 2005). We expect the production and creation of emotions to be continuous. Just as individuals live their lives, simultaneously experiencing macro, meso, and microlevels, it is important that a theory of emotions provide insights into the intricate ways in which emotions and EE infuse into all levels of social life. Accordingly, we began to explore EC as a macro- and mesolevel construct that can be sustained even as micro enactments produce a plethora of positive and negative valenced emotions.

Emotional climate

EC is experienced as a dialectical relationship between the individual and collective. Perceived EC is mediated by participants' histories of the EE imbued in fields that are salient to them. For example, if teachers and students rate EC for the three-minute interval from the 39th to the 42nd minute of class, the experienced EC is mediated by what happened in class in the previous 39 minutes, what has happened in class during previous lessons, and what is likely to happen for the remainder of the class period. However, during the three-minute interval participants are involved simultaneously in other activities i.e., fields. Hence, interpersonal conflict earlier in the day can preoccupy students for an entire day or more, increasing the likelihood that their emotional states are negatively valenced and they will experience the EC associated with any activity/field

negatively. Similarly, if a person receives good news in the morning it is possible that happiness will afford that individual experiencing a positively valenced EC even though others experience negatively valenced EC. Although participants might be encouraged to check their emotions at the door, emotional state is not easily controlled by agency. Accordingly, a sad person might remain sad despite efforts to become happy and an angry person might continue to be angry. Although participants might try to forget what happened earlier or set aside what is to happen after class it might not be possible to change their emotional states. In this way EC assessments are mediated by past, present, and future and also by micro, meso, and macrolevels of social life.

Even though EC is mediated continuously by many factors, the meanings of events, as they unfold, are mediated by EC, which is an important structure to consider in research on what happens and why it happens. As is the case for all structures, EC is a resource for production and creation of culture and is *in play* continuously. In various studies we have recently begun to study EC in relation to the teaching and learning of science. The method we employ in class time is for students to rate EC every three minutes using a clicker, which transmits the rating electronically to a computer database. We have used a similar approach rating EC from video files. In both cases we use a scale where 5 represents highly positive, 4 positive, 3 neutral, 2 negative, and 1 highly negative. In a current study in which 15 two-hour lessons were videotaped, each of five researchers rated EC at three-minute intervals in all lessons. EC profiles were then produced for each researcher. Because researchers were positioned differently in social space we did not expect coherence across researchers and we expected that different researchers would use different narratives to depict the salience of the peaks and troughs in their EC profiles. These different narratives would capture variations in ontology, epistemology, and axiology. In this ongoing study for which an EC trajectory is shown in Figure 2, I was the teacher in a doctoral level class, two researchers were students, and two were former students. Figure 2 presents my EC profile compared to an average of the EC data from the five researchers.

