Multi-Method, Multi-Theoretical, Multi-Level Research in the Learning Sciences

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We examine methodologies and methods that apply to multi-level research in the learning sciences. In so doing we describe how multiple theoretical frameworks inform the use of different methods that apply to social levels involving space-time relationships that are not accessible consciously as social life is enacted. Most of the methods involve analyses of video and audio files. Within a framework of interpretive research, we present a methodology of event-oriented social science, which employs video ethnography, narrative, conversation analysis, prosody analysis, and facial expression analysis. We illustrate multi-method research in an examination of the role of emotions in teaching and learning. Conversation and prosody analyses augment facial expression analysis and ethnography. We conclude with an exploration of ways in which multi-level studies can be complemented with neural level analyses.

Keywords: interpretive research, video ethnography, conversation analysis, prosody analysis, emotion, facial expression analysis, neural analyses

The multi-level methods we adopt in our research are interpretive, theoretically grounded in post-structural hermeneutic phenomenology (Madison, 1988), and consistent with Frederick Erickson's (1986) presentation of interpretive research as an activity in which participants' subjectivities interact. Although Erickson's approach primarily involved qualitative data resources, he did not create a dichotomy of qualitative and quantitative data. Furthermore, Erickson did not regard the data form (i.e., qualitative) as the distinguishing characteristic of interpretive research. Instead, he described interpretive research as embracing participant observation, by which the researcher was part of the social setting being investigated. Critical to interpretive research were checks and balances to ensure that the evidence supporting assertions outweighed the evidence against, and that all exceptions to assertions were fully interpreted. Research questions and the associated design used to initiate a study were regarded as heuristic; not a blueprint for the research. Instead, design was re-examined continuously as data were interpreted as the study unfolded, the design being contingent on what was learned from the study. In interpretive research design, analysis, interpretation, and reporting back to participants were regarded as simultaneously occurring and ongoing activities.

Since 1984, our research has employed interpretive approaches initially being informed by ongoing studies of what we had learned previously, connections to other research and theoretical frameworks, and what we wanted to learn next (i.e., which problems had the highest priority for our research). The start-out questions were typically broad, related to overarching phenomenological (what is happening?) and hermeneutic (why is that happening?) frameworks. Within those broad questions were subsets of more specific questions that necessitated particular methods and procedures to be followed. The specific questions were initiating and at the time they were famed they reflected the researchers' intentions/interests. As the title of the approach implies, interpretive research is driven by continuous interpretation of data. Questions are answered fully and partially, other questions arise, some questions seem less important and are set aside, and others are fine-tuned based on what we have learned from interpretations. The resources used to undertake the research are emergent and contingent, as are questions to focus inquiry. As the questions and priorities change to reflect what is learned from a study so too do procedures and methods. These changes are not idiosyncratic, random, and haphazard but are part of a scientific methodology-expected, and purposeful.

PURPOSE

The purpose of this paper is to present a methodology for conducting multi-level research and provide insights into the methods used in this approach to research. To the extent possible we provide examples from ongoing research, including a study of Vicky, a new teacher in her first year of teaching science in a private school situated on the east coast of Australia. The study included Vicky as a teacher researcher and involved some of her students in the conduct of the research. A primary focus of this research was on emotions and the ways in which they mediated the enactment of science education in Vicky's classes.

EVENT ORIENTED SOCIAL RESEARCH

As researchers we endeavor to find out what is happening in the fields of study through careful analyses of participants' voices, including our own. As we ascertain what is happening we seek to understand why it is happening, making sure that diverse perspectives are retained in analyses. We regard difference and sameness as resources and interpret each in relation to the other. Our interpretive perspective regards culture as patterns having thin coherence and ever-present contradictions (Sewell, 2005). As individuals conduct social life, they enact culture in fields, comprised of structures, including actors and what they do. Fields do not have boundaries and, as a result, they interpenetrate. In this way structures emanating from particular fields become resources for action in other fields.

Social analysis cannot be reduced to individual actions but must include actors' interactions with social artifacts including other actors' enactment, schemas, and other material/concrete artifacts. Each interaction structures subsequent interactions and the conduct of participants in a field. When cultural enactment is fluent, resources become available just in time, are appropriate, and anticipate what is to happen. In contrast, when these criteria are not met there can be a breach in the flow of enactment, experienced by participants as contradictions.

The processes of understanding what is happening and figuring out why it is happening are ongoing. We do not sample randomly and do not differentiate between data resources in terms of whether they are qualitative or quantitative. Instead we access many data resources continuously, in a hermeneutic project that focuses on making sense of social practices. Typically, we use digital video recorders to capture social practices within classrooms. Accordingly, we analyze all available video files, identifying salient events within them. Events are defined in terms of contradictions that arise as culture is enacted. If the research lens is focused at the meso level during an interpretive study, then events can be defined in terms of what happened either side of a selected contradiction. William Sewell Jr. highlighted the importance of structures being transformed during an event, which is regarded as a catalyst for individual, collective, and institutional change (Sewell, 2005). Following Sewell, we decided that event-oriented social research would involve the identification of breaches in enactment and ruptures of social equilibria.

Event selection is analogous to using a zoom lens, and mesoanalyses usually involves relatively short events, in the vicinity of two to three minutes. We expect interpretive research to yield a rich set of assertions and associated contradictions that can be explored further through microanalyses. Events at the micro level are nested within events selected as salient at a meso level. Analyses occur within and across social levels (i.e., in this case micro and meso levels), usually beginning with a narrative of what happened, its significance, and why it happened. Often we request participants to identify and select events from an activity, using software such as QuickTime Pro (7.5.6) and StudioCode to edit and analyze video files. The researcher selecting an event provides a description of what happened and why the event was selected.

Narratives, like all stories, are not descriptions of everything that happens. Rather they represent what happened that was considered most important and show how what happened interconnects central characters and events. We obtain narratives from participants, expecting different stakeholders to describe what happened in diverse ways and identify different events as salient. When we interpret data resources we retain different perspectives, ensuring that in addition to reporting patterns of coherence, we also report and learn from contradictions.

