

Stability of beliefs in mathematics education: a critical analysis

PETER LILJEDAHL, SUSAN OESTERLE AND CHRISTIAN BERNÈCHE

The field of mathematics education has assumed for too long that stability is an inherent and definable characteristic of beliefs. In this article we explore the validity of this claim through the critical analysis of 92 journal articles, conference papers, and book chapters. Using a stringent definition of what it means for a belief to be stable, we conclude that the body of research on mathematical beliefs is inconsistent in its use of this construct. The aggregated results of our analysis also indicate that stability and instability are not mutually exclusive characteristics of beliefs.

Our motivation for this article stems from the contradictory and varying existing literature on the nature of beliefs in mathematics education in general, and how this literature pertains to the notion of stability of beliefs in particular. On the one hand, there exists a large body of work explicitly claiming that beliefs are stable. On the other hand, there is an equally large body of work explicitly claiming that beliefs are not at all stable and are subject to change. Add to this the even larger body of work where such claims are implied one way or the other through the results of the research that they report and we are faced with a field of research that can be seen as disparate at best, and incoherent at worst. In this article we present the results of a critical analysis of this seemingly contradictory body of literature and bring forth a cogent formulation of beliefs in mathematics education as it pertains to stability. Our primary goal in this work is to answer two questions:

- What are the possible ways that stability of beliefs is being interpreted within the mathematics education research community?
- What does the existing literature on beliefs research in mathematics education say about whether beliefs are stable or not?

Peter Liljedahl, *Simon Fraser University*

Susan Oesterle, *Douglas College*

Christian Bernèche, *Simon Fraser University*

Methodology

The body of literature published in the area of beliefs in mathematics education over the last 15 years is massive and, although not representative, we did make efforts to ensure that the literature we chose for our critical analysis was drawn from all corners of the field. We looked for both contemporary literature and more dated literature. We looked for works containing the words *beliefs* or *affect* within the title or the abstract. And we looked for publications written by people known to be working in the field. In the end, 92 journal articles ($n=26$), conference papers ($n=49$), and book chapters ($n=17$) (all of which are henceforth referred to as articles) were identified as being about beliefs¹ – 40 of which are specifically referenced in this article and listed in the references. These articles were selected for their relevance to the topic of our analysis and were identified as being part of our data set, so to speak, prior to any analysis. The majority of these (85) were published between 1997 and 2009 with the remaining articles (7) being published between 1971 and 1992. This uneven temporal spread is due in part to the accessibility of more contemporary literature as well as the proliferation of beliefs research in the last 15 years. Having said that, we were also deliberate in our efforts to also include some of the more classic and pivotal works in beliefs research.

Table 1. *Breakdown of sources of literature (n=92) journal articles*

Source	Number
Journal articles	26 (28 %)
Conference papers	49 (53 %)
Book chapters	17 (18 %)

Each article was coded for a number of variables, not all of which will be dealt with in this article. The codes relevant to the critical analysis presented here were:

- Research question and/or intention of the article
- Authors' initial assumptions about the stability of beliefs
- Methodology used (if relevant) – in particular, was stability of beliefs measured in some way?
- Results
- Conclusions drawn – in particular, do the authors conclude something about the stability of beliefs?

In addition to these five objective variables, we imposed one subjective code. Regardless of the author(s) initial assumptions and final conclusions regarding the stability of beliefs, we added a code for our interpretation of what the article was able to claim with respect to stability. To do this we formulated a working understanding of what it meant for a belief to be stable. In particular, we considered any evidence of change in beliefs as an indicator that the beliefs being considered were not stable. That is, *change* \Rightarrow *not stable* and *no change* \Rightarrow *stable*. This is a very stringent and uncompromising understanding of what it means for a belief to be stable that does not take into consideration the type of belief, the nature of the change, or any number of characteristics of beliefs and/or change that might be relevant. Nonetheless, this subjective code was introduced into the analysis and, in the end, proved to be very useful in drawing attention to the large number of ways that the concept of stability is used within the field.

By contrasting the claims of the authors against our very stringent understanding of stable, an additional code was able to be assigned to each article. This code reflected the implicit interpretation of what stability meant for each author. Through the use of a constant comparative method, these codes evolved, splitting and collapsing together, until eight distinct themes emerged – each one representing a different interpretation of what it means for a belief to be stable. In what follows we present the results of this analysis.

