

## Research Article

# Uncertainty and the Reform of Elementary Math Education

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This paper investigates the notion of uncertainty as elementary teachers engage in conversations intended to develop their understanding and implementation of reform-based mathematics teaching. Using a narrative methodology, several sources of teacher uncertainty are investigated: teaching and learning, the subject, and improving one's own teaching. The data analysis indicates two important findings. The first is the importance of substantive and syntactic subject knowledge as a necessary foundation for teachers to understand uncertainty in terms that renew their classroom practice. The second is the need to develop and sustain communities in which teachers value opportunities to critique their classroom practices.

## 1. Introduction

The *Curriculum and Evaluation Standards for School Mathematics* [1], with its constructivist emphasis on students' understanding of mathematical processes, has been highly influential in shaping mathematics curricula in Canada. The Ontario Mathematics Grade 1–8 Curriculum [2, page 5] is “based on the belief that students learn mathematics most effectively when they are given opportunities to investigate ideas and concepts through problem solving and are then guided carefully into an understanding of the mathematical principles involved.” One result of this emphasis has been the very real challenge for teachers not accustomed to teaching from this perspective, a challenge chronicled in the United States by Stigler and Hiebert [3].

Within the teacher professional learning literature challenges such as these have generally been described in terms of the conversations about the knowledge bases that teachers can draw on in order to improve their instruction. Specifically in the mathematics education literature, “the great challenges posed to reform-oriented teachers have led to much energy being focused on the problem of supporting them in their efforts to learn and relearn how to teach mathematics” [4, page 316]. In particular, much work has gone into how teachers can develop the combination of procedural and conceptual mathematical knowledge considered necessary if reform-based mathematics is to be seen as a credible

“mathematics for teaching” [5]. The development of a teacher constructed “mathematics for teaching” has the potential to generate understandings of mathematics that are context specific to teaching [6]. Indeed, recent research [7] suggests that teachers' pedagogical content knowledge had a substantive positive effect on student learning. The current, predominant, construct of elementary teachers' mathematical knowledge is a hybrid of traditional higher mathematics and instructional methodology, a hybrid that has not served teachers, or students, well [8].

Professional learning conversations that promote the development of teachers' understanding of reform-based mathematics, as well as appropriate development of teacher beliefs, are to be encouraged, although such conversations often overlook one of the key conditions necessary for the promotion of educational change: the sense of uncertainty that teachers often have toward reforms [9]. Educational reforms, which seem almost perpetual in many jurisdictions, are periods of uncertainty for teachers, as Davis and Simmt [10, page 341] explain: “teachers will have to unlearn much of what they believe, know, and know how to do while also forming new beliefs, developing new knowledge, and mastering new skills.” Floden and Clark [11, page 505] state:

*Surprisingly little has been published about the stance teacher education should take toward uncertainty. Writings about teacher education stress how much teachers can learn, rather than*

*what to do about the uncertainties that remain. Numerous reviews describe the “knowledge base” that teachers can draw on. Essays advocate providing teachers with knowledge and skills that will help them provide effective instruction or enable them to see classrooms from a variety of perspectives . . . . The residual uncertainty of teaching is an unpleasant, apparently unacknowledged problem for teacher education.*

The paucity of extant literature on teacher uncertainty continues to the present day. This paper is presented in seven parts. In Section 2 we discuss the notion of uncertainty, its forms and sources. In Section 3, we explain the context of our research. The fourth section will introduce and justify the methodology that guided the research. In Section 5 we interrogate the data using the three forms of uncertainty proposed by Floden and Clark [11]. In Section 6 we discuss our findings, before offering our implications for practice in the final section.