AUTHENTICITY CRITERIA FOR EVENT ORIENTED SOCIAL RESEARCH

We regard social research as an activity that has numerous goals and beneficiaries. Above all, the research should be conducted with the highest ethical standards in which communication is open and honest. The goals of different stakeholders in research should be visible to participants, and involvement in the research should be voluntary with individuals being aware that they are involved in research and have current knowledge of what is happening in a study.

We adopt Egon Guba and Yvonna Lincoln's (1989) authenticity criteria to address individual and institutional benefits that arise from the conduct of research. Two of these criteria address learning from research. First, often referred to as ontological authenticity, all participants in research should change their ontologies as research is undertaken. There are obvious implications for the design of a study, which should seek to show how participants from each stakeholder group learn from the study and change their ways of being in the social world. Common ways to document ontological authenticity are changing narratives and changing ways of being in the research fields–as depicted in video vignettes. Difference is an important lens we use in examining ontological authenticity. We expect participants to have many ways of interpreting what happens in social life since their interpretations of what happens reflects their positions in social space. As they learn from a study, participants' descriptions of social life change to reflect their learning. We do not look for ontological changes to produce uniformity only, but also to expand differences.

A second aspect of learning that is a valued authenticity criterion is to understand others' perspectives, through a lens of valuing difference. Studies should be designed to educate stakeholders about different perspectives between and within salient stakeholder groups (e.g., researchers, teachers, students, school leaders). The purpose of making differences visible is not to extinguish them but to learn about and from difference. Valuing difference is regarded as a way to produce solidarity within a research project.

Epistemologically we regard practices as knowledge. Accordingly, changes in practice are regarded as changes of knowledge in action. Two authenticity criteria address beneficence. As a result of being involved in research, individuals and institutions should benefit from their participation. At an individual level this criterion can be viewed through the lenses of equity and social justice. It is not just a case of individuals benefiting from research, but those individuals who are not well placed socially should be provided with resources to expand their beneficence. Hence, the design should examine ways in which the research helped those who were not well placed to benefit from the research. At an institutional level, studies can describe how participation in research benefited an institution.

Beneficence also can be examined in relation to others learning from a study and changing their practices and the structures of the institutions in which they participate. Such changes are often accomplished by ripple effects as participants in a study change and disseminate those changes through their interactions with others who are not participants in the research. These changes can be introduced intentionally through interventions and inadvertently because coparticipants learn from one another by being and interacting with one another.

Through publication, researchers disseminate what they have learned in ways that afford readers and viewers deciding whether and what they can learn and change. Accordingly, ways in which research is presented should involve thick descriptions that allow others to decide whether and how research applies to them. A focus for authors is to join and contribute to a dialogue, providing necessary details and lines of thought to educate others who choose to join the dialogue. It is not for authors to claim that research is generalizable as much as it is to show its potential relevance to different stakeholders who choose to access the media being used to disseminate research. Appropriately, the agency for deciding what aspects of research are applicable to others' professional practices reside with stakeholders (other than the researchers) and collectives in which they participate.

RESEARCHING EMOTIONS IN TEACHING AND LEARNING

Following more than a decade of research in urban high schools, emotions emerged as central in the production of learning environments to support science learning. Since emotions are embodied, socially distributed, and continuously reproduced and transformed this area is fertile for educational researchers (Tobin, 2010). We employ frameworks of Jonathan Turner (2007) and Randall Collins (2004) to identify and analyze emotions, using video files that afford repeated replay and manipulation of speed in research that integrates what we learn from analyses of prosody and the content of verbal interaction, body movements and orientation, gestures, facial expressions, and eye movements and gaze. Collins employed microanalysis to examine interactions in terms of focus, synchrony, and entrainment in relation to the development of what he referred to as shared mood. He employed the idea of positively and negatively valenced emotional energy as an important "in-the-moment" construct to consider in social research. As we began to use Collins's framework ethnographically there was an interest in identifying the discrete emotions produced in the moment. This led us to Turner's research on facial emotions and a theory that posited four primary emotions (i.e., happiness, fear, sadness, anger) that explained a plethora of secondary and tertiary emotions in terms of elaborations of combinations of the primary emotions.

Emotional climate

During social activity, such as events within a science lesson, emotions are produced in the moment. Through interactions there is a continuous flux of emotional energy that can be linked to the salience of events experienced and the associated valence of discrete emotions. Social artifacts within events can be saturated with emotional energy and when individuals think about the event at a later time they can experience similar emotions to those experienced when the event first occurred. Similarly, when a similar event occurs, emotions like those produced originally can be reproduced. For example, when Vicky introduced a lesson on flotation she enacted a theatrical activity in which she and one of the students, whom she referred to as Professor Wiley, role played by a TV compère and a famous scientist, respectively. The activity took six minutes of class time and was characterized by humor, overt happiness, collective laughter, and good-natured banter (Tobin, Ritchie, Hudson, Oakley, & Mergard, in press). When we discussed the activity with Vicky during research meetings, positive emotions like those produced during the activity were re-created when Vicky: reviewed events selected from the Professor Wiley activity; discussed offprints from events within the activity; and replayed and analyzed audio files selected from the activity. Similarly, one year after the original class, when we discussed the Professor Wiley activity with some students from the class, the students reproduced high levels of positive emotional energy when they recalled incidents from the activity.

We use the construct emotional climate (EC) to refer to the emotional energy imbued in social artifacts. Like other constructs in event-oriented social research the timescale associated with EC can vary depending on focus. For example, a lesson could be a unit associated with EC, or EC might be considered in relation to any meso- or micro-level event within a lesson. EC also can be referenced to much longer timescales, such as grade 10 science for an entire year or for a multi year program of study. In each of these cases thinking about a particular scenario can reproduce emotions associated with original experiences in ways that aggregate over time.

