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Corresponding Author	Family Name	**Tobin**
	Particle	
	Given Name	**Kenneth**
	Suffix	
	Division	The Graduate Center
	Organization	City University of New York
	Address	365 Fifth Avenue, New York, NY, 10016-4309, USA
	Email	ktobin@gc.cuny.edu
	Email	ktobin0@gmail.com
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Chapter 8
Using Collaborative Inquiry to Better Understand Teaching and Learning

Kenneth Tobin

Abstract In a research career that exceeds 40 years there have been continuous changes in my research methodology on a number of dimensions. The most salient differences involved changes in the theoretical framework that began with logical positivism and gradually changed to embrace sociological and cultural frameworks such as hermeneutic phenomenology, reflexivity, culture, and ethics. A necessity to include multiple voices to obtain participants' perspectives catalyzed ontological issues, including how to deal with difference and embrace polysemia. As well as researching patterns of coherence I adapted methodologies to build understanding based on research on contradictions, which defined events. Thus event-oriented inquiry sought to understand social life through intensive research on spikes in coherence trajectories. Authentic inquiry drew attention to priorities given to theory and improvement of practice on the one hand and multilectical relationships that considered authenticity holistically – recursively considering goals associated with changing ontologies while learning from others, teaching others about personal standpoints and practices, and ensuring that institutions and all individuals benefit from participating in research. I conclude with cautions about the transcendent nature of social inquiry and a reminder of obligations researchers have to participate ethically in research dialogues, listen to learn, and enact right speech to foster social justice for all.

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K. Tobin (✉)
The Graduate Center, City University of New York, 365 Fifth Avenue,
New York, NY 10016-4309, USA
e-mail: ktobin@gc.cuny.edu; ktobin0@gmail.com

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Science Curricula as a Central Factor in the Reform of Science Education

In the 1960s there was an energetic debate about the necessity to change the nature of K-12 science education. At the time it appeared to science educators like me that there was agreement on the need for change and what needed to change, as well as healthy disagreement on what to change to and how to get there. John Lake, an influential science teacher educator from my native state of Western Australia, characterized the debate at the elementary level in terms of three nationally funded elementary science curriculum projects from the United States: Science – A Process Approach; the Science Curriculum Improvement Study; and the Elementary Science Study (Lake 1974). These curriculum projects had striking similarities and differences in their approaches to science education – each embracing science inquiry, but emphasizing different outcomes, and prescribing somewhat distinctive roles for teachers and students. Similar investments in curriculum projects having these characteristic orientations, also occurred at middle (e.g., Intermediate Science Curriculum Study) and secondary levels (e.g., Chem Study, Harvard Project Physics, Biological Science Curriculum Study). Differences spanned a variety of orientations (e.g., inquiry, historical, conceptual themes, and psychological foundations). Lake and many others at the time expected that research on the different approaches would somehow identify which approach was preferable and provide a pathway for improving science education. However, this was not to be. Even though there was a great deal of research undertaken on the enactment of different curriculum projects, the macro question of which approach was better was never answered definitively and I maintain that questions like these cannot be decided empirically or decisively by research. Research questions and associated research designs were oversimplified and answers usually failed to take into account participants' voices or quality of enactment. The question of which curriculum is best is macro in that it applies to multiple social fields and does not consider the importance of context, especially issues of implementation fidelity and details concerning the nature and quality of interactions among participants. Furthermore, debates about "which is best" seem to imply that social interaction is irrelevant. Myron Atkin and Paul Black (2003, p. 37) commented: "Both the 'teacher-proof' characterization and the concept of teacher-as-faithful-implementer later came to epitomize what many people saw as the arrogance of this style of curriculum development." It was assumed that teacher training would produce acceptable levels of implementation fidelity, which would then create experiences needed for all individuals to learn. To a large degree it was assumed that adherence to the activities suggested in the curriculum guides, which incorporated psychological learning theories, would enable all students to learn. Equity was considered in terms of opportunities to participate. Atkin and Black (p. 37) remarked succinctly that: "it did not work very well."

Chapter Overview

Although projects like the Elementary Science Study advocated student roles that emphasized autonomy and enjoyment, they did not consider students as research collaborators, curriculum developers, and coteachers. In effect, expanded roles for youth were constrained to peer collaboration – most notably cooperative learning (Johnson and Johnson 1999). In this chapter I describe a wider range of collaborative roles of participants in science education, including doing research for the purpose of improving learning environments, curriculum development, and teacher education. In so doing I illustrate how participants' roles have changed in relation to associated changes in research methodology. Research methodologies I address in the chapter include interpretive, authentic, and event-oriented inquiry. A particular focus concerns the standpoint of difference as a resource and its relationships to polyphonia, polysemia, and multilogicality. The centrality and high value our research squad assigned to collaborative inquiry are illustrated in cogenerative dialogue (hereafter cogen) and coteaching. In a broad treatment of polysemia I show how multilogicality and multilevel research provide complementary windows into social life and combine with other research methodologies to diverse perspectives on science education.

