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Keywords (separated by "-")	Collaboration - Reflexive inquiry - Interpretive inquiry - Authentic inquiry - Event oriented inquiry - Multilevel inquiry - Multilogicality		

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Kenneth Tobin

Abstract In a research career that exceeds 40 years there have been continuous 5 changes in my research methodology on a number of dimensions. The most salient 6 differences involved changes in the theoretical framework that began with logical 7 positivism and gradually changed to embrace sociological and cultural frameworks 8 such as hermeneutic phenomenology, reflexivity, culture, and ethics. A necessity to 9 include multiple voices to obtain participants' perspectives catalyzed ontological 10 issues, including how to deal with difference and embrace polysemia. As well as 11 researching patterns of coherence I adapted methodologies to build understanding 12 based on research on contradictions, which defined events. Thus event-oriented 13 inquiry sought to understand social life through intensive research on spikes in 14 coherence trajectories. Authentic inquiry drew attention to priorities given to theory 15 and improvement of practice on the one hand and multilectical relationships that 16 considered authenticity holistically – recursively considering goals associated with 17 changing ontologies while learning from others, teaching others about personal 18 standpoints and practices, and ensuring that institutions and all individuals benefit 19 from participating in research. I conclude with cautions about the transcendent 20 nature of social inquiry and a reminder of obligations researchers have to partici- 21 pate ethically in research dialogues, listen to learn, and enact right speech to foster 22 social justice for all. 23

Keywords Collaboration • Reflexive inquiry • Interpretive inquiry • Authentic 24 inquiry • Event oriented inquiry • Multilevel inquiry • Multilogicality 25

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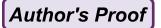


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26 Science Curricula as a Central Factor

in the Reform of Science Education

In the 1960s there was an energetic debate about the necessity to change the nature of 28 K-12 science education. At the time it appeared to science educators like me that 29 there was agreement on the need for change and what needed to change, as well as 30 healthy disagreement on what to change to and how to get there. John Lake, an 31 32 influential science teacher educator from my native state of Western Australia, characterized the debate at the elementary level in terms of three nationally funded 33 elementary science curriculum projects from the United States: Science – A Process 34 Approach; the Science Curriculum Improvement Study; and the Elementary Science 35 Study (Lake 1974). These curriculum projects had striking similarities and differ-36 ences in their approaches to science education – each embracing science inquiry, but 37 emphasizing different outcomes, and prescribing somewhat distinctive roles for 38 teachers and students. Similar investments in curriculum projects having these 39 characteristic orientations, also occurred at middle (e.g., Intermediate Science 40 41 Curriculum Study) and secondary levels (e.g., Chem Study, Harvard Project Physics, Biological Science Curriculum Study). Differences spanned a variety of orientations 42 (e.g., inquiry, historical, conceptual themes, and psychological foundations). Lake 43 and many others at the time expected that research on the different approaches would 44 somehow identify which approach was preferable and provide a pathway for improv-45 46 ing 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 47 macro question of which approach was better was never answered definitively and I 48 maintain that questions like these cannot be decided empirically or decisively by 49 research. Research questions and associated research designs were oversimplified and 50 51 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 52 53 social fields and does not consider the importance of context, especially issues of implementation fidelity and details concerning the nature and quality of interactions 54 among participants. Furthermore, debates about "which is best" seem to imply that 55 social interaction is irrelevant. Myron Atkin and Paul Black (2003, p. 37) 56 commented: "Both the 'teacher-proof' characterization and the concept of teacher-57 as-faithful-implementer later came to epitomize what many people saw as the 58 arrogance of this style of curriculum development." It was assumed that teacher 59 training would produce acceptable levels of implementation fidelity, which would 60 then create experiences needed for all individuals to learn. To a large degree it was 61 assumed that adherence to the activities suggested in the curriculum guides, which 62 incorporated psychological learning theories, would enable all students to learn. 63 Equity was considered in terms of opportunities to participate. Atkin and Black 64 (p. 37) remarked succinctly that: "it did not work very well." 65