## 2. Uncertainty

Fullan [12] describes educational reform as often beset by conflict, ambiguity, and uncertainty. The reasons for these negative responses are not difficult to locate, with most reforms being “implemented with insufficient evidence for their positive effects, with goals that are too broadly or too vaguely formulated, and with less than adequate designs” [13, page 85]. One consequence of these perceived implementation shortcomings are teachers’ sense of uncertainty toward reform. Van den Berg [14, page 582] defines uncertainty as relating “primarily to a shortage of information, a lack of clearly consistent information with regard to rights, obligations, tasks, and responsibilities.” In their detailed analysis of teacher uncertainty, Floden and Clark [11] have discussed three sources of teacher uncertainty. A primary source is the uncertainty of influence that teachers have: never being sure about what their students understand, or how their students’ understanding has changed in response to the classroom instruction. Second, teachers face uncertainties over content: what to teach and their own incomplete understanding of difficult concepts. A combination of uncertainty regarding influence and content can undermine teachers’ sense of authority, as they balance these uncertainties with the need to appear in control of teaching and learning within the classroom. Third, there is uncertainty that about how they can improve on their own classroom practices.

Understanding these sources of uncertainty and their potential impact on teachers and teaching is important, but for the purpose of this paper, we are particularly interested in the distinction between the uncertainty about knowledge and the uncertainty of action. This distinction is “the difference between lacking a skill and being unclear or undecided about what goal is desired, between uncertainty about how to do what is wanted and uncertainty about what is wanted” [11, page 523]. This distinction is particularly relevant for reform-based math education, which may seem:

*Alien to people who have experienced mathematics instruction only in traditional ways. Teaching in the ways envisioned by the authors of the reform documents is hard. It calls for both knowledge and flexibility on the part of the teacher, who must provide support for students as they engage in mathematical sense making. This means knowing the mathematics well, having a sense of when to let students explore and when to tell them what they need to know, and knowing how to nudge them in productive directions [15, page 272].*

Reform mathematics requires that teachers have “to change their attitudes and orientations towards their work” [9, page 91]. The major difficulty with this requirement is that practicing teachers develop their beliefs and knowledge from many years spent in the classroom as both students and teachers. The result is that many teachers have little experience with reform-based models of instruction and will revert to the traditional North American “problem-solving” pedagogies that do not facilitate the conceptual understanding required for abstract thought [3]. Thus, in seeking to redevelop their procedural and conceptual knowledge, classroom teachers must seek to develop an in-depth understanding of the meanings associated with any changes to content or pedagogy. If mathematics teachers only develop a surface understanding of new materials, then there is a very real risk that they will not attend “to the underlying mechanism of developing students’ mathematical reasoning through problem solving” [16, page 5].

Schoenfeld [15, page 272-3] sums up the source of teachers’ uncertainty of knowledge and action thus:

*When superficial aspects of reform are implemented without the underlying substance, students may not learn much at all. The logistical problems of supporting reform in substantive ways should not be underestimated. Teachers who had themselves been taught in traditional ways were now being asked to teach in new ways and not given much support in doing it.*

Uncertainty of knowledge and uncertainty about action help to explain a major difficulty that many elementary teachers, being preservice, beginning, or experienced, have with reform math: “we often teach to our strengths, and in the areas of our teaching practice where we doubt our efficacy, we may avoid teaching that content or using those teaching methods” [17, page 7].

What has been said so far might suggest that uncertainty is only to be viewed in a pejorative light. But this is not the case. By carefully considering and specifying the sources of teacher uncertainty, there is potential for teachers to benefit from enhanced opportunities for teaching and learning. It may be that “doubt “triggers” teacher learning (and) the need to resolve uncertainty is a major factor driving human activity” [17, page 9]. As described by Wheatley [17], uncertainty can foster disequilibrium and change, teacher reflection, and productive collaboration, as well as supporting teachers’

motivation to learn and a responsiveness to diversity. Importantly for coming to grips with math reforms, “comfort with uncertainty is necessary for the kind of activity and thinking required by progressive reforms.” Each of these attributes of teachers’ responses to uncertainty has three important implications for the reform of elementary mathematics. The first is that the goals of reform-based mathematics, such as conceptual understanding, are harder to assess than the more traditional content knowledge. Second, reform-based teaching methods, which may be unfamiliar to teachers whose only experience is with more traditional methods, are often seen as lacking rigour and credibility [3]. Third, if teachers are to conduct the conversations necessary to embrace reform-based mathematics, then they must be prepared to accept uncertainty in those conversations [18].