Changing Faces of Research and Science Education

Macro level approaches to framing research questions and the assumptions shared by science educators involved in research, teacher education, curriculum development, and policy, have striking similarities, many of which persist today. For example, a one-size-fits-all approach to theory may derive from adherence to empiricism and models for generalizability that are grounded in inferential statistics. The idea that the results of research applied to a sample and are generalizable to a population provide an underpinning for many graduate level courses in research methods and concerns with internal and external validity of scientific designs for research. Even when arguments were advanced for the use of qualitative data in research, the pressure to apply parallel criteria to interpretive research methods resulted in quality and authenticity criteria being developed and applied that appeared to embrace research that employed experimental and quasi-experimental designs. Accordingly, participants in interpretive research are often considered to be subjects and are referred to as a sample – inadvertently buying into a set of traps that would expose the methodologies and associated methods as deeply flawed and inferior to methodologies that embraced inferential statistics. The labeling of research methodologies as qualitative and quantitative set the stage for a debate that would take for granted many tenets of logical positivism. These included assumptions like the following: measurements and data are objective; the best outcomes from research are parsimonious rather than complex; well-designed

research will gradually contribute to discovering a social reality or truth; samples involved in research should be randomly selected to be representative of a population to which outcomes are generalized; the presence of research and researchers does not affect outcomes; random selection of subjects from representative sites in a target area (e.g., city, state, nation) allow differences in individual attributes to cancel out and those that cannot be ignored in a model can be measured and statistically controlled.

Instead of definitive research in the decades that followed the 1960s, mainstream perspectives on the nature of science and axiological commitments of scholars and policymakers framed curricular choices and emphases included in hundreds and perhaps thousands of reports that recommended the reform of science education (Hurd 1997). Furthermore, rather than dramatically changing the faces of science education, reports that advocated reform and associated methods to enact reforms of various persuasions appear to have reproduced forms of science education that have proved to be resilient. Today the cycle continues – there are still calls for reform of science education and what happens in science classrooms bears a family resemblance to what happened in the 1960s when the Sputnik curriculum revolution was in full swing. Of course there were notable exceptions. For example, within the *Science Curriculum Improvement Study*, Mary Budd Rowe researched factors associated with science inquiry, as it was represented in verbal interaction (Rowe 1969). Her seminal work identified wait time, the duration of pauses within utterances, as an important variable associated with the quality of verbal interaction and the presence of pauses between utterances (Tobin 1987). Also, Rowe identified other factors, such as the incidence of verbal rewards, associated with characteristics of verbal interaction that made notable differences to participation levels and the quality of verbal interaction (Rowe 1974). Research like Rowe's addressed an assumption that issues concerning the quality of social interactions are important aspects of learning. Also, her work highlighted the fallibility of the assumption that the curriculum project used was the decisive variable related to the quality of science education and science achievement. There is no guarantee that what is designed and intended will occur during enactment. Certainly curriculum resources, planning, and local school-based factors all contribute to the quality of learning environments. Rowe's research emphasizes that social interactions are paramount when science learning is researched. Of course, the implications are that research about enacted curricula can provide insights into how resources are accessed and appropriated.

What is happening in science classes? A broad question like this would have many answers depending on the context in which science education is embedded. For example, I expect science in a prekindergarten classroom to be quite different than science at a high school level, and for a given grade level science in urban schools might differ from science in rural and suburban schools. Similarly, salient variations in context might include social constructs such as nationality, social class, gender, native language, and religion. The mediating roles of social constructs such as these are almost axiomatic. Perhaps not so obvious is that what happens also depends on how you look and what you can and do see. For example, in 1984 Jim Gallagher and I focused on classroom management, mainly because high school youth in our study

were disruptive. Like so many classroom researchers at that time we made sense of learning and doing science education through Piagetian lenses, and adopted a stance that classroom order necessitated teachers establishing and maintaining effective control over students (Tobin and Gallagher 1987).

Knowledge does not exist independently of knowers or structured fields in which knowledge is both represented and enacted. A radical aspect of this assertion is that knowledge is only "known" when it is represented, as Erving Goffman (1983) noted, as a result of an interaction with social artifacts. Alfred Schutz (1967) put it another way; namely, that stocks of knowledge come to hand just in time during social interaction. This is an important idea with many implications for researchers. Social resonance focuses on knowledge as it is produced in the moment as structures unfold. Enactment, that is cultural production, supports fluency when it is timely, anticipatory, and relevant. For this to occur structures are anticipated as they unfold, and the knowledge needed to appropriate them comes to hand at precisely the right time. Since this process is continuous and involves a multifaceted structural flux, most of the process is automatic, beyond awareness, and non agentic. Emmanuel Lévinas (1999) referred to this process as passivity and Wolff-Michael Roth (2007) highlighted the importance of passivity to the agenda of science educators. To tap into passivity it is important to employ methodologies and associated methods that allow participants to become aware of their conduct and interactions that support their practices. Once they become aware they can reveal their ontologies in stories about what is happening and why is it happening. The analysis and interpretation of such stories can be an important thread in research in science education.

Here I argue that appropriate research needs to incorporate multiple methodologies and methods to examine curricular issues in ways that reflect their complexity, yield outcomes that are contingent and nuanced, and acknowledge that decisions about which approach is best will inevitably involve issues associated with axiology, ontology, and epistemology. Furthermore, experienced realities in the social world appear to be mediated by structures that situate individuals in different places in social space. If this is the case then research and science education would necessarily access participants' perspectives and understand similarities and differences in the realities participants perceive in a study. An important part of research methodology concerns ways in which similarities and differences are handled during analysis and interpretation. Theoretical stances concerning polysemia also are salient to ways on which research is designed and conducted.

