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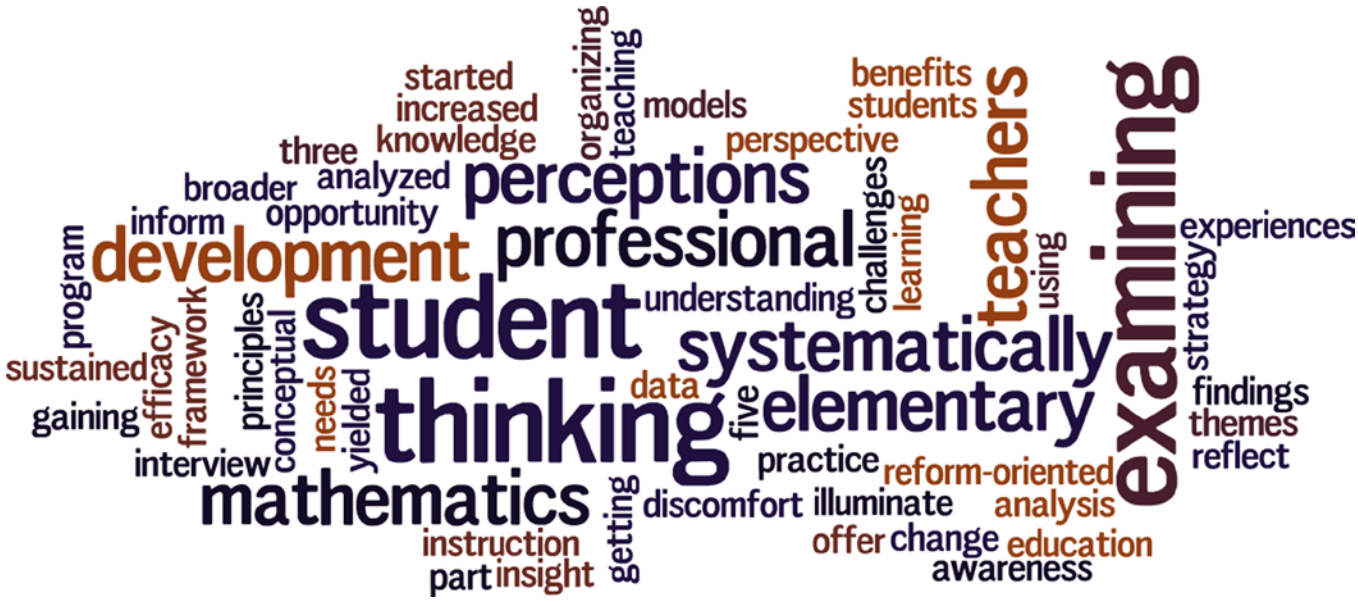

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Teachers' perceptions of examining students' thinking: Changing mathematics instructional practice

Katie L. Anderson-Pence[1]*

Abstract: This paper seeks to illuminate teachers' perceptions of the challenges and benefits of systematically examining students' thinking as part of a professional development program in elementary mathematics education. Using a framework of models of conceptual change and principles of discomfort, three elementary teachers' perceptions of their experiences with reform-oriented mathematics instruction and systematically examining students' thinking were analyzed. Analysis of interview data yielded five organizing themes. Findings offer insight into understanding the efficacy of examining students' thinking as a professional development strategy.

Subjects: Continuing Professional Development; Mathematics & Numeracy; Teaching & Learning

Keywords: conceptual change; discomfort; motivation; qualitative research; reform-oriented mathematics; self-efficacy

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*Corresponding author: Katie L. Anderson-Pence, Department of Teaching & Learning, University of Colorado Colorado Springs, Colorado Springs, USA
E-mail: kander19@uccs.edu

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Additional information is available at the end of the article

1. Introduction

Over the past two decades, organizations such as the National Council of Teachers of Mathematics (NCTM) (1991, 2000, 2014) and the National Governors Association Center for Best Practices and Council of Chief State School Officers (NGA Center & CCSSO) (2010) have attempted to improve the teaching of mathematics by outlining standards for instructional practices and student learning. These standards describe classrooms in which students engage in worthwhile mathematical tasks, participate in robust mathematical discussions, and develop deep mathematical understanding through the use of various models and representations. Acknowledging the key role of the teacher in the classroom (Mewborn, 2003), NCTM has also called for teachers to have a deep understanding of the mathematics they teach, to facilitate

