

Understanding change through a high school mathematics teacher's journey to inquiry-based teaching

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Abstract This article focuses on an experienced high school mathematics teacher who changed her practice without participating in planned interventions aimed at producing this change. It reports on the nature of the teacher's change from her perspective and an interpretation and understanding of the change from the researcher's perspective. It illustrates how meaningful change can occur when the process is initiated and rooted in the teacher's experience based on a tension in self and/or practice that is personal and real to him or her. It discusses three types of change that are possible depending on the level of engagement of the teacher in professional development opportunities: instrumental change, conceptual change, and foundational change.

Keywords High school mathematics teacher · Self-development · Change · Inquiry teaching

Introduction

Studies that deal with mathematics teacher change tend to focus on teachers, often at the elementary school level, who participate in some planned intervention provided by the researchers intended to lead to particular change in terms of the teachers' thinking, knowledge and/or teaching. In this study, the focus is on an experienced high school mathematics teacher who worked at changing her teaching without such planned interventions. This article reports on the nature of the teacher's change from her perspective and an interpretation and understanding of the change from the researcher's perspective.

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Related literature

The topic of teacher change is common in the research literature on education. Many recent publications in mathematics education have addressed issues and situations regarding mathematics teacher change as a direct or indirect focus. For example, Fennema and Nelson (1997) present theoretical perspectives for studying, analyzing, and understanding mathematics teacher change, descriptions of contextual variables to be considered as one studies and attempts to understand teacher change, and descriptions of professional development programs that resulted in teacher change. Cooney (2001) discusses teacher change, particularly as related to change in beliefs about mathematics and mathematics teaching. He offers an analysis of how beliefs are constructed and how beliefs might be changed. He emphasizes that mathematical activities that integrate content and pedagogy in a reflective way can serve as powerful entry points for prospective teachers' reconceptualization of teaching mathematics. Tirosh and Graeber (2003) present general factors influencing mathematics teacher change and considerations in carrying out change. They identify factors that provide an impetus for change, which include: reactions to social and economic beliefs; beliefs about the nature of mathematics, teaching and learning; value and beliefs reflected in the new curriculum and in tests; and reactions to test results. Chapman (1999, 2001, 2002) has also addressed change. Her work shows the importance and role of a self-development process framed in a narrative perspective to facilitate change in elementary teachers' thinking and teaching of problem solving. It also shows the relationships among belief structure, pedagogical tensions, and generative metaphors as a way of explaining change in high school mathematics teachers' practice over their career.

Other works focus indirectly on change in the context of teacher learning or education. In particular, approaches to facilitating learning that will lead to change in teachers' knowledge and practice are highlighted. For example, one section of Even and Ball (2008) considers the learning of prospective and experienced teachers as they engage in the practice of teaching mathematics. The section discusses processes of learning in and from practice that include reflection, collaboration, communication and various models, tools, and strategies. In Tirosh and Wood (2008), the focus is on describing and critically analyzing a range of tools, in particular, various types of cases and tasks, used in mathematics teacher education to facilitate various proficiencies needed for teaching mathematics.

This body of publications on mathematics education offers a variety of ways to think about and conduct interventions that facilitate teacher learning and allow change to take place. However, change is still problematic in terms of achieving it in practice as intended by planned interventions. As suggested in this pair of special issues of JMTE, we still need to understand the motivation for change, opportunities for teachers to change themselves to promote learning of mathematics, and how all this relates to the learning of mathematics. In this article, we contribute to aspects of these factors by examining a teacher's story of change, a story that is about the teacher and not a planned intervention of the researcher to bring about change. We consider change to involve significant transformation in the teacher's thinking and practice from a traditional-classroom view of mathematics and mathematics pedagogy.

Theoretical perspective

A theoretical perspective consistent with a self-determined approach to change is being associated with this study because of the focus on a teacher as the architect of her change.

The theoretical underpinnings, then, are associated with processes of reflection (Schön 1983), inquiry (Dewey 1938), and noticing and researching from the inside (Mason 1994, 2002).

