PROFESSIONAL GROWTH IN THE MATHEMATICS TEACHER AS AN INTERCONNECTED NETWORK OF CHANGE

James C. Willingham
James Madison University
willinjc@jmu.edu

This exploratory case study investigated interactions among internal and external factors and an elementary mathematics teacher's classroom practices and learning outcomes during a longitudinal professional development program. Data from the critical case of a teacher engaged in professional change supported an examination of the interaction of these domains and provided a rich narrative regarding the importance of these interactions in sustained teaching change. The model of professional change evidenced by this case adds to an expanding body of knowledge regarding the Interconnected Model of Teacher Professional Growth.

Keywords: Affect, Emotions, Beliefs, and Attitudes; Instructional Activities and Practices; Instructional Leadership; Teacher Education-Inservice/Professional Development

Introduction and Background

Three decades ago, an important transition in the study of mathematics teacher change began when the largely ignored question of how teachers' conceptions of mathematics affected their instructional practices was first widely considered (Thompson, 1984). Questions such as this expanded the focus on effective mathematics teaching from teachers' knowledge of mathematics to their conceptions of mathematics and its teaching (Ernest, 1989; Guskey, 1986; Philipp, 2007; Thompson, 1984). This shift highlighted that constructs including teachers' beliefs, views, and attitudes about mathematics were essential components of their teaching practices, that these practices slowly evolved in response to a myriad of other factors, and that teachers in transition operated in a dual reality between their espoused and enacted conceptions (Clark & Hollingsworth, 2002; Ernest, 1989; Guskey, 1986; Pajares, 1992; Philipp, 2007).

Recently, research has considered how these dispositions impact professional development in four important ways. First, the models examining the influence of teachers' conceptions on their classroom practices have grown increasingly sophisticated and begun to account for the nonlinear relationships among the factors involved in these relationships (Clarke & Hollingsworth, 2002; Wilkins, 2008). Second, a variety of professional development programs have supported long-term changes in teachers' conceptions of teaching mathematics and their associated practices (Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Wilson & Berne, 1999). Third, researchers have presented a diverse range of models to describe the stages through which teachers transition as their conceptions and practices evolve (Andreasen, Swan, & Dixon, 2007; Farmer, Gerretson, & Lassak, 2003). Finally, research has explored the impact of a multitude of other factors, such as the school setting, the teacher's perspective concerning professional development activities, and the types of learning activities implemented in the classroom, on teachers' conceptions and implementation of teaching practices (Clarke et al., 2013; Opfer & Pedder, 2011).

Purpose

A complete model of mathematics teacher development must describe the teachers' motivations and dispositions for their teaching as well as the influence of these factors on areas such as the teacher's implementation of learning activities, interactions with students and the classroom environment, and interpretations of professional development experiences (Goldsmith & Shifter, 1997; Opfer & Pedder, 2011; Wagner & French, 2010). The principal purpose of this study was to explore the interaction of these factors in an elementary teacher engaged in the process of mathematics teaching change during a longitudinal professional development program. This intent led to the primary research question of the study reported here: How do factors including a mathematics teacher's knowledge, beliefs, and attitudes influence her engagement in professional development and ultimately interact with her classroom teaching practices and student outcomes?

Theoretical Framework

A well-developed model of teacher change, the Interconnected Model of Teacher Professional Growth (IMTPG, Clarke & Hollingsworth, 2002), provided a lens through which to view teacher change throughout this study. In this theoretical model (see Figure 1), four domains identified by Guskey (1986) were expanded, and the relationships among them were described in terms of enactment and reflection similar to those posited by Ernest (1989). The domains of this model included the personal domain (knowledge, beliefs, and attitudes), the external domain (outside sources of information), the domain of practice (enacted classroom experiences), and the domain of consequence (salient outcomes involving student learning). Two processes, *enactment* and *reflection* mediated interactions among these domains. Enactment is the active process of operationalizing ideas from one domain into another, while reflection is a determined consideration of the experiences of one domain as they influenced another. The authors posited that interactions within these domains occurred within a specific *change environment* consisting of a particular set of elements, unique to each teacher, that would facilitate or inhibit experiences within each of the model's domains (Clarke & Hollingsworth, 2002).