Chapter Overview

Although projects like the Elementary Science Study advocated student roles that 67 emphasized autonomy and enjoyment, they did not consider students as research 68 collaborators, curriculum developers, and coteachers. In effect, expanded roles for 69 youth were constrained to peer collaboration – most notably cooperative learning 70 (Johnson and Johnson 1999). In this chapter I describe a wider range of collabora-71 tive roles of participants in science education, including doing research for the 72 purpose of improving learning environments, curriculum development, and teacher 73 education. In so doing I illustrate how participants' roles have changed in relation to 74 associated changes in research methodology. Research methodologies I address in 75 the chapter include interpretive, authentic, and event-oriented inquiry. A particular 76 focus concerns the standpoint of difference as a resource and its relationships to 77 polyphonia, polysemia, and multilogicality. The centrality and high value our 78 research squad assigned to collaborative inquiry are illustrated in cogenerative 79 dialogue (hereafter cogen) and coteaching. In a broad treatment of polysemia I 80 show how multilogicality and multilevel research provide complementary windows 81 into social life and combine with other research methodologies to diverse perspectives on science education. 83

Changing Faces of Research and Science Education

Macro level approaches to framing research questions and the assumptions shared 85 by science educators involved in research, teacher education, curriculum development, and policy, have striking similarities, many of which persist today. For 87 example, a one-size-fits-all approach to theory may derive from adherence to 88 empiricism and models for generalizability that are grounded in inferential statis-89 tics. The idea that the results of research applied to a sample and are generalizable 90 to a population provide an underpinning for many graduate level courses in research 91 methods and concerns with internal and external validity of scientific designs for 92 research. Even when arguments were advanced for the use of qualitative data in 93 research, the pressure to apply parallel criteria to interpretive research methods 94 resulted in quality and authenticity criteria being developed and applied that 95 appeared to embrace research that employed experimental and quasi-experimental 96 designs. Accordingly, participants in interpretive research are often considered to 97 be subjects and are referred to as a sample – inadvertently buying into a set of traps 98 that would expose the methodologies and associated methods as deeply flawed and 99 inferior to methodologies that embraced inferential statistics. The labeling of 100 research methodologies as qualitative and quantitative set the stage for a debate 101 that would take for granted many tenets of logical positivism. These included 102 assumptions like the following: measurements and data are objective; the best 103 outcomes from research are parsimonious rather than complex; well-designed 104

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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 112 perspectives on the nature of science and axiological commitments of scholars and 113 policymakers framed curricular choices and emphases included in hundreds and 114 perhaps thousands of reports that recommended the reform of science education (Hurd 1997). Furthermore, rather than dramatically changing the faces of science 116 education, reports that advocated reform and associated methods to enact reforms of 117 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 119 science education and what happens in science classrooms bears a family resem-120 blance 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 122 Curriculum Improvement Study, Mary Budd Rowe researched factors associated with 123 science inquiry, as it was represented in verbal interaction (Rowe 1969). Her seminal 124 work identified wait time, the duration of pauses within utterances, as an important 125 variable associated with the quality of verbal interaction and the presence of pauses 126 between utterances (Tobin 1987). Also, Rowe identified other factors, such as the 127 incidence of verbal rewards, associated with characteristics of verbal interaction that 128 made notable differences to participation levels and the quality of verbal interaction 129 (Rowe 1974). Research like Rowe's addressed an assumption that issues concerning 130 the quality of social interactions are important aspects of learning. Also, her work 131 132 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. 133 There is no guarantee that what is designed and intended will occur during enactment. 134 Certainly curriculum resources, planning, and local school-based factors all contrib-135 ute to the quality of learning environments. Rowe's research emphasizes that social 136 137 interactions are paramount when science learning is researched. Of course, the implications are that research about enacted curricula can provide insights into how 138 resources are accessed and appropriated. 139

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 150 learning and doing science education through Piagetian lenses, and adopted a stance 151 that classroom order necessitated teachers establishing and maintaining effective 152 control over students (Tobin and Gallagher 1987).