If teachers are to enact reform-based mathematics in their classrooms, they need to simultaneously embrace uncertainty and develop the necessary self-confidence for improving the teaching and learning that occurs in their classrooms. They need both “faith (and) doubt . . . not as antagonists but working side by side, to take us around the unknown curve” (Smith, cited in [17], page 14-15). The faith and doubt that the participating teachers had toward this research project, and how they interpreted the inherent uncertainties of that engagement may have facilitated, or limited, opportunities for professional learning.

This consideration of uncertainty leads us to our research questions. The first question is to what extent elementary teachers make the distinction between uncertainty of knowledge and uncertainty of action. The second, related, question is to ask how the research project provided opportunities for teachers to align their classroom practice with the ideals of reform mathematics.

### 3. Context

In 2007 the Elementary Teachers’ Federation of Ontario (ETFO), with funding from the Government of Ontario, implemented the Teachers Learning Together project. This one-year project involved voluntary “teams of teachers from the same school or similar roles to come together (and) work with university facilitators to explore an action research question they created” [19, page 7]. The research group that is the focus of this paper initially consisted of seven elementary (up to Grade 5) teachers. One of these teachers, Anna, joined the group after the start of the project. (Note that pseudonyms are used for all teachers in the study.) All teachers were drawn from two schools operating in the same board district and knew each other before the start of the project. Over the summer prior to the school year, the group attended a two-day summer conference organized by ETFO. The goal of the group was shaped by the conversations at this meeting and could be described as finding a better way to close the gaps in their students’ mathematical knowledge. The group’s facilitator, Bethany, had extensive experience in the development of reform-based strategies and was pursuing a Master of Education in math education at the time of the project.

According to Bethany, the question for the group was “how does developing mathematical models in realistic contexts impact our teaching practice?” Bethany summarized the reasoning behind the desire to change from more traditional teaching strategies as:

*We came to the issue of (knowledge) gaps when you had kids two years in a row. Never again would you question what a colleague did the year before, thinking “this whole class can’t not remember that, obviously they did not do it” . . . It was a week and a half into the year, and they went, “oh yeah, I kind of remember this.” You know what, you covered it. You taught them, you imposed it top down and taught them the rules.*

In addition to the summer conference, the group had four full day meetings over the course of the year. On the suggestion of Bethany, the meetings referenced the commonly available *Contexts for Learning Mathematics* [20]. The teachers agreed, based on Bethany’s guidance, that the materials would provide substance for their conversation.

Having teachers in sequential grade levels provided a variety of opinions during the meetings and potentially benefitted students who would be taught consistently from a reform-based perspective. During the meetings, the teachers discussed encountering problems with getting their students used to a more exploratory type of teaching, and how the benefits of shared strategies would benefit students in subsequent years. All of the teachers mentioned the high level of supporting the group offered, as they attempted to implement the strategies they discussed. Interestingly, even though the question had been decided prior to the first meeting, their research question was not really brought into the meetings to help focus the group discussions.

### 4. Methodology: Interpreting Uncertainty

For the purpose of investigating our research questions, we believe that it is appropriate to use the forms of uncertainty described by Floden and Clark [11]: uncertainties about learning and teaching, subject matter, and how to improve one’s own teaching. In order to develop these descriptors and make sense of the meanings of reform math that the teachers develop, we believe that an interpretative approach is justified [21]. Under such an approach, “education is considered to be a process, and school is a lived experience. Understanding the meaning of the process or experience constitutes the knowledge to be gained” [21, page 4]. Such an approach does not seek to confirm existing theories, and rather, it seeks to “describe and understand the characteristics of the teacher’s working environment and the significance of such for the teachers themselves” [14, page 613].

Four meetings were held though the 2007/2008 school year. Each was audio-taped and then transcribed. The transcripts were interrogated through analysis of narrative, which relies on “concepts derived from previous theory or logical possibilities and are applied to the data to determine whether instances of these concepts are to be found” [22, page 13].