Within this change environment, two types of teacher shifts arise as specific interactions occurred between the domains (Clarke & Hollingsworth, 2002). The first of these, termed a *change sequence*, occurred any time one domain exerted influence on another. These changes were often temporary and typically enacted in some form of professional experimentation quickly abandoned by the teacher. However, change sequences occasionally lead to further interactions between the domains, resulting in a more permanent transition. These extended interactions are part of a *growth network* and represented the product of teacher development.

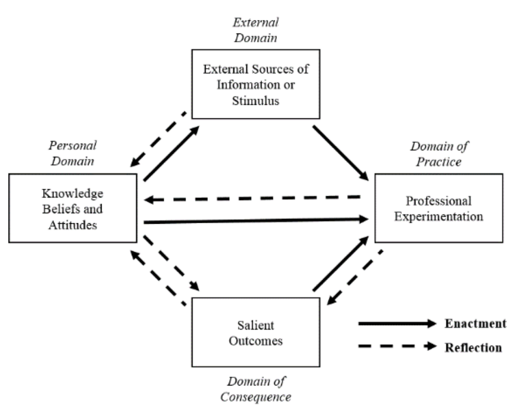

Figure 1: The Interconnected Model of Teacher Professional Growth

Methodology

An exploratory, holistic single-case design (Yin, 2014) supported consideration of modeling teacher change with the IMTPG. The study focused on Gale Martin, a second-grade teacher, deemed significant as evidence from her engagement in an ongoing professional development project, Project Influence, indicated that she represented the critical case of a teacher displaying strong growth mindset characteristics and engaging in the processes of teaching change.

Data Collection

The data collected throughout the study focused on how Ms. Martin's experiences, beliefs, and practices influenced her described and observed mathematics teaching practices and her adaptation of a demonstration lesson for use in her classroom. Data sources included historical records of her mindset and beliefs, semi-structured interviews, classroom observations, artifacts of the observed and enacted demonstration lessons, reflective journal entries, and artifacts from Ms. Martin's lessons. The researcher collected this data across four stages, including a participant selection process, baseline classroom observations, Ms. Martin's engagement in the demonstration lesson through her professional development project, and her adaptation and enactment of the demonstration lesson in her own classroom.

Data Analysis

The researcher then organized this body of data in chronological fashion, corresponding approximately with the data collection stages described above, and completed a simple time series analysis (Yin, 2014). A holistic analysis of themes, "not for generalizing beyond the case, but for understanding the complexity of the case" (Creswell, 2012, p. 101), was performed for each stage of data through open coding with reduction of these codes into themes consistent with the theoretical framework. Themes emerging from each stage of analysis guided interpretation and coding of the next stage, with all stages revisited for completion.

The Participant

The researcher selected Ms. Gale Martin, a Caucasian female in her mid-thirties, as the critical case for the study. Rationales for this selection included historical survey data indicating persistent growth mindset characteristics, a positive record of changes in beliefs regarding the teaching and learning of mathematics, and observational records indicating a change in classroom teaching practices consistent with the mindset and belief data. Ms. Martin was an elementary mathematics teacher in her second year of teaching second grade and her fifteenth year of teaching elementary school who taught in a rural elementary school of approximately 330 students in a southeastern state, who was engaged in her third year of ongoing professional development for mathematics teaching.

The Demonstration Lesson

As part of the study, Ms. Martin observed a second-grade demonstration lesson conducted by the faculty of Project Influence with a lesson goal of "engaging students in thinking about subtraction with regrouping, while potentially representing the process symbolically" (Demonstration Lesson, October 28, 2015). The lesson involved students interacting with the following task in a problem-solving format.

> On Thursday, Tara was at home representing numbers with base-ten blocks. The value of her blocks was 304. When she wasn't looking, her little brother grabbed two longs and a flat.

> What is the value of Tara's remaining blocks? Use pictures, words, and/or symbols to describe how you solved the problem.

Students worked in pairs to solve the problem and participated in mathematical discussions across pairs, small groups, and the whole group under guidance of an expert teacher.

Results

The unique strength of a teacher's classroom practices exists in their ability to mediate the outcomes of their students' learning (Hiebert & Grouws, 2007). The IMTPG suggests that a variety of interactions among the domains described previously mediate both the practices the teacher selects and their students' outcomes, and a complete description of these interactions would be impossible in a report of this scope. Instead, this section contains a detailed description of the interactions between two sets of specific domains, the external domain to the domain of practice and the domain of practice to the domain of consequence. These exemplars then support a general description of the manner in which the IMTPG summarizes the teacher's experiences throughout Project Influence.