Schön (1983) suggests that teachers could orchestrate their own change if they are helped to develop a “stance” of looking at their own practice by analyzing, adapting, and always challenging their assumptions, in a self-sustaining cycle of reflecting on their own theory and practice, learning from one problem to inform the next problem. Reflection enables practitioners to assess, understand, and learn through their experiences. It is a personal process that usually results in some change for them in their perspective of a situation or creates new learning for them. It starts with their own experiences and, if applied to practice, can result in improvement.

Dewey's (1938/1991) process of inquiry also suggests a basis for teacher change. Simplified, this process consists of five steps that begins with (i) a puzzling situation that initiates (ii) the generation of questions, which, in turn, direct the perception of the teacher to notice certain features of the situation which lead to (iii) the formulation of a solving suggestion, and (iv) the elaboration of these through reflective thinking, into hypotheses or possible lines of action. These are (v) enacted through experimental testing in the concrete situation, and the process, guided again by perception and thinking, begins again. It is a continuous process of what Dewey called successful living or intelligent action that results in growth. According to Burbules and Biesta (2003), the outcome of this process is twofold—a change in the teachers and students, with the way they think and know, and a change in the situation, that includes the way curriculum gets enacted.

Mason (1994, 2002) discusses processes that also provide a basis for teachers to take ownership of their change. These processes, “researching from the inside” and “noticing”, require that teachers examine their own experience of work on themselves while addressing the question of how to support students in learning mathematics. They have to work on themselves, informed by research, and shared practice. Two key factors that define the uniqueness of these bases of teachers' learning are “*introspective observation* (in which an inner witness observes the self caught up in the action ...) and *interspective observation* (in which people share observations as witness to each other, yielding objectivity from negotiated subjective information)” (Mason 2002, p. 85). Mason (1994) explains, “The core of researching from the inside is attending to experience ... so as to develop sensitivities to others and to be awake to possibilities” (p. 180). He defines noticing as “a collection of practices both for living in, and hence learning from, experience, and for informing future practice” (Mason 2002, p. 29). It is “a reference to lived experience through an invitation to check something out in your own experience” (Mason 2002, p. xi).

The preceding notions embody a common theme that provides a theoretical perspective of framing teachers' change in which the teacher takes responsibility for the change. This theme emphasizes the use of evidence based on personal experience to initiate and support learning and facilitate change. It requires that teachers engage in the following ways of knowing: (i) examine their own experience of work on themselves while addressing the question of how to support students in learning; (ii) attend to experience so as to develop sensitivities to others and to be awake to possibilities; (iii) focus on problems and experiment with situations; and (iv) engage in introspective and interspective observations.

Research process

In this case study, the focus is on the thinking and experience of Brea, a high school mathematics teacher for 18 years, as a means of investigating the process and nature of change in her practice. The researcher (first author) met Brea when she started collecting data with a participant at Brea's school for a study on beginning secondary school mathematics teacher growth in mathematical knowledge for teaching. Based on the initial conversation between the two, the researcher became interested in Brea's journey of change, which seemed to be a unique story of change, as a means of learning from it implications for supporting change in the teaching of mathematics. Brea expressed interest in sharing her story for this purpose, and the study was planned in collaboration with her in terms of her role in it. Since the researcher's goal was to learn from Brea's story, there was no intentional intervention by the researcher to aide her progress. The interaction with Brea was mainly for data collection and collaboration on telling her story. In fact, at the beginning of the study, she had already established a vision of what she wanted to become and was in the first year of adopting it in her teaching. This vision embraced notions of inquiry as a way of teaching and learning.

Inquiry, as a basis of teaching or a way of learning is well established in the literature (e.g., Dewey 1938; Schwab 1967; Wells 1999). However, it is a complex idea that can mean different things depending on the context or perspective involved. In relation to teaching and learning, some common notions associated with inquiry are learner-focused, question driven, investigation/research, communication, reflection, and collaboration. For example, inquiry-based teaching allows students' questions and curiosities to drive curriculum, honors previous experience and knowledge, makes use of multiple ways of knowing, and allows for creation or adoption of new perspectives when exploring issues, content, and questions. Students are given the opportunity to direct their own investigations and find their own answers. In an inquiry-based mathematics classroom, students take on the role of, and learn how to *be*, mathematicians. In this study, the intent is to understand change and not inquiry beyond its use in the teacher's story. It is Brea's way of interpreting inquiry that is relevant and not a prescribed theoretical perspective. This explains the reason for briefly noting it here and not in the theoretical perspective section of the article. Brea's use of it will be revealed in her story later in this article.