There are two groups of concepts in our analysis. The first are the forms of uncertainty explicated by [11, page 506] uncertainty “about what their students know, what effects teaching has had and will have, what content they should be trying to teach, what instructional authority they have, and how they can improve their teaching.” The second are the meanings that the teachers develop toward their work. Wenger [23, page 52] argues that practices are “about meaning as an experience of everyday life.” With educational reforms “teachers do not blindly apply policy but, rather, give shape to policy. That is, teachers interpret, adapt, and even transform reforms, as they put them into place” [14, page 616]. For these reasons, understanding the interpretations that teachers place on reforms is an important area of research.

A crucial feature in seeking to understand the work of the teachers is the level of involvement which two of the authors (Kajander and Holm) had with the teachers over the years before the project. This work has included maintaining a presence in classrooms, attending professional development activities, and working together on subject association events. These experiences have given each researcher different insights into the work of the teachers. We consider the research group in this project as a community that fostered the conditions necessary for teachers to consider uncertainty in terms of reforming their classroom practices. The three teachers whose narratives were used in this paper were selected, as they most clearly illustrated the challenges that teachers face in dealing with different forms of uncertainty.

## 5. Three Forms of Uncertainty

In this section we draw on the transcripts to consider three teachers, Marie, Anna, and Helen, whose experiences reflect the sources of uncertainty described by Floden and Clark [11]: uncertainties about learning and teaching, subject matter, and how to improve one’s own teaching. Each of these teachers was a participant in the research group led by Bethany. In the following excerpts, we have attempted to capture both the uncertainty felt by the teachers—about both knowledge and action—and a sense of the conversations that allowed the teachers to reform their classroom practices.

*5.1. Uncertainty about Learning and Teaching.* The first sources of teacher uncertainties are around teaching and learning. The teachers in our study exemplified this. Marie was uncertain about the mathematical understanding in her kindergarten class. She sensed that her students were struggling in mathematics, even though they appeared to understand what she was teaching them using a more traditional pedagogy. The introduction of more model-based approaches appeared to be having a positive impact on her class:

*Bethany: It is about them talking; do they appear to know less when you’re teaching in this way?*

*Marie: It’s making me more aware of what they know.*

*Bethany: So, you’re more aware?*

*Marie: Yes, of what the kids know, because it’s usually the ones whose hands go up right away, it’s usually those three, the really bright ones that you hear from a lot. But when you do a think, pair, and share and then say tell me what so and so said in your own voice, a lot of them have a hard time with that.*

Another teacher, Anna, acknowledged her difficulty in letting the students work on their own and explore the contexts being given to them. She admitted that she knew that the strategies she had been relying on were not the most effective ways to teach. Her reluctance to relinquish her control over “teaching” the students was accompanied by her acceptance that what she was doing currently was not helping her students learn the content she was attempting to show them, as this excerpt with another teacher attests:

*Anna: I’m still showing a lot.*

*Marie: You want to control what they do, and how they do it?*

*Anna: Yes, that’s a huge, I need to stop doing that.*

*Gail: You’re just teaching them to wait for that.*

*Anna: Then they’re not really learning are they because...*

*Gail: They wait for somebody to get a hand up, and then turn off because they just know every time that the kids are going to have the answer?*

*Anna: Yes*

By the last meeting, Anna seemed much more comfortable with letting her students explore the problems and did not feel the need to use a lot of pencil and paper work. She seemed to have embraced the ideas the group was discussing and had worked on implementing them into her kindergarten class. “I was just saying that, I’m constantly reminding myself to let go of the teacher talk and me directing them towards the answer. It’s still a struggle for me.”

*Helen struggled with the demands placed on her by the provincial curriculum:*

*I was really having difficulty thinking that I’m trying to cram everything down their throats at once. Why, I do not know, it (the curriculum) said to. Sometimes I think we need to step back and say for our students: “let us concentrate, let us do one thing really well instead of trying to do two things poorly.”*

Further conversations served to highlight that the root cause of Helen’s uncertainty was an over-reliance on the textbook and the curriculum, produced by her own attitude to the subject:

*Helen: If I do not cling to it (the curriculum), it won't get done.*

*Bethany: I think it's about confidence . . .*

*Helen: It does not get done anyway.*

*Bethany: That's the point, just because I'm covering it, it's not going to get it done.*

*Helen: I am one of these sort of math phobia kind of girls, and I see how that translates into my teaching style. Whenever I get nervous, I scurry back to the textbook or the program because I figure that I cannot go wrong if I'm sticking with that.*

Helen's admission is important, as it reiterates the relationship between teaching and learning and the subject matter. Subject knowledge, both substantive and syntactic, is foundational to being able to teach the subject, and it is toward uncertainty regarding the subject that we now turn.