Knowledge does not exist independently of knowers or structured fields in which 154 knowledge is both represented and enacted. A radical aspect of this assertion is that 155 knowledge is only "known" when it is represented, as Erving Goffman (1983) noted, 156 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 159 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 162 knowledge needed to appropriate them comes to hand at precisely the right time. 163 Since this process is continuous and involves a multifaceted structural flux, most of 164 the process is automatic, beyond awareness, and non agentic. Emmanuel Lévinas 165 (1999) referred to this process as passivity and Wolff-Michael Roth (2007) 166 highlighted the importance of passivity to the agenda of science educators. To tap 167 into passivity it is important to employ methodologies and associated methods that 168 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 170 what is happening and why is it happening. The analysis and interpretation of such 171 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, 174 yield outcomes that are contingent and nuanced, and acknowledge that decisions 175 about which approach is best will inevitably involve issues associated with axiology, 176 ontology, and epistemology. Furthermore, experienced realities in the social world 177 appear to be mediated by structures that situate individuals in different places in 178 social space. If this is the case then research and science education would necessarily access participants' perspectives and understand similarities and differences in the 180 realities participants perceive in a study. An important part of research methodology concerns ways in which similarities and differences are handled during analysis and 182 interpretation. Theoretical stances concerning polysemia also are salient to ways on 183 which research is designed and conducted.

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My approach to research, which began in 1973, involved a gradual shift from 185 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 189 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 191 relatively slow. The most noticeable shifts involved changes from positivistic 192 methodologies grounded in psychology to hermeneutic-phenomenological inquiry 193 related to areas of sociology and anthropology. Increasingly I became aware that I 194

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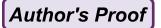
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would learn more from research that was multi-voiced and included different robust perspectives among members of our research squad. As I developed a greater understanding of cultural sociology and constructs such as structure and field, I began to 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. 240 Often policy decisions are based on either-or thinking about choices.

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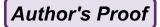
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Although science educators' methodologies and associated methods have changed 242 continuously for the four decades I have been a science education researcher, I am still 243 surprised by policy level pronouncements that are akin to main effects in statistically 244 oriented research which produces assertions that have thick coherence – as if contra- 245 dictions are not considered in models on which policy tenets are framed. Examples 246 include assertions like the following: inquiry methods enhance science learning; argument strategies improve science achievement, and open-ended questions increase 248 science achievement. One-size-fits-all claims are devoid of nuance and appear to 249 ignore quality – for example, as if inquiry no matter how well, or fully it is enacted is 250 preferable to no inquiry. There are many potential problems associated with research 251 intended to validate best practices. Using a theoretical framework that includes levels 252 of social life (macro, meso, micro): fields that are dynamically structured and 253 unbounded, the enactment of any curriculum project is subject to an ever changing 254 flux of structures that can produce culture that is simultaneously the same and different 255 than what is produced when the "same" curriculum is enacted in another time and 256 place. Rather than viewing enactment like a horse race it makes sense to adopt an 257 approach that embraces phenomenology – learning from researchers' insights into 258 what is happening from the perspectives of the participants and why it is happening. In 259 this way landscapes can be created to reveal possibilities associated with the use of 260 different curriculum projects in the context of them being enacted in different circumstances. Rather than producing simplified models in terms of clearly defined, signif- 262 icant variables, there are advantages in retaining complexity, acknowledging the 263 salience of meanings in use, and recognizing that experiences described by language 264 are underrepresented and always will mean more than can be expressed/represented 265 using language. What is learned from such an approach to research would be grounded 266 in contexts associated with the research (i.e., structures) and any claims about "what 267 works" would be nuanced and considered an integral part of knowledge produced in 268 the study. Users would understand that what is learned is replete with ever-present 269 contradictions and any project involving enactment would necessitate contingent 270 adaptivity that addresses the goals of individuals and collectives, levels of success, 271 and dynamics of the agencylpassivity dialectic (here the vertical bar denotes a 272 dialectical relationship). Different theories highlight patterns and associated contra-273 dictions, 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 277 and describe what happened in an activity are dialectically related. The relationship is 278 synergistic in the sense that applying different theoretical frameworks provides new 279 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 281