External Domain to Domain of Practice

Ms. Martin cited her involvement with immersion activities as one of the most impactful experiences of Project Influence and attributed much of the change she had implemented to these opportunities to experience effective teaching and learning practices first hand.

> I've told people this, and I'll continue to tell people this. Project Influence is the best professional development I've ever had, because it's so useful and it's so purposeful. It helps me be a better teacher, because I see it in action, I'm immersed in it. So it's not somebody standing in the room telling me all of these things I need to do, I'm in the middle of those practices. Us being the student with the teacher, helps us come back to our classroom and know how we need to do that with our kids. That's just been the most meaningful thing. (Selection Interview, September 9, 2015)

This description suggested that in addition to highlighting effective teaching practices these experiences provided opportunities to return to the classroom and experiment with new methods of instruction and to evaluate their success with elementary students. In addition to the practices she encountered, Ms. Martin also cited the influence of the project faculty who modeled these instructional techniques.

> [The Project Influence facilitator], just her enthusiasm and the way she ran the classroom, I really thought, "Hey, this is definitely something that I can do, I'm already doing a lot of this." So I guess it just fed into what I was kind of already doing. (Selection Interview, September 9, 2015)

This enthusiasm and affirmation of her teaching practices, both those that were effective and in place prior to involvement with the project and those adopted from the project itself, appeared to have provided continued motivation for change for Ms. Martin.

When asked to identify specific teaching practices that modeled during these activities, Ms. Martin described the facilitator allowing learners to have their own ideas and guiding conversations about mathematics from those ideas rather than toward solutions.

> The way she facilitated the classroom, the way she let us have our own ideas and never shot anybody down. That's another thing that I really like, we don't talk about answers. That was another thing that I had to change, because yeah, they want to know the answer, I want to know the answer, that's just something that you've always done. I've changed that also. (Selection Interview, September 9, 2015)

In this quote, Ms. Martin once again attributed specific changes in her classroom practices to her experiences during Project Influence and alluded to a belief about mathematics teaching, allowing learners to do the thinking about mathematics, which appeared to have evolved during her experiences with the project.

Domain of Practice to Domain of Consequence

Ms. Martin described the biggest change that had occurred in her classroom in recent years as involving a shift from problem performing to problem solving (Rigelman, 2007). She elaborated on how her changes in instruction had impacted her students' learning and described the importance of problem solving for her students.

> It is a big shift. It's probably the biggest shift that I have just seen, the impact that it has on their learning. They are learning, like the whole of problem solving is so important. . . for them to be able to have their own ideas and me not say, "Oh, this is how we're going to do it," or, me give them a thought or an idea and let them cling to that because they will. If they think that this is Ms. Martin's way, they want to do what Ms. Martin is doing. (Background Interview, September 18, 2015)

In describing this change in learning, Ms. Martin emphasized the independent problem-solving ability that had developed in her students. She contrasted this independent thinking with that of problem performers, who she described as focused on the solution to a problem rather than understanding the process of solving it.

> If you're just performing you're just giving an answer. Maybe you really don't know why you got that answer or how you came to that answer, you're just giving the answer because that's the final result. Problem solving involves so many more life skills that these kids are going to need, not just finding a solution, but there are just many different ways that problems can be solved and there's not just one right path and one right answer. (Background Interview, September 18, 2015)

The combination of independent thinking, a focus on deep understanding, and the ability to recognize that problems are solvable in more than one way formed the basis of the life skills Ms. Martin associated with her students' transition to problem solving over problem performing.

Later in the school year, Ms. Martin referenced how these changes in problem-solving approaches had caused other changes in her students' abilities to see connections between their thinking. She also described the reasons for this success.

> Well, for example today in math, I had them sharing out their examples or their solutions strategies to the test that we did at the end of class. And you would have certain kids say, "Well, my strategy looks a lot like Sarah's strategy." So they're mirroring or they're

> recognizing that their strategies looks similar to another strategy in the room. And here it is November, so we're moving along on that trajectory. And as far as continuing that, I think you just still tell them, pulling those cards and making everybody responsible for an answer. And they know that they're going to have to provide some sort of answer and some sort of discussion. (Point of View Interview, November 4, 2015)

In this quotation, Ms. Martin recognized that her students are progressing toward the goal of recognizing and connecting different mathematical ideas and attributed this success to her classroom practices related to accountability. She also expressed a desire to continue utilizing these practices in order to encourage and support these changes.