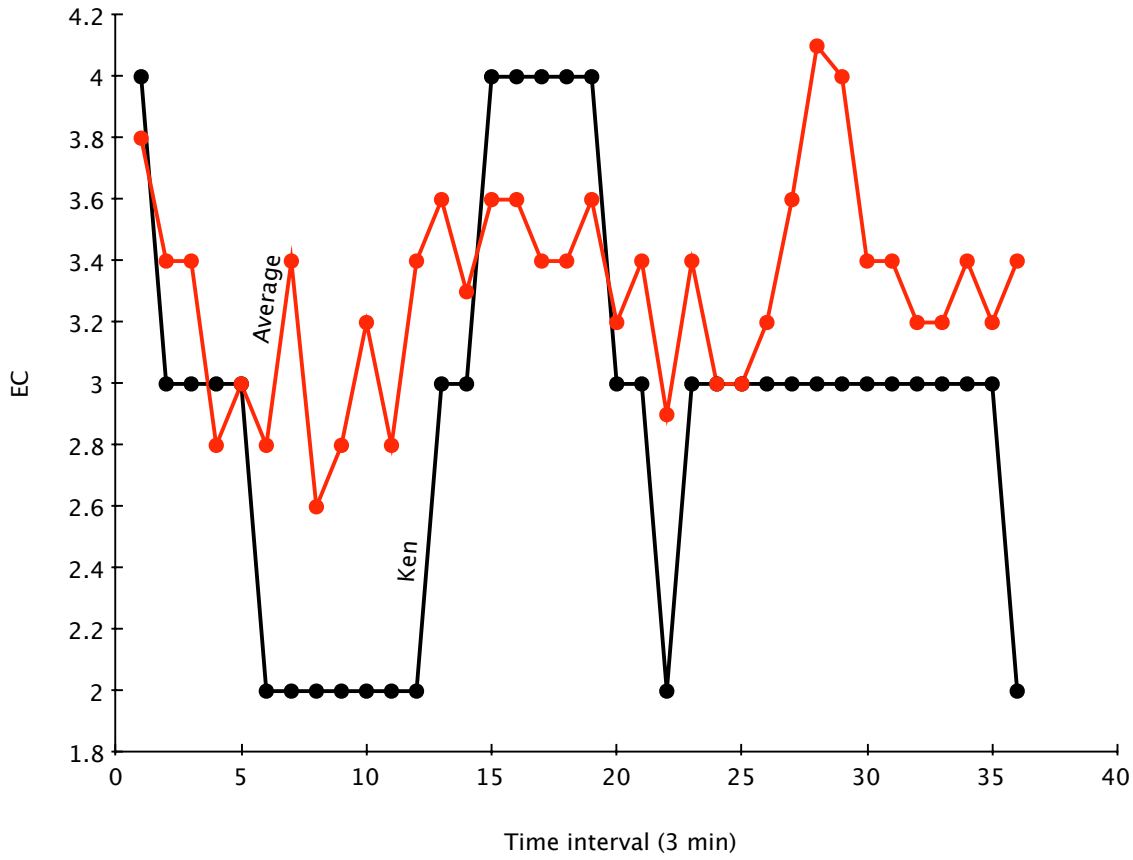


Figure 2. My EC trajectory compared to the average trajectory based on 5 researchers.

Researchers use the EC trajectories to identify salient regions that become objects for microanalysis. Typically an event is noteworthy to a participant and/or researcher for a given reason, which becomes the first level of analysis i.e., a narrative/story. In the instance of the data represented in Figure 2 the most interesting regions we felt warranted microanalyses were the 7th, 18th and 30th coding intervals. These events were then inspected by each of the researchers who identified salient events associated with those intervals. If an event overlaps the borders of those intervals, the entire event is captured, irrespective of the arbitrary three-minute boundaries. Referred to as video vignettes, these events usually vary in length from a few seconds to a few minutes. After a narrative is produced, follow-up analyses include discourse, conversation, and prosody analyses.

Disruption in a classroom can occur when students fail to maintain an intensive and enduring focus. The reasons for failing to maintain focus might be due to youth perceiving science as not interesting and lacking relevance to their lifeworlds. Based on our ongoing research it is extremely important that positive EC is initiated and sustained throughout each science lesson and from one lesson to the next. When this happens the science class can become imbued with positive EE – i.e, the teacher and students can look forward to the next science class and enjoy being involved even if negative emotions having a short duration are produced at a microlevel. On the other hand, if the class is consistently negatively valenced in regard to EE, the science class can be imbued with

negative EE and students will arrive with dispositions to enact negative emotions such as dislike, unhappiness, frustration, boredom, and anger. The challenge teachers and students face in reversing negatively valenced EE can be great.

At a microlevel success is important because of its association with the production of positive emotions involving happiness. Individual success can be associated with the emergence of positive EC. Since there is a dialectical relationship between individual and collective, individual success is interrelated with collective action and success. Empirically, evidence of successful collective action would be evident at the microlevel as synchrony and entrainment. Synchrony involves coherence of actions across space and/or time. For example, at a given moment in time, i.e., a singularity, the actions of a collective would be coherent. A simple example of this is seen in Figure 3 with the students focusing on an investigation they are undertaking. In this case shared focus on the materials used in the investigation is evidence of synchrony. Any form of action can signify synchrony, including head and body movement, gesture, prosody, and forms of collective action such as laughter and clapping. Evidence of synchrony also can be obtained by examining actions across time. A spoken word might be associated with a particular gesture, head nod, or smile, for example.

Entrainment also can be observed at the microlevel. An argument for entrainment would include collective synchrony, that is, resonance throughout the field. As was the case with synchrony, an argument for entrainment would probably include diverse forms of action. According to Collins' theory of interaction ritual chains, synchrony and entrainment can establish micro emotional climates that afford shared mood i.e., an accumulation of emotions oriented in the same positive or negative direction. As the shared mood repeats over time, synchronized actions can unfold in resonance with the reproduction of the shared mood. Collins refers to collective actions of this type as collective effervescence. Common examples with a positive orientation include laughter, clapping, and supportive chanting. In most instances a salient event would be identified during ethnography and selected digital vignettes would subsequently be analyzed to obtain meso and microlevel data. If the purposes of analyses were to explore the identities of participants, important foci would include analyses of encounters, looking at the extent to which positive and negative emotions unfolded and inscribed events with emotional valence.