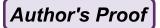
the following: what to tweak, what to expand, what to truncate, and what to discuss? It is important to realize that as well as shedding light on activity, theoretical lenses obscure other valuable aspects of an activity. This standpoint embraces the relevance of bricolage and polysemia to social inquiry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



dialectically related, each recursively associated and presupposing others' existence. 327 From this perspective, as individuals collectives enact culture in a field, their pro- 328 ductions (transformationslreproductions) are interconnected. A recursive relationship 329 between individual and collective implies that changes in one are reflected in the other; 330 the actions of any individual becoming resources for actions of a collective. That is, all 331 individuals in a field are "in action" simultaneously and continuously, enacting culture 332 that has a cascading effect since everybody's actions are resources for everybody 333 else's cultural production. If a teacher acts in ways to expand the learning possibilities 334 of others then, from this perspective, everybody is a teacher for everybody else 335 because acting in a field provides resources to support others' learning. That is, 336 teachinglearning are dialectically related and it is impossible to think of one without 337 the other. Interrelationships between teacher and learner are inextricably linked and 338 whereas learning cannot be separated from teaching, neither can teaching be separated 339 from learning. Learners' actions mediate the possibilities for teaching at every 340 moment enactment occurs in a particular field. Accordingly, it makes no sense to 341 think of teaching in isolation from particular collectives, including students. As most 342 teachers readily acknowledge, the way a person teaches one group of students is often 343 quite different from the manner in which the same person teaches another group. To 344 argue otherwise and assume that teaching can be considered independently of learning 345 and learners is fraught with the potential for failed expectations. For example, 346 accountability systems grounded in assumptions that teaching is a commodity that is 347 transferable across contexts, including schools and students, is suspect at least and 348 damaging at worst.

A current trend among scholars in science education is to consider identity as an 350 outcome (Varelas 2012). There is acceptance of the idea that identities are forged as 351 individuals participate in multiple fields as time unfolds. As individuals think back on 352 what was accomplished in those fields, memory traces reconstruct what happened in 353 much the way that a highlights reel is put together. Events that stand for enactment in a 354 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 357 returns to a field over time. Whereas most recent studies think of identity as fluid and 358 context dependent very few theoretical models have considered the full implications 359 of an individual collective relationship. If individuals are considered in relation to 360 collectives in which they practice, then it makes sense for identity to be theorized 361 dialectically rather than as a property of an individual.

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Participants Doing Research to Understand and Improve Practice

I began to include high school youth as student researchers in a study I undertook 365 with Stephen Ritchie, in Tallahassee Florida (Ritchie et al. 1997). In that study we 366 utilized a middle school female as a student researcher and, although it did not work 367

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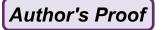
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out as we envisioned or planned, we both retained our commitment to the idea that youth could provide valuable insights into what was happening and why it was 369 happening. The initial problem we encountered was that the student researcher was 370 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 372 different because the students provided their perspectives on the quality of teaching, 373 suggesting ways to make improvements that would suit them. In other words their 374 interests were central (Tobin 2000). Initially our tendency was to privilege their 375 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 377 about teaching and learning involved their participation in the activity. There was 378 value in them speaking with other youth about teaching and learning, and their 379 teachers, who were older and obviously different from them in many social 380 categories. Engaging in dialogue with others who differed markedly in a number 381 of social categories appeared to be a most valuable thing to do. 382

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 414 developed cogen (Tobin and Roth 2006). We highly valued activities in which 415 teachers dialogued with youth, not only sharing the amount and frequency of talk, 416 but also listening and being heard by one another. Accordingly, we decided to 417 undertake research on the nature of the dialogues and change the structure to expand 418 its potential for improving learning environments and schooling more generally 419 (Tobin and Roth 2006). Based on what we learned from youth dialoguing with 420 teachers about "how to better teach kids like me." We labeled the activity cogen 421 because we expected participants to speak and listen in ways that were focused, in 422 synchrony, and entrained across time and space. Cogen acknowledged that consensus 423 was a goal of an activity in which participants understood one another's perspectives 424 and goals, and endeavored to reach consensus on what was to happen next in class. A 425 valued structure was the right for anyone to have and retain different perspectives 426 while participating fully in the fields of class and cogen.

The research in which Roth and I developed cogen was situated in West Philadel- 428 phia. As we developed cogen we also created and researched a coteaching model in 429 which new teachers taught together in urban classrooms for the purpose of better 430 accommodating the needs of urban youth while at the same time learning to teach by 431 teaching at the elbow of another (Tobin and Roth 2006). Cogens were organized to 432 include four or five students together with all participating coteachers, researchers, 433 university supervisors, etc. The requisite for being involved was that all participants in 434 cogen needed to have been substantively and collaboratively involved in the teaching 435 and learning of a lesson. Initially the purpose of cogen was to focus on participation in 436 a dialogue that would identify ways in which the quality of the teaching and learning in 437 the class could be improved in subsequent lessons. Typically cogens at the middle and 438 high school level occurred after school or at lunchtime and occupied 40 min to an hour. 439 Gradually cogen was regarded as an integral part of teaching and learning and teachers 440 and students accepted cogen as part of the ongoing curriculum. The number of 441 participants often included a whole class, and at times one-on-one cogen occurred 442 when a teacher and student met together to resolve classroom-based issues.