Support for the Interconnected Model of Teacher Professional Growth

The description of Ms. Martin presented here suggested a reflective practitioner deeply invested in the process of transitioning to reform-oriented instruction. However, the multitude of connections between Ms. Martin's conceptions of teaching and learning mathematics, mathematics teaching practices, experiences in Project Influence, and insights into her students' mathematical development offer substantial evidence that these change processes do not occur in isolation and require an extensive support network to initiate and maintain. Based on evidence regarding these factors and their relationships, I present a generalized growth network for Ms. Martin's change environment in Figure 2.

This growth network presents a model of the incremental changes Ms. Martin described experiencing throughout her time in Project Influence combined with the processes observed as she adapted a demonstration lesson from Project Influence for use in her classroom. In this generalized network, some conception of the teaching and learning of mathematics, such as Ms. Martin's valuation of students' thinking and communicating about mathematics or her ideas regarding the manner in which a specific piece of mathematics content should be taught, influenced her interpretations of and interactions during an activity from Project Influence (Arrow 1). Examples of these activities included immersion in a problem-solving task or the observation and debriefing of a demonstration lesson. Ms. Martin's reflections on this experience (Arrow 2) then served to either confirm or incrementally reshape the conception in question. Under the recent influence of this conception, Ms. Martin then adapted some aspect of the Project Influence experience, such as a new classroom norm, questioning practice, or mathematical task, for enactment in her classroom (Arrow 3). Reflecting on this enactment's outcomes, such as the success of a lesson or changes in her students' affect or mathematical understanding (Arrow 4), served to further reinforce or extinguish the conception (Arrow 5) and reinitiate the cycle through external interactions or further classroom experimentation. Although specific examples of this process appear later in this discussion, the current example serves to explain the general processes in play as Ms. Martin's beliefs and classroom practices changed.

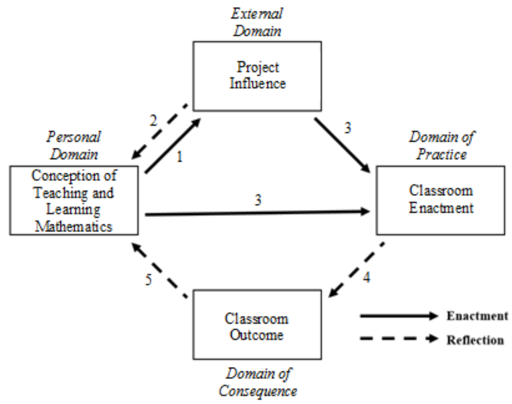

Figure 2: The Generalized Growth Network for Ms. Martin's Change Environment

Discussion and Conclusion

The generalized growth network for Ms. Martin's change environment models specific descriptions of her experiences in Project Influence combined with evidence collected as she adapted the demonstration lesson she observed as part of the study for use in her classroom. Three examples of the specific evidence for this growth network, one related to each of Ms. Martin's goal layers (Willingham, 2017), are provided here in order to illustrate their impact on the process of teacher change (see Figures 3, 4, and 5). These models each share a common pathway (Arrow 1 in each diagram) representing the influence of Ms. Martin's personal domain characteristics on her interpretations of her professional development experiences. Additionally, as the examples provide evidence of the same growth network pathways across different domain characteristics, the diagrams share common labeling of these pathways tailored to each diagram (e.g., 2a, 2b, 2c represent reflective pathways between domains at three different goal levels).

The first example, situated at the level of Ms. Martin's global goals, involves changes in Ms. Martin's beliefs and teaching practices regarding the value of students' thinking and communicating about mathematics (see Figure 3). Although the primary evidence for this growth network developed from Ms. Martin's descriptions of her changes in practices based on her earliest experiences with Project Influence, the network parallels the reinforcement of these beliefs and practices during her implementation of the demonstration lesson. In this growth network, Ms. Martin became involved with Project Influence due to her desire to continue improving her abilities as a mathematics teacher, which she attributed to her own growth mindset and love of mathematics (Arrow 1).