This offprint from a video file represents a singularity in which three students collaborate. They focus on color changes in the beaker as an indicator shows increasing acidity. There is a high level of synchrony in successive offprints prior to and after this one. Inspection of successive offprints provides a singular | plural perspective in which each frame assumes those prior to it and anticipates those to follow.

Figure 3. Synchrony and entrainment in a laboratory investigation.

The documentation of evidence relating to identity would involve micro and meso analyses of action and activity. Evidence would include EC and success, nuanced by evidence of synchrony, entrainment, solidarity, and collective action. The extent that identity inscriptions from one field transfer to another is salient because fields are considered unbounded. In an analytical sense, identity can be referenced to activity i.e., to a single field. However, the theoretical standpoint we employ regards all activity as dialectically interrelated with an individual's lifeworld; the implication being that macroanalyses are essential to studies of identity. Inscriptions associated with social life writ large i.e., simultaneous participation in multiple activities, will always mediate identity inscriptions associated with participation in any activity.

Prosody and emotions

Participants in cogen became aware of the centrality of emotions in all interactions and events that occurred in a science class. As our research expanded and we became interested in the emotional content of talk, students and teachers also were interested in prosody and one class drew attention to the anger their teacher displayed as he taught. The students drew his attention to features of his speech they interpreted as anger. The teacher assured them he was not angry, he was interested in their learning, and would attend to what they had told him about the way he spoke. Apparently, differences in ethnicity between the students and teacher led to misunderstandings about the emotional content of interactions and these misunderstandings mediated the creation of emotions, in this case creating negative emotions such as frustration and anger on the part of students who perceived the teacher as angry with them for no good reason. Building trust, respect, and tolerance were outcomes of cogen – not just for students, but also for the teacher. Hence, the production of success in cogen created social bonds associated with affection between participants, increasing solidarity with the potential to translate to cosmopolitanism in the science class.

Emotions are a central part of action; that is, when we act our emotions are put on display in how we move and use our bodies, including gestures, facial expressions, head movements, and speech. For example, when we are excited, those who are with us experience our excitement as we interact with them. High-energy teachers, for example, communicate their emotions to a class in the way they coordinate their bodily actions and characteristics of their speech. Similarly, if a person is angry, others having a history of interacting with that person will anticipate the anger, because it is visible in the person's actions. Humans who have intense and prolonged experiences with others can quickly pick up their emotions based on just a small number of encounters – “Oh, she is in a bad mood, I should avoid her for a while!” Or, “he is angry, I should let him sort this out before I raise these issues with him.” These are just two examples of the kinds of thoughts I have when I approach people that I know and quickly size up their emotions prior to commencing my interactions with them. In our research we have begun to zero in on ways to measure the emotional content of actions.

Analyzing prosody

The software we use to examine the prosody of speech is called PRAAT (Boersma, & Weenink 2010). Digitized audio files are entered into PRAAT and Fourier analyses are undertaken. The first display shows the energy distribution over the duration of the sounds contained in the file. Segments of the entire file can be conveniently selected, affording detailed microanalyses of segments that are shorter than 10 seconds. Because prosody analyses are extremely time-consuming, we use ethnography to identify those verbal interactions that are salient to our research and thereby warrant intensive analyses. For selected segments we obtain separate spectra for pitch (frequency) and intensity (loudness). For any interval of time that is less than 10 seconds, we can zoom in to analyze the fine structure over hundredths of a second, or we can zoom out to obtain more of a holistic view of the profile for time intervals of up to 10 seconds. Analyses such as these afford frequency and intensity profiles, giving insights into the intonation of utterances used during verbal interaction. These profiles can provide contexts for interpreting transcriptional information, pointing to emotional type, strength and valence, and attitudes such as curiosity, certainty, and excitement.

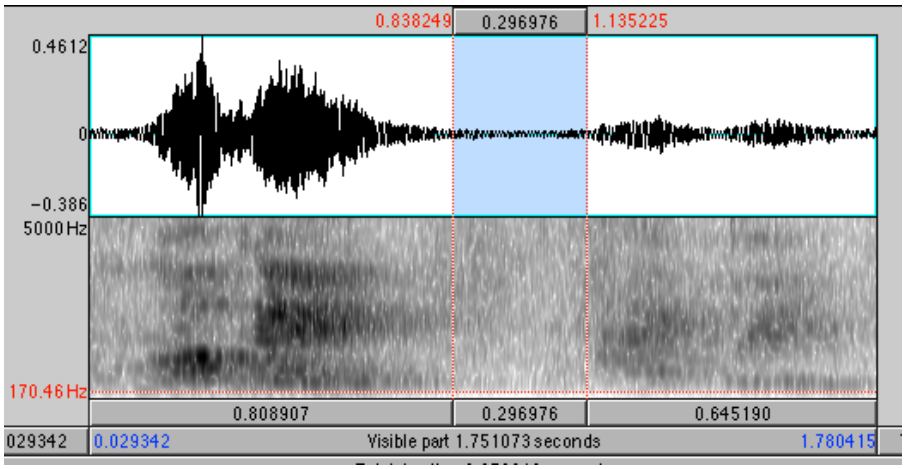
PRAAT affords more sophisticated analyses of frequency. For a given utterance, analyses yield a frequency distribution depicting the formants contained in the sound i.e., overtones. The profiles I discussed in the previous paragraph are examples of the fundamental frequency (F_0) represented in a given sound over the time of the analysis. The analysis can also show high-level formants and their distribution over time. Formant analyses contain useful information about the EE of speech (Scherer 2003). As the EE increases the high-level formants show greater intensity in comparison to speech associated with lower levels of EE.