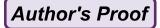
Cogen focused on the idea that dialogue had the purpose of converging to 444 produce consensus. Even though individuals may not be in agreement it was 445 essential for participants to reach consensus and then accept responsibility for 446 enacting what had been agreed. This was to change in a number of ways that 447 reflected emergence, contingence, and the synergistic nature of the research in 448 which we engaged. First, we noticed that students who had participated in cogen 449 began to coteach with their teachers. Acceptance of the responsibility for enacting 450 what had been agreed to in cogen resulted in those students assisting the teacher in a 451 variety of ways that included managing the class and most importantly, assisting 452 students with their understandings of what was being taught.

The research drew attention to an important set of dialectical relationships: 454 teacherllearner and teachingllearning to name two. As we reviewed what was 455 happening in classrooms and in cogen it was apparent that there would be times 456

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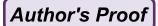
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when teachers would be learners with respect to their students and at other times students would be learners with respect to their "official" teachers. These theoretical realizations provided new ways of looking into classrooms and of undertaking research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



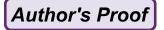
Initially our work on cogen was broadly theorized within a framework of 503 cultural sociology. We broadened this framework to include the Heideggerian 504 notion of learning by being in with others (Heidegger 1996). This idea was very 505 prominent in our thinking about coteaching and ways in which actors became like 506 the other by being with the other. This theoretical frame was applied also to the 507 ways in which participants in cogen learned from one another. Because of our use 508 of Randall Collins' framework concerning interaction ritual chains our initial 509 concern was with synchrony in speech (Collins 2004). Accordingly, we structured 510 cogen to focus on the distribution of speech, and synchrony and entrainment within 511 and across interactions. For example, when somebody spoke we expected to see a 512 strong focus on the speaker and signs of synchrony involving all or most partici- 513 pants in relation to the speaker. Similarly, at the same time we expected to see 514 synchrony distributed across the entire community i.e., entrainment. Each speaker 515 was expected to act not only for his/her self but also for others; that is, to provide 516 opportunities for social resonance. Other structures also applied to equity in terms 517 of who spoke orally – the number of turns of talk and the duration of talk. 518 Furthermore, we emphasized the obligation of participants to speak for others, 519 meaning that speakers should be attentive to the necessity of others making sense 520 of what was being said and connecting with it in a multitude of ways. Speaking for 521 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 523 behaviorism. We did not want to assume that because people were not speaking 524 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 526 included inner as well as outer speech. We were explicit concerning legitimate 527 participation including the thinking that occurs as others spoke. We consider this to 528 be salient because the purposes of inner speech can be as varied as the purposes of 529 outer speech (Vygotsky 1962). Obviously, focus, synchrony, and entrainment involve 530 actions on the inside as well as actions on the outside – actions that are not directly 531 accessible to others. Since we had legitimated inner speech we felt it was necessary to 532 address the obligation of each participant to speak out when, and as necessary. This is 533 what I mean by right speech. We considered there was an ethical responsibility for 534 right speech to occur – that is, for individuals to contribute when they could advance 535 collective goals and goals of individuals within a collective. We did not want 536 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 540 coteaching models. Initially these models were designed to afford learning to teach 541 for preservice teachers in circumstances where the resident teachers were unwilling 542 to surrender their classes because they themselves were experiencing difficulties 543

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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 546 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 548 forward with this idea on the understanding that we would study it so that we could 549 learn what worked, what we needed to tweak, and what we needed to discard. The 550 initial experiment was so successful that we decided to adopt coteaching as a model 551 552 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 553 would enact coteaching and it was very much work in progress. In this case 554 collaborative research was a necessity to develop heuristics that could be used to 555 improve the quality of coteaching and broaden its use beyond initial teacher 556 certification to include professional development of practicing teachers. 557