Researchers involved in a study of Vicky's teaching reviewed a video file of a flotation lesson and at three-minute intervals each recorded a measure of EC for that three-minute episode using a five-point scale of very positive (5), positive (4), neutral (3), negative (2), and very negative (1). Even though we allowed researchers to decide what criteria to use as a basis for their ratings, the generalizability coefficient for differentiating intervals of time based on average EC (generalizing over researchers) was 0.9. Figure 1 contains a plot of EC and time from the flotation lesson. The first two time intervals show EC measures for the Professor Wiley activity. Fluctuations from high to medium to relatively low raise questions about the salience of EC as it is imbued in events as compared to EC as it is represented in a macro sense (i.e., for the whole lesson or a series of lessons) (see also, Fredrickson & Joiner, 2002). Despite fluctuations such as those seen in Figure 1 the lesson as a whole might be imbued with highly positive EC because of surplus positive emotions associated with the Professor Wiley segments). Average EC for the lesson was 3.4 (slightly positive) with a standard deviation of 0.6. The range extended from a minimum of 2.6 (just below neutral) to a maximum of 4.8 (highly positive).

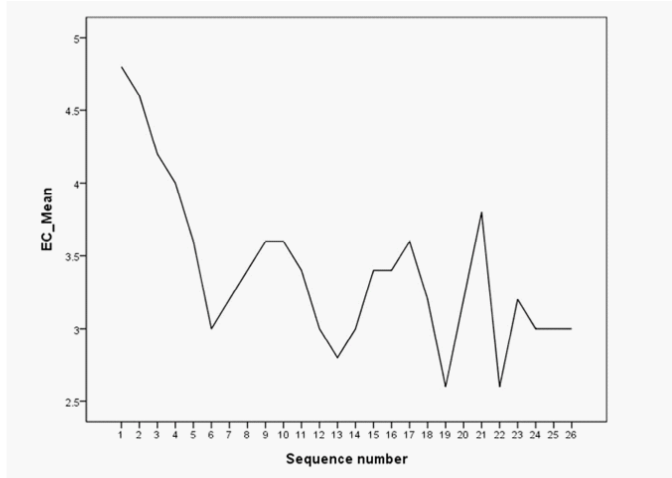

Figure 1. Mean EC as a function of time.

We used the EC plot heuristically to write a narrative for the entire lesson and for events we identified within the lesson. The EC curve raised our curiosity about the change points (1, 6, 9, 13, 17, 19, 21, and 22). We then extracted each of the eight three-minute segments, carefully editing each to ensure that the events contained within them were complete. Selecting events necessitated extending some segments, shortening others, and deleting non-salient events within segments. Microanalysis then focused on event analysis, including conversation, prosody, and other non-verbal analyses.

Coordinating conversation and prosody analysis

When an event is identified the prosody of the interactions is described qualitatively using video and audio tracks. Care is taken to make note of prominent features of the distributions of the power of the waves in the air, intensity of utterances, fundamental frequency, intonation, overlapping speech, simultaneous speech, and interruptions. Conversation analysis is often augmented by prosody analysis when microanalyses are undertaken. A transcript is produced for conversation analysis and to locate utterances for prosodic analysis, adapting conventions of Have and inserting measures of relevant time intervals, fundamental frequencies, and intensities of utterances (Have, 2010). The transcript routinely includes measurements of characteristics such as intonation, frequency contours of syllables and words, variations in loudness/intensity, cadence, gestures, body movements and orientations, facial expressions, and gaze (Roth & Tobin, 2010). Conversation and prosody analysis mainly involve coordination of frame-by-frame analysis of the video file to capture such important factors as gestures, eye gaze, and head orientation with computer-aided analyses of the acoustic waves from the video soundtrack. We use PRAAT software (http://www.fon.hum.uva.nl/praat/) to measure time intervals between utterances in seconds (s), fundamental frequencies of acoustic waves in

Hertz (Hz) and acoustic intensity (i.e., the amount of energy of a sound wave in the air standardized for time and area) of utterances in micro Watts per square meter (μWm^{-2}; Roth & Tobin, 2010). When it is relevant to do so, we analyze higher frequency spectra for utterances, inspect formants, and obtain and analyze a spectral slice for singularities of interest (e.g., when emotions peak) (Tobin, 2010).

In-the-moment emotions

Based on the EC plot in Figure 1, we used StudioCode to create separate movies for high, medium, and low EC episodes and then analyzed the three movies separately. The analysis of the low EC video revealed a contradiction in Vicky's vocal expression as she used piercing sounds with the intention of disrupting student enactment and refocusing attention. We found this practice repeated numerous times in the negative EC movie and decided to analyze these sounds at the micro level.

We coordinated frame-by-frame analysis with prosody analysis to identify the moment when vocal expression contained maximum energy. The two offprints in Figure 2 are instances of nagging in which Vicky is approximately the same distance from the microphone. In each case the acoustic wave associated with the most intense utterance had more than twice the power in the air of the wave associated with the entire phrase in which the most intense utterance was embedded. The orientation of Vicky's body, including the way she held her head, placed her arms in relation to the body, and positioned her shoulders appear to have sufficient similarities to warrant further investigation of similar features when Vicky endeavors to gain control over her students. Similarly, characteristics of prosody invite deeper investigation of the distribution of energy as a function of frequency and time during utterances that have high power in the air.

We involved participants in the analysis and interpretation of data so that we can obtain their self-reports and learn from them–even though we do not privilege self-report data. The involvement of participants in the analysis and interpretation allows them to understand what we are learning from a study and creates opportunities for reflexivity and positive change in their practices. Their participation strengthens research by making it more polysemic–presenting opportunities for us to learn from multiple meaning-making frameworks. For example, in the present study, Vicky and several students were shown offprints similar to those in Figure 2. Without having to listen to the audio file, Vicky and the students immediately recognized the facial expression, orientation of the head to the rest of the body, and upper body posture, associating these characteristics with the teacher being "crabby." The students indicated they did not work as well when Vicky was crabby because they were afraid to get involved, especially if they had incorrect answers. Vicky concurred and added that nagging moves were prevalent in her approach to teaching, especially as the lesson progressed and students became inattentive.

The involvement of Vicky and some of her students in the research affords our addressing of the authenticity criteria we adopted in this research. Also, it is part of a reflexive methodology in which participants become aware of forms of conduct and thereby create possibilities for discussing what happens, identifying possibilities for change, and introducing changes in the conduct of science education specifically and social life generally. We employ an activity called cogenerative dialogue (hereafter cogen; Tobin & Roth, 2005) as a research methodology and catalyst for improving the quality of teaching and learning. Cogen is described later in this paper.