Katie L. Anderson-Pence

ABOUT THE AUTHOR

Katie L. Anderson-Pence is a former elementary school teacher and is currently an assistant professor in the Department of Teaching & Learning in the College of Education at the University of Colorado Colorado Springs. She teaches courses in Elementary Mathematics Education in the Teacher Education and Licensure Program and coordinates with partnership schools to support and supervise pre-service teachers. Her research interests in mathematics education include: classroom discourse, teacher development, and technology—including virtual manipulatives.

PUBLIC INTEREST STATEMENT

In general, change is not easy. Sometimes, changes are frustrating and paralyzing. At other times, changes are educative and empowering. This paper examines the changes experienced by three elementary teachers as they examined their students' thinking and incorporated what they learned into their lessons. The teachers' comments shed light on the importance of positive self-efficacy and motivation in overcoming challenges and making positive and long-term changes.

meaningful mathematical discourse, and to reflect on the outcomes of each lesson (National Council of Teachers of Mathematics, 2007). Such instruction requires teachers to examine students' mathematical thinking and to use that examination to inform their lessons. The implementation of such reform-oriented techniques requires a substantial change in the beliefs and attitudes of most teachers toward teaching mathematics—a change that can be quite challenging.

This study explored teachers' perceptions of changing their own instructional practice as a result of focusing on students' mathematical thinking. The following research questions guided the study:

- What do elementary teachers perceive as challenges and benefits of systematically examining students' thinking?
- How do elementary teachers perceive the impact of examining students' thinking on their professional growth?

2. Literature review

Among the various options for professional development programs (Loucks-Horsely, Stiles, Mundry, Love, & Hewson, 2010), examining students' thinking has been demonstrated to be influential in transforming how teachers view their role in the classroom and how they implement reform-oriented instructional techniques (Hawley & Valli, 2000; Love, Stiles, Mundry, & DiRanna, 2008). The following sections highlight key ideas related to examining students' thinking and the processes of changing instructional beliefs, knowledge, and practice.

2.1. Examining students' thinking

Little (1999) describes the examination of students' thinking as "the systematic, sustained study of student work, coupled with individual or collective efforts to figure out how that work results from the practices and choices of teaching" (p. 235). The use of student work in professional development gives teachers the opportunity to examine their teaching practices in the context of their own students' learning needs, and the disequilibrium often caused by such an examination acts as a catalyst for transformational thinking (Thompson & Zeuli, 1999). Thus, as teachers examine students' thinking, they are more likely to make meaningful changes in their instruction. Various protocols exist for the examination of students' thinking as found on the websites for National School Reform Faculty (http://www.nsrfharmony.org/) and Looking at Student Work (http://www.lasw.org/). Despite the variety of protocols, they generally follow the same general format (Loucks-Horsely et al., 2010):

- Identification of a focus or goal by answering the question: "What do we want to learn from the student work?"
- Selection of student work that relates directly to the identified goal and outcomes.
- In-depth analysis of student work and its relationship to teacher practice.
- Reflection on the implications and applications of what is learned to teaching.

Through this reflective process, teachers begin to apply current research and think differently about their teaching practices (Everett, Luera, & Otto, 2006; Fullan, 1999). Reflection enables teachers to objectively examine their practice and to make necessary changes to improve it.

Research has suggested that as teachers examine student work and witness learning results, they are more likely to make sustained and effective changes to their teaching knowledge, beliefs, and practices (Borko, Jacobs, Eiteljorg, & Pittman, 2006; Carpenter, Fennema, & Franke, 1996; Jacobson & Lehrer, 2000). For example, in a follow-up study on a professional development program focused on students' thinking, Franke, Carpenter, Levi, and Fennema (2001) found that four years later all 22 teachers in the study still incorporated children's thinking into their lessons. They also found that half of the teachers had continued their own learning and had become intimately knowledgeable about their current students' mathematical thinking. Likewise, Busi and Jacobbe (2014) and Doerr (2006) reported increased levels of teachers' understanding of the diversity of students' thinking and how that diversity may be

used to inform instruction. Kazemi and Franke (2004) described their work with ten elementary teachers during monthly meetings to examine and analyze students' thinking. At the beginning of the school year, these teachers found it difficult to identify the details of students' problem-solving strategies. However, as they gained more experience with examining and discussing student work, these teachers became more adept in recognizing mathematical ideas embedded in their students' thinking and in designing future instruction based on their students' needs.