Data collection focused on capturing Brea's story leading up to and during the first year of transforming her practice to inquiry teaching. Data sources consisted of:

- (i) Open-ended interviews that addressed, for example, Brea's past and present thinking about mathematics and its teaching and learning, key events that influenced or defined her journey of change, her thinking about inquiry and how she conceptualized it in relation to teaching and learning mathematics, her actual experiences as she engaged in inquiry-based teaching, and challenges and constraints in the classroom that impacted her adoption of this way of teaching and her way of dealing with them.
- (ii) Journal writing in which Brea reflected on her journey of change.
- (iii) *Storying* in which Brea told (during interviews) or wrote stories that described specific events or situations at different stages of her journey of change. These were based on what she considered to be significant or were prompted by the researcher during the interviews. The stories were also about her changed practice, which included detailed narrative descriptions of examples of her inquiry-based lessons.
- (iv) Discussions between Brea and the researcher to clarify their thinking about change.
- (v) Classroom observations of Brea's inquiry-based lessons.

Interviews and discussions were audio taped and transcribed. Field notes were made of the instructional processes of the lessons observed and copies of teaching artifacts were obtained.

Data analysis focused on creating descriptions of the nature of Brea's change from her perspective and an interpretation of the change from the researcher's perspective. Thematic analytic strategies were used to achieve these outcomes. This involved coding the data in different ways to identify major patterns and related themes. For example, first, the stories were analyzed by attending to particular elements of their structures adapted from Labov (1982), that is, the orientation, complicating action, evaluation, and resolution. The contents of the stories were also scrutinized to identify other issues or situations that appeared to be significant in relation to the nature of and influences on change. Second, all of the data were reviewed to identify significant thinking and behaviors by focusing on statements and actions that reflected Brea's judgments, intentions, expectations, and values regarding her pre-inquiry and inquiry teaching and her journey to change her practice. The review also included identifying, for example, significant turning points and tensions in her journey, related influences on them and shifts resulting from them; the roles of the teacher, students, and mathematics in her inquiry teaching; and factors in the classroom that impacted her adoption of inquiry teaching and her way of dealing with challenges in enacting it. This information was used to identify, refine, and elaborate emerging major themes based on significant patterns in the data. Verification procedures included coordinated analysis of the multiple sources of data, cross-checks between researcher and a research assistant, elimination of initial themes based on disconfirming evidence and feedback from Brea.

The emerging themes were used to frame different accounts of Brea's change and the researcher's learning about change. The researcher and Brea collaborated on creating two accounts of her change. For the first account, Brea reviewed the emerging themes to establish whether her perspective and experiences were represented appropriately and to make revisions based on evidence. She confirmed the themes to frame this account of her story of change. The key themes identified were "silencing" and "giving voice" to mathematics, teacher and students; journey to inquiry; and transformation to inquiry-based discourse. Using these themes, Brea and the researcher selected text from the data to develop the account of her change. In this article, instead of the complete resulting account organized by these themes, there is room only for a condensed version presented as "change experienced by Brea" focusing on some core ideas of how and what she changed. For the second account, Brea's journey was described as a narrative (i.e., a temporal account) based on themes of turning points or shifts in her experience, thinking and practice during her journey of change and factors influencing changes in the journey. These two accounts were central to the development of the account of the researcher's considerations about change. They were used to interpret, for example, the nature of the turning points and levels or depth of the changes, relationships between turning points and the nature of the changes, and influences on changes or lack of changes in Brea's journey. A condensed version of the researcher's perspective and interpretation of change is presented here as the theme: "change as a self-transforming journey".

Change experienced by Brea

The following is an abbreviated version of the account of Brea's story, in her voice, to highlight the changes she experienced in her thinking and actions.

For most of my teaching career, I felt my job was to simplify mathematics. As a student of mathematics, I was led to believe that math should be simple, then when I started teaching, I thought that's what my job was—to make math simple into little bits so the students could consume it and regurgitate it. So I aimed to cover the curriculum in consumable bits that could easily be delivered and tested.