My approach to research, which began in 1973, involved a gradual shift from quasi experiments and inferential statistics to test hypotheses to interpretive methods using predominantly qualitative data resources, affording emergent and contingent approaches to researching classrooms and schools in ways that were less reductive than our previous research that focused on variables and testing of pre-developed models. Even though it felt at the time that shifts in my methodologies were momentous, in a historical context they appear to be gradual and relatively slow. The most noticeable shifts involved changes from positivistic methodologies grounded in psychology to hermeneutic-phenomenological inquiry related to areas of sociology and anthropology. Increasingly I became aware that I

would learn more from research that was multi-voiced and included different robust perspectives among members of our research squad. As I developed a greater understanding of cultural sociology and constructs such as structure and field, I began to understand the power of constructs such as multilogicality, transcendence, and the desirability of using different lenses to study social life. An increase in the complexity of our work necessitated the development of multilevel research methodologies and methods and involvement of teachers and students as researchers.

In my first 20 years of research, theories for teaching and learning were frequently grounded in constructivism and developmental psychology. Social interactions were important, but given a pervasive unruly characteristic of science classrooms the highest priority often was directed to establishing and maintaining control over students. Innovative ways of looking at motivation to learn were incorporated into theories of student agency (e.g., Brophy 1987). As different constructs were used to focus research, the answers to what is happening and why that is happening changed – as did implications for practice, orientating science curriculum, teaching, learning, teacher education, policy, and research.

One noteworthy limitation of our approach, which was beyond our awareness, was the potential impact of the way we considered/dealt with non-confirming data. Frederick Erickson (1986) made it clear that assertions needed to be modified to be consistent with all data – that is, nuance had to be built into the wording of assertions and to some extent non-confirming data had to be explained in the light of a study's assertions. The approach was consistent with a Geertzian model for culture (Geertz 1973) – consisting of thick coherence being enacted in fields contained by strong boundaries. At the time I was most heavily involved in interpretive research and it never occurred to me that culture was central to our research in ways that would deeply relate to my assumptions about epistemology, ontology, and axiology.

Joe Kincheloe and I described how social sciences and associated research and curriculum development have been saturated by pervasive systems of logic that include tenets of positivism, including a tendency to seek simplified causal models that afford prediction, control, and accountability (Kincheloe and Tobin 2009). Lake's idea that answers to macro-level questions such as, "Which approach to curriculum is best?" could be answered definitively (and objectively) by research is flawed – an example of an oversimplified question that implies causal relationships among sets of variables. The idea that curriculum quality can be considered independently of context reflects a reductive view of social life – one that easily could overlook social interactions that make far more meaningful differences than those associated with the type of curriculum used to enact science education. A key point to emphasize is that theoretical frameworks illuminate social life in ways that raise specific issues as salient and at the same time they obscure other ways of framing social life. In science education this point often appears not to have been acknowledged. Possibly due to tenets of positivism, theories are often considered as right or wrong rather than as alternative ways of experiencing, describing and making sense of social life. Different theories highlight patterns and associated contradictions, affording particular ways of construing and learning from research. Furthermore, little research has examined axiology, the values hierarchy that mediates what is

considered central and of high priority as distinct from peripheral and of low priority. Often policy decisions are based on either-or thinking about choices.

Although science educators' methodologies and associated methods have changed continuously for the four decades I have been a science education researcher, I am still surprised by policy level pronouncements that are akin to main effects in statistically oriented research which produces assertions that have thick coherence – as if contradictions are not considered in models on which policy tenets are framed. Examples include assertions like the following: inquiry methods enhance science learning; argument strategies improve science achievement, and open-ended questions increase science achievement. One-size-fits-all claims are devoid of nuance and appear to ignore quality – for example, as if inquiry no matter how well, or fully it is enacted is preferable to no inquiry. There are many potential problems associated with research intended to validate best practices. Using a theoretical framework that includes levels of social life (macro, meso, micro): fields that are dynamically structured and unbounded, the enactment of any curriculum project is subject to an ever changing flux of structures that can produce culture that is simultaneously the same and different than what is produced when the "same" curriculum is enacted in another time and place. Rather than viewing enactment like a horse race it makes sense to adopt an approach that embraces phenomenology – learning from researchers' insights into what is happening from the perspectives of the participants and why it is happening. In this way landscapes can be created to reveal possibilities associated with the use of different curriculum projects in the context of them being enacted in different circumstances. Rather than producing simplified models in terms of clearly defined, significant variables, there are advantages in retaining complexity, acknowledging the salience of meanings in use, and recognizing that experiences described by language are underrepresented and always will mean more than can be expressed/represented using language. What is learned from such an approach to research would be grounded in contexts associated with the research (i.e., structures) and any claims about "what works" would be nuanced and considered an integral part of knowledge produced in the study. Users would understand that what is learned is replete with ever-present contradictions and any project involving enactment would necessitate contingent adaptivity that addresses the goals of individuals and collectives, levels of success, and dynamics of the agency|passivity dialectic (here the vertical bar denotes a dialectical relationship). Different theories highlight patterns and associated contradictions, affording particular ways of construing and learning from research.

Dealing with Difference in Research on Teaching and Learning

The relationship between an activity and theoretical frameworks used to experience and describe what happened in an activity are dialectically related. The relationship is synergistic in the sense that applying different theoretical frameworks provides new ways of looking at the activity and characterizing practices and their interrelationships. Theoretical lenses used to shed light on activity are reflected in questions like

the following: what to tweak, what to expand, what to truncate, and what to discuss? It is important to realize that as well as shedding light on activity, theoretical lenses obscure other valuable aspects of an activity. This standpoint embraces the relevance of bricolage and polysemia to social inquiry and acknowledges that there are downsides to privileging any one set of frameworks.

A hermeneutic-phenomenological perspective adopts a stance that you can learn about social life by understanding participants' experiences in social life. Furthermore, the approach emphasizes that experiences should be represented by participants' voices. This approach invites possibilities of different accounts of experiences shared by participants who occupy different locations in social space. That is, polyphonia expands possibilities for learning about social life and invites a stance be taken on polysemia. How will researchers handle differences in the process of learning from research?