2.2. Changing instructional beliefs, knowledge, and practice

Many factors influence teachers' experience with changing their instructional beliefs, knowledge, and practice. Gregoire's (2003) Cognitive-Affective Model of Conceptual Change (CAMCC) describes the transformation process of teachers when faced with conceptual change in their subject matter beliefs (see Figure 1). Change that occurs in a classroom is affected by how the teacher perceives personal goals and prior beliefs in relation to the reform message presented. The CAMCC model suggests that weak motivation to change, perceived lack of subject matter knowledge, or indifference toward the change can result in a superficial belief change. On the other hand, a teacher with strong motivation to change and who possesses sufficient self-efficacy—belief in one's ability to produce an effect (Bandura, 2001)—can experience a more powerful conceptual change in belief and attitude. The degree to which a teacher embraces change depends upon prior beliefs and experiences. Contextual factors, including teachers' time and available resources, also influence change. Gregoire (2003) suggests that teachers should be given the opportunity to practice incorporating change into their classrooms while receiving feedback and assistance during implementation. Those who wish to implement change need to recognize that increasing teachers' motivation alone is not enough to change their beliefs. Teachers need time to reflect on the challenge and receive appropriate conceptual support. Lastly, a teacher's epistemological beliefs will also have an effect on changes made in the classroom (Gregoire, 2003).

As teachers consider changing instructional practice, they likely encounter varying degrees of discomfort and uncertainty that may impede the process of change. As a result of a 3-year study of middle school teachers' implementation of a reform-oriented mathematics curriculum, Frykholm (2004) identified four types of discomfort: (a) cognitive, (b) beliefs-driven, (c) pedagogical, and (d) emotional. The question remains, however, as to whether these types of discomfort are debilitating or educative in teachers' change processes. Frykholm (2004) suggests that debilitating discomfort most likely arises when teachers lack sufficient content knowledge (cognitive discomfort), strongly disagree with the philosophy of reform-oriented curricula (beliefs-driven discomfort), or possess a low tolerance for discomfort (emotional discomfort). Teachers experiencing debilitating discomfort are less likely than teachers not experiencing such discomfort to sustain any lasting change of practice. However, teachers' abilities to tolerate discomfort seem to correlate positively with a view of discomfort as educative and part of the learning process. Frykholm (2004) suggests that beliefs-driven and emotional discomforts possibly present the most debilitating impact on teachers' change processes.

Teachers' beliefs about themselves also enable them to exercise control over their thoughts and actions and to be self-organizing, proactive, self-reflecting, and self-regulating. A teacher's self-efficacy (i.e. belief in one's ability to produce an effect) determines thoughts, actions, feelings, and self-motivation (Turner, Warzon, & Christensen, 2011). These effects or actions are produced through cognitive, motivational, and affective processes (Bandura, 2001). As new challenges are posed, a teacher normally experiences some amount of stress. Teachers with high self-efficacy approach difficult tasks as challenges to be mastered (Bandura, 2001). This attitude leads them to set challenging goals and maintain strong commitment to those goals. When setbacks or failures occur, they increase their efforts. When teachers believe that they have enough resources and skills to cope with the challenges, then positive change is likely to occur. In contrast, teachers who doubt their capabilities shy away from difficult tasks, which they view as personal threats. They have low expectations for themselves and a low level of commitment to goals. When faced with difficulties, they dwell on their personal deficiencies or other obstacles rather than focusing on the tasks at hand.