No. Guys thank you. One at a time. (1)

54 μwm^{-2}
No
135 μwm^{-2}

Scuze me. I said one at a time. Thank you. (2)

57 μwm^{-2}
Scuz
124 μwm^{-2}

Figure 2. Nagging utterances analyzed in terms of prosody and proxemics.

Vicky's emotions as she analyzes her own teaching

We were interested in Vicky's enactment during reflective sessions in which she dialogued with the researcher as she used StudioCode to analyze videotapes of her teaching. The involvement of teachers as researchers of their own practices is often advocated as an important way to learn about teaching and provide insights into ways in which teaching, learning, and associated learning environments can be improved. As Vicky viewed the videotape replay, she used StudioCode to categorize various aspects of the emotional climate in her classroom, with a focus on emotional aspects of her teaching. As she did so she dialogued with a researcher, who was also a lecturer at the university in which Vicky had undertaken a degree in science teacher education. We selected several events from the reflective session for further analysis, often because of the emotional expression that occurred. In one of these Vicky entered a code to represent her emotions and explained that she felt fearful: "so I guess I was a little bit anxious about how that would work." Figure 3 contains a graphical representation from PRAAT that shows Vicky's dialogue at the time when she expressed this utterance. The wave trace at the top shows the energy distribution of the sound wave as a function of time. At the bottom of Figure 3 there is a continuous curve that shows the intensity level of the sound as a function of time (it is continuous because of the background noise). The broken curve shows the fundamental frequency F_0 as a function of time (plotted between 75 and 700 Hz). The information in Figure 3 shows a concentration of energy in the first word: "so." The time taken to utter the word was approximately 0.3s. Because of the amount of energy and the intonation of the word we decided to look at its prosody in more detail. The graphical representations contained in Figure 4 isolate the word "so." The variation in the intensity of the sound, approximately 66 dB throughout, is small and so too is the change in F_0, which is approximately 233 Hz. Further analyses in Figure 5 show the distribution of higher level harmonics during speech, produced at the same time as F_0. In linguistic analyses these are referred to as formants. The lower panel of Figure 5 shows two ways in which these are represented. First, the variation in gray shade reflects variations in energy as a function of time across a frequency band from 0 to 5000 Hz. As the word "so" is uttered there are five reasonably stable harmonics/formants in which energy is distributed (i.e., F_1-F_5).

Shortly after the first utterance Vicky expressed emotions in her face and voice when she exclaimed: "o::h this sucks." Because there was more emotion in this expression than in the utterances surrounding it, we undertook microanalysis. Most energy was in the first word: "o::h." The information in Figure 6 shows that the one syllable word had two parts with most energy in the first part, with a discernible change in frequency about 33s into the audio file, midway through "o::h." Table 1 contains the frequency and power contributed by each of the formants associated with the sound wave at that moment in time. Most power is associated with F_1 (121 Pa^2-s), which contains four times the power of F_0 (29 Pa^2-s). That is, what we heard as an emotional utterance contained

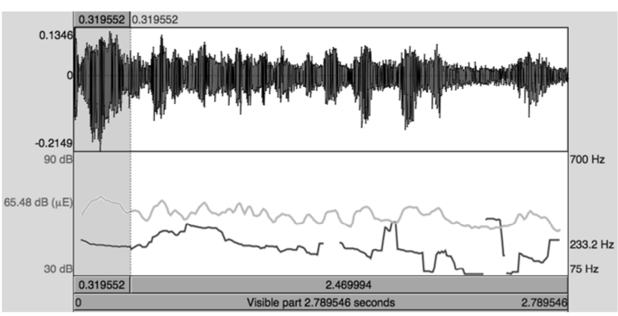

Figure 3. Prosody analysis using PRAAT.

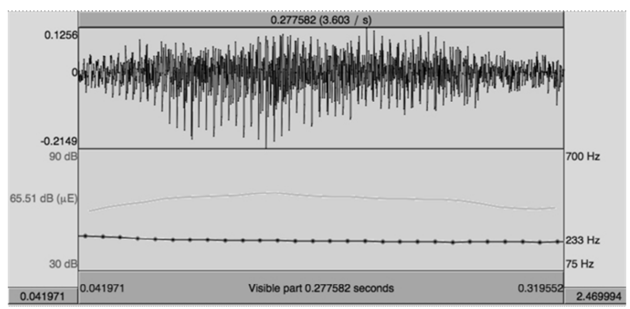

Figure 4. Analysis of sound intensity and fundamental frequency of an utterance.

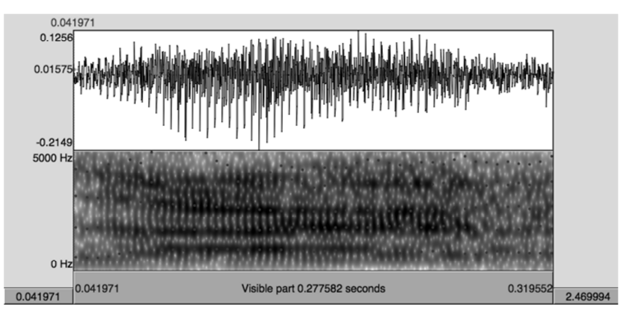

Figure 5. Prosody analysis showing energy distribution and formants (F_1-F_5) as functions of time and frequency.

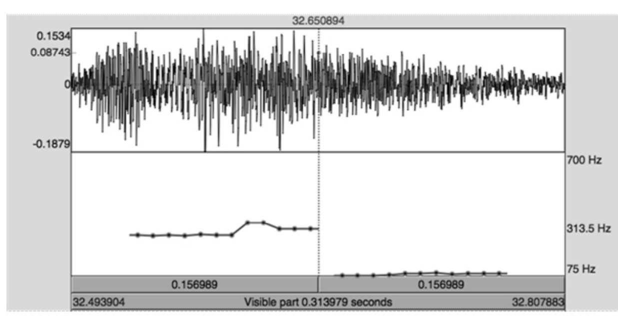

Figure 6. Analysis of F_0 for o::h.

more energy in F_1 than Vicky's normal speech in which nearly all of the energy is expressed in F_1.