I planned to teach, not prepared to teach. Units were outcomes based, laid out in a day-by-day orderly manner. I delivered lessons with notes already compiled with set examples, complete with what pages and questions to do in the text. I did not realize how important the intellectual part of this job is and how I very easily could get or did get wrapped up in the skills and techniques of what to do in a classroom.

Discourse has always been fundamental in my classroom, even when I wasn't really working in inquiry. Conversation and dialogue has been the basis of my class. So the notion of relationship and conversations with kids was always there, but I never stepped outside of my preplanned boundary. In my classes, I would think kids were asking 'good' questions, but I now realize they were for clarification or procedural. We never critically entered a topic, looked at the bloodlines or cared for it in a way that honored it. If a student asked a question that seemed off topic or confusing to me, I would seldom really listen, often dismissing it. Even though we might discuss more than one way to a solution of an assigned problem, there was still *a* solution, that is, the problem was treated as closed. The focus of my efforts then would be on the students and building relationships, having conversations etc. At times I felt I was doing a good job because I was liked and I liked the kids also. Each semester brought newness in the form of students but the topics were set, flattened and I wondered how much longer I could do this.

Since starting to engage in the inquiry kind of work that we are doing in my classroom, mathematics has become beautiful again. I want my students to understand that mathematics is not simple, that it is complex and complicated, that it does exist in the world, that it is a 'living discipline', that it has bloodlines. I want them to understand that there are patterns, but there are also no answers, there is no certainty. When they enter into the field, they are contributing in some way to it, but it is not meant to be simple and easy. I am finding that it is the structure of the mathematics and the patterns and the connections that seems to keep coming up as an entry point for me to be able to start to look at something to do with the kids. It is through its structure, patterns and connectedness I can see many possibilities. Where does this come from? Why do we still talk about it? How does it live and contribute to the world today?

There are times I see clearly the mathematical connections either through the structure of math, its beauty, complexity or imagery. The world has opened up and through discourse math presents itself as complicated, uncertain, and unfinished. It is no longer, as tends to be in the math classroom, certain, linear, and algorithmic. I have begun to see more connections within topics and in interdisciplinary ways. The more we enter into a topic, the more exciting it becomes, it all seems new to me again, it is exciting and alive. But there are challenges. For example: How do I open topics in a generous way? Do I look for the topic in the world or see the world through the topic?

Discourse continues to be fundamental in my classroom. Topics always open up with conversation. Students are always in partner or groups talking. They are always writing and sharing in some way, so that their work is always public in some form. But unlike the pre-inquiry classroom, the world has now opened up in the discourse and conversations are rich and complicated, answers are uncertain, the work constantly

unfinished. I now want students to question, and wonder, and ask why. I want them to make connections and to see things as interconnected. I am also now deeply trying to listen to their inquiries. There are now portals in my lessons that call me to really listen, become attuned to what students are wondering about.

They are wondering about math and are inquiring into topics that come up in class. For example, we were talking about the names of polynomial functions with a degree of one to five. A student asked, "What about 6, 7 etc.?" He was assigned the task of finding out about this for us all. The next class he said he could not look it up last night but four others responded that they had.

What I have noticed of late is the openness of my students to think and go places they have not before. As I open a topic, I never know where it will go. More often than not, we end up in territory way beyond the 'curriculum' for that grade. For example, the grade 10's, in a conversation about the sine and cosine of supplementary angles, ended up describing the unit circle. In an assignment in which they researched the life of a mathematician, they then wrote about how they could come to understand who they were and who they could become. It seemed natural to discuss these things. Yet I know if I had tried this before, I would not have had the open reception or the effort they put into their writing. I am constantly amazed at their thoughtfulness; at times they seem so much smarter than I. I truly feel privileged to be in the face of the young.

The students are continually seeing things in ways I never imagined. They are contributing to the field and are starting to understand they have a role in it. Every time when I give a test, now that I changed the way I do things, I learn something completely new. There are ways they look at things that I would have never ever considered and would have never been able to come out had I given them a multiple choice test or in any other way.