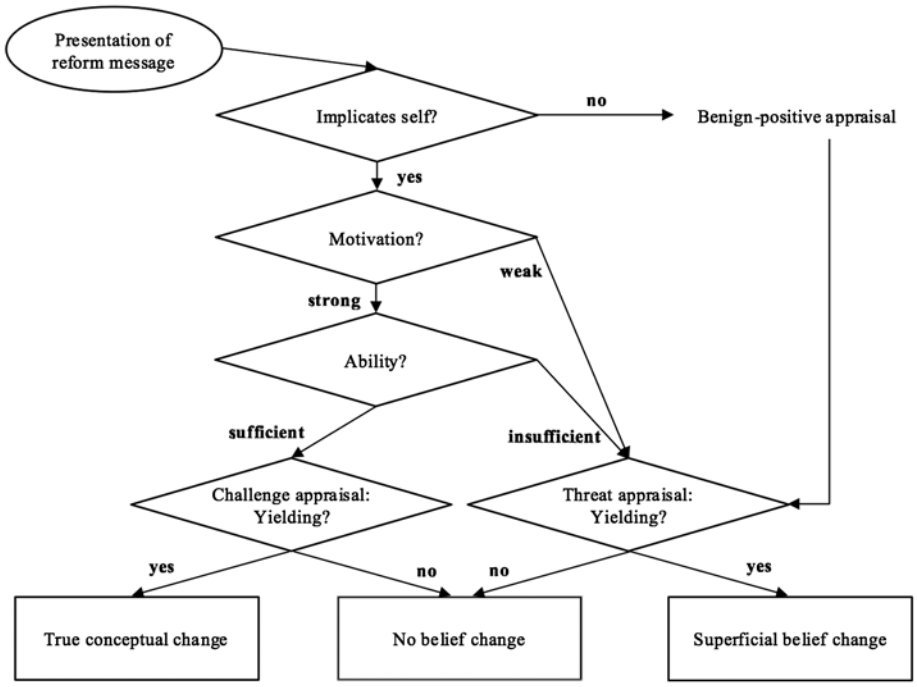

Figure 1. Cognitive-affective model of conceptual change (Gregoire, 2003).

The literature also reveals reasons why teachers may resist change. According to Zimmerman (2006), individuals may fail to recognize the need for change because they perceive the current situation as more desirable than trying something new. More effort might be required to develop new skills or habits, so they prefer to maintain the status quo. Also, previously unsuccessful efforts at change may cause teachers to be skeptical of other attempts. Further, familiar ways of doing provide a sense of security for most people. Teachers may lose this sense of security when faced with changing established instructional patterns. Zimmerman (2006) stated that proposed changes in instruction may threaten teachers' expertise and skill in teaching. They may not feel confident in their abilities to implement the change; therefore, they may resist it.

3. Methodology

This study was part of a larger mixed methods study that examined teachers' growth and change with respect to their knowledge, beliefs, and attitudes related to mathematics teaching and learning (forthcoming). In this larger study, 52 elementary teachers participated in a 2-year Elementary Mathematics Endorsement Program, hereafter referred to as Endorsement. The 18-credit Endorsement included coursework on learning principles, research-based teaching strategies, and mathematics content specific to grades K–6 (e.g. whole number operations, rational numbers, geometry, algebra). Teachers' growth was measured by reflective journal assignments throughout the Endorsement and by the administration of pre- and post-assessments given at the onset and completion of the Endorsement. The pre- and post-assessments measured teachers' knowledge, attitudes, and beliefs related to mathematics teaching and learning and were, respectively:

- Learning Mathematics for Teaching (LMT) Instrument (Hill, Schilling, & Ball, 2004)
- Self-Report Survey: Elementary Teachers' Commitment to Mathematics Education Reform (Ross, McDougall, Hogaboam-Gray, & LeSage, 2003)
- Integrating Mathematics and Pedagogy (IMAP) Web-Based Beliefs Survey (2001)

Teachers in the Endorsement designed a capstone project during the last semester of coursework in which they systematically examined their students' thinking and used it to inform their instruction. Through this project, teachers had the opportunity to implement the principles and practices

that they had learned during their coursework, to evaluate the results of their implementations, and to reflect on their instructional practice. Teachers reported the results of their projects in a written format of their choice (e.g. formal paper, outline, PowerPoint presentation, or theatrical production) and made "poster session" summary presentations to their colleagues and district administrators. This paper focuses on the teachers' perceptions at the end of the Endorsement having reflected on their instructional practice and their students' thinking in the capstone project.