Table 1
Power Distribution Across the Formants for an Emotional Utterance of o::h

Formant	Frequency	Power
F_0	299 Hz	29 Pa^2-s
F_1	710 Hz	121Pa^2-s
F_2	1437 Hz	14Pa^2-s
F_3	3055 Hz	4Pa^2-s
F_4	3972 Hz	3Pa^2-s

Vicky's emotions as she teaches

The study of emotions in a reflexive activity was interesting because it confirmed some research done by Klaus Scherer (2003), which suggested that emotional energy was associated with a shift in the distribution of energy from F_0 to F_1. In this reflexive activity, Vicky was relaxed and her voice was not strained as she expressed a full range of emotions while dialoguing with a co-researcher and analyzing video files of her own teaching. As an illustration of the way in which context can be examined in studies that employ conversation and prosody analyses, we identified an instance in Vicky's teaching of a grade 10 science class in which she expressed negative emotions, which we referred to as nagging. Figure 7 shows Vicky at the front bench of her science lab, calling on the class to pay attention. The physical orientation of her body is typical

Figure 7. Body orientation during emotional utterances in class and while reflection on teaching.

of the way in which she uttered nagging utterances, which were intended to establish control over the students. Her body orientation is a marked contrast to the relaxed way in which she undertook reflection on her teaching. As Vicky uttered "thanks grade 10" the nagging sound appeared to contain energy in the higher-level frequency formants. The intensity of the sound wave (123 μWm^{-2}) was extremely high in comparison to the intensity of the sound wave at other times during the lesson. The information in Figure 8 shows the energy distribution as a function of time and frequency and also the formant structure. Table 2 shows a different pattern in the distribution of power across the formants than was evident in the reflective activity when Vicky expressed emotion in a more relaxed context (i.e., Table 1). In the class the amount of energy in formants F1, F_2, and F_3 is relatively high, approximately 3 times the amount of power contained in F_0.

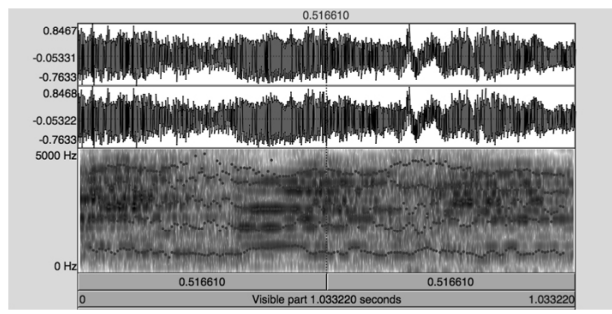

Figure 8. Prosody analysis for a negatively valenced, control-oriented utterance in a grade 10 class.

Table 2
Power Distribution Across the Formants for a Nagging Utterance of: Thanks grade 10

Formant	Frequency	Power
F_0	334 Hz	245 Pa^2-s
F_1	879 Hz	740Pa^2-s
F_2	2016 Hz	630Pa^2-s
F_3	2708 Hz	775Pa^2-s
F_4	3515 Hz	86Pa^2-s

Facial expression of emotions

Paul Ekman's seminal research on facial expressions and its incorporation into facial recognition software drew attention in many different regions of the face in the representation and expression of facial emotions (Ekman, 2004). Our initial efforts to use computer software to analyze facial expressions from videotape have provided us with a model that can also be used in microanalytic studies of the facial expression of emotions. In the analysis of facial expressions we address 12 action units shown in Figure 9.

The same action units provide a basis for computer analysis undertaken on each frame of a video file.

- Vertical movement of center of lower lip
- Vertical movement of center of upper lip
- Horizontal movement of left mouth corner
- Horizontal movement of right mouth corner
- Vertical movement of left mouth corner
- Vertical movement of right mouth corner
- Lifting of left cheek
- Lifting of right cheek
- Blinking of left eye
- Blinking of right eye
- Raising of left brow
- Raising of right brow

Figure 9. Action units used in eMotion software.

Ekman's model was derived from Darwin's studies of emotion and incorporates a framework that assumes that muscle actions are used to express emotions facially in much the same way from one person to another. Ekman's system includes six emotions, Turner's primary emotions plus disgust and surprise. Ethnographic methods can incorporate this framework to analyze emotions as curricula are enacted. Sound and video files are used in the analysis, which involves repeated observations of the images played at regular speed, slow speed, and frame-by-frame progression. For selected events, we augment meso level analyses with micro analyses of facial expression using a software package (eMotion; Sebe et al., 2006) that provides for each frame in a video file a distribution of measures of seven facial expressions: neutral, happiness, anger, sadness, fear, surprise, and disgust. The software requires a full-face view for an analysis. Figure 10 is a facial view of Stephen Ritchie and the table to the right shows the distribution of emotions in terms of Ekman's classifications. The line graph at the bottom of the figure shows a continuous trace of emotional valence versus time. If high-density video recorders are used in research, it is possible to extract faces from offprints and use the computer software to measure the facial expression of emotions. In these cases StudioCode can be used to identify full-face video images from selected micro events, for use in an analysis using eMotion. Video files can be produced for each participant in the research, beginning with several frames that depict neutral emotions. In many contexts in our research we can use the camera built into the screen of a computer to obtain suitable facial images. Figure 10 shows the mask used to track the 12 action units changes of which provide vectors that have been calibrated to produce the measures of facial expression of emotions.

Figure 10. Measuring facial expression of emotions using computer software.

The use of facial emotion software has an added advantage in that it sensitizes and trains researchers to see facial emotions in meso level studies. That is, what we learn through microanalysis alters how we see during ethnographic analyses. We regard this as eliciting a state of critical awareness and subjectivity in the research process—part of a reflexive research methodology.