The following are examples of two lessons that reflect my first attempt at implementing an inquiry approach in teaching these mathematics topics.

Example 1 This lesson is on the topic, systems of equations. In the past, I would say the topic was more specifically solving linear and non-linear systems using technology. I would have given several examples. The students would talk about it in partners and then as a class. Textbook work or a worksheet would be assigned.

I now treat the topic as part of an ongoing conversation of a larger theme of mathematics, i.e., equations. Throughout the semester, prior to this lesson, we had been talking about what it means to solve an equation, how the structure of algebra worked, and what complicated things or made an equation more complex. We also discussed the role of the leading coefficient on a function and how the factored form of a polynomial indicated the zeros of the function. The students have some understanding of how many possible answers an equation could have in the real number system based on the degree of the equation. We also discussed what would happen if there were two variables in the equation, how could this possibly work? After some discussion with their partners, they came to the conclusion that in order for there to be a solution for two variables, there had to be at least two equations. We then looked at where solutions occurred graphically. The following is a snapshot of how the next lesson proceeded.

I opened the lesson by asking for an example of a linear function and a quadratic function. The students gave:

$$y = x^2 + 2x + 10$$

$$y = 2x + 3$$

I plotted these functions on the overhead, graphing calculator and asked the class to talk about what they noticed. They responded that the two functions did not intersect. Therefore, there was no real solution. One student then asked, “Why does the quadratic not cross the x -axis?”

“Good question!!!” I thought. This was not directly related to the topic of the lesson, but I allowed the students to take up this question that was rooted in their curiosity. We then discussed what we knew at that point about integral and non-integral zeros and how they relate to factored form of the equation. I provided examples of different structures for the students to examine and to explain what they noticed. Students responded that it must have something to do with whether the function is factorable. We tested this with a different equation, i.e., $y = -x^2 + 2x + 11$.

The students graphed it on their calculators and found there were zeros except they were irrational. I then asked, “what determines if there are zeros or not, if it is not just whether we can factor it?” Students felt it must have something to do with the combination of the coefficients and the constant.

Students tried several examples and discussed with their partners what role the discriminant $\sqrt{b^2 - 4ac}$ played in determining the nature of the zeros. Quickly they found that if the discriminant was greater than zero, there were solutions. If the discriminant was less than zero, there were no real solutions.

We then discussed briefly the complex number system and imaginary numbers. We also talked about why a negative number was problematic and can lead to no solution. Students talked about radical functions and their understanding of not being able to take the square root of a negative number (this was a previous conversation coming alive again).

At this point, the lesson cycled back to its intended topic and the original examples we started with at the beginning of the lesson....

Example 2 This unit is on the topic of circles and lines which encompasses the coordinate and circle geometry portion of the curriculum. I began by having students write in their journals everything they knew about circles and lines. It may or may not be math related, but attempt to include math in some way. It can be in words, pictures or whatever. They then shared with their partners. We discussed briefly where circles and lines come from. I shared with them that the word circle comes from ‘small ring’ or ‘persons surrounding a center of interest’. Its history goes back to the discovery of the wheel. The first theorems date back to 650 BC with the mathematician Thales. The word line has links to ‘rope, row of letters’ and ‘rope, cord, string’. Linear functions go back to the discovery of the Cartesian plane and Rene Descartes.

We then talked about how circles and lines exist in the world. I then sent them on a journey around the school with their journals to find any examples of where circles and lines exist, together or separate, visible or behind the scene. When they came back together, they talked in groups about what they found and tried to generalize their findings.

All groups came to the conclusion that the world is made up of circles and lines. They categorized their findings of circles and lines as existing in structure, math, art, science, relationships between things, language, human bodies, relationships with a purpose, and relationships that cannot be explained, and one girl call her category ‘mind relationships’. I asked what she meant by that and she responded ‘those you can imagine to exist’.

Change as a self-transforming journey

While the preceding section highlighted the nature of Brea's change from her perspective, this section highlights the journey of change in terms of the researcher's learning/perspective. Excerpts of Brea's voice are weaved throughout.

Brea's journey began when she started to experience a lack of intellectual challenge and satisfaction in dealing or engaging students with the mathematics. Strong feelings emerged regarding her viability as a teacher. As she explained,

Each semester ... the topics were set, flattened and I wondered how much longer I could do this. I constantly wondered if there was a better way.