A revolution in my thinking occurred when I shifted my research to urban schools and included urban youth as researchers and teacher educators (Tobin et al. 2005). The catalyst for reform was that the schools, in inner city Philadelphia, were beyond my experience. Furthermore, when I endeavored to teach in ways that were consistent with how I believed science should be taught in urban schools, my failure to succeed was so pervasive that I needed to take stock of not only my own knowledge but also what was reported as the published "knowledge base of science education." The knowledge needed to teach urban youth had to be enacted. It did not exist independently of the dynamic structures of the urban science classes I had to teach. On the contrary, the knowledge to teach urban youth occurred where the rubber hits the road – in urban classrooms – constituted in dynamic structures as they unfold and are appropriated in chains of interactions. Knowledge of how to teach urban science education could not be separated from all participants' actions – that is, it was in the moment and certainly not something I possessed alone. Furthermore, only some of the knowledge was accessible to language. My experience was a notable example of knowledge being distributed across interaction chains that occurred in a field and that descriptions of research, available in research reports, to positively impact learning had to be enacted appropriately.

An ongoing problem in education generally and science education specifically is an emphasis on individualism. From this perspective learning is regarded as something that individuals do independently of others and elaborate assessment systems are developed based on this premise (Tobin 2012). Aligning with this assumption is a tendency to hold teachers accountable for their students' learning, narrowly construed and assumed to occur primarily at school. That is, science achievement for a particular period of time is a reflection of science teaching at a school during that period of time. At the very least the premises underlying assumptions like these are over-simplifications of very complex processes. The implications of enacting policies based on such assumptions are likely to have profound impacts on education in the near and distant future and have probably been associated with many of the inequities and inadequacies documented in the literature.

How might we think alternatively about individuals and collectives? In our research, for almost two decades, we have considered individual|collective as

dialectically related, each recursively associated and presupposing others' existence. From this perspective, as individuals|collectives enact culture in a field, their productions (transformations|reproductions) are interconnected. A recursive relationship between individual and collective implies that changes in one are reflected in the other; the actions of any individual becoming resources for actions of a collective. That is, all individuals in a field are "in action" simultaneously and continuously, enacting culture that has a cascading effect since everybody's actions are resources for everybody else's cultural production. If a teacher acts in ways to expand the learning possibilities of others then, from this perspective, everybody is a teacher for everybody else because acting in a field provides resources to support others' learning. That is, teaching|learning are dialectically related and it is impossible to think of one without the other. Interrelationships between teacher and learner are inextricably linked and whereas learning cannot be separated from teaching, neither can teaching be separated from learning. Learners' actions mediate the possibilities for teaching at every moment enactment occurs in a particular field. Accordingly, it makes no sense to think of teaching in isolation from particular collectives, including students. As most teachers readily acknowledge, the way a person teaches one group of students is often quite different from the manner in which the same person teaches another group. To argue otherwise and assume that teaching can be considered independently of learning and learners is fraught with the potential for failed expectations. For example, accountability systems grounded in assumptions that teaching is a commodity that is transferable across contexts, including schools and students, is suspect at least and damaging at worst.

A current trend among scholars in science education is to consider identity as an outcome (Varelas 2012). There is acceptance of the idea that identities are forged as individuals participate in multiple fields as time unfolds. As individuals think back on what was accomplished in those fields, memory traces reconstruct what happened in much the way that a highlights reel is put together. Events that stand for enactment in a field are reconstructed and it is perhaps in association with these events that individuals construct images of "self" in particular fields. Obviously these constructed images are based on a reduced database and are subject to ongoing revision as an individual returns to a field over time. Whereas most recent studies think of identity as fluid and context dependent very few theoretical models have considered the full implications of an individual|collective relationship. If individuals are considered in relation to collectives in which they practice, then it makes sense for identity to be theorized dialectically rather than as a property of an individual.

Participants Doing Research to Understand and Improve Practice

I began to include high school youth as student researchers in a study I undertook with Stephen Ritchie, in Tallahassee Florida (Ritchie et al. 1997). In that study we utilized a middle school female as a student researcher and, although it did not work

out as we envisioned or planned, we both retained our commitment to the idea that youth could provide valuable insights into what was happening and why it was happening. The initial problem we encountered was that the student researcher was not interested in our research and we found it difficult to motivate her to participate as a researcher. In contrast, my research at the University of Pennsylvania was quite different because the students provided their perspectives on the quality of teaching, suggesting ways to make improvements that would suit them. In other words their interests were central (Tobin 2000). Initially our tendency was to privilege their voices because their perspectives were valued. It took time and different frameworks for us to realize that quite likely the greatest benefits of students speaking about teaching and learning involved their participation in the activity. There was value in them speaking with other youth about teaching and learning, and their teachers, who were older and obviously different from them in many social categories. Engaging in dialogue with others who differed markedly in a number of social categories appeared to be a most valuable thing to do.