Possible meanings of *stability* of beliefs

In Furinghetti and Pehkonen's (2002) work on conceptualization of beliefs, opinion among their participants was split regarding the relative accuracy of the characterization that beliefs are "one's stable subjective knowledge (which also includes feelings) of a certain object of concern to which tenable grounds may not always be found in objective considerations" (Pehkonen, 1998, p. 44). The researchers found that the source of this split was confusion around the word stable, "since in the case of beliefs it can be understood in different ways" (Furinghetti & Pehkonen, 2002, p. 50).

One way to understand stable is the uncompromising definition we imposed onto the literature in our sample – if change is shown or declared then the beliefs in question are not stable. This understanding was useful in bringing forth the many nuanced ways in which stability is interpreted within the mathematics education research literature we analysed. By coding the articles in our sample using the understanding of stable as meaning no change we were able to identify instances in which

the authors had differing views of what it meant for a belief to be stable. The sometimes stark contrast between our analysis of the results of an article and the author's claims about the stability of beliefs not only highlighted that there was a nuanced understanding at play, but also accentuated what that nuanced understanding was. Through our recursive analysis of these contradictions, eight themes emerged with regards to the nuanced interpretations of stability. In what follows we present and exemplify each of these themes.

Stable beliefs \neq changes in beliefs are not possible

The first theme to emerge from this analysis was the realization that an author could claim beliefs are stable and simultaneously embark on a course of intervention. For example, Ross and Bruce (2005) cite Woolfolk Hoy and Burke-Spero (2005) in stating that teachers' efficacy beliefs tend "to be stable teacher characteristics, formed in preservice education and the early years of teaching" (p.1). Regardless, they seek to examine the "effects of professional development program on teachers' beliefs about their instructional capacity" (p.1). Likewise, Chang (2002) assumes that teachers' beliefs can be difficult to change, yet seeks to present how one teacher's beliefs changed over the course of two years. Charalambous, Panaoura and Phillipou (2009), meanwhile, assume that beliefs are stable yet explore the effectiveness of a mathematics content course based on the history of mathematics in changing participants' beliefs and attitudes about mathematics.

We found 12 such instances of seeming incongruity between initial assumptions about the stability of beliefs and subsequent action. However, as will be seen in the remaining emergent themes, these are only incongruities when viewed through the lens of our definition of stability. These researchers embarked on their research with the understanding and expectation that some change was possible. By looking more closely at these cases we begin to see the varied and nuanced ways in which stability was interpreted by these researchers.

Some beliefs are stable

Many of the authors in our sample made a distinction between different beliefs and claimed that some of these were more susceptible to change than others. The most common distinction of this type had to do with the dissimilarity between newly formed beliefs and older, more established beliefs. For example, Tillema (2004) found that preservice teachers' newly constructed beliefs about teaching, even if they seem stable,

are vulnerable to change in the face of the reality of practice. At the same time, the efficacy beliefs in preservice teachers are seen as under development and thus, not even considered stable (Charalambous, Philippou & Kyriakides, 2008). Taken together, young teachers' beliefs can be seen as not yet stable, or firm, as Gooya (2007) refers to them. In essence, the sentiment of research that distinguishes between new and old beliefs is that new beliefs are either in development (still changing) or, when first formed, vulnerable to change. In contrast, older beliefs – with static representations – are less likely to change (Charalambous & Philippou, 2003). But the distinction between new and old is not the only one found in the literature.

Kaiser (2006), in her research, found that after 18 months of intervention, only the surface beliefs of practicing teachers had changed. In contrast, Kaasila, Hannula, Laine and Pehkonen (2005, 2006) assumed that core beliefs are more stable and less likely to change. This distinction between core beliefs and peripheral beliefs (Green, 1971) can be used as a way to describe empirical results, as in the case of Kaiser (2006), but often it is used ontologically. That is, a core belief is, by definition, stable. Hence, those beliefs that change are not core. From such a perspective it is possible to simultaneously claim that (core) beliefs are stable *and* report on changes in (peripheral) beliefs.

Beliefs are difficult to change

Related to the idea that some beliefs can change is the notion that some beliefs are difficult to change. "For an individual, belief change involves deserting the familiar for the unknown and therefore, it is often difficult and challenging" (Stuart & Thurlow, 2000, p. 481). For example, Kassila, Hannula, Laine and Pehkonen (2005, 2006), in their study on the impact of preservice teachers' experiences as students of mathematics, on their views of mathematics concluded that it was possible for the preservice teachers to change their beliefs. However, they also concluded that realizing these changes was difficult. The same can be true of all of the empirical research in this critical analysis – whether change occurred in the participants or not, it was difficult. In the instances of success, often extreme measures of intervention were taken. This will be discussed more in a subsequent section.