**5.2. Uncertainty about Subject Matter.** The second source of uncertainty for teachers is uncertainty with regard to the subject matter. Math in general, and reform math specifically, is a source of anxiety and concern for many elementary teachers. Marie was an experienced teacher with a stronger background in math than many of her colleagues. This appears to have made her more comfortable about using the different strategies the group discussed. She noticed very early on the changes that were occurring in her students, and the benefits of a more constructivist approach to math would have for her students:

*It's interesting because Helen and I were talking about showing them the algorithm. Now I see the benefit of building those models with the students as opposed to telling them or showing them this is how it's done. They just have to build that conceptual understanding themselves. I think I see the value of using a mathematical model like you said, as opposed to necessarily a manipulative as a tool for thinking.*

The transcripts indicate that Anna has a strong substantive knowledge of math which was communicated in a very traditional teaching style:

*Before I would have just focused on the one task they were supposed to be doing. Can they do it or cannot they, and now . . . Now I'm starting to recognize that there are big ideas and I ask them what I'm doing. I am not just teaching what the lesson plan told me, I'm realizing there's more.*

By the end of the research project, Anna was reporting a substantial change in her teaching practices, shifting decidedly toward a reform-minded stance:

*This all goes to the fact that we're not necessarily teaching them the content; we're teaching them . . . the thinking. They need to know how to think through things and not just math, it's everything, so I see it all fitting together now.*

Helen's math phobia and reliance on the textbook and curriculum are already been described. Although she always seemed to have an open mind, her level of anxiety never seemed to diminish during the year, even though she was aware of her anxiety:

*Even though I've done that this year (relying on the textbook), I'm aware that I'm doing it, and I think that awareness will lead me to bigger and better things . . . I want to know that they have it, that they understand it. If they do not get it, they're not going to be able to achieve these expectations, so for my own teaching I want to understand this, but for my assessment, I'm assessing on the curriculum.*

Helen's comments here that are, in a sense, to be expected, for "appreciating the extent of uncertainty can, after all, be unsettling" [11, page 515]. However, they also mask the danger of looking for certainty in a textbook or curriculum, a failure to improve one's teaching: "a teacher in quest of certainty will be drawn toward factual content that can be taught by rote memorization and tested by requests for recall. Since the present is more certain than the future, a desire for certainty pulls towards a focus on immediate, obvious, specific difficulties, away from global, long-term plans and goals" [11, page 513].

**5.3. Uncertainty about Improving One's Own Teaching.** Finally, teachers experience anxiety about their performance in general and about improving their own teaching. In the final meeting of the group, Marie stated that she was of the mind that the group was just getting started learning about how to teach mathematics:

*Now I think I see the benefit of building those models with the students as opposed to telling them or showing them this is how it's done . . . they just have to build that conceptual understanding themselves. I think I see the value of using a mathematical model . . . as a tool for thinking.*

Marie also mentioned that she and Bethany kept in close contact about the methods being used, so that being at a different school did not hinder her growth in any way. She claimed that she fully saw the benefits of using a model-based approach to teach mathematics and is hoping to continue learning more about these methods to use in her classroom in the future.

Anna quite clearly saw positive changes in her students based on the reform-based teaching that she had used thus far in her classroom. To improve on her teaching, she planned to keep recognizing the problems her students encountered during her lessons:

*I had done measurement and then there was problem in here about measuring smiles, and I thought it was easy, we'd done it already: "How can we find out whose smile is the biggest?" Oh, we can count teeth, and I couldn't get him away from that. I said my teeth are bigger, your teeth are smaller, everyone's teeth are different, but he was stuck on using the non-standard units. He was stuck on those non-standard units because I had forced that on them.*

Based on her previous comments, Helen appears to be more concerned with the certainty of the curriculum. Despite her difficulties with math, she does hold out some hope of being prepared to implement some reform math strategies: "I would just say the instruction that we got from Tony (a visiting math consultant) was very good because it allowed me to sort of open up my mind."