As director of teacher education at the University of Pennsylvania I inherited a research project proposed by Fred Erickson – largely premised on the idea that students could provide teachers with good ideas on how to be better teachers for kids like them (Tobin et al. 2005). The initial plan called for two youth to serve as advisers to new teachers at least once a week. We instructed the new teachers to select youth from their classes, keeping in mind their differences from one another, often selecting students who were having difficulties in the class. The advantages of the activity were evident almost immediately in that students were not only invited to evaluate the quality of teaching, but also to make specific suggestions about changes to enact. Many of these made an immediate difference and were highly visible, becoming objects for further dialogue in face-to-face meetings. Other benefits were less obvious. For example, in many cases the students involved had not had opportunities to speak with authority and be heard by adults – who were regarded as authority figures (e.g., teachers, school administrators). Not only did the youth make suggestions, but also they received requests for elaboration, clarification and further input. The youth felt respected and demonstrated shared responsibility for the quality of learning environments. During their regular face-to-face meetings the youth and their teachers developed social bonds that, in many cases, transferred into classroom settings. Evidence of such social bonds included cooperative interactions with the teacher and others and efforts to minimize their own and others' disruptive practices.

An unanticipated problem was that the students' voices were privileged in the activity. The youth were regarded as authorities and most of them spoke about exemplary teaching in terms of teachers effectively controlling students. Furthermore, they often considered high quality learning environments in terms of being silent and busy – for example, copying notes from the chalkboard or from a textbook (Tobin et al. 1999). Although youth were sincere, honest, and forthright, a problem resided in their logics about good teaching and learning, including their values concerning what was most important. Frequently students had bad ideas that were oversimplified and included strategies such as corporal punishment, isolation of offenders from others in the class, and exclusion of troublemakers from the class.

Listening to and Learning from Others' Voices

Emerging from the idea of students being mentors for their teachers, Roth and I developed cogen (Tobin and Roth 2006). We highly valued activities in which teachers dialogued with youth, not only sharing the amount and frequency of talk, but also listening and being heard by one another. Accordingly, we decided to undertake research on the nature of the dialogues and change the structure to expand its potential for improving learning environments and schooling more generally (Tobin and Roth 2006). Based on what we learned from youth dialoguing with teachers about "how to better teach kids like me." We labeled the activity cogen because we expected participants to speak and listen in ways that were focused, in synchrony, and entrained across time and space. Cogen acknowledged that consensus was a goal of an activity in which participants understood one another's perspectives and goals, and endeavored to reach consensus on what was to happen next in class. A valued structure was the right for anyone to have and retain different perspectives while participating fully in the fields of class and cogen.

The research in which Roth and I developed cogen was situated in West Philadelphia. As we developed cogen we also created and researched a coteaching model in which new teachers taught together in urban classrooms for the purpose of better accommodating the needs of urban youth while at the same time learning to teach by teaching at the elbow of another (Tobin and Roth 2006). Cogens were organized to include four or five students together with all participating coteachers, researchers, university supervisors, etc. The requisite for being involved was that all participants in cogen needed to have been substantively and collaboratively involved in the teaching and learning of a lesson. Initially the purpose of cogen was to focus on participation in a dialogue that would identify ways in which the quality of the teaching and learning in the class could be improved in subsequent lessons. Typically cogens at the middle and high school level occurred after school or at lunchtime and occupied 40 min to an hour. Gradually cogen was regarded as an integral part of teaching and learning and teachers and students accepted cogen as part of the ongoing curriculum. The number of participants often included a whole class, and at times one-on-one cogen occurred when a teacher and student met together to resolve classroom-based issues.

Cogen focused on the idea that dialogue had the purpose of converging to produce consensus. Even though individuals may not be in agreement it was essential for participants to reach consensus and then accept responsibility for enacting what had been agreed. This was to change in a number of ways that reflected emergence, contingence, and the synergistic nature of the research in which we engaged. First, we noticed that students who had participated in cogen began to coteach with their teachers. Acceptance of the responsibility for enacting what had been agreed to in cogen resulted in those students assisting the teacher in a variety of ways that included managing the class and most importantly, assisting students with their understandings of what was being taught.

The research drew attention to an important set of dialectical relationships: teacher|learner and teaching|learning to name two. As we reviewed what was happening in classrooms and in cogen it was apparent that there would be times

when teachers would be learners with respect to their students and at other times students would be learners with respect to their "official" teachers. These theoretical realizations provided new ways of looking into classrooms and of undertaking research on teaching and learning.

Over approximately 15 years of research and development the purposes of cogen have expanded. For example, because teachers and students differ quite significantly from one another in terms of salient social categories there is an opportunity for participants in cogen to develop adaptive forms of culture for successfully interacting with different others. We regard cogen as a seedbed for cultural production. When it is viewed in this way cogen is an activity that is quite central for new teachers to learn how to successfully teach in urban schools usually characterized by diversity and social categories such as race, ethnicity, native language, English proficiency, religion, and sexual orientation. Through careful selection of participants in cogen it is possible for them to learn how to interact successfully in culturally adaptive ways (Shady 2014). Even though a number of doctoral studies have been undertaken in which cogen has been used to improve the quality of teaching and learning and school level environments (e.g., Bayne 2012), there is obviously much more research that can be done within a sociocultural framework in which collaborative dialogue between individuals who are different from one another can be studied as it evolves in dynamically rich contexts.