A more specific form of difficult change is slow change (Nisbet & Warren, 2000). For example, in her research on teachers' experiences in curriculum reform, Yates (2006) found that some change in beliefs about mathematics and the teaching of mathematics occurred, but that the change took place over a long period of time. Likewise, Op't Eynde,

De Corte and Verschaffel (2001) found that students' beliefs about problem solving in mathematics are slow to form and, once established, are equally slow to change even in the face of intervention. These examples, along with the earlier examples of old vs. new beliefs, really accentuate the role that time plays in the formation and maintenance of beliefs.

Another specific conception of beliefs as difficult to change is *resistance to change* (Cooney, 2001; Swan, 2007). Such resistance can be interpreted as taking great effort or being slow to change, as in the aforementioned examples. However, it can also manifest in the examples where change occurs in the face of intervention or exposure to certain environmental conditions, but once these are removed there is a return (gradual or otherwise) to some initial state. The metaphor of elasticity would be appropriate if it were not for the image that elastics are easily stretched (changed). Instead, the term of memory is used, and is meant to be understood in the same context as memory foam or memory metal – two materials that are resistant yet pliable and always return to their initial shape. There is ample research in teacher education that would fit into this category. Teachers' beliefs and practices have been shown to change during the course of an inservice professional development intervention, but once this intervention is complete, the teachers regress back to their previous state (Tillema, 2000). Research on students' beliefs has also shown that particular forms of teaching and classroom culture affect students' beliefs during their time in that setting (Grouws & Cramer, 1989).

Beliefs are relatively stable

This juxtaposition of different beliefs with different types of stability can suggest the notion that beliefs are relatively stable. That is, under one interpretation, in relation to other beliefs some beliefs are stable. So, based on the literature presented in a prior section, it can be conceived that old beliefs are relatively stable (in relation to new beliefs) and core beliefs are relatively stable (in relation to surface beliefs). However, relatively stable can have an alternative meaning. It can mean that beliefs are stable in relation to other cognitive or affective constructs; like emotions McLeod (1992)².

There is a third meaning of relative within the context of belief change. This has to do with the preservation of relative order of the participants as measured against one particular variable. For example, Collier (1972) found that high achieving preservice teachers had less formal views about mathematics and were less ambivalent in their views of mathematics instruction when compared to lower achieving peers. More relevant, however, is that although these views changed somewhat

during their teacher preparation program, the less formal views about mathematics and the less ambivalent views of mathematics instruction were still the domain of the higher achieving participants. Such a conception of stability is really not about beliefs at all, but rather about the relative ranking of participants. The same phenomenon can occur within any variable – belief related or otherwise. Although not so much the case in the research by Collier, there is nothing in such a conception of stability to preclude the drastic renovation of beliefs. In fact, in research by Liljedahl, Rolka and Rösken (2007), changes in beliefs were drastic, yet there was a strong preservation of the relative order of the participants. That is, those participants who were less progressive in their views of mathematics teaching and learning at the beginning of the course were, for the most part, less progressive in their views at the end of the course, even though many of their views could now be classified as progressive.

A fourth conception of relative beliefs emerges out of the same research (Liljedahl, Rolka & Rösken, 2007). Namely, along with relative consistency of beliefs among participants, there was relative consistency across different beliefs within individuals. For example, teachers who tended to see mathematics as a constructive process also tended to see mathematical learning as discovery and construction of relationships, and the teaching of mathematics was seen as the creation of contexts and environments in which students could encounter and experience mathematics in meaningful and authentic ways. That is, there was stability between related beliefs.

Beliefs are stable but can be changed with intervention

An overarching theme in regards to the stability of beliefs is the assumption that beliefs will not change on their own. In the face of appropriate intervention, however, change can occur. Ross and Bruce (2005) claim that teachers' efficacy will remain unchanged unless it is "disturbed by fundamental changes in teacher work" (p.1). They further argue that implementation of a professional development program aimed at the implementation of reform approaches to teaching constitutes such fundamental change. Their research concluded that change was effected through the intervention. Likewise, Swan (2007) claims that teachers' beliefs and practices are extremely resistant to change – even in the face of intervention. Yet, goes on to show how "a modest programme, supported by careful task design, supported by video and other guidance has enabled a group of teachers to re-examine their beliefs and practices concerning mathematics, teaching, and learning" (p. 235). Similarly, both Grootenboer (2008) and Chang (2002) claim that beliefs are stable but

have the hope that change can occur if the intervention is appropriate. In both cases the research fulfils their hopes.