She interpreted the resulting tension as a problem with her teaching approach and sought alternative ways to work with the content as a resolution.

I would seek workshops, professional learning communities (funded by the school system) and conferences to attempt to answer these wonderings. Most of my professional development then was to seek techniques that could be applied to my classes, how to deliver a topic under the guise of an 'investigative' approach, how to assess better, how to write better projects.

This resulted in some change in her teaching, but it provided only short-term relief from the tension.

I would leave excited but then it would flatten out quite quickly and I was back in the same routine of stand and deliver or give an investigation and discuss the forgone conclusion the students were to discover for themselves.

Brea, thus, continued to experience the initial tension, but it now included strong feelings regarding her identity as a teacher. This shifted her interpretation of the tension as a problem with herself and she sought resolution by engaging with colleagues.

I also struggled with my identity as a teacher. If I tried to express my frustration, I was met with statements like 'it is only a job' or 'it is not who you are it is just what you do'. This never sat well with me, nor did it fill my spirit. There had to be more to this so I kept searching.

This section of the journey resulted in change in level of awareness of self. The initial tension continued but had evolved as a problem of her thinking and actions. She continued to seek resolution in the context of this shift in awareness.

I chose to get involved with groups that seemed to be thinking about teaching and learning, assessment and instruction in thoughtful ways yet the discourse was still not around math as a living discipline.

About 2 years along this journey, Brea's openness to interact with others about alternative ways of teaching allowed her to attend to a new, unexpected opportunity. A new colleague at her school, Tom (pseudonym), whose role included providing support for the large number of beginning teachers hired that year, had a strong interest in inquiry teaching. He was an experienced social studies teacher and had started a Ph.D. program in interpretive studies in education that exposed him to an inquiry learning/teaching perspective. Brea's interaction with him redefined the journey and destination.

Last fall, Tom arrived at [my school] and began to open conversation around the concept of inquiry. Every time we talked, I felt more and more intrigued; something seemed to be calling me. I went to a Galileo [a center at the University] presentation [on inquiry] and I was hooked. Is this what I have been seeking? What was inquiry?

Brea had evolved to another level of awareness of self as she resonated with notions of inquiry. She now perceived the resolution to the initial tension regarding her thinking and practice as dependent on her understanding of inquiry. Thus, the problem she now perceived was how to make sense of inquiry in order to implement it in her teaching.

At first I kept longing for someone to just show me what inquiry was. I would listen to Donald (pseudonym) [a professor who worked in the interpretive and inquiry perspective and supervised student teachers at the school] and Tom talking, nodding, hoping they would not stop because the minute they did, I was lost again. I still have not embodied the language but the more time I spend in this space the complexities become more evident.

The experience in this space began to shift her thinking about mathematics. She began labeling it as “a living discipline.” But this created a new tension in terms of what this meant and what was inquiry in the high school mathematics classroom and the search for a resolution.

Math as a ‘living discipline’ is just beginning to makes sense, but I could not image it, again, seeking someone to just show me. I went to the math inquiry workshop at the University in June and was disappointed that no one could talk to an understanding of what inquiry was in their classrooms.

It was now 10 months since Brea was introduced to the idea of inquiry. Her thinking was changing but not to a level to change her practice. Failure to obtain knowledge meaningful to her led to a reframing of her journey and approach to resolving the problem of making sense of inquiry. She came to the realization that the answer was not “out there.”

I realize now that I needed to find my way, more importantly, who was I in all of this? Inquiry became a way of being, complicated, nonlinear, unpredictable, ambiguous, abundant and uncertain. This is about the time I stopped sleeping at night. I realized I had to find my own way in this, it was my struggle. I began to question who I was, what did it mean to teach, what is my place in the social and cultural world in which I and the students live, how could they then become something otherwise?