Cogen also has been used as a research methodology to afford students and teachers enacting roles of researcher (Tobin and Llena 2011). Within a methodology that involves the enactment of cogen, teachers and students can enact a variety of methods that provide windows into the science of teaching and learning (i.e., the learning sciences). A feature of cogen is that it is an activity structured to foster polyphonia and associated radical listening (i.e., "making an effort to understand others' standpoints without seeking to change them" Hayes et al. 2010, p. xix). That is, everybody is encouraged to participate actively, and as they do so others listen with the explicit purpose of making sense of what is being said and exploring its affordances. Seeking alternatives is done only after a speaker's perspective is understood and its possible affordances have been fully explored. The speaker has a responsibility to "speak for the other" assisting to help others understand what is being proposed and to see its affordances. The speaker has a responsibility to promote interaction with the knowledge that focus will be maintained on the issue that is on the table until there is agreement to move on. At the same time radical listening occurs all participants are encouraged to practice right speech, especially if inequities/injustices are occurring in cogens or the class. When the structural aspects of cogen are enacted the research addresses the authenticity criteria (Tobin 2006) I adapted from Egon Guba and Yvonna Lincoln (1989). That is, participants all get a chance to lay out their ontologies and as a result of objectifying them they can expand and adapt them. Similarly, through radical listening all participants learn about one another's ontologies without seeking to change them. Right speech allows participants to focus on the affordances of all ideas, creating a climate in which consensus can be reached on how to improve the quality of science education institutionally. Similarly, as individuals listen and reflect on their own standpoints, they are well placed to benefit their and others' personal learning.

Initially our work on cogen was broadly theorized within a framework of cultural sociology. We broadened this framework to include the Heideggerian notion of learning by being in with others (Heidegger 1996). This idea was very prominent in our thinking about coteaching and ways in which actors became like the other by being with the other. This theoretical frame was applied also to the ways in which participants in cogen learned from one another. Because of our use of Randall Collins' framework concerning interaction ritual chains our initial concern was with synchrony in speech (Collins 2004). Accordingly, we structured cogen to focus on the distribution of speech, and synchrony and entrainment within and across interactions. For example, when somebody spoke we expected to see a strong focus on the speaker and signs of synchrony involving all or most participants in relation to the speaker. Similarly, at the same time we expected to see synchrony distributed across the entire community i.e., entrainment. Each speaker was expected to act not only for his/her self but also for others; that is, to provide opportunities for social resonance. Other structures also applied to equity in terms of who spoke orally – the number of turns of talk and the duration of talk. Furthermore, we emphasized the obligation of participants to speak for others, meaning that speakers should be attentive to the necessity of others making sense of what was being said and connecting with it in a multitude of ways. Speaking for others embraced a responsibility of each person for learning of the collective.

An initial concern we had in structuring cogen was that we needed a hedge against behaviorism. We did not want to assume that because people were not speaking explicitly that inner speech was not happening. Since we could not access individuals' inner thoughts it was important to emphasize to all participants that activity included inner as well as outer speech. We were explicit concerning legitimate participation including the thinking that occurs as others spoke. We consider this to be salient because the purposes of inner speech can be as varied as the purposes of outer speech (Vygotsky 1962). Obviously, focus, synchrony, and entrainment involve actions on the inside as well as actions on the outside – actions that are not directly accessible to others. Since we had legitimated inner speech we felt it was necessary to address the obligation of each participant to speak out when, and as necessary. This is what I mean by right speech. We considered there was an ethical responsibility for right speech to occur – that is, for individuals to contribute when they could advance collective goals and goals of individuals within a collective. We did not want individuals to sit quietly pursuing their own goals without accepting responsibility to participate equitably, ethically, and responsibly to benefit others in a collective.

Learning to Teach from and with Others

At the time we developed cogen we also were very interested in the development of coteaching models. Initially these models were designed to afford learning to teach for preservice teachers in circumstances where the resident teachers were unwilling to surrender their classes because they themselves were experiencing difficulties

that often appeared insurmountable (Tobin et al. 2001). Accepting the advice of a school principal we decided to allow two preservice teachers to teach together without any supervision from a resident teacher. We were able to do this because the school principal was able to obtain emergency certification for the preservice teachers so that the coteaching activity was legally viable. We decided to move forward with this idea on the understanding that we would study it so that we could learn what worked, what we needed to tweak, and what we needed to discard. The initial experiment was so successful that we decided to adopt coteaching as a model for the entire high school teacher education program. At the time we had not fully worked out the characteristics of a heuristic that could be used to guide those who would enact coteaching and it was very much work in progress. In this case collaborative research was a necessity to develop heuristics that could be used to improve the quality of coteaching and broaden its use beyond initial teacher certification to include professional development of practicing teachers.

In order to undertake research on coteaching we opted for a collaborative approach that included new teachers, resident teachers, and high school youth as researchers. It was immediately evident that cogen was a suitable activity for research meetings. Accordingly, we folded coteaching and cogen together for the purpose of improving the quality of teaching and learning. As we did so we developed rules that structured the "talk about praxis" to ensure that power was distributed throughout all participants and that all participants were involved equitably. We had already included most of these ideas into the rule structure and use of the term dialogue was consistent with our theorizing the activity in terms of the work of Lev Vygotsky (1962) and Mikhail Bakhtin (1986).

Searching for and Learning from Spikes in the Curve

How to learn from difference? Having a background in physics and mathematics I am well grounded in statistical analyses in which residuals are calculated and often regarded as error or, having no meaningful consequence. The usual approach is to identify and interpret central tendencies taking them to account for the magnitude and source of variance. However, there are also methodologies that search for outliers and make sense of them. In the context of every voice representing lived experience I had a goal to interpret data resources in terms of central tendencies and contradictions. William Sewell's event-oriented inquiry opened up promising possibilities. He regarded an event as analogous to a rupture of a coherence trajectory – a spike in the curve. For example, if a teacher's average pulse rate while teaching is 98 bpm then a rise to 160 bpm might constitute a spike in the curve. An event would be selected to contain the spike. That is, all salient data would be examined before, during, and after the rapid increase in pulse rate. The selection of an event would be based on all data and would include the spike in pulse rate. Event analysis would then involve a bricolage consisting of methodologies such as multilevel, interpretive, and authentic inquiry.