Intervention does not always have to be seen as positive, however. Nor does it have to be seen as something deliberate. Tillema (2000) found that beliefs can "be severely challenged and become overruled by the preconditions set by practice" (p. 576). This same notion was seen in the aforementioned literature on different beliefs in general, and in preservice and novice teachers' relatively new and vulnerable beliefs – in these instances, vulnerable to the realities of practice.

Source of beliefs

Beliefs do not exist *ex nihilo*. They are shaped by our experiences and knowledge, both of which are acquired over time (Green, 1971). Gómez-Chacón (2005), and McLeod and McLeod (2002) are examples of researchers who have identified the importance of the social context on the formation of beliefs.

One area where research has made substantial progress is in recognizing the important role that the social context plays in shaping student beliefs and student learning. In fact, the pendulum has moved so far from a focus on the individual learner to the learner in a social context that it appears that some researchers think that learning by an individual is unlikely, if not impossible (McLeod & McLeod, 2002, p. 121).

Social context aside, the role of experience is identified by many as an important influence on the formation of beliefs (Bandura, 1997; Kajander, 2005). This is especially relevant in the formation of teachers' beliefs about the teaching and learning of mathematics. "Prospective elementary teachers do not come to teacher education feeling unprepared for teaching" (Feiman-Nemser, McDiarmid, Melnick & Parker, 1987). "Long before they enroll in their first education course or math methods course, they have developed a web of interconnected ideas about mathematics, about teaching and learning mathematics, and about schools" (Ball, 1988). These ideas are more than just feelings or fleeting notions about mathematics and mathematics teaching. During their time as students of mathematics they first formulated, and then concretized, deep seated beliefs about mathematics and what it means to learn and teach mathematics (Fosnot, 1989; Skott, 2001). Beyond the pre-teaching years of schooling, Tobin, Tippins and Hook (1992) identify the early years of teaching as a powerful influence on the formation of teachers' beliefs.

Staying with the theme of preservice teachers, Uusimaki and Nason (2004) investigated the sources of preservice teachers' negative beliefs and anxieties about teaching mathematics. They found that the

negative beliefs about mathematics were most often formed in primary school where they, as learners, encountered negative experiences with mathematics. These negative experiences carried forward and became the primary source for anxiety when as preservice teachers, they were required to teach mathematics.

Changes in beliefs are unlikely to change practice

Unlike the many instances of research which is predicated on an assumption that beliefs are stable, much research begins by assuming that change is possible, but then follows this up with a disclaimer that they doubt that the resulting change will have a significant effect on practice (Raymond, 1997; Vacc & Bright, 1999). For example, Cordy, Gadanadis and Namukasa (2005) anticipated that the preservice teachers immersed in a problem solving rich mathematics course would change their beliefs with respect to mathematics and mathematics teaching. As expected, there were measurable changes in the participants' beliefs. However, they cautioned that "a single course experience cannot create comprehensive or permanent changes in teachers' perceptions of mathematics and mathematics teaching. Neither can we assume that such an experience will significantly affect teachers' classroom practice" (p.5–6). Kajander (2005) measured for a similar variable within the context of a mathematics methods course and found similar results. She is also cautious about whether these changes will persist into practice. Mizell and Cates (2009) found that an extra mathematics content course produced some significantly different beliefs in their participants. In particular, they found an increase in confidence among the preservice teachers involved in the study. However, they also found that the participants grew more conservative in their conceptions of teaching, specifically in their views of the role and effectiveness of the use of worksheets. This is likely the result of the conservative, workbook driven teaching methods experienced in the additional content course.

Grootenboer (2008), on the other hand, assumed that beliefs would remain stable for a group of preservice teachers participating in their initial teacher education course. The results of this research showed that within the three categories of responses explored, practice remained stable. However, he does acknowledge that there may have been some small changes in the beliefs or the formation of some new beliefs in his participants, but doubted that they would be significant enough to change practice in the way that was intended.