3.1. Participants

Three elementary teachers who had completed a capstone project in the Endorsement were interviewed on their experience—one fifth-grade teacher and two sixth-grade teachers with a combined 56 years of teaching ranging from 16 to 21 years. These elementary teachers were chosen because of their unique profiles on the pre- and post-assessments from the larger study—either making significant or negligible gains on each assessment. At the time of the interview, each teacher had a bachelor's degree and was pursuing a master's degree in education. The selected teachers teach students in three different schools in one school district.

Ethical considerations were upheld in accordance with current guidelines (National Commission for the Protection of Human Subjects of Biomedical & Behavioral Research, 1978). Teachers' participation in this study was solicited after their completion of the Endorsement, and their participation or non-participation had no effect on their employment or academic status. Having given informed consent, teachers were free to withdraw from the study at any time and were not required to respond to any interview question that they felt uncomfortable answering. Teachers' privacy was maintained through the use of pseudonyms, and security measures were taken to safeguard the collected data. The following sections give a description of each participant's school and classroom.

3.1.1. Shannon

The first teacher, Shannon, teaches fifth grade in an elementary school of about 450 students. In her classroom, students sit in groups of four with their desks facing each other. A SMART Board™ is located at the rear of the classroom along with a roundish table for small-group meetings. A whiteboard at the front of the classroom displays the daily schedule and assignments. The walls and bulletin boards display posters, student work, and other visuals for a variety of subjects. The mathematics displays include a number line and posters for place value, divisibility rules, and mathematics vocabulary words. Shannon's enthusiasm for learning shines through in her teaching, and she is attentive to her students' needs.

Shannon was selected for this study because the pre- and post-assessments indicated that she started with limited knowledge and traditional attitudes toward mathematics instruction and demonstrated a major shift toward reform mathematics by the end of the Endorsement. Additionally, the beliefs measure indicated that she started with views already well-aligned with reform mathematics instruction.

3.1.2. Barbara

The second teacher, Barbara, teaches sixth grade in an elementary school of about 750 students. In Barbara's classroom, students sit in groups of five or six at long rectangular tables. Each table is equipped with a supply center: a plastic crate with pencils, colored pencils, glue sticks, and hanging file folders for keeping students' loose papers. Below each supply center, there is a space for students' textbooks when not in use. A roundish table at the front and a rectangular table at the rear of the classroom provide spaces for small groups to meet. The walls are lined with student-created posters. The whiteboard at the front of the classroom displays the daily schedule and a list of the learning objectives for each lesson. Barbara's infectious smile greets all who enter her classroom, and she strives to engage her students in meaningful mathematics lessons.

Barbara was selected for this study because, like Shannon, the pre- and post-assessments indicated that she started the Endorsement with limited knowledge and somewhat traditional attitudes toward mathematics instruction, but exhibited beliefs already well aligned with reform mathematics

instruction. However, unlike Shannon, the pre- and post-assessments indicated little change in her knowledge and attitudes toward reform mathematics by the end of the Endorsement.

3.1.3. Natalie

The third teacher, Natalie, teaches sixth grade in an elementary school of about 750 students. In Natalie's classroom, students sit at desks arranged in either pairs or longer rows. A whiteboard and pull-down screen is located at the front of the classroom along with two computer stations and a document camera. A roundish table for small-group meetings is located at the rear of the classroom. The walls and bulletin boards display posters for a variety of subjects. The mathematics displays include student-generated posters for calculation procedures and professionally made posters for place value, geometry, fractions, and other mathematics symbols. Natalie has high expectations for her students in both academics and behavior, and she provides a supportive environment for her students' success. She warmly greets students individually as they enter the classroom and shows genuine concern for their well-being.

Natalie was selected for this study because the pre- and post-assessments indicated that she started with limited knowledge and very traditional views of mathematics instruction and demonstrated a major shift toward reform mathematics instruction by the end of the Endorsement.

3.2. Data collection and analysis

The purpose of this study was to explore teachers' perceptions of changes their own instructional practice as a result of systematically examining students' mathematical thinking. Therefore, interviews provided the main source of data for analysis. One semi-structured interview was conducted with each teacher following an observation of the teaching of a mathematics lesson on the same day. Questions on the interview protocol focused on the process of systematically examining students' thinking, the teachers' opinions of the capstone project, and the teachers' perceptions of how the examination of students' thinking impacted their instructional practice (see Table 1). Interviews lasted 20–30 minutes and were conducted during teachers' preparation time at their convenience. Interviews were audiotaped and transcribed within one week of the interview (Creswell, 2012). Next, individual follow-up questions were emailed to each participant along with a copy of the participant's interview transcription. This resulted in chains of email conversations that provided further data for analysis and clarification on the initial interview responses.