During her first experiences with Project Influence, Ms. Martin became aware of reform-oriented teaching practices related to the value of students' thinking and communicating about mathematics due to the modeling of Project Influence's faculty and witnessing these practices in use in a demonstration lesson. Based on these experiences Ms. Martin developed goals for her classroom aligned with these practices (Arrow 2a). Operationalizing these goals, Ms. Martin described adopting the norms and problem-solving approaches she had experienced in Project Influence to her own classroom (Arrow 3a), and noted the influence that these practices had on her students' abilities in this area, which she later described as students' classroom maturity (Arrow 4a). Ms. Martin described these changes as transformative to both her way of thinking about (Arrow 5a) and teaching mathematics (Arrow 3a) and elected to continue her involvement with Project Influence when given the chance (Arrow 1), initiating a cyclic process.

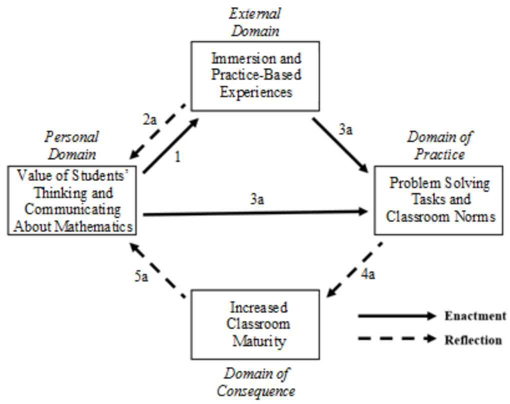

Figure 3: The Growth Network for Ms. Martin's Beliefs and Practices Regarding the Value of Students' Thinking and Communicating About Mathematics

In other iterations of this growth network, Ms. Martin's goals at different levels were involved. As an example, during her activities involving the demonstration lesson of this study, she described considering how the lesson matched with her envisioned mathematics learning trajectory (see Figure 4). Her reflections on aligning this lesson involved finding an appropriate place in the trajectory for its use (Arrow 2b) and planning for the lesson by preparing her students to engage with its content by referencing concepts from earlier in the year. She then considered the types of interactions she would use to address struggles she had witnessed from students in the observed demonstration lesson (Arrow 3b). Once the lesson was enacted, Ms. Martin reflected on its specific outcomes (Arrow 4b), and considered these outcomes in terms of the sequence of lessons and unit in which it was situated (Arrow 5b).

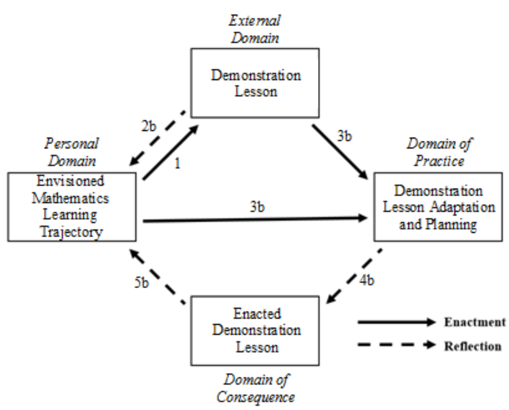

Figure 4: The Growth Network for Ms. Martin's Envisioned Learning Trajectory

The same set of contexts provide insight to the changes to the demonstration lesson Ms. Martin made based on her specific content goals for her enacted lesson (see Figure 5). In this case, her reflections from the demonstration lesson focused on the manner in which she would prepare her students to examine how different representations of numbers support thinking about numeric operations such as subtraction (Arrow 2c). These reflections, along with the core activity from the demonstration lesson, helped Ms. Martin prepare her students to work with this idea during the enacted demonstration lesson by scaffolding the idea in the lesson immediately preceding it (Arrow 3c). Immediately following this lesson Ms. Martin described monitoring her students' progress with the content goals of the enacted lesson (Arrow 4c) in order to determine the course of the remaining lessons in the sequence (Arrow 5c).