To gain a better understanding of the salience of power in the air it is important to look at the relative power of the utterances made by different actors. For example, at the beginning of the event, when the teacher was teaching from the front of the class, he projected his voice so that everyone could hear him. To provide a sense of what the teacher's prosody was like when he taught normally I provide a short transcript and analysis.

01 Tchr: OK. (0.8s, 15.6 μwm^{-2})
02 S: I agree (0.65s)
03 Tchr: How many jumps do we have in here to go from milliliters
to liters? (5.0s, 9.8 μwm^{-2})
04 S: Three liters (0.8s)
05 Tchr: Three right? (0.7s, 12.5μwm^{-2})
0.3s
06 Tchr: Three liters. (1.7s, 4.2 μwm^{-2})

To get the students' attention the teacher initiates the utterance with OK, with power that is above his average during this event (10.5 μwm^{-2}). The pattern in this event is similar to what is found for all events analyzed when the teacher teaches. He initiates an utterance with high levels of power and as the utterance continues it diminishes in power. He uses

above average power when he wants to emphasize a correct answer (e.g., three right?) or get someone's attention.



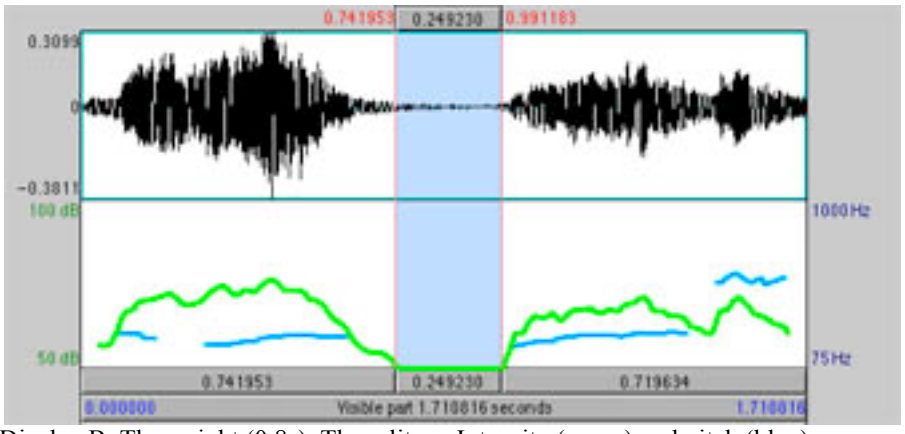
OK. (0.3s) I agree.

Figure 4. Prosodic features as the teacher teaches the whole class from the chalkboard.

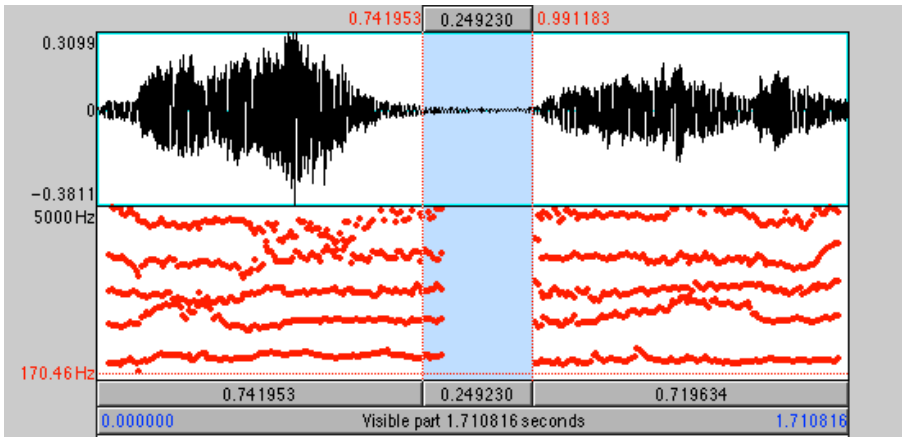
The Figure shows the energy distribution of the wave as a function of time. In the lower panel the gray bands show how energy is distributed across frequency as a function of time. The second syllable of OK (i.e., kay) contains more energy in the higher frequencies. In contrast, "I agree," spoken by a student, contains lower energy.