Two important points appear to emerge from the data, and these form the basis of the discussion to follow. The first is that substantive and syntactic knowledge of the subject appears to underpin conversations about teaching practices and improvements to one's own teaching. Both Marie and Anna engaged in conversations about their classroom practices, while Helen deflected the conversation to her math phobia. The second is the value that all three teachers appear to place on opportunities to discuss teaching and learning within the group. It is these two points that we develop in the discussion.

## 6. Discussion

Talbert [24, page 356] believes that the reform of math education relies on the "leadership and commitment of teacher communities." Our analysis of the data supports the notion that communities can play a crucial position in elementary math reform by providing an opportunity for teachers to engage in conversations that raise teachers' awareness of uncertainties and develop strategies for reducing those uncertainties. Equally importantly, our analysis also highlights the importance of substantive and syntactic knowledge in underpinning those conversations. Drawing on the experiences of Marie, Anna, and Helen allows us to consider the concept of teacher uncertainty and its relation to reform math. By considering the teachers' responses to the three forms of uncertainty, we postulate that an individual teacher's substantive and syntactic knowledge of mathematics is foundational to the conversations that allow teachers to accept uncertainty and move beyond traditional forms of math teaching toward a more reform oriented stance.

A serious issue with math education in North America is the belief in the certainty of mathematical knowledge. Math education has been dominated by highly discursive forms of instruction for the past century [15]. An unintended result of this dominance has been the development and persistence of teacher identities that are closely aligned to this view of the subject, a view that downplays the syntactic knowledge of the discipline. This certainty of knowledge results from the discursive traditions that most teachers have experienced

throughout their own school and undergraduate careers. This unexamined, and often unacknowledged, belief in the certainty of mathematical knowledge has a clear implication for the pedagogical actions of elementary teachers, with certainty of knowledge promoting certainty of action.

A teacher in quest of certainty will be drawn toward factual content that can be taught by rote memorization and tested by requests for recall. Since the present is more certain than the future, a desire for certainty pulls toward a focus on immediate, obvious, specific difficulties, away from global, long-term plans and goals [11, page 513].

Helen's self-professed math phobia exemplifies this quest for certainty. Without a firm understanding of the substantive and syntactic knowledge of the subject, she retreated to the certainty offered by the textbook and curriculum. This is a common course for teachers facing uncertainty, as Floden and Clark [11, page 515] state: "constructivist views of student and expert knowledge, for example, are at odds with the commonly held conception that children will understand anything that is clearly explained, and that the curriculum has the untroublesome character of received truth, scientifically and permanently proven." The danger of pursuing certainty is clear: "we often teach to our strengths, and in the areas of our teaching practice where we doubt our efficacy, we may avoid teaching that content or using those teaching methods" [17, page 7].

Marie and Anna appear to have a better understanding of the substantive and syntactic knowledge of math, but teachers will always have some uncertainty around subject knowledge [11]. What is important to note is that both teachers were uncertain about the effects of the teaching and learning occurring in their classrooms. Realizing that some teaching strategies are ineffective in a classroom is part of every teacher's experience, and this is a crucial realization for new teachers to come to. For "ambiguity and uncertainty serve as the starting point of any inquiry, they are the necessary conditions for anyone to take inquiry seriously" [25, page 238].

With their certainty of knowledge in math, Marie and Anna could have chosen to downplay their uncertainties and continue to teach, as they had in the past. This response is a common one and has led Wheatley [17, page 12] to stress that the authority of fundamental knowledge is "one of the major forces that has obstructed inquiry-oriented education." The uncertainty around the effectiveness of their teaching drives these teachers to question and begin to experiment with reform strategies in their classrooms. Through thinking and doing teachers learn about teaching: action in trying out new approaches is imperative, for it is through "informed experiments, pursuing promising directions, and testing out and refining new arrangements and practices that we make the most headway" [12, page 63]. Uncertainty of knowledge in teaching and learning is leading the teachers into the uncertainties of how they can challenge and improve their own teaching.