Emotions and physiological change: Work in progress

Research suggests that emotions change physiological processes and vice versa. Although most changes occur passively, emotions and physiological variables can be manipulated. Pierre Philippot, Gaëtane Chapelle and Sylvie Blairy (2002) connected the production of emotions to breathing patterns that were similar across individuals and clearly differentiated for different emotions. The use of characteristic breathing patterns associated with an emotion led to the production of that emotion. For example, happiness/joy was produced when participants used slow, deep, regular breathing through the nose. Similarly, anger was produced with fast, deep, irregular nasal breathing, and sadness occurred when participants used nasal breathing with average amplitude and frequency.

Consistent with a standpoint that a goal of research is to produce and refine theory and catalyze positive changes for participants in research and the institutions in which they practice, a number of teacher researchers have already adapted these ideas in their inner-city science and mathematics classes in New York City. As they teach they monitor their pulse rate using a finger pulse oximeter, which measures blood oxygen saturation, pulse rate, and pulse strength at a rate of three data points per second. Bluetooth technology is used to transmit data to a computer from an oximeter, which is worn like a wristwatch and consists of a short cable connected to a thimble worn on the index finger. When the pulse rate reaches a threshold of 120 beats per minute (bpm), for example, teachers change their practices by consciously focusing on their breathing, the way they are moving in the classroom, and their in-the-moment emotions.

Students in the class are aware of the teacher's goal of maintaining a pulse rate between a resting rate (e.g., 68 bpm) and a target threshold (e.g., 120 bpm). Being aware of the social body in the moment is an important intervention that is already allowing teachers and students to be more mindful as science and mathematics curricula are enacted.

MINDFULNESS: A PATHWAY FOR FUTURE RESEARCH

Historically, science process skills were an important goal of science education. Problems in social life generally were thought to be solved using process skills–transcending subject matter and contexts in which process skills were learned (Tobin & Capie, 1982). In the past few decades, there has been increasing acceptance that generalizable skills such as those represented as basic and integrated process skills probably are more grounded/connected to fields in which they were learned (Roth, 1995). However, recent research suggests there are in-the-moment benefits of participating in science. For example, exploratory research in Taiwan used a program in physics for senior citizens to delay the onset of pre-Alzheimer symptoms (Liu, 2010). A plausible interpretation of this research is that participation in physics focused participants' attention, resulting in desirable forms of brain activity and associated physiological processes. Chia Ju Liu's study aligns with research on mindfulness, which Kirk Warren Brown, Richard Ryan, and J. David Creswell (2007) defined as "receptive attention to and awareness of present events and experience" (p. 212). Brown and his colleagues explained that mindful compared to conceptual processing involves a receptive state of mind in which attention is oriented toward registering facts observed, shutting down habitual processing, and making efforts to be present in the moment. In an extensive review of research Brown, Ryan and Creswell highlighted many advantages of mindfulness. As well as being less emotional, individuals had greater: control over their thought processes; awareness of experience while being immersed in it; objectivity; tendency to defer judgment; likelihood to act as ecological stewards; levels of cooperation with others; and social attunement. Mindfulness training is advantageous for mental health, well-being, physical health, self-regulation, and interpersonal behavior. For example, Davidson et al. (2003) reported that mindfulness, involving meditation, produces demonstrable effects on brain and immune function. Connecting back to the previous section of the paper, meditation can be associated with obtaining control over the body and the mind, often through focusing on some aspects of the body, such as breathing. Although mindfulness is a holistic construct there is empirical evidence to support five underlying constructs: (a) non-reactivity to inner experience; (b) observing/noticing/attending to sensations/perceptions/thoughts/feelings; (c) acting with awareness/automatic pilot/concentration/non-distraction; (d) describing/labeling with words; and (e) non-judging of experience (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). These constructs together with illustrative practices for each are listed in Table 3.

Table 3
Constructs and Practices Associated with Mindfulness

Non-reactivity to inner experience	I perceive my feelings and emotions without having to react to them.
	In difficult situations, I can pause without immediately reacting.
Observing/noticing/attending to sensations/perceptions/thoughts/feelings	I pay attention to sounds, such as clocks ticking, birds chirping, all cars passing.
	When I'm walking, I deliberately notice the sensations of my body moving.
Acting with awareness/automatic pilot/concentration/non-distraction	It seems I am "running on automatic" without much awareness of what I'm doing.
	When I do things, my mind wanders off and I'm easily distracted.
Describing/labeling with words	I have trouble thinking of the right words to express how I feel about things.
	I can easily put my beliefs, opinions, and expectations into words.
Non-judging of experience	I think some of my emotions are bad or inappropriate and I shouldn't feel them.
	I tell myself I shouldn't be thinking the way I'm thinking.

In ongoing research, we are using the framework from Table 3 as a heuristic for making specific activities in lessons more mindful. In so doing, we acknowledge that teachers and students are frequently better placed to decide when a more mindful approach is likely to be beneficial. In the next section we consider the importance of cogenerative dialogue (i.e., cogen) as the context for reflexive dialogue that could produce outcomes such as decisions to enact more mindful learning and teaching practices. In addition, we raise the possibility that cogen can be infused into lessons and is an ideal activity in which to enact mindfulness.

On the basis of ongoing research in Australia and the United States, we have learned that positive emotions are beneficial in certain activities, such as theatrical genres. Similarly, negative emotions such as anger and frustration can produce less than optimal learning environments (Tobin & Llena, in press). More research is needed to examine all the genres of activity in which action and emotion should be separated and those in which it is useful for emotions to be associated with classroom practices. It is possible that mindfulness may be desirable in micro-and meso-contexts while positive EC might always be desirable in a macro sense. Additional multi-level research is a priority.