The journey now became a process of self-understanding, self-construction of knowledge and experimenting with possibilities. This introspection allowed her to confront initial ways of thinking about mathematics, curriculum, teaching, and learning in relation to what she was now learning about inquiry. Conflicts in the two allowed her to understand her confusion in making sense of the latter. For example, she now realized that her initial view of mathematics as *certain, linear, algorithmic* was a barrier to understanding mathematics as a *living discipline*. Similarly, her initial view of teaching mathematics as *to simplify, to cover in consumable bits that could easily be delivered and tested* was a barrier to understanding it as inquiry, that is, *complicated, non-linear, unpredictable, ambiguous, abundant, and uncertain*.

This shift in understanding herself became a liberating experience in identifying the path she wanted to continue on and the teacher/self she wanted to be. She continued to talk

with Tom, and enrolled in a graduate course with Professor Donald in the fall semester, a year after her introduction to inquiry. These experiences allowed her to develop sophisticated ways of describing her teaching as reflected in the excerpts of her voice. At this point in her journey, Brea also decided to try and live inquiry in her classroom as she continued to think about and make sense of it conceptually. She had now changed her thinking in a way not yet reflected in her teaching. But this seemed to give her the strength, courage and purpose to deal with the challenges/obstacles to implement her emerging version of inquiry in her classroom. For example, she used her experience along her journey to inquiry to deal with students' initial opposition to her approach.

Each time I begin a course, we would talk about the student's perceptions of what math is and how to be and act like a mathematician. Most of their perceptions seem to be related to a subject that is meant to be controlled, predictable and certain. Our classroom conversation is often around other possibilities, attempting to unpack where their beliefs come from including our position in the grid.

Brea transformed her classroom discourse by listening to students differently, as she described in her story. She began to give voice to, or recognize the voice of, students, thus empowering them. She shifted her concern from being the expert voice to a concern for the authenticity of students' voice. Her lessons were transformed into an inquiry model that required students to expose initial and emerging thinking, question, explore, notice, conjecture, prove/validate, and generalize in learning high school mathematics. Her view of mathematics as a living discipline and the curiosity of the students played a key role in guiding the flow of the lesson. She began to demonstrate in her practice the kinds of knowledge, practices, and dispositions typically attributed to inquiry-oriented teachers (e.g., Lampert and Ball 1998; NCTM 2000), for example: a level of comfort with ambiguity and uncertainty; understanding the provisional nature of knowledge, responsiveness to students and a commitment to exploring their thinking and making sense of their ideas; knowing how to teach for understanding; and a commitment to building a community of inquiry in the classroom.

In this fourth year of her journey, Brea's initial tension that started the journey was resolved. She no longer experienced a lack of intellectual challenge and satisfaction in dealing with or engaging students with the mathematics. But this did not mean an end to her growth. Instead, teaching had become a continuous learning and growing experience for her. She also resolved the tension in relation to self (identity). Not only was her practice transformed, but this journey resulted in a change of self in a broader way.

Not only did I change in my classroom, I began to look at all my roles differently, as a curriculum leader, colleague, friend and wife. It was in the deepest sense of my being that transformation was and is taking place. I hear, see and feel things differently.

Thus, for Brea, change was a self-transforming journey.

Reflection on change

Many studies on change have focused on the importance of beliefs and related tensions in interpreting change (e.g., as previously noted, Cooney 2001; Chapman 1999, 2001, 2002). While beliefs are relevant to Brea's story, the intent is not to explicitly address beliefs, but

to highlight some characteristics of change and the process to achieve meaningful change based on this study.

In Brea's story, change is a challenging journey to a desired but undefined destination. It requires not only a desire by the teacher to change but also the belief that alternatives that are more beneficial are possible. The journey is complex, layered, not linear, and ridden with uncertainty. Consistent with the theoretical perspective outlined earlier, it embodies cycles of experiencing and acting on (seeking resolution of) tensions in herself and teaching. Based on Brea's case, a cycle could consist of four stages in which the teacher:

- (i) Experiences a cognitive and emotional tension. This could consist of thoughts and strong feelings that something fundamental regarding practice is not or is no longer working as expected or providing a satisfying experience for the teacher. It has become obstructive.
- (ii) Attends to (or connects with) the tension. For example, acknowledges existence of tension and uses/recognizes the strength and persistence of the tension as motivation or rationale to act to resolve it.
- (iii) Interprets the tension as a problem.
- (iv) Seeks resolution.