Figure 5 contains two panels that show different characteristics of the same utterance, hence the upper panel is the same in each case. In Display B, the intensity of the wave as a function of time appears as a continuous trace with a scale in decibels (dB) on the left hand side of the display. The scale ranges from 50 dB to 100 dB. The frequency trace is discontinuous because in some cases there is silence (0.25s between utterances) and on other occasions F_0 is outside of the range of the frequency scale, which is from 75 Hz to 1,000 Hz (right hand side of Display B).

The lower panel of Display C shows a formant analysis with frequency of the formants shown as a function of time. In this case five formants (F_0 to F_4) are shown on a scale that ranges from 0 Hz to 5,000 Hz (left hand side of the lower panel in Display C).



Display B. Three right (0.8s). Three liters: Intensity (green) and pitch (blue).



Display C. Three right (0.8s). Three liters: Formant analysis

Figure 5. Analyses of energy distribution, intensity, pitch and time

During a routine set of classroom interactions prosody analysis usually reveals numerous alignments in terms of pacing, pitch, and intensity. Synchrony also occurs in terms of intonation, with successive speakers inflecting utterances as evidence of a shared mood. Research on these alignments and synchronies must take account of natural variations in the voices of adults and children, males and females, for example. We've seen examples of science teachers intentionally producing misalignments in an endeavor to change the emotional climate in the classroom. For example, high energy teaching might involve exaggerated body movements, including verve, and oral deliveries that are loud, unusually contoured in regard to frequency and intonation, and energy laden (i.e., high intensity in the higher order formants). If participants become-like the other by being-with the other then the students in the class of a high-energy teacher might begin to interact in high-energy ways simply by being-in the classroom with the teacher. Of course symmetry can be anticipated and a loud and noisy class creates a structural milieu to afford loud and noisy teaching. My point is, that misalignments or asynchronies can be intentional; the purpose being to alter the emotional climate and to create shared mood of a particular sort.

Misalignments can also cause trouble. We have experienced classroom climates that have spiraled out of control as successive speakers infused high-energy emotions into their speech. We called this heating up the climate. We noticed in the same classes, that when students spoke after one of their peers had made an angry utterance, their speech contained less EE than that of the angry speaker (Roth & Tobin 2010). That is, they spoke "under" the previous speaker. Speaking over or speaking under is equivalent to heating up or cooling down the climate respectively. When participants know the culture of the other, it seems they can anticipate what is to come based on what they have experienced so far, and they can act accordingly in ways that do not produce trouble. That is, they act appropriately to reproduce cultural fluency, thereby affording the motives of the collective.

The promise of collaboration in science education

Those who adopt deficit perspectives often have a ghetto mentality in which schools associated with particular social categories are projected as inferior e.g., urban, rural, low socioeconomic, etc. What knowledge students have is regarded as incorrect, not useful, and of little relevance to learning power discourses – such as science. The value in knowing what students think and believe is frequently seen as identifying misconceptions to be extinguished and replaced by social truths about the world. Schools may be characterized as dysfunctional, involving youth who are unsupervised, undisciplined, and without the benefits of both parents being present in the home. One-parent homes are depicted as the norm, where a supporting parent, usually the mother, has to work two or more jobs just to make ends meet. Adults are represented as relatively undereducated, assigning little value to education, failing to emphasize the benefits of a good education, and neglecting to push children hard to succeed at school.

An alternative to the use of deficit perspectives is to understand youth and their lifeworlds. If educators understand the neighborhoods in which their students live, they can identify what they do, how they do it, and when and how they succeed. Teachers who study their students' culture outside of schooling have windows into the inquiry skills embedded in everyday practices. These might be regarded as foundations on which deep canonical knowledge can be built. The knowledge students have that produces success in their lifeworlds can be regarded as capital – a basis for learning even more and succeeding in other fields, such as those associated with school. From this perspective what students know and can do are objects for expanding inquiry skills, not objects for extinction.