Cogen and mindfulness

Cogen was developed as an activity to use in teacher education contexts in which coteaching occurred. One problem that needed to be addressed was to allow for stakeholder groups to have input into the quality of teaching and learning while identifying aspects that might be changed with the goal of improving learning environments. The discourse to be enacted in cogen was dialogic and special attention was focused on the equitable distribution of talk among participants, maintaining focus on the topic of dialogue, and listening attentively with the purpose of learning rather than opposing what was being said. All participants in cogen would enact roles that were specific to cogen and to the extent possible, they would not privilege their contributions because of the symbolism associated with their positions within institutions such as school. For example, it was important that students, teachers, school leaders, and researchers could contribute to an unfolding dialogue and to have their contributions treated with respect and to be genuinely regarded as resources to learn and improve learning environments. There have been numerous important outcomes of cogen but for the purposes of this paper, we focus on cogen as an activity in which all participants are able to produce new cultural resources that are adaptive to cultural differences and produce success. Importantly, the adaptive culture produced in cogen has served participants well in other fields of social life, including classrooms, school generally, further education, and the home. Because of the priority given to allowing each person to contribute in her/his own voice, and to maintaining focus until there is consensus on what is to be done to improve the quality of curricula, cogen emerged as a research method that provided important insights into our understanding of social theory and its applications to education. In a context of an activity in which dialogue is central, it is clear that mindfulness is a priority in cogen. Accordingly, it is possible that participants in cogen can learn to be mindful as they interact to solve problems that emerge during cogen. Also, it is possible that mindful practices could be enacted in other fields, just as cogen has been regarded as a seedbed for the production of many different forms of new culture.

Cogen is a useful research methodology for multi-level research because sociocultural frameworks associated with cultural sociology, philosophies of difference, sociology of emotions, and speech genre theory support it. Since any topic can focus on cogen the purpose of the dialogue in cogen can be to contribute to any aspect of the research as it unfolds, including design, analysis and interpretation, dissemination, and accomplishing authenticity criteria.

Participants in cogen were selected serially and contingently so that all stakeholder groups were represented and diversity was maximized. The optimal number of participants is approximately five to eight when cogen is used as a research method. However, worthwhile outcomes have been obtained when the number of participants in cogen has varied from two through to whole class groups. Although it has been customary to schedule cogen in out-of-school times, there is no imperative for this to happen. Since cogen is a field and we theorize fields to have no boundaries, it is possible for participants to move seamlessly in and out of cogen even though they remain in the same space for lengthy periods of time. This occurs with small groups of five to eight meeting at lunch times and when teachers infuse cogen into their teaching, thereby including the whole class. With just a few exceptions the latter scenario has hardly been researched. A priority is to examine ways in which cogen affords improved learning and teaching when it is infused as an activity in lessons associated with school curricula. Cogen appeals as the ideal place for mindfulness to be infused into school curricula with a plethora of desirable outcomes. This idea appeals as a fertile area for research in the learning sciences.

Social neuroscience and multi-level analyses

Science education research has recently included studies at the neural level (Liu, 2010). However, the equipment available for neural level research does not allow for extensive movement, including movement of muscles surrounding the mouth while talking, movement of the head, gestures, and body movements in general. On the contrary, stable and interpretable measures can be obtained when participants in research are relatively inactive in a physical sense but are active in their brain use. Accordingly, it is important to have clear purposes for research at the neural level and ways in which it can illuminate other studies done at the ultra-micro level. Usha Goswami and Dénes Szűcs exhorted, “Once we have greater understanding of causal mechanisms at the sensory level, across the whole brain, the field can move on to exploring how mechanisms of learning and development relate to individual differences in educational attainment and thus how educational intervention can be optimised” (Goswami & Szűcs, 2011, p. 656). After giving some thought to ways in which our research might be informed by neural level analyses we collaborated with Liu and her Taiwanese colleagues in a study that examined reflexive practices involved with learning to teach. As part of this study Tobin studied his neural processing as he observed his teaching of a doctoral level class. As he reviewed a selected vignette on a computer, an electroencephalographic (EEG) analysis was undertaken and infrared techniques were used to track his eye movements. The vignette was salient for him because it involved his own teaching. Figure 11 is an offprint from a videotape of Tobin's face during the experiment in which EEG and eye tracking data were obtained. Tobin is wearing a cap and various parts of his face are taped. We were interested to ascertain whether his facial expressions during the reflexive activity could be measured using eMotion. In Figure 11, the table to the right of his face shows that at this particular moment his facial expression contained 42% anger, 50% disgust, and 3% sadness.

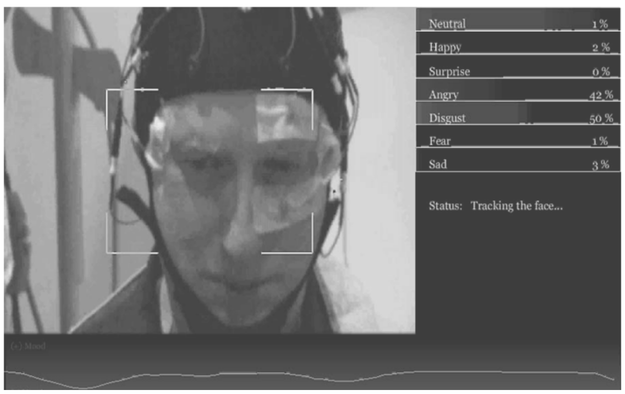

Figure 11. Facial expression of emotions during reflexive activity in which EEG and eye tracking are measured.

Because of the vast amount of data obtained using EEG and eye tracking analyses, we studied the vignette of Tobin's teaching and identified five salient events involving participants for whom his emotional responses would likely vary. Three events concerned students in the course and two involved former students who were co-researchers in this study. Of the three events involving students, two had the potential to produce negative emotions because of the students involved. For example, even though Tobin was watching a vignette selected from the first lesson of a course conducted two years ago, his interactions with several of the students throughout the course were sometimes negative and he felt they disrespected aspects of his teaching and the conduct of the course. The vignette was edited to begin with one of these students speaking and with her image in the central field of the camera. It would not be surprising therefore if Tobin expressed negative facial emotions unintentionally as he looked at these students and listened to them speak. A transcript of the vignette follows.

Turn	Speaker	Transcript	Duration of utterance
01	Zuringa	Um I'm Zuringa Wallengrat Um I I work at Bryne (0.7)	3.6s
02	Ken	Where do you live (0.2)	0.5s
03	Zuringa	Moranda (0.1) Donchester (0.2)	1.5s
04	Ken	Oh Ok (0.8) Where's that (0.8)	1.7s

The most salient features of a prosodic analysis of the audio file are that at the moment Zuringa utters Donchester, F_0 is 173 Hz, F_1 is 600 Hz, and F_2 is 1586 Hz. Most power is contained in F_1 (1122 μPa^2-s) followed by F_0 (320 μPa^2-s). The power contained in F_2 also was non-zero (229 μPa^2-s).