A thematic analysis of the data involved (a) preliminary reading and exploration of the interview transcripts, (b) generating initial codes and pulling direct quotes to highlight patterns, (c) collapsing of categories into organizing themes, and (d) identifying patterns in the organizing themes to determine global themes (Boyatzis, 1998; Braun & Clarke, 2006). This analysis identified three global themes and several organizing themes (see Table 2).

Validity and reliability were established through triangulation of different data sources (Merriam, 2009; Yin, 2009): (a) interview responses, (b) classroom observations, and (c) member checking by sharing preliminary results of the analysis with the participants who provided feedback on the accuracy of the interpretations (Merriam, 2009). To support the construct validity of the study, the data were compared with established literature on teacher change (e.g. Bandura, 2001; Frykholm, 2004; Gregoire, 2003; Turner et al., 2011) to determine if the findings were consistent with current trends or whether the findings provided new insights.

4. Findings

The following sections describe the three categories of organizing themes that emerged from the analysis of the semi-structured interviews: perceived challenges, perceived benefits, and perceived change and growth.

4.1. Perceived challenge of systematically examining students' thinking

The one organizing theme that emerged relating to perceived challenges of systematically examining students' thinking was *uncertainty of getting started*. The teachers' comments on this topic

Table 1. Semi-structured interview protocol for teacher's experience with examining students' thinking

Category	Interview prompts
Capstone project	Tell me about your capstone project.
	Why did you decide to focus on this particular topic?
	What did you learn from doing your capstone project?
Difficulties	How have you found the experience of examining students' thinking in your classroom?
	What did you find difficult while systematically examining your students' thinking?
	Why was it difficult?
	What did you like about examining students' thinking in your capstone project?
	If you were to systematically examine students' thinking again in your classroom, what would you want it to look like?
	What would you do differently?
Change and growth	How would you describe your teaching practice and philosophy?
	Can you think of a memorable story that exemplifies this practice?
	In your opinion, how did the capstone project influence your teaching of mathematics?
	In what ways do you think you have changed the most in your teaching of mathematics?
	How do you think students best learn mathematics?
	Tell me about your typical math lesson.
	What else would you like to share with me about your experience with your examination of students' thinking?

Table 2. Global and organizing themes in the thematic analysis

Global themes	Organizing themes
Perceived difficulties of systematically examining students' thinking	Getting started
Perceived benefits of systematically examining students' thinking	Opportunity to reflect on practice
	Gaining knowledge to inform teaching
Perceived change and growth in instructional practice	Increased awareness of students' needs
	Broader perspective and sustained learning

centered around the enormity of narrowing down a specific aspect of students' thinking to examine. For example, Barbara commented, "[It was difficult until] I could figure out what I wanted. That was the hard thing of all the different things .... Once I zeroed in, then it all fell into place. But it was like, 'Oh, I could do this! Or I could do this!'"Natalie also felt uncertain, even after having decided on a topic, as illustrated by her comment "I wasn't sure if what I was doing was right." She also recalled that the process was very time consuming. Shannon felt the most overwhelmed by the process. She reflected,

> It was tough. It was. In fact, it stressed me out because I didn't really know how to do it .... I even took off a day. I took a personal leave day to sit down and do it because it stressed me so badly.

In terms of Frykholm's (2004) Teacher Discomfort framework, the concerns caused by this challenge could be classified as either cognitive or emotional discomfort. The cognitive discomforts created by not knowing exactly how start the project combined with the emotional discomforts of feeling overwhelmed had potentially debilitating effects. Shannon's comment that the enormity of the project

"stressed [her] out" reflects this emotional discomfort. However, each of these teachers successfully completed their capstone project of systematically examining student work. Perhaps their success was due to a high sense of self-efficacy, which helped them to approach the undesirable tasks as challenges to be mastered, rather than impossible undertakings (Bandura, 2001).