Difference as a resource for learning

In a review of social differences being a resource for solidarity I present the situation in which people migrate to the United States and many of them find their way to New York City where they have family, relatives, and people from their native and nearby countries. Accordingly, there can be population clusters in a large city in which there are high proportions of people from the same country – shared cultural capital that affords them interacting together to produce success. Also, by living together, sometimes in conditions

of high density i.e., many people in a relatively small space, participants can create and produce new culture that reflects their day-to-day lives in the United States. Another way to say this is that immigrants from a particular part of the world share culture to begin with and when they arrive in the United States they interact together to produce success and new forms of culture i.e., they produce a diaspora –or a home away from home (Hall 1990). To take an example, there are many immigrants from the Dominican Republic living in the Bronx. These immigrants may arrive in the United States with young children or, soon after arriving, they might have children who subsequently grow and attend schools in the Bronx. These children learn to communicate with their parents and others from the Dominican Republic including youth who will attend the same school. Accordingly, when these students arrive at school they possess cultural capital associated with their lifeworlds in the Bronx, carried to the United States with immigrants from the Dominican Republic. It is little wonder that the children find comfort in working together with others who are ethnically Dominican. When it comes to interacting with others in the class they may be faced with the challenge of making sense of culture associated with Puerto Rican and Haitian immigrants and African Americans. If students are to succeed in their interactions across ethnic groups it is important they have the cultural resources to support their goals of learning from one another.

The challenges associated with the diversity of students in a science class are heightened when the social categories applicable to their science teacher are considered. For example, the science teacher previously described in this paper is an immigrant from the Philippines. He had to learn to speak Spanish and when he did so his accent made it difficult for students to understand him. Similarly, his English dialect was difficult for students to understand and he had difficulty understanding them. These difficulties in producing success, for example during verbal interaction, made it difficult to initiate and sustain cultural fluency and success in achieving goals. Accordingly, frustration often crept in to the classroom and set the stage for an EC that was continuously neutral at best and often negative. There was a priority to learn from what others had done with cogen and applied in the Bronx to produce successful science classes.

Learning about and from others' culture

Our venture into cogen arose from a desire to recognize students' expertise concerning teaching them science (Tobin, & Roth 2006). We quickly realized that like most others, students had good and bad ideas about teaching and learning. However, engaging them in conversations about teaching and learning seemed highly beneficial. As a consequence, we organized small group conversations among students and their teachers, to occur as soon as practicable after a science lesson had occurred. From the beginning we had invited student participants who differed as much as possible from one another.

The initial research on cogen focused on ways in which participants negotiated consensus on what should change in the classroom and whether desirable changes occurred. Over several years of research we noticed the salience of cogen as providing a social space in which consensus could be produced across important social categories often associated with inequities in science education. Furthermore, we realized that cogen was a field in

which teachers could learn about diverse students' culture through face-to-face encounters. Notably, students also could learn about their teachers' culture through direct experience in being able to produce successful outcomes. We adopted the metaphor of cogen as a seedbed for cultural production. Figure 6 is an offprint from a digital file of cogen, providing evidence of focus, synchrony, entrainment and positive emotions.

Rosemarie maintains the attention of others in cogen through the use of her voice (prosody) and associated gestures. All participants are tuned in to what she has to say and there is evidence of entrainment. Rey and Selenia show amusement as Rosemarie emphasizes her point.

Figure 6. Maintaining focus, synchrony and entrainment.

Once we began to study the ways in which teachers and students learned to adapt to one another's culture it became clear that important culture was being created as students and teachers interacted successfully over a period of time. Passive creation of culture also contributed to teachers and students becoming like the other by being with the other. As we began to understand how transformation and reproduction of culture was being afforded by agency and passivity the potential of cogen became apparent – not just for improving teaching and learning, but also for enhancing many social institutions through collaborative processes. At its heart cogen embraces collaboration with others rather than endeavoring to control them. This is the agency side of the agency | passivity dialectic. Also salient is receptivity to learn from and teach others by being with them in multiple fields in which science education is practiced.

The central features of cogen are:

- using dialogue to produce consensus among participants selected on the basis of their differences on important social categories that characterize a science class;
- focusing on improving identified aspects of social life in a particular institution;
- sharing turns at talk and duration of talk;
- acting to afford successful participation of all others involved in cogen;
- adopting radical listening to attend to others' suggestions with a view to understanding them and testing their viability before suggesting adaptations or alternatives;

- maintaining positive EC during cogen; and

- accepting responsibility to enact agreed to changes to improve the quality of science education in all fields in which it is enacted.