Beliefs are situated

A final emergent theme with regards to the stability of beliefs is a body of literature that does not recognize stability or changes in beliefs as relevant. Focusing on context, Skott (2009) uses "the notions of context and practice to develop a locally social approach to understanding the belief–practice relationships" (p. 27). He concludes that his results "contextualise the act of teaching in intersubjectively established and continually re-generated settings and suggests that we acknowledge the simultaneous existence of multiple, possibly conflicting, actual and virtual communities of a teacher's practice" (p. 44). Not only does such a consideration for the situated and contextual notion of beliefs relieve us of the concern for stability, it also alleviates the critics of inconsistencies between decontextualized beliefs and situated practice. Leatham (2006) makes a similar plea with respect to the need for researchers to see teachers' beliefs as cohering with their practice. "It is counterproductive to ignore the beliefs with which teachers' practices currently cohere as we look beyond to the beliefs with which teachers might want their practices to cohere or yet further to the beliefs with which mathematics education researchers desire that these practices cohere" (p. 99).

The five researchers who embody this perspective all view belief change as something measured and measurable from the perspective of an observer. For the teacher or student who is in the experience, beliefs are not changing – they are situated.

Critical analysis

As shown in the previous section, stable has many meanings within the mathematics education research community. These nuanced and contradictory understandings make it impossible to say anything summative about the collective research results of our field. By retroactively imposing a standard onto the body of work that comprises our field, however, a meta-result can begin to emerge. This is exactly what we have done in this critical analysis. In this section we look at the results of this coding with respect to only those codes that have to do with stability (or instability) of beliefs.

We deemed relevant to this analysis any article that explicitly addresses the stable or changing nature of beliefs. This reduced our initial sample set from 92 articles to 70 articles. We then analysed this smaller sample of articles according to the following four codes:

- Authors' initial assumptions about the stability of beliefs
- Methodology used (if relevant) – in particular, was stability of beliefs measured in some way?

- Conclusions drawn – in particular, do the authors conclude something about the stability of beliefs?
- Our conclusion about stability as informed by our interpretation of the results

As mentioned earlier, our own analysis of whether or not beliefs are stable was informed by our uncompromising understanding that stability requires that no change be documented or declared.

Using these codes we were able to first classify the relevant sample of literature into two distinct categories:

1. Studies in which belief change *is not* measured. ($n = 20$, 29 %)
2. Studies in which belief change *is* measured ($n = 50$, 71 %)

Belief change *is not* measured

The articles in this category are not necessarily non-empirical. Although seven of these are theoretical in nature, the remaining 13 articles are empirical studies where changes in beliefs are just not measured. Most of these 13 use single sampling methodologies. The lack of empirical evidence does not prevent the authors from making claims about the relative stability of beliefs, however. Only four of these articles make claims that beliefs are stable, while the remaining 16 contain at least some references to beliefs being susceptible to change. These results are summarized in table 2.

Table 2. *Breakdown of authors non-empirical claims about stability (n=20)*

Claim	Number
Beliefs are stable	4 (20 %)
Beliefs are susceptible to change	16 (80 %)

Belief stability *is* measured

Within the 50 articles that use empirical methodologies to measure for change or stability of beliefs, the initial breakdown is done using our analysis of the results of the research. That is, each article was classified as to whether or not any changes in beliefs were demonstrated. Of the 50 articles, 47 demonstrated changes in beliefs, one showed stability, and two were inconclusive. Looking closer at the 47 articles where change was demonstrated, we see that 21 of the authors claimed the opposite – that their research showed that beliefs were stable. Rather, they claimed that some beliefs changed, that beliefs were relatively (or mostly) stable,

that change was difficult or slow, that beliefs were stable but subject to change if the intervention was just right, that change was unlikely to affect practice, and so on. That is, although a change in beliefs was shown the authors explained away these changes using a variety of nuanced understandings of stability. These results are summarized in table 3.

Table 3. Breakdown of empirical articles on stability

Shown	Number (n=50)	Claimed	Number
to not change	1 (2 %)	to be stable	1 (100 %)*
to change	47 (94 %)	to be stable	21 (45 %)*
		to change	26 (55 %)*
inconclusive	2 (4 %)	to change	1 (50 %)*
		no claim	1 (50 %)*

Note. * percentage of the number shown.