This difference in the forms of uncertainty that these three teachers face is significant, as it appears to impact on their engagement with the conversations within the group. The conversations provide examples of how the group, as a

community, provided a climate for teachers to exchange ideas openly and frankly. Talbert [24, page 348] observes “open and honest professional exchanges, in which teachers share failures and successes in lessons, is key to reform at the level of community.” Importantly, these conversations were focused on the content and strategies of reform-based mathematics and extended over the course of a school year. We argue that, because these conversations took place in an atmosphere that allowed the open exploration of the uncertainty felt by the teachers, participation in the conversations gave Marie and Anna the opportunity to develop an improved understanding of their classroom practices and the capacity to continue to challenge their thinking. Helen’s voice was much more muted in these conversations, her limited subject knowledge appearing to close opportunities for engagement in the conversation.

## 7. Concluding Remarks

Uncertainty is part of every teacher’s professional life. In this paper, we have considered three sources of uncertainty: uncertainty about teaching and learning, about the subject, and about improving one’s own teaching. All are important throughout the life of any teacher, but it would appear that uncertainty toward the knowledge base of the subject can corrode conversations that aim to promote reform-based math. This has serious implications for both pre- and in-service teacher educators. Preservice elementary teachers require, as a minimum, a working substantive and syntactic knowledge base in math if they are to engage in conversations on teaching and learning math. For in-service teachers the situation is more problematic, as they may be simultaneously faced with uncertainty in all three forms. If long-term, teacher-centered, supportive learning environments are not sustained for these teachers then the danger of continuing, or reverting, to teaching as they were taught remains.

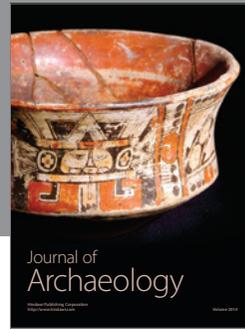
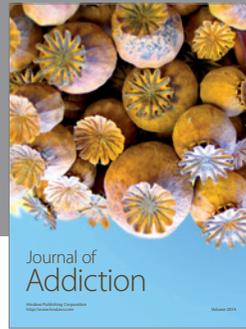
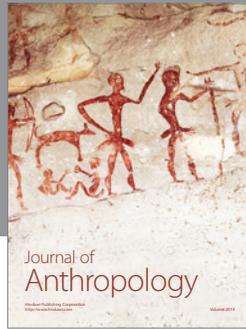
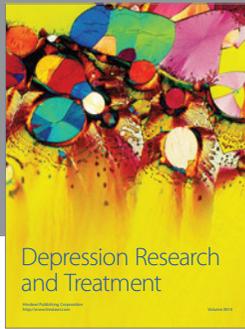
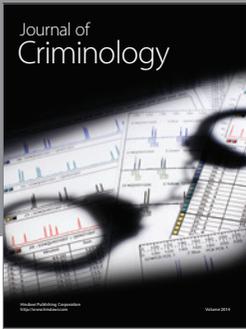
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## References