Event selection begins with the identification of a significant contradiction. After that all data resources I used in the process of identifying and then analyzing an event. A feature of event-oriented inquiry is that we examine what is learned contingently so that the design for subsequent research can be expensive, taking account of what has been learned and continuing to learn more using whatever methodologies make sense in the circumstances. As is the case with other methodologies examined in this chapter event oriented inquiry is considered as a valuable component of a multilogical bricolage that underpins social inquiry that focuses on the science of teaching and learning.

Authentic Inquiry as an Overarching Methodology

Questions about the purposes of research arise from the adoption of models that involve participants as researchers. For example, we pondered the goals of research in terms of models that had privileged theory over practice in the sense that research that produced a new theory was favored over research that improved practices (Arendt 1958). We slowly increased our value for many purposes of research, favoring models in which different goals could be pursued collaboratively by stakeholders who learned from one another, respected the rights of others to hold different understandings and in fact different practices, and actively seek to attain equity, ensuring that all participants benefited from the research. I adapted Guba and Lincoln's models for fourth-generation evaluation (Guba and Lincoln 1989) to embrace polysemia and to accept all stakeholder groups as potential researchers (Tobin 2006) by adapting the four authenticity criteria proposed by Goober and Lincoln, authentic inquiry included two sets of goals related to theory production and to related to improved practices. This approach was consistent with Hannah Arendt's reminder that changes in theory and practice were both valued outcomes from activities such as research.

In order to emphasize authentic inquiry we focused on the creation of models that could be used to educate all participants about the research and what we were learning. Also we designed interventions to afford changes in all participants' understandings, their understandings of one another, different understandings and practices, and changes in conduct for individuals and collectives within the group of research participants.

One form of intervention we designed was quite direct and the other was relatively indirect. For example, a direct intervention involves the use of breathing to ameliorate teachers' and students' expressing high intensity emotions as increases in pulse rate and strength and low levels of oxygen dissolved in the blood. Based on our ongoing research and published literature (Philippot et al. 2002) we designed a breathing meditation intervention which we have now implemented to increase mindfulness at the start of each lesson. That is, the intervention reflects research undertaken by others and what we had learned from our ongoing research.

We also knew from our ongoing research that becoming aware of the unaware can provide participants with things to think about and possibly change. For example, in my research in urban schools, becoming aware that my habitus was breaking down led me to analyze video frame by frame and to get a student researcher to be a mentor for me (Tobin et al. 1999). Recently we have allowed teachers and students to wear finger pulse oximeters in class so that they would become aware of their physiological expression of emotions. Once they were aware of the possible salience of factors like pulse rate, strength of polls, and oxygenation they could use breathing techniques and other practices to gain control over these physical indicators of emotion – when, if, and as necessary.

Finally, we develop sets of characteristics for important constructs that we felt might be improved by allowing participants to become more aware about them. We refer to lists of characteristics for given constructs as heuristics. Two examples that have salience to this chapter are coteaching and cogen. Based on our ongoing research we developed lists of characteristics for coteaching and cogen and asked participants to think carefully about each characteristic in relation to their own conduct. The following are examples of heuristics we developed for cogen: I am respectful to others; I try to get others to contribute to discussions; I try to make sense of what others are saying; Others have opportunities to speak as much as I do; Others try to make sense of what I am saying; and I maintain focus. The following five point scale is provided for each characteristic: 5 = Very often or always, 4 = Often, 3 = Sometimes, 2 = Rarely, 1 = Never or very rarely. In addition, space is provided for participants to comment in regards to their experience with each characteristic. Becoming aware created of the characteristics for a construct like cogen creates a higher potential for participants to make changes on selected characteristics if, when, and as necessary. Importantly, awareness also opens up possibilities for passive change. If a person opens themselves to learning from others then it is possible that changes can occur in characteristics on a heuristic without conscious goals being formulated to make a change.

Heuristics afford change by heightening participants' awareness of characteristics associated with constructs that have emerged from our research as salient – in this case to coteaching and cogen. Heightened awareness creates a context for changing specific characteristics when and as it is deemed desirable to do so. We explicate characteristics of a construct (e.g., mindfulness) as short statements about the construct. The short statements serve the purpose of bringing particular characteristics to the awareness of those who use the heuristic. The inclusion of a Likert scale affords participants connecting each characteristic to their perceptions of its frequency of occurrence in a specific field. We try not to be repetitive, but instead include characteristics to stimulate reflexivity (Bourdieu 1992). As particular uses of a heuristic change in their contextual details we expect the characteristics included in the heuristic to be adapted to better-fit contextual details. We use the metaphor of "shape shifter" to convey the idea that a heuristic can change its characteristics for contexts of interest. Heuristics are used as part of authentic inquiry that employs design studies (Brown 1992) to plan, test, assess and adapt in an ongoing, non-linear cycle, as interventions are planned and validated to afford

changes related to characteristics included in heuristics, or characteristics like those included in heuristics. At any moment in time, heuristics reflect our best and are enacted and disseminated to others. Accordingly, the structure of cogen and science teaching and learning in the participant schools will consistently evolve. In terms of emotions, emotional climates and physiological constructs, we will initially create descriptive landscapes. Through dialogues about these data and interrelationships among constructs, participants in the research will become aware of the possibilities for manipulating what happens in class to produce measures and patterns deemed to be desirable.