Final analysis

The results of the analysis on the aforementioned 70 articles can be combined to say something about the authors' views about the stability of beliefs. Even when the question of stability is left up to the varying interpretations of researchers 43 of the 70 (61 %) research articles make some claim regarding changes in beliefs. When looking only at the empirical evidence 47 of the 50 (94 %) articles demonstrated evidence of the susceptibility of beliefs to change.

Conclusions

In mathematics education research there is a general "lack of consensus about a definition of mathematical beliefs" (Törner, 2002, p. 73). Our critical analysis has shown that stability is not a concise construct. It does our field no good to continue to treat it as if it is. Not only does it blur what it is we claim about the nature of beliefs, it also prevents us from being able to say anything collectively about our research. The critical analysis presented here has shown a varied and disparate use of the term stability from difficult to change, to slow to change, to resistant to change. It has been used selectively to talk about core beliefs, or old beliefs, or firm beliefs, as though these beliefs always were, and always will be, core, old, or firm. And it has been used to talk about beliefs in the absence of

intervention, or in the face of intervention, or after an intervention. Ironically, the only commonality between all of these conceptions of stability is the explicit or implicit undercurrent of change. Difficult, or slow, or resistant to change does not mean unable to change. Relatively stable beliefs are not unwavering. Core beliefs, or old beliefs, do not exist *ex nihilo*. Each of these conceptions is predicated on the fact that change is not only possible, but is a natural part of the development of beliefs and the reaction of beliefs in the face of experiences. Thus, even stable beliefs (by whichever definition of stability is used) can change.

Our critical analysis confirmed this. Authors had no difficulty allowing the ideas that beliefs are stable and that beliefs can (and do) change, to coexist within their work, whether these constructs were stated explicitly or existed implicitly within the empirical evidence of their research. It seems as though, within the field of beliefs research in mathematics education, these ideas are not antonyms. As such, it is not helpful to our work to have one of these constructs exist at the exclusion of the other. As researchers we need to be careful in our usage of these terms so as not to allow the use of one to insinuate the absence of the other.

Taken together, it is imperative that when talking about beliefs in mathematics education we stop using the characteristic of stability as a defining quality. This is not to say that the idea of stability be completely expunged from belief research, but rather that it become a term that is used as a result of empirical research, capable of actually measuring change, and even then with qualification and definition as to what is meant by its use.

References

In what follows only the 40 publications explicitly referenced within this article are listed. The remaining 52 can be provided upon request.

- Ball, D. (1988). Unlearning to teach mathematics. *For the Learning of Mathematics*, 8(1), 40–48.
- Bandura, A. (1997). *Self-efficacy: the exercise of control*. New York: Freeman.
- Chang, C. (2002). Taiwanese inservice mathematics teacher's beliefs and values can change. In A. D. Cockburn & E. Nardi (Eds.), *Proceedings of the 26th conference of the International Group for the Psychology of Mathematics Education* (Vol. 1, p. 270). Norwich: University of East Anglia.
- Charalambous, C. Y., Panaoura, A. & Philippou, G. (2009). Using the history of mathematics to induce changes in preservice teachers' beliefs and attitudes: insights from evaluating a teacher education program. *Educational Studies in Mathematics*, 71, 161–180.