4.2. Perceived benefits of systematically examining students' thinking

Two organizing themes emerged relating to perceived benefits of systematically examining students' thinking. The first theme to emerge from the teachers' responses was the benefit of *reflecting on their teaching practice*. For example, Shannon recounted the following realization:

> This telling, getting up and just showing [the students] how to do it … I could see where it was not as effective …. I thought, 'There's something missing here.' I didn't know what it was but [I knew] there had to be more.

Likewise, Barbara reflected, "For me personally, it just made me look inward and really made me think. How can I fine-tune this? How can I tweak this to make it better?" Both of these teachers demonstrated high levels of self-efficacy, in that they believed that they had the ability to identify and make positive changes in their instructional practice. They took ownership of their instruction and sought to improve it.

The second organizing theme that emerged was *gaining knowledge to inform teaching*. Many of the comments related to this theme followed directly from teachers' comments on the value of reflection, discussed previously. For example, when discussing her experience, Shannon stated, "It's the knowledge and the informing that counts for me—what I learn that I can take back with my kids." She went on to describe how she planned her instruction based on her examination of students' thinking. "I realized [that I needed to] put proofs and put conjectures and have [the students] prove—have them use mathematical language to express how they say it and how they're thinking." Likewise, Barbara recognized the benefit of closely examining students' thinking.

> One of the things that we're really trying to push is to get to those students who are not getting it, and then figuring out a way that we can help them. That's what [examining student thinking] did. It was helping me zero in and see how I could help move them along.

Shannon further pointed out parallels between systematically examining students' thinking and lesson study (Lewis, Perry, & Hurd, 2004). She recognized both as processes for making instructional changes based on her students' needs.

> It's kind of like lesson study …. I'm not someone that likes to just do things exactly patterned. I like to say, 'Ok this is lesson study. Now how is it going to fit in? I'm going to change this and I'm going to change that and I'm going change this.' That's me. Ha-ha. I'm that kind of a teacher. I can't teach out of a textbook. I take my lessons, I start from scratch, and I pull all my resources together and I build on my lessons.

In terms of Gregoire's (2003) CAMCC, the enormity of systematically examining students' thinking may have been viewed by these teachers as a threat because of perceived insufficient ability (i.e. cognitive discomfort, not knowing how to do it) in this area. However, the actual project was viewed as a worthy and attainable challenge. It appears that for these teachers, the perceived benefits of systematically examining students' thinking overpowered the debilitating effects of discomfort, resulting in an overall positive experience for these teachers.

4.3. Perceived change and growth in instructional practice

Two organizing themes emerged related to teachers' perceived change and growth in instructional practice. First, when asked about what they had learned from systematically examining students' thinking, the teachers' responses reflected an *increased awareness of student needs*. For example, Barbara learned to be more patient with students who needed "a little bit more time and practice. It

just took more time—practice, practice, practice." Likewise, Natalie remarked, "I just learned that kids learn things in different ways .... So that's the thing that I learned the most—that kids are adaptable."

Second, the teachers' comments reflected a *broader perspective and sustained learning*. For example, Natalie recognized connections to instructional practice other than mathematics.

> I think it just broadened my vision a lot more. Just going through the process of it and seeing what the kids learned broadened what I knew .... It carries over into reading comprehension strategies and what we do there, and how I can differentiate.

Shannon observed that since systematically examining her students' thinking, she has learned new things on a consistent basis.

> I find when we share strategies and we look at [problems] in different ways, [the students] make connections that they normally wouldn't make .... And I make connections as a teacher. Every year, I'm always surprised when someone comes up with something, and I go 'Wow! That just builds on mine!' So it's exciting.

Likewise, Natalie remarked on her own learning, "I must have learned something because it's still here. It's still with me, and I still do it. Now it's a natural part of what I do. So I think overall ... as difficult as it was ..., it was so beneficial." In terms of Gregoire's (2003) CAMCC, these comments are reflective of true conceptual change.

5. Discussion

The three teachers interviewed for this study had similar, yet unique experiences with systematically examining their students' thinking and enacting instructional change. Their comments provide insight into how teachers perceive changes in their instructional practices.