In order to undertake research on coteaching we opted for a collaborative 558 approach that included new teachers, resident teachers, and high school youth as 559 researchers. It was immediately evident that cogen was a suitable activity for 560 research meetings. Accordingly, we folded coteaching and cogen together for the 561 purpose of improving the quality of teaching and learning. As we did so we 562 developed rules that structured the "talk about praxis" to ensure that power was 563 distributed throughout all participants and that all participants were involved 564 equitably. We had already included most of these ideas into the rule structure and 565 use of the term dialogue was consistent with our theorizing the activity in terms of 566 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 569 well grounded in statistical analyses in which residuals are calculated and often 570 regarded as error or, having no meaningful consequence. The usual approach is to 571 572 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 573 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. 575 William Sewell's event-oriented inquiry opened up promising possibilities. He 577 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 578 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, 580 during, and after the rapid increase in pulse rate. The selection of an event would be 581 582 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 583 authentic inquiry.

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Event selection begins with the identification of a significant contradiction. After 585 that all data resources I used in the process of identifying and then analyzing an 586 event. A feature of event-oriented inquiry is that we examine what is learned 587 contingently so that the design for subsequent research can be expensive, taking 588 account of what has been learned and continuing to learn more using whatever 589 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 591 component of a multilogical bricolage that underpins social inquiry that focuses on 592 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 595 involve participants as researchers. For example, we pondered the goals of research 596 in terms of models that had privileged theory over practice in the sense that research 597 that produced a new theory was favored over research that improved practices 598 (Arendt 1958). We slowly increased our value for many purposes of research, 599 favoring models in which different goals could be pursued collaboratively by stakeholders who learned from one another, respected the rights of others to hold 601 different understandings and in fact different practices, and actively seek to attain 602 equity, ensuring that all participants benefited from the research. I adapted Guba 603 and Lincoln's models for fourth-generation evaluation (Guba and Lincoln 1989) to 604 embrace polysemia and to accept all stakeholder groups as potential researchers 605 (Tobin 2006) by adapting the four authenticity criteria proposed by Goober and 606 Lincoln, authentic inquiry included two sets of goals related to theory production 607 and to related to improved practices. This approach was consistent with Hannah 608 Arendt's reminder that changes in theory and practice were both valued outcomes 609 from activities such as research.

In order to emphasize authentic inquiry we focused on the creation of models 611 that could be used to educate all participants about the research and what we were 612 learning. Also we designed interventions to afford changes in all participants' 613 understandings, their understandings of one anoth different understandings 614 and practices, and changes in conduct for individuals and collectives within the 615 group of research participants.

One form of intervention we designed was quite direct and the other was 617 relatively indirect. For example, a direct intervention involves the use of breathing 618 to ameliorate teachers' and students' expressing high intensity emotions as 619 increases in pulse rate and strength and low levels of oxygen dissolved in the 620 blood. Based on our ongoing research and published literature (Philippot 621 et al. 2002) we designed a breathing meditation intervention which we have now 622 implemented to increase mindfulness at the start of each lesson. That is, the 623 intervention reflects research undertaken by others and what we had learned from 624 our ongoing research.

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626 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 627 example, in my research in urban schools, becoming aware that my habitus was 628 629 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 630 teachers and students to wear finger pulse oximeters in class so that they would 631 become aware of their physiological expression of emotions. Once they were aware 632 of the possible salience of factors like pulse rate, strength of polls, and oxygenation 633 they could use breathing techniques and other practices to gain control over these 634 physical indicators of emotion – when, if, and as necessary. 635

Finally, we develop sets of characteristics for important constructs that we felt 636 might be improved by allowing participants to become more aware about them. We 637 refer to lists of characteristics for given constructs as heuristics. Two examples that 638 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 640 participants to think carefully about each characteristic in relation to their own 641 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 643 sense of what others are saying; Others have opportunities to speak as much as I do; 644 Others try to make sense of what I am saying; and I maintain focus. The following 645 five point scale is provided for each characteristic: 5 = Very often or always, 646 4 = Often, 3 = Sometimes, 2 = Rarely, 1 = Never or very rarely. In addition,647 space is provided for participants to comment in regards to their experience with 648 each characteristic. Becoming aware created of the characteristics for a construct 649 like cogen creates a higher potential for participants to make changes on selected 650 characteristics if, when, and as necessary. Importantly, awareness also opens up 651 possibilities for passive change. If a person opens themselves to learning from 652 653 others then it is possible that changes can occur in characteristics on a heuristic without conscious goals being formulated to make a change. 654

