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Development and Validation of Pre-service Teachers' Personal Epistemologies of Teaching Scale (PT-PETS)

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DEVELOPMENT AND VALIDATION OF PRE-SERVICE TEACHERS' PERSONAL EPISTEMOLOGIES OF TEACHING SCALE (PT-PETS)

A Dissertation

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of

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Ji Hyun Yu

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This is dedicated to God Almighty, my husband, my son, my parents, and my family for their unconditional love, support, inspiration, and unfailing faith in me.

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Although there are still lots of uncertainties ahead, I believe and WE believe that "God will make a way where there seems to be no way". All I need to do is be open, ready, and willing!

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ABSTRACT

Yu, Ji Hyun. Ph.D., Purdue University, December 2013. Development and Validation of Pre-service Teachers' Personal Epistemologies of Teaching Scale (PT-PETS). Major Professor: Peggy Ertmer.

The Internet has changed not only how we conceptualize knowledge, but also how we learn in classroom. Knowledge is not any longer transmitted from experts to non-experts, but is constructed through communication, collaboration, and integration among a network of people. In this context, teachers are expected to facilitate student-centered learning by helping students to construct knowledge through higher-order thinking rather than reproduce a series of facts. Although a growing body of research suggests that teachers' beliefs about the nature of knowledge and the process of knowing, that is personal epistemology, are related to their teaching and their students' learning, little work has done to examine its role of teachers' personal epistemologies in preparing future generations of teachers.

The purpose of this study was to develop and validate an instrument designed to assess pre-service teachers' personal epistemologies of teaching (PT-PETS). The PT-PETS was administered to two samples of pre-service teachers. Factor analysis of the results revealed a multidimensional construct composed of three factors: Construction of Teaching Knowledge, Contextuality of Teaching Knowledge, and Complexity of Teaching Knowledge. The Construction of Teaching Knowledge consists of 9 items (i.e.,

Teaching knowledge is handed down by external authority or constructed by individuals). The Contextuality of Teaching Knowledge consists of 8 items (i.e., Teaching knowledge is viewed as absolute or contextual). And the Complexity of Teaching Knowledge contains 3 items (i.e., Teaching knowledge is viewed as an accumulation of facts or comprise highly interrelated concepts).

Structural equation modeling was used to examine the nomological relationships between the three latent constructs of the PT-PETS and other factors related to knowledge construction. Results indicate that pre-service teachers' perceptions of their instructors' pedagogical practices are positively related to their beliefs in the Complexity of Teaching Knowledge. Interestingly, pre-service teachers' knowledge sharing self-efficacy is negatively related to their personal epistemologies of teaching, while their information evaluation self-efficacy is positively related to them. However, the mediating role of information evaluation self-efficacy was found to enhance the positive indirect effect of knowledge sharing self-efficacy, while simultaneously reducing its negative direct effect to personal epistemologies of teaching. In general, pre-service teachers who reported experiencing inductive teaching practices by their instructors were more likely to be aware of the complexity of teaching knowledge. Students who reported feeling confident in both sharing knowledge and evaluating information also tended to be those who hold sophisticated beliefs in the nature of teaching knowledge and the process of knowing. Overall the Pre-service Teachers' Personal Epistemologies of Teaching (PT-PETS) provides a psychometrically sound instrument for teacher educators and researchers interested in understanding pre-service teachers' personal epistemologies and knowledge construction.

CHAPTER 1. INTRODUCTION

1.1 Introduction

The impact of technology on society is unquestionable. Apart from the question whether technology is good, bad, or neutral, it is an astonishing fact that the world's knowledge is accessible to anyone with a networked computer today. That is, the democratizing tendencies of emerging technologies such as sharing, openness, free access, and decentralization, can potentially revolutionize the way in which individuals, communities, and various organizations engage with the rest of the world (Croteau, Hoynes, & Milan, 2012; Land, Hannafin, & Oliver, 2012). Particularly, the crowdsourcing technologies (e.g., wikis, social networking, and social voting) have intensified the evolution toward "countering absolutist and encouraging relativist understanding of knowledge" (Tabak & Weinstock, 2011, p. 180). This phenomenon, then engenders questions related to "How has technology changed our perceptions of knowledge?", "Who owns knowledge in a networked society?", and "What does this new perception of knowledge mean for schools?"