Because of the potential for negative emotions to be produced, we analyzed Tobin's facial expressions during utterance 03, when Zuringa responded to Tobin's query about where she lived. As is shown in Figure 11, as soon as Zuringa started to speak Tobin's facial expression reflected anger and disgust. In contrast, when Tobin looked at and listened to two former students who were collaborating with him on the research, his facial expressions of emotion were positive, reflecting happiness and associated positive elaborations.

One of the concerns we had about measuring facial emotions when a skullcap was involved was whether the protocols used in the calculation of emotions would be marred by restrictions to the face (e.g., tape attached above and below the left eye). Accordingly, Tobin once again reflected on the vignette of his teaching, this time without measuring EEG and eye tracking. The data obtained from the videotape of Tobin doing this allowed the relationship between emotions measured in each of the contexts to be analyzed statistically. Even though his responses to Zuringa speaking would not be the same on two different occasions, the information presented in Figure 12 shows that when Zuringa began to speak (i.e., at

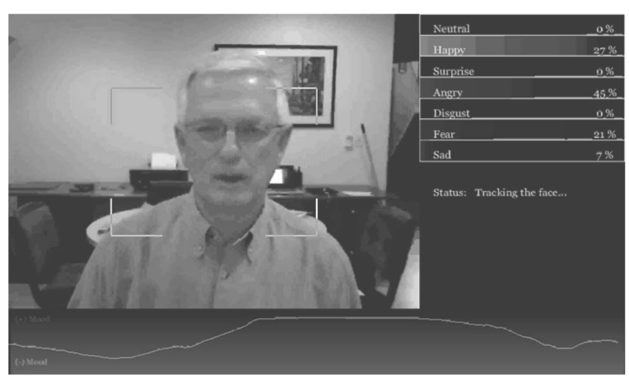

Figure 12. Facial expression of emotions during a reflexive analysis of a vignette without EEG and eye tracking analyses.

the same moment represented in Figure 11) Tobin's facial expression comprised 45% anger, 21% fear, and 27% happiness. Obviously these analyses provide ample data for interesting investigations of the relationships between the facial expression of emotions, brain processes, and eye movement. It is likely that recalibration of the facial expression of emotions software may be necessary because of its use in classroom research where talking and body movement occur frequently.

The relationship between physiological variables and emotions can be explored using a finger pulse oximeter, to obtain measures of time, pulse rate, oxygen concentration in the blood, and plethysmographic waveform amplitude (volume of blood flow). The Nonin oximeter provides extensive data three times per second. To demonstrate the method Tobin undertook reflection on the same vignette he reviewed using analyses of facial expression, eye gaze and EEG analyses. Because of a deteriorating relationship between Tobin and the two students who spoke in the vignette, it is likely that the sight and sound of these two students would afford passive structuring of negative emotions. Accordingly, it is not surprising that pulse rate throughout the vignette is far above Tobin's resting pulse rate (63 beats per minute - bpm) and the oxygenation of his blood is lower than the rest level of 96%. During the vignette the pulse rate based on 299 measures varied from 68 to 75 bpm and averaged 70 bpm. The standard deviation was 1.3. As Zuringa began her second turn at talk, Tobin's pulse rate jumped to 73 bpm and within a second it reached 75 bpm. Analysis of variance, comparing the means prior to Zuringa speaking with those obtained during utterance 03, showed significant differences in heart rate and oxygenation, although the differences may have little practical significance. Suffice to say that the data obtained using the oximeter can be used to differentiate differences in heart rate and percentage of oxygenation as emotional energy changed during an activity. As we noted in regards to teacher researchers using oximeters to intervene in their classrooms, much larger differences in measures are obtained in activities where there are large swings in emotional type and magnitude.

WHERE TO NEXT?

Several aspects of Sewell's theory of culture are salient to multilevel research. For example, there is a necessity to pay attention to contradictions and difference as well as coherence and sameness. We find power in the dialectical relationship between seeming dichotomies such as these. If we theorize that constructs that are often assumed to be dichotomies in fact coexist as expected conditions of social life, then research can be planned to identify and learn from contradictions and difference and their connections to the transformation of fields. These ideas are important when data resources are aggregated to build trans-level understandings of theory and practice.

There is a tendency for serious researchers to look askance at the possibilities available to learn at the neural level and to ponder the relevance of neural level theories and research for classroom practice. Simultaneously, there is a tendency for some program officers at agencies such as the National Science Foundation to regard neural level work as a pathway to ascertaining truths about learning and teaching. As is evident from social neuroscience, it is most important to plan research that connects across the levels and then in the spirit of emergent designs, to take what is learned to adapt and expand multi-level designs. Our first foray to the neural level provided a large mass of extremely rich data. However, the mining of these data to contribute to what we are learning at other levels necessitates an expansion of the theoretical frameworks and adoption of new research methods. The information we learned about the expression of emotions as Tobin reflected on his teaching provided an impetus to design micro studies of prosody, facial expression, and physiological factors such as pulse rate, oxygenation, and blood flow. These studies will take one and possibly more than one decade to successfully enact. At the same time, theoretical and multi-level empirical work on mindfulness has enormous implications for research that embraces collaborative models of teaching and learning. The connections of research in social neuroscience, such as that undertaken by Davidson and his colleagues (Davidson, 2010), to the work we have started on mindfulness in classrooms is central to a necessary revolution in teaching, learning, and learning to teach. We acknowledge that the research on neural processing and meditation together with everyday applications of mindfulness in recreation activities such as yoga and the burgeoning research on mindfulness in psychology were extremely persuasive to us as we pondered priorities for research in the learning sciences. Multi-level, multi-theoretic, and multi-method research are at the heart of the emergence of a science of teaching and learning. Clearly, there is much to be done and many tools are available to support the twin goals of event oriented social research–to produce theory while improving practice.

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