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

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changes related to characteristics included in heuristics, or characteristics like those 671 included in heuristics. At any moment in time, heuristics reflect our best and are 672 enacted and disseminated to others. Accordingly, the structure of cogen and science 673 teaching and learning in the participant schools will consistently evolve. In terms of 674 emotions, emotional climates and physiological constructs, we will initially create 675 descriptive landscapes. Through dialogues about these data and interrelationships 676 among constructs, participants in the research will become aware of the possibilities 677 for manipulating what happens in class to produce measures and patterns deemed to 678 be desirable.

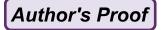
Brown et al. (2007, p. 212) describe mindfulness as "receptive attention to and 680 awareness of present events and experience," involving nonjudgmental attention to 681 present-moment experiences (e.g., sensations, cognitions, and emotions and sights, sounds and smells in the environment). According to Brown, Ryan, and Creswell, 683 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 686 thought processes; awareness of experience while being immersed in it; objectivity; tendency to defer judgment; likelihood to act as ecological stewards; levels of 688 cooperation with others; and social attunement, Baer and Sauer (2009) regard 689 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 692 can reduce focus, productivity, and physical well-being. 693

Examples of characteristics developed for the mindfulness heuristic are: I am 694 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 698 characteristic in the heuristic participants are asked to specify the frequency of 699 occurrence that applies to their enacting the characteristic.

Research suggests that an increase in mindfulness will enhance wellness. For 701 example, Davidson et al. (2003, p. 564) report that mindfulness, involving medita-702 tion, produces demonstrable effects on brain and immune function. Davidson 703 identified six emotional styles corresponding with specific locations in the brain 704 (Davidson with Begley 2012). Resilience varies from individuals who are slow to 705 recover from adversity through to those who recover quickly when adverse cir- 706 cumstances arise. Outlook is an emotional style that pertains to how long a person 707 can sustain positive emotion. Social intuition relates to the extent to which a person 708 is adept at picking up social signals from others around him/her. Self-awareness 709 concerns how well an individual perceives bodily feelings that reflect emotions 710 (e.g., facial expressions, body temperature, pulse rate). Sensitivity to context has to 711 do with an individual being able to regulate emotional conduct to take account of 712 context. Finally, Attention concerns the sharpness and clarity of a person's focus. 713 Individuals have a tendency to exhibit characteristic positions along continua 714 associated with these emotional styles – positions that are not set in stone! 715

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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 microlevel 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.

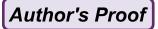
Reflections on the Changing Faces of My Research Methodologies

Doing research and science education is a journey I began more than 40 years ago. 730 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 733 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 735 research is an important part of science education and that more is learned by 736 studying teaching and learning in many different contexts that include, but are not 737 738 limited to: science, mathematics, music, martial arts, gardening, and everyday activities such as driving a motor vehicle. 739

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 con-757 versation is polyphonic, polysemia, multilevel, and radically continuous. Just as it 758 is my privilege to join and contribute to the dialogue, that is research, the dialogue 759 will continue with fresh voices, hopefully informed by the echoes of earlier 760 conversations. The science is the dialogue that continues, a dynamic flux that 761 moves through time and space, illuminating experience in particular ways while 762 failing to even notice most of what happens. What we know and can learn is 763 radically transcendent, and this thought alone suggests that what we know must 764 be expressed with nuance, humility, and radical doubt – realizing that our knowl-765 edge is necessarily incomplete and inadequate. Having said that, we must continue 766 to participate in the dialogue, being open to learn from difference and when the 767 circumstances demand, speak forthrightly about what we know, need to know, and 768 when and how to promote social justice. At the bottom, it is a great privilege to do 769 research with others and the price to pay for the privilege is ethical conduct, 770 compassion for others' well-being, and preparedness to respect and learn from 771 others while maintaining willingness to educate them. 772

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Author Queries

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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).	~40
AU4	Please confirm the inserted year, volume number a ge range for Shady (2013).	