Brown et al. (2007, p. 212) describe mindfulness as "receptive attention to and awareness of present events and experience," involving nonjudgmental attention to present-moment experiences (e.g., sensations, cognitions, and emotions and sights, sounds and smells in the environment). According to Brown, Ryan, and Creswell, being mindful involves orienting attention toward registering facts observed, shutting down habitual processing, and making efforts to be present in the moment. As well as being less emotional, mindful individuals have 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. Baer and Sauer (2009) regard mindfulness as a type of attention or awareness that includes qualities such as openness, acceptance, non-judging, non-reactivity, curiosity, and compassion. A concern expressed by Brown and Ryan (2003) is that attachment to emotions can reduce focus, productivity, and physical well-being.

Examples of characteristics developed for the mindfulness heuristic are: I am curious about my feelings as they occur; I easily find words to describe my feelings; I observe my thoughts without being caught up in them; I perceive my emotions without having to react to them; I am compassionate to myself when things go wrong for me; and I quickly recover when things go wrong for me. For each characteristic in the heuristic participants are asked to specify the frequency of occurrence that applies to their enacting the characteristic.

Research suggests that an increase in mindfulness will enhance wellness. For example, Davidson et al. (2003, p. 564) report that mindfulness, involving meditation, produces demonstrable effects on brain and immune function. Davidson identified six emotional styles corresponding with specific locations in the brain (Davidson with Begley 2012). *Resilience* varies from individuals who are slow to recover from adversity through to those who recover quickly when adverse circumstances arise. *Outlook* is an emotional style that pertains to how long a person can sustain positive emotion. *Social intuition* relates to the extent to which a person is adept at picking up social signals from others around him/her. *Self-awareness* concerns how well an individual perceives bodily feelings that reflect emotions (e.g., facial expressions, body temperature, pulse rate). *Sensitivity to context* has to do with an individual being able to regulate emotional conduct to take account of context. Finally, *Attention* concerns the sharpness and clarity of a person's focus. Individuals have a tendency to exhibit characteristic positions along continua associated with these emotional styles – positions that are not set in stone!

Depending on context and life experiences the primary patterns for any of the six emotional styles can vary due to neuroplasticity of the brain. This is a promising scenario as far as education is concerned because individuals might want to change their tendencies as far as some or all of the emotional styles are concerned – if, when, and as necessary. The research by Davidson and colleagues provides micro-level data, associated theories, and empirical validation for the plasticity/adaptability of the brain, raising promising scenarios for education to design and enact curricula that afford the development of tools related to changing emotional styles. Consistent with my involvement in multilevel research (Tobin and Ritchie 2011), our ongoing research is developing interventions that can be used in classrooms and other social institutions to afford individuals changing their emotional styles if, when, and as they choose to do so.

Reflections on the Changing Faces of My Research Methodologies

Doing research and science education is a journey I began more than 40 years ago. In that time I have focused my research on teaching and learning science and learning to teach science. Over time the focus has gradually evolved to building understandings of teaching and learning and learning to teach. Without privileging positivistic definitions of the nature of science, I referred to this evolving research focus as building a science of teaching and learning. My standpoint is that the research is an important part of science education and that more is learned by studying teaching and learning in many different contexts that include, but are not limited to: science, mathematics, music, martial arts, gardening, and everyday activities such as driving a motor vehicle.

As I explained in the chapter, the research methodologies I employed began with positivism and radical behaviorism (Vargas 1972), and gradually evolved to incorporate post-Piagetian constructivism and individual learning (von Glasersfeld 2007), reflexive sociology (Bourdieu 1992), cultural sociology (Sewell 2005), sociology of emotions (Collins 2004), and multilogicality (Kincheloe 2008).

At the present time our methodologies are constantly in flux as improvements in technology provide enhanced tools for multilevel research and we increasingly seek alternative knowledge systems to identify promising frameworks to illuminate our research (e.g., Buddhism, acupuncture, yoga). Our acceptance of methodological bricolage has produced a pastiche of methodologies that include the following forms of inquiry: interpretive, reflexive, multilevel, and authentic. Within this framework we see new knowledge about learning and teaching, embrace theoretical generalizability (Eisenhart 2008), and insist that research produce institutional improvements and equity for all participants. The project on which we have embarked his expansive and there is no logical endpoint, just as there was not a set beginning.

Long before my first formal study of science teaching and learning I was curious about teaching and learning science and gradually developed the tools that allowed

me the privilege of joining a conversation that is ongoing. Importantly, the conversation is polyphonic, polysemia, multilevel, and radically continuous. Just as it is my privilege to join and contribute to the dialogue, that is research, the dialogue will continue with fresh voices, hopefully informed by the echoes of earlier conversations. The science is the dialogue that continues, a dynamic flux that moves through time and space, illuminating experience in particular ways while failing to even notice most of what happens. What we know and can learn is radically transcendent, and this thought alone suggests that what we know must be expressed with nuance, humility, and radical doubt – realizing that our knowledge is necessarily incomplete and inadequate. Having said that, we must continue to participate in the dialogue, being open to learn from difference and when the circumstances demand, speak forthrightly about what we know, need to know, and when and how to promote social justice. At the bottom, it is a great privilege to do research with others and the price to pay for the privilege is ethical conduct, compassion for others' well-being, and preparedness to respect and learn from others while maintaining willingness to educate them.

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Author Queries

Chapter No.: 8 0002102864

Queries	Details Required	Author's response
AU1	Please check the usage of single quote for "another's'" in the sentence "Also we designed interventions to afford. . .".	
AU2	The references Brown et al. (2007), Brown and Ryan (2003), Davidson et al. (2003) are not provided in the reference list. Please provide.	
AU3	Please provide in-text citation for Elmesky and Tobin (2005), Kincheloe (2003), Roth and Tobin (2010).	
AU4	Please confirm the inserted year, volume number and page range for Shady (2013).	