- Charalambous, C. Y. & Philippou, G. N. (2003). Enhancing preservice teachers' efficacy beliefs in mathematics. In M. A. Mariotti (Ed.), *Proceedings of the 3rd congress of the European Society for Research in Mathematics Education*. Bellaria: ERME.
- Charalambous, C. Y., Philippou, G. N. & Kyriakides, L. (2008). Tracing the development of preservice teachers' efficacy beliefs in teaching mathematics during fieldwork. *Educational Studies in Mathematics*, 67, 125–142.
- Collier, C. (1972). Prospective elementary teachers' intensity and ambivalence of beliefs about mathematics and mathematics instruction. *Journal for Research in Mathematics Education*, 3, 155–163.
- Cooney, T. J. (2001). Considering the paradoxes, perils, and purposes of conceptualizing teacher development. In F. L. Lin (Ed.), *Making sense of mathematics teacher education* (pp. 9–31). Dordrecht: Kluwer.
- Cordy, M., Gadanidis, G. & Namukasa, I. (2005). Teachers doing mathematics as experiential therapy. In G. M. Lloyd, M. Wilson, J. L. M. Wilkins & S. L. Behm (Eds.), *Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Roanoke: All Academic.
- Feiman-Nemser, S., McDiarmid, G., Melnick, S. & Parker, M. (1987). *Changing beginning teachers' conceptions: a description of an introductory teacher education course*. Paper presented at the annual meeting of the American Educational Research Association, Washington.
- Fosnot, C. (1989). *Enquiring teachers, enquiring learners: a constructivist approach for teaching*. New York: Teachers College Press.
- Furinghetti, F. & Pehkonen, E. (2002). Rethinking characterizations of beliefs. In G. Leder, E. Pehkonen & G. Törner (Eds.), *Beliefs: a hidden variable in mathematics education?* (pp. 39–57). Dordrecht: Kluwer.
- Gómez-Chacón, I. M. (2005). Affect, mathematical thinking and intercultural learning: a study on educational practice. In M. Bosch (Ed.), *Proceedings of the 4th congress of the European Society for Research in Mathematics Education* (pp. 194–204). Sant Feliu de Guixols: Fundemi IQS–Universitat Ramon Llull.
- Gooya, Z. (2007). Mathematics teachers' beliefs about a new reform in high school geometry in Iran. *Educational Studies in Mathematics*, 65, 331–347.
- Green, T. (1971). *The activities of teaching*. New York: McGraw-Hill.
- Grootenboer, P. (2008). Mathematical belief change in prospective primary teachers. *Journal of Mathematics Teacher Education*, 11, 479–497.
- Grouws, D. & Cramer, K. (1989). Teaching practices and student affect in problem-solving lessons of select junior high mathematics teachers. In D. B. McLeod & V. M. Adams (Eds.), *Affect and mathematical problem solving: a new perspective* (pp. 149–161). New York: Springer-Verlag.

- Kaiser, G. (2006). The mathematical beliefs of teachers about applications and modelling – results of an empirical study. In J. Novotná, H. Moraová, M. Krátká & N. Stehliková (Eds.), *Proceedings of the 30th conference of the International Group for the Psychology of Mathematics Education* (Vol. 3, pp.393–400). Prague: Charles University.
- Kajander, A. (2005). Towards conceptual understanding in the pre-service classroom: a study of evolving knowledge and values. In G. M. Lloyd, M. Wilson, J. L. M. Wilkins & S. L. Behm (Eds.), *Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Roanoke: All Academic.
- Kaasila, R., Hannula, M. S., Laine, A. & Pehkonen, E. (2005). Autobiographical narratives, identity and view of mathematics. In M. Bosch (Ed.), *Proceedings of the 4th congress of the European Society for Research in Mathematics Education* (pp.215–224). Sant Feliu de Guixols: Fundemi IQS–Universitat Ramon Llull.
- Kaasila, R., Hannula, M. S., Laine, A. & Pehkonen, E. (2006). Facilitators for change of elementary teacher students' view of mathematics. In J. Novotná, H. Moraová, M. Krátká & N. Stehliková (Eds.), *Proceedings of the 30th conference of the International Group for the Psychology of Mathematics Education* (Vol.3, pp. 385–392). Prague: Charles University.
- Leatham, K. R. (2006). Viewing mathematics teachers' beliefs as sensible systems. *Journal of Mathematics Teacher Education*, 9, 91–102.
- Liljedahl, P., Rolka, K. & Rösken, B. (2007). Affecting affect: the re-education of preservice teachers' beliefs about mathematics and mathematics learning and teaching. In M. Strutchens & W. Martin (Eds.), *The Learning of Mathematics* (69th NCTM Yearbook) (pp.319–330). Reston: NCTM.
- McLeod, D. (1992). Research on the affect in mathematics education: a reconceptualization. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp.575–596). New York: Macmillan.
- McLeod, D. & McLeod, S. (2002). Synthesis – beliefs and mathematics education: implications for learning, teaching, and research. In G. Leder, E. Pehkonen & G. Törner (Eds.), *Beliefs: a hidden variable in mathematics education?* (pp. 115–123). Dordrecht: Kluwer.
- Mizell, J. A. & Cates, J. (2004). The impact of additional content courses on teacher candidates' beliefs regarding mathematics content and pedagogy. *Issues in the Undergraduate Mathematics Preparation of School Teachers*, 4 (May). Retrieved July 15, 2009 from <http://www.k-12prep.math.ttu.edu/journal/curriculum/mizell/article.pdf>
- Nisbet, S. & Warren, E. (2000). Primary school teachers' beliefs relating to mathematics, teaching and assessing mathematics and factors that influence these beliefs. *Mathematics Teacher Education and Development*, 2, 34–47.