Because fields have no boundaries the culture from other fields can be enacted during cogen. Frequently, structures that are established in the classroom are appropriated in cogen with consequences for participants. For example, a teacher might be displeased with some aspects of the class that has just been completed. She might join the cogen still angry and seize the opportunity to chide students with whom she had problems in the class. In so doing she would be violating some of the cogen rules. In such instances it is important that other participants can call the cogen to order so that all participants adhere to the agreed-upon rules. Similarly, if the teacher monopolizes the talk, or conducts an inquisition in an accusatory tone, the violation of rules is just as damaging as when students show disrespect for the teacher or other students. Accordingly, it is important that the rules of cogen explicitly address how to act when any participant violates the rules.

Learning from other scholars

The advantages of being reflexive about the theoretical framework used in a study are that changes to it afford new ways of seeing social life, identifying foci for research, and methods for doing research. The use of sociocultural theory gradually evolved because of the need to avoid making assumptions that just didn't make sense in educational research. There was nothing to be gained, for example, by assuming that students in a class acted independently of one another – thereby meeting an assumption for the model used in statistical analysis. On the contrary, we were interested in studying dependence – how students learned together and assumed teaching roles to help others learn. Also, we did not buy into the need to hypothesize a priori, preferring designs that were responsive to what we learned and what was happening. What is important to stress is that adopting a new theory is adopting a new ontology, allowing us to tell and elicit different stories about being in the social world. It is not that suddenly the world looks different. Consistent with learning about almost anything, the new is initially foreign and it takes time in the field to experience through the lenses of a new theory.

We adopt a polysemic approach to ontology, assuming that ontology derives from lived experiences in an individual's lifeworld. Since ontology is structured, we anticipate that the stories an actor tells about social life will be mediated by extant structures. Accordingly, a rendered ontology is never individual only, since it depends on the collectives and structures associated with each person's lifeworld.

Our approach to research is both multilevel and multi-method. The methodology we adopt in designing multilevel research is to reject determinism of what is learned at any of the levels employed in research. Consistent with social neuroscience we prefer designs that employ data across adjacent levels of social life i.e., global ⇔ macro; macro

⇔meso; meso ⇔micro; and micro ⇔neural. Each of the four levels of design complements the others and no particular analysis is regarded as more important than another. Each contributes to a portrait of social life that can take many forms. At any of the levels the theories used to frame the design afford what is experienced and hence what is learned.

There is a crisis in science education that is ongoing. For as long as I have been involved in the field there has been a mainstream that feeds on itself and rarely takes account of research that does not cohere with it. Scholars within the mainstream stay focused and disregard research that differs from their sense of priorities for research, appropriate methods to employ, and necessary changes needed in the field. These mainstream scholars are nourished by national funding agencies and they play a major part in sustaining the mainstream through their roles as peer reviewers in numerous fields, including proposal and paper review. These scholars are silent on what our research group has done and how it connects to what they have done. If they are pushed on their stances they remain silent. As I learned from my research into urban classrooms there is nothing as disrespectful as denial of existence – being silent about other scholars' work is disrespectful and potentially devastating for the field. As Paul Ricœur (1992) noted about life: we are privileged to join a conversation that is extant. We join for a time, contribute what we can and learn from the conversation. Then we leave it. The conversation continues, hopefully enriched by our contributions, but now mediated by those who remain to participate. If the science education conversation is to have relevance to the issues of the day, as they unfold, it seems highly desirable that the ongoing conversation is enriched by the resources of the day. Can we afford to be silent about the work of others? What are the costs of silence? If the transformation and reproduction of science education is to produce a field that is diverse, vigorous, and productive in improving humanity, it is timely and appropriate to incorporate radical listening into the collaborative practices that characterize the science education conversation on the road ahead. Who will join the conversation to listen, learn, and contribute to the improvement of science education?

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References

Bakhtin, M. (1988). *Rabelais and his world* (H. Iswolsky, Trans.). Massachusetts: MIT Press.

Boersma, P., & Weenink, D. (2010). *Praat: Doing phonetics by computer* (Version 4.3.27) [Computer program]. Retrieved April 12, 2010, from http://www.praat.org/

Collins, R. (2004). *Interaction ritual chains*. NJ: Princeton University Press.

Fraser, B.J., Rennie, L.J., & Tobin, K. (1991). The learning environment as a focus in a study of higher-level cognitive learning. *International Journal of Science Education*, *12*, 531-548.

Guba, E., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newbury Park, NJ: Sage Publications.

Hall, S. (1990). Cultural identity and diaspora. In P. Williams & L. Chrisman (Eds.), *Colonial discourse and post-colonial theory* (pp. 392–403). New York: Columbia University Press.

Harding, S. (1998). Multiculturalism, postcolonialism, feminism: Do they require new research epistemologies? *Australian Educational Researcher*, *25*(1), 37 – 51.

Heidegger, M. (1996). *Being and time* (J. Stambaugh. Trans.). Albany: State University of New York Press.