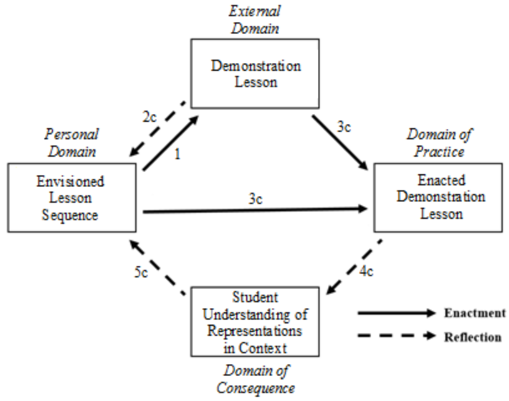

Figure 5: The Growth Network for Ms. Martin's Lesson Goals for Her Enacted Demonstration Lesson

Ms. Martin's descriptions supported interpreting the first example given here as reinforcing her current beliefs and practices due to her experiences with the demonstration lesson in this study. In this case, all three of the examples shown share the same form of initial change sequence as their first enactment pathways (Arrow 1 in Figures 3, 4, and 5). In these shared pathways, a goal-dependent conception of the teaching and learning of mathematics, each at a different goal level, influenced Ms. Martin's interpretations of the demonstration lesson. These layered change sequences then lead to unique connected growth networks in which the mediating pathways are identical while the specific domain foci are dependent on Ms. Martin's pedagogical goals. This highly connected, multidimensional growth network offers a potential explanation for why Ms. Martin's experiences in Project Influence were so influential on her beliefs and teaching practices.

Although Ms. Martin's circumstances are obviously unique, her case provides an exemplar for the manner in which a growth-oriented mindset mediates the internal and external factors of teacher change. For those involved in the development of mathematics teachers, two features of this mediation are the most instructive: the layering of mathematical goals at a variety of pedagogical levels, and the incorporation of explicit reflection in the translation of the activities and practices of professional development programs to the classroom. For Ms. Martin, these layered goals involved the personal growth of her students, the intentionality of her learning trajectory, and the core intention of a single mathematics lesson. Well-designed professional development programs should consider opportunities for participating teachers to define their own goals along similar levels, and then use these goals to frame explicit conversations regarding the manner in which key features of the program translate to the classroom to support their attainment.

References

Andreasen, J. B., Swan, B. A., & Dixon, J. K. (2007). A framework for identifying stages of teacher change resulting from extended mathematics professional development. *Focus on Learning Problems in Mathematics*, *29*, 13-29.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, *18*, 947-967.

Clarke, D., Roche, A., Wilkie, K., Wright, V., Brown, J., Downton, A., . . . Worrall, C. (2013). Demonstration lessons in mathematics education: Teachers' observation foci and intended changes in practice. *Mathematics Education Research Journal*, *25*, 207-230.
Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: Sage Publications.
Ernest, P. (1989). The knowledge, beliefs and attitudes of the mathematics teacher: A model. *Journal of Education for Teaching*, *15*, 13-33.
Farmer, J. D., Gerretson, H., & Lassak, M. (2003). What teachers take from professional development: Cases and implications. *Journal of Mathematics Teacher Education*, *6*, 331-360.
Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*, 915-945.
Goldsmith, L. T., & Shifter, D. (1997). Understanding teachers in transition: Characteristics of a model for the development of mathematics teaching. In E. Fennema & B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 19-54). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice*, *8*, 381-391.
Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed*.), Second handbook of research on mathematics teaching and learning* (pp. 371-404). Greenwich, CT: Information Age.
Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Sage Publications.
Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of Educational Research*, *81*, 376-407.
Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62,* 307–332.
Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F. K. Lester Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 257-315). Charlotte, NC: Information Age Publishing.
Rigelman, N. R. (2007). Fostering mathematical thinking and problem solving. *Teaching Children Mathematics, 13*, p. 308-314.
Thompson, A. G. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. *Educational Studies in Mathematics*, *15*, 105-127.
Wagner, B. D., & French, L. (2010). Motivation, work satisfaction, and teacher change among early childhood teachers. *Journal of Research in Childhood Education*, *24*, 152-171.
Wilkins, J. L. (2008). The relationship among elementary teachers' content knowledge, attitudes, beliefs, and practices. *Journal of Mathematics Teacher Education*, *11*, 139-164.
Willingham, J. C. (2017). Revealing layered mathematical learning goals through an examination of mindset*,* In E. Galindo, & J. Newton (Eds.), *Proceedings of the 39th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 1170 – 1177). Indianapolis, IN: Hoosier Association of Mathematics Teacher Educators.
Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of Research in Education*, *24*, 173-209.
Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage Publications.