The epistemological paradigms in schools are postulated by a tension between two conflicting viewpoints about knowledge. One viewpoint is that knowledge should be filtered and sorted only by experts and that it should be transmitted from instructors to students. From this authoritarian and conservative viewpoint, teachers' role comprises that of the primary information giver, emphasizing one right answer. The other, more recently accepted viewpoint about knowledge is that knowledge is created through networks of people, relying on the synergizing efforts of collaboration to support knowledge accumulation and verification (Wagner & Back, 2008). The underlying assumption here is that knowledge cannot be separated from interactions among individuals in a specific domain (Jonassen, 2013). In this sense, Dede (2008) described knowledge as "the collective agreement that may combine facts with other dimensions of human experience, such as opinions, values, and spiritual beliefs" (p. 80). From this viewpoint, students are expected to become the crowd to create comparable knowledge, skills, and experience (Meszaros, 2010). Facing the tension between expert and networked knowledge, teachers are increasingly searching for ways to help students gain reflection, metacognition, and epistemic awareness, as deliberate and intentional mechanisms, that are needed for students to evaluate the veracity of ideas and multiple perspectives, while evaluating problems or solutions (Greenhow, Robelia, & Hughes, 2009; Jonassen, 2000). Teachers, too, like other knowledge workers, are encouraged to monitor the epistemic nature of what they observe, hear, and read in their teaching contexts in order to acquire necessary knowledge and to share knowledge with peers. Through this process, they may reach the stage of being able to ask: "How do we know what we know?", "How do we choose what and whom to believe?", and "When do we decide that we know enough?" As they further experience teaching, their answers become more sophisticated. The idea that individuals hold beliefs about knowledge and the process of knowing has been investigated in a large body of work on *personal* *epistemology*, which focuses on a special kind of belief, *epistemological beliefs*,[1] as an empirical object of inquiry at the individual level (Hofer, 2001).

Although personal epistemology is not a widely researched topic in teacher education (Silverman, 2007), there is an emerging body of evidence that those beliefs may vary and change depending on teachers' context (e.g., Olafson & Schraw, 2006; White, 2000; Yadav & Koehler, 2007), and/or as the result of their formal and informal professional development experiences (e.g., Brownlee et al., 2001; Gill, Ashton, & Algina, 2004); which, in turn, affect their teaching practices (e.g., Sinatra & Kardash, 2004). These studies indicated that "teachers with sophisticated personal epistemologies are more likely to be able to engage in ill-structured problem solving, and argue based on evidence for a 'best' solution" (Brownlee et al., 2011). Considering that beliefs about 'what counts as knowledge' are a central determinant to what a field knows about its subject matter (Pallas, 2001), whether and how one contributes to knowledge advancement is determined across communities of practice. In terms of this issue, Broudy (1977) argued that 'knowing that' and 'knowing how' need to be enriched with a third category of 'knowing with' as "a context within which a particular situation is perceived, interpreted, and judged" (p. 12). However, the need that teachers' personal epistemologies should be specified in terms of teacher professional knowledge seems to be undetermined. One possible reason is that most studies of teachers' personal epistemologies have used several existing instruments designed for students' beliefs about either *general knowledge* (e.g., "For success in school, it is best not to ask too

[1] Since the term 'personal epistemology' reflects the individual, not philosophical, nature of beliefs about knowledge, it is more widely used than the term 'epistemological beliefs' in education research (Brownlee et al., 2012).

many questions") or *content knowledge* (e.g., "History is unrelated to day to day life"). Only a few researchers (e.g., Fives & Buehl, 2009) have indicated that the conceptualizations, instruments, and analyses applied in studies on teachers' personal epistemologies are problematic due to reliability and validity issues based on the lack of attention to teacher-specific knowledge. Furthermore, they suggested the need for research into "how beliefs about teaching knowledge evolve as engagement in the profession becomes more enactive" and "how these beliefs influence and are influenced by other important variables on learning to teaching and teaching practices" (p. 404). Particularly, given that teachers need to have the opportunities to "jointly explore new teaching methods, tools, and beliefs, and support each other" (Ertmer, 2005) for successful teaching, the increasing integration of emerging technologies into teacher education programs has rendered it necessary to explore the impact of such technologies on teachers' understanding of the dynamic nature of knowledge sharing and validation.

Thus, this study aimed to develop a reliable and valid instrument (1) to assess the extent to which an individual teacher holds epistemological beliefs about teacher professional knowledge and (2) to elucidate the relationship between these beliefs and other variables of teachers' perceptions on knowledge acquisition and sharing.

1.2 Purpose of the Study

The purpose of this study was three fold:

1. To develop the *Pre-service Teachers' Personal Epistemology of Teaching Scale* (PT-PETS),
2. To examine if the PT-PETS has practical relevance and acceptable psychometric properties for reliability, validity, and utility as an instrument,

3. To validate the PT-PETS by examining the relationship between teachers' beliefs about the nature of teaching knowledge and their self-efficacies related to knowledge construction.

1.3 Assumptions

This study is based on the assumption that there is a developmental progression in personal epistemology from *naïve* beliefs (i.e., absolutist views: simple, right-and-wrong viewpoints), to more *sophisticated* beliefs (i.e., relativistic views: complex, diverse viewpoints). Pintrich (2002) proposed: "Epistemological development is a function of internal psychological mechanisms as well as contextual facilitators and constraints" (p. 403). This means that personal epistemology may change with age and with education or expertise (Hofer & Pintrich, 2002). Therefore, this study is based on the assumption that pre-service teachers' beliefs about knowledge become more *sophisticated* as they progress through their four-year teacher education programs. Furthermore, these beliefs may be influenced by demographic characteristics, such as gender, school years, ethnicity, or majors.