Jimenez-Aleixandre, M. P., & Erduran, S. (2008). Argumentation in science education: An overview. In S. Erduran, M. P. Jimenez-Aleixandre, (Eds). *Argumentation in science education: perspectives from classroom-based research* (pp. 3-27). Dordrecht: Springer.

Juffé, M. (2003). *Lévinas, passivity and the three dimensions of psychotherapy*. Paper presented at Psychology for the Other: Seminar on Emmanuel Lévinas, Seattle University, Seattle, WA. Retrieved August 28, 2007, from http://www.seattleu.edu/artsci/psychology/conference/2003/archive2003.html.

Lévinas, E. (1999). *Alterity, & transcendence* (M. B. Smith, Trans.). New York: Columbia University Press.

Olitsky, S. (2006). Facilitating identify formation, group membership, and learning in science classrooms: What can be learned from out-of-field teaching in an urban school. *Science Education*, *91*, 201-221.

Piaget, J. (1964) Development and learning. *Journal of Research in Science Teaching*, *2*, 176-186.

Ricoeur, P. (1992). *Oneself as another* (K. Blamey, Trans.). Chicago: University of Chicago Press. (First published in 1990).

Roth, W.-M. (2007). Theorizing passivity. *Cultural Studies of Science Education*, *2*, 1-8.

Roth, W.-M., & Tobin, K. (2010). Solidarity and conflict: Prosody as a transactional resource in intra- and intercultural communication involving power differences. *Cultural Studies of Science Education,* 5,••• - •••.

Scherer, K. R. (2003). Vocal communication of emotion: A review of research paradigms. *Speech Communication*, *40*, 227–256. DOI:10.1016/S0167-6393(02)00084-5.

Sewell, W. H. Jr. (2005). *Logics of history: Social theory and social transformation.* Chicago: University of Chicago Press.

Shady, A. (2008*). Immigration and cultural as factors mediating the teaching and learning of urban science*. Unpublished doctoral dissertation (AAT 3325395). New York: City University of New York.

Smardon, R. (2004). Streetwise science: Toward a theory of the code of the classroom. *Mind, Culture and Activity*, *11*, 201-223.

Tobin, K. (Ed.). (1993). *The practice of constructivism in science education*. Hillsdale, NJ: Lawrence Erlbaum & Associates.

Tobin, K. (2000). Becoming an urban science educator. *Research in Science Education*, *30*, 89-106.

Tobin, K. (2007). Collaborating with students to produce success in science. *The Journal of Science and Mathematics in South East Asia*, *30*(2), 1-44.

Tobin, K. (2009). Repetition, difference and rising up with research in education. In K. Ercikan & W.-M. Roth, (Ed.) *Generalizing from educational research* (pp. 149-172). New York: Routledge.

Tobin, K., & Capie, W. (1982). Relationships between classroom process variables and middle school science achievement. *Journal of Educational Psychology*, *74*, 441-454.

Tobin, K., Elmesky, R. & Seiler, G. (Eds). (2005). *Improving urban science education: New roles for teachers, students and researchers.* NY: Rowman & Littlefield.

Tobin, K., Espinet, M., Byrd, S.E., & Adams, D. (1988). Alternative perspectives of effective science teaching. *Science Education*, *72*, 433-451.

Tobin, K., & Gallagher, J.J. (1987a). The role of target students in the science classroom. *Journal of Research in Science Teaching*, *24*, 61-75.

Tobin, K., & Gallagher, J. J. (1987b). What happens in high school science classrooms? *Journal of Curriculum Studies*, 19, 549-560.

Tobin, K., Kahle, J.B., & Fraser, B.J. (Eds). (1990). *Windows into science classrooms: Problems associated with higher-level learning.* London: Falmer Press.

Tobin, K., & LaMaster, S. (1995). Relationships between metaphors, beliefs and actions in a context of science curriculum change. *Journal of Research in Science Teaching 32*, 225-242.

Tobin, K., & Llena, R. (2010). Producing and maintaining culturally adaptive teaching and learning of science in urban schools. In C. Murphy and K. Scantlebury, (Eds). *Coteaching in international contexts: Research and practice* (pp. 79-104). Dordrecht: Springer.

Tobin, K. & Roth, W-M. (2006). *Teaching to learn: A view from the field*. Rotterdam, NL: Sense Publishing.

Tobin, K., Seiler, G., & Walls, E. (1999). Reproduction of social class in the teaching and learning of science in urban high schools. *Research in Science Education, 29*, 171-187.

Turner, J. H. (2002). *Face to face: toward a sociological theory of interpersonal behavior*. Palo Alto: Stanford University Press.

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