Shannon already held reform-oriented beliefs, and she experienced a major shift in knowledge and attitudes related to mathematics education. She acknowledged this change and recognized that she had gained knowledge from many "different points of view." This openness to new and different approaches to teaching contributed to Shannon's change process. She recognized the need to improve her teaching and perceived the change as an attainable challenge. She readily implemented reform-oriented teaching practices as she learned and studied about them. For example, she recounts that prior to her capstone project, her instruction involved presenting the students with multiple methods to solve an addition or subtraction problem and expecting the students to choose the method that best suited them. By examining her teaching practice, Shannon realized the value of having the students use mathematical language to explain conjectures and prove methods in their own words—as opposed to the teacher telling and explaining how and why methods work. This focus on students' thinking and use of mathematical language is closely aligned with reform-oriented mathematics (National Council of Teachers of Mathematics, 2014). Instructional change occurred naturally for Shannon. Her belief structure already aligned with the change, and she did not experience beliefs-driven discomfort (Frykholm, 2004). The cognitive and pedagogical discomfort that she did experience proved to be educative rather than debilitating.

Barbara already held reform-oriented beliefs related to mathematics education. However, according to the pre- and post-assessments, her knowledge and attitude remained more traditional. Similar to Shannon, she was open to changing her instructional practice, and used the capstone project as an opportunity to "look inward" to examine her teaching style. This self-examination prompted Barbara to make small adjustments, and to "fine-tune" her teaching to make it more effective and more compatible with current research. Many of Barbara's instructional practices already reflected reform-oriented mathematics instruction (e.g. the use of manipulatives to build students' conceptual understanding). However, her view that struggling students just need to practice more and be more organized reflects a more traditional attitude toward mathematics instruction. In regard to her

teaching practice, Barbara experienced little discomfort (Frykholm, 2004), and so did not to enact sizable changes in her instructional practice (Gregoire, 2003).

Natalie experienced a major shift toward reform-oriented mathematics instruction. She recognized that this change was not superficial; even three years after completing her culminating project, she has continued to implement the teaching practices developed in the process. For example, prior to systematically examining her students' thinking, she had focused her teaching on a single method for solving specific problem types. Since she started to examine her students' thinking, Natalie has come to value students' discussion of alternative problem solving strategies—an instructional practice strongly aligned with reform-oriented mathematics. This awareness of students' learning processes "broadened [her] vision," strengthened her motivation to assimilate new teaching practices, and increased her perceived ability to enact the change (Gregoire, 2003). Even though the instructional change was difficult, she embraced it and had confidence that it would help her students learn mathematics more deeply.

6. Implications

Just like students, teachers have a variety of skills and dispositions that affect their learning and growth trajectories in professional development situations. It is important for designers of professional development to recognize the challenges that many teachers face as they attempt to make changes and improvements to their instructional practice. At the same time, when using the examination of students' thinking as a professional development strategy, facilitators should provide adequate support so that any discomfort experienced is educative rather than debilitating.

7. Limitations and future research

This study was designed to examine how elementary teachers perceived the change in and development of their teaching practices related to mathematics, therefore the sample size was limited to three teachers. However, the small sample size of the study may limit the generalizability of the results. All of the teachers in this study teach in the upper elementary grades in the same school district. It is possible that findings may differ with teachers from different backgrounds or in different teaching situations. Future research could be conducted with teachers of other grade levels and in other locations to determine similarities and differences with the findings of this study. Additionally, this study focused on making instructional changes in mathematics. Further research could be conducted to see if similar results are found with making instructional changes in other academic areas.

8. Conclusion

This study supports the value of systematically examining students' thinking as a professional development strategy. Despite the challenges, the teachers in this study had overall positive experiences with the process in their classrooms. The teachers identified challenges and benefits related to examining students' thinking and reflected on their growth and on how their instructional practice had changed. Themes emerging from the study suggested that although these teachers found it difficult to begin the process, they appreciated the opportunity to reflect on their practice and gain new knowledge to inform their teaching. They recognized an increased awareness of their students' needs in mathematics as well as in other content areas. These teachers' perceptions of the challenges and benefits of examining students' thinking offer insight into understanding its influence as a professional development strategy.

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Author details
Katie L. Anderson-Pence[1]
E-mail: kander19@uccs.edu
[1] Department of Teaching & Learning, University of Colorado Colorado Springs, Colorado Springs, USA.

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