The assumption that there are multiple independent components of personal epistemology is also suggested by the literature. Based on the results obtained from research using quantitative questionnaire instruments, the number of components is either three (e.g., Qian & Pan, 2002), four (e.g., Elder, 2002; Hofer, 2000), or five (e.g., Schommer-Aikins, 2002; Schraw, Bendixen, & Dunkle, 2002; Wood & Karsdash, 2002). This study follows the suggestion of Hofer and Pintrich (1997) that there are four knowledge-specific independent components and that learning-related components (e.g., quick learning, innate ability) should be excluded. Furthermore their instrument has become one of the most widely used measures of personal epistemology and has been used in studies around the world. In addition, I agree with the arguments of Hofer and Pintrich and their followers about why the definition of personal epistemology should exclude views about learning: for example, the viewpoints about learning should be excluded to improve the definitional clarities among sub-factors; and psychological definitions of epistemology should correspond with philosophical ones (Hofer & Pintrich, 1997; Sandoval, 2009).

In addition to the multiplicity of components, the domain-specificity of personal epistemology is also assumed. In general, domains are synonymous with school subject areas (e.g., mathematics, science, reading, social studies) and disciplines (e.g., mathematics, chemistry, psychology, statistics). This study focuses on teacher professional knowledge that teachers, as life-long learners are to gain, regardless of the specific content knowledge needed.

Finally, it also assumed that teacher education programs can support pre-service teachers' development towards more sophisticated beliefs about knowledge needed for effective teaching. Although there is no consensus on how this should happen, several scholars highlight how effective reflections on personal epistemology can be achieved (e.g., Bendixen & Corkill, 2011; Fives, 2011; Marra & Palmer, 2011; Walker, Brownlee, Exley, Woods, & Whiteford, 2011). Collectively, they implemented specific forms of instruction designed to enhance pre-service teachers' critical thinking on specific educational issues and explicit reflection on their beliefs about knowledge and the knowing process. Results showed that pre-service teachers tended to engage in higher-order thinking rather than reproducing knowledge through those interventions (e.g., Maggioni & Parkinson, 2008; Valanides & Angeli, 2005; Yadav & Koehler, 2007). Research also indicated that students' personal epistemologies are related to their preferences for learning environments. For example, Tsai (2000) revealed that students who hold relativist personal epistemologies showed stronger preferences toward constructivist-oriented learning environments. For further investigation of this finding, several studies have investigated changes in personal epistemology within technology-supported learning environments, as described earlier. Kim, Kim, Lee, Spector, and DeMeester (2013) indicated that "teacher beliefs about the nature of knowledge and learning have been rarely studied, especially in technology integration contexts" (p. 83) due to lack of appropriate methods and measures, despite the key role of epistemological beliefs, as fundamental beliefs, in knowledge interpretation and cognitive monitoring (Pajares, 1993). They found the positive relationship between teachers' beliefs about the nature of knowledge, beliefs about effective ways of teaching, and technology integration practices. Andreassen and Bråten (2013) examined the relationship between teachers' self-efficacy on source evaluation (i.e. evaluation of the trustworthiness of sources) and their dependence on the features of source, when using the Internet to learn about an educational issue. The findings show that teachers were more likely to emphasize the producer (i.e., author and web address) than the product (i.e., content, layout, and publication date), suggesting further studies on the relationships between teachers' personal epistemology and their evaluation of information obtained from the Web.

Based on these assumptions, the proposed instrument of this study, PT-PETS, will be used to examine the development of personal epistemology using group comparisons of gender, school years (e.g., beginning versus final year pre-service teachers), majors (e.g., early childhood education, elementary education, secondary education), and area of specialization (e.g., English, mathematics, social studies, science). Additionally, the PT-PETS will be used to examine how pre-service teachers' beliefs about teaching knowledge influence their perceptions of knowledge acquisition, sharing, and validation within online communities of practices.

1.4 Research Questions

Four research questions will guide this study:

1. To what extent can a reliable measure of *Pre-service Teachers' Personal Epistemology of Teaching Scale (PT-PETS)* be developed?
2. To what extent can evidence of internal structure validity be identified for the newly developed PT-PETS?
3. What are the relationships between pre-service teachers' personal epistemologies of teaching and their perceptions of knowledge sharing and information evaluation in a conceptual nomological net?

1.5 Overview of Study

This dissertation proposal consists of five chapters, a reference list, and an appendix. Following this introductory Chapter one, Chapter two presents an in-depth review of the relevant literature for examining personal epistemology within teacher education. Chapter three discusses the current paradigm of scale development research and details the procedure utilized to develop a self-report measure of the Pre-service Teachers' Personal Epistemologies of Teaching (PT-PETS) with the following three phases: Phase one presents scale development methods to create a draft of the proposed instrument with support of a panel of experts, Phase two utilized factor analysis techniques