- Op't Eynde, P., De Corte, E. & Verschaffel, L. (2001). In M. van den Heuvel-Panhuizen (Ed.), *Proceedings of the 25th conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp.25–32). Freudenthal Institute, Utrecht University.
- Pehkonen, E. (1998). On the concept 'mathematical beliefs'. In E. Pehkonen & G. Törner (Eds.), *The state-of-art in mathematics-related belief research: results of the MAVI activities* (pp.37–72). Department of Teacher Education, University of Helsinki.
- Raymond, A. M. (1997). Inconsistency between a beginning elementary school teacher's mathematics beliefs and teaching practice. *Journal for Research in Mathematics Education*, 28 (5), 550–576.
- Ross, J. A. & Bruce, C. (2005). Teachers' beliefs in their instructional capacity: the effects of in-service. In G. M. Lloyd, M. Wilson, J. L. M. Wilkins & S. L. Behm (Eds.), *Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Roanoke: All Academic.
- Skott, J. (2001). The emerging practices of novice teachers: the roles of his school mathematics images. *Journal of Mathematics Teacher Education*, 4 (1), 3–28.
- Skott, J. (2009). Contextualising the notion of 'belief enactment'. *Journal of Mathematics Teacher Education*, 12, 27–46.
- Stuart, C. & Thurlow, D. (2000). Making it their own: preservice teachers' experiences, beliefs, and classroom practices. *Journal of Teacher Education*, 51 (2), 113–121.
- Swan, M. (2007). The impact of task-based professional development on teachers' practices and beliefs: a design research study. *Journal of Mathematics Teachers Education*, 10, 217–237.
- Tillema, H. H. (2000). Belief change towards self-directed learning in student teachers: immersion in practice or reflection on action. *Teaching and Teacher Education*, 16 (5-6), 575–591.
- Tobin, K., Tippins, D. & Hook, K. (1992). *The construction and reconstruction of teacher knowledge*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.
- Uusimäki, L. & Nason, R. (2004). Causes underlying pre-service teachers' negative beliefs and anxieties about mathematics. In M. J. Høines & A. B. Fuglestad (Eds.), *Proceedings of 28th conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp.369–376). Bergen University College.
- Vacc, N. N. & Bright, G. W. (1999). Elementary preservice teachers' changing beliefs and instructional use of children's mathematical thinking. *Journal for Research in Mathematics Education*, 30 (1), 89–110.
- Woolfolk Hoy, A. & Burke-Spero, R. (2005). Changes in teacher efficacy during the early years of teaching: a comparison of four measures. *Teaching and Teacher Education*, 21, 343–356.

Notes

- 1 In selecting articles based on the term beliefs we recognize that we will have missed literature in which authors may have chosen to express their ideas about what we would refer to as, beliefs, using terms such as dispositions, conceptions, attitudes, or any number of other ways.
- 2 Although McLeod (1992) does not state directly that beliefs are stable in relation to emotions this can be (and often is) inferred from his seminal chapter.

Peter Liljedahl

Dr. Peter Liljedahl is an Associate Professor of Mathematics Education in the Faculty of Education at Simon Fraser University in Vancouver, Canada. He is a former high school mathematics teacher who has kept his research interests and activities close to the classroom. He regularly works closely with teachers, schools, school districts, and ministries of education on issues pertaining to the improvement of teaching and learning. His primary research interests are teacher beliefs, teacher education, and creativity in mathematics.

liljedahl@sfu.ca

Susan Oesterle

Dr. Susan Oesterle is a Mathematics instructor in the Faculty of Science & Technology at Douglas College in New Westminister, Canada. Over the last few years she has been heavily involved in developing and teaching in a Graduate Diploma Program for Mathematics and Science Teaching, a two-year program which provides an opportunity for practicing elementary and middle school teachers to build their knowledge-base and improve their teaching of these subjects. Her current research interests include pre-service and in-service teacher education, teacher beliefs, and issues concerning mathematics teacher educators.

oesterles@douglascollege.ca

Christian Bernèche

Christian Bernèche is a PhD student in Mathematics Education at Simon Fraser University in Vancouver, Canada. He has been teaching for over two decades and is presently teaching Grade 6. He is a member of his local Professional Development Committee and strongly believes in self-directed professional growth plans. His area of interest in research is student perceptions about learning and teaching mathematics.

cbernech@sfu.ca