This four-stage process suggests that meaningful change can occur when the process is initiated and rooted in the teacher's experience based on a tension in self and/or practice that is personal and real to him or her.

Brea's journey also suggests three types of change that she went through: instrumental change, conceptual change, and foundational change. *Instrumental change* focuses on what and how, without understanding the why or self behind it. It consists of new techniques or activities the teacher learned and can adapt to her teaching, but limited only to those situations (e.g., specific mathematics concepts) for which it was learned. The teacher's overall practice does not change. Instead, it is initially sprinkled with some new techniques that eventually gets absorbed in the old way of thinking, but on the surface, still gives the appearance of change. *Conceptual change* includes a change in understanding of why a technique works and when and how to apply it beyond the situation in which it was learned. *Foundational change* involves a change in orientation of self (identity) and practice (actions)—change in the foundation of practice, the thinking on which it is built. The teacher thinks in new ways and is empowered to transform her teaching as a whole. Brea's story suggests that the theoretical perspective of reflection, inquiry, and noticing discussed earlier are central to achieving foundational change as a way of knowing self, learning from experience and evolving or transforming self and practice. It was not until Brea became introspective that her thinking and teaching began to change fundamentally. Her thinking shifted to a humanistic perspective of mathematics as a living discipline and an inquiry perspective of teaching and learning in which learner-focusedness was central.

Brea achieved instrumental change when she initially sought new techniques to use in her teaching, viewed the workshops' leaders as experts with *the* answers, and looked for the right answers. She achieved conceptual change when she started interacting with colleagues in a way that viewed learning as collaboration with others and the leaders as mentors to facilitate her understanding. She achieved foundational change when she viewed learning as a self-authoring way of knowing in which her own knowledge and experiences were important to the learning process and there may be no one right answer. Brea's journey through all three levels of change was not intentional. It was what made sense to her as a way to achieve change at each segment of the journey. It is not clear whether it was necessary for her to experience all three levels or if she could have started

the journey at the third with appropriate intervention regarding inquiry. However, high school teachers are more likely to be open to the instrumental or conceptual level if they view change as involving their practice and not self. They are more likely to view interventions that focus on alternative techniques and led by experts as more useful and may resist interventions aimed at foundational change or only attend to aspects of them that relate to their desired level of change.

Since it is the teacher who eventually determines the level of change he or she desires, planned interventions can be problematic if they do not match the level in which the teacher is interested. However, the level of change of interest to the teacher may not be the most appropriate for his or her situation. For example, foundational change is what is needed for traditional teachers to become non-traditional, inquiry-oriented teachers. But this change could be the most challenging to achieve through planned intervention based on the theoretical perspective discussed in this article. A key issue is getting teachers to experience or attend to a tension involving self and practice. Teachers may need to experience an authentic tension based on actual, personal classroom experience and not an artificially created one, for example, by showing them what is wrong with their thinking or practice based on theory. But even if they experience a tension, they could ignore it or associate it with external factors and not self, that is, shift attention away from their own failings and put it on circumstances outside their control. Another issue is getting the teachers to accept their role in the process, that is, they have to do it for themselves and take ownership of the process and change. They have to be willing to examine their thinking and not just what they do. A third issue is getting the teachers to accept uncertainty as an inherent feature of the journey while believing that the destination will be worthwhile. While Brea showed that foundational change is possible for high school teachers to achieve, for many of them, including those interested in change, the journey to this change may be less appealing. Traditional teachers are less likely to be open to uncertainty, self-learning and acceptance of tension. But Brea's story reinforces that planned interventions based on the theoretical perspective described in this article need to consider the importance of not separating self from practice but attending to both in facilitating fundamental change in teaching.

In spite of these issues, on a general level, this study suggests that planned intervention must take into account that it is the teacher who controls his or her destiny. Through Brea's story, it is evident that such interventions cannot prescribe the level of evolution or lay out opportunities for the teacher to evolve. A teacher is capable of making her own evolutionary choices for the future but needs liberated awareness of the present and past. The teacher's unreflective appreciations have to be in some way challenged. It is the incompatibilities that arise within the teacher's experience that force him or her to pay attention and to be more likely to be open to some level of change.

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