- [1] National Council of Teachers of Mathematics, *Curriculum and Evaluation Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, Va, USA, 1989.
- [2] Ontario Ministry of Education, *The Ontario Curriculum Grades 1-8: Mathematics*, Queen’s Printer Ontario, Toronto, Canada, 2005.
- [3] J. W. Stigler and J. Hiebert, *The Teaching Gap: Best Ideas from the World’s Teachers for Improving Education in the Classroom*, The Free Press, New York, NY, USA, 1999.
- [4] L. R. van Zoest and J. V. Bohl, “Mathematics teacher identity: a framework for understanding secondary school mathematics teachers’ learning through practice,” *Teacher Development*, vol. 9, no. 3, pp. 315–345, 2005.
- [5] D. L. Ball, H. C. Hill, and H. Bass, “Knowing mathematics for teaching: who knows mathematics well enough to teach third grade, and how can we decide?” *American Educator*, vol. 29, no. 3, pp. 14–46, 2005.
- [6] J. Baumert, M. Kunter, W. Blum et al., “Teachers’ mathematical knowledge, cognitive activation in the classroom, and student progress,” *American Educational Research Journal*, vol. 47, no. 1, pp. 133–180, 2010.
- [7] R. J. Sternberg and J. A. Horvath, “A prototype view of expert teaching,” *Educational Researcher*, vol. 24, no. 9, pp. 9–17, 1995.
- [8] P. Sleegers, F. Geijsel, and R. van den Berg, “Conditions fostering educational change,” in *Second International Handbook on Educational Leadership and Administration*, K. Leithwood and P. Hallinger, Eds., Kluwer Academic Publishers, Dordrecht, The Netherlands, 2002.
- [9] C. Thompson and J. S. Zueli, “The frame and the tapestry: standards-based reform and professional development,” in *Teaching as the Learning Profession*, L. Darling-Hammond and G. Sykes, Eds., Handbook of Policy and Practice, pp. 341–375, Jossey-Bass, San Francisco, Calif, USA, 1999.
- [10] B. Davis and E. Simmt, “Understanding learning systems: mathematics education and complexity science,” *Journal for Research in Mathematics Education*, vol. 34, no. 2, pp. 137–167, 2003.
- [11] R. E. Floden and C. M. Clark, “Preparing teachers for uncertainty,” *Teachers College Record*, vol. 89, no. 4, pp. 505–534, 1988.
- [12] M. Fullan, *What’s Worth Fighting for?: Working Together for Your School*, Australian Council for Education Administration, Hawthorn, Australia, 1991.
- [13] K. van Veen and P. Sleegers, “How does it feel? Teachers’ emotions in a context of change,” *Journal of Curriculum Studies*, vol. 38, no. 1, pp. 85–111, 2006.
- [14] R. Van den Berg, “Teachers’ meanings regarding educational practice,” *Review of Educational Research*, vol. 72, no. 4, pp. 577–625, 2002.
- [15] A. H. Schoenfeld, “The math wars,” *Educational Policy*, vol. 18, no. 1, pp. 253–286, 2004.
- [16] C. Lewis, R. Perry, and A. Murata, “How should research contribute to instructional improvement? The case of lesson study,” *Educational Researcher*, vol. 35, no. 3, pp. 3–14, 2006.
- [17] K. F. Wheatley, “The potential benefits of teacher efficacy doubts for educational reform,” *Teaching and Teacher Education*, vol. 18, no. 1, pp. 5–22, 2002.
- [18] S. Wilson and J. Berne, “Teacher learning and the acquisition of professional knowledge: an examination of research on contemporary professional development,” in *Review of Research in Education*, Iran-Najed and P. D. Pearson, Eds., vol. 24, pp. 173–209, American Educational Research Association, Washington, DC, USA, 1999.
- [19] Elementary Teachers’ Federation of Ontario, *Teachers Learning Together: Action Research Resource*, Elementary Teachers’ Federation of Ontario, Toronto, Canada, 2007.
- [20] C. T. Fosnot, *Contexts for Learning Mathematics*, Heinemann, Portsmouth, UK, 2007.
- [21] S. Merriam, *Qualitative Research and Case Study Applications in Education*, Jossey-Bass, San Francisco, Calif, USA, 1998.

- [22] D. E. Polkinghorne, "Narrative configuration in qualitative analysis," in *Life, History and Narrative*, J. A. Hatch and R. Wisniewski, Eds., pp. 5–24, Falmer, London, UK, 1995.
- [23] E. Wenger, "Communities of Practice," Cambridge University Press, Cambridge, UK, 1998.
- [24] J. E. Talbert, "Professionalism and politics in high school teaching reform," *Journal of Educational Change*, vol. 3, no. 3–4, pp. 339–363, 2002.
- [25] M. S. Gabella, "Unlearning certainty: toward a culture of student inquiry," *Theory Into Practice*, vol. 34, no. 4, pp. 236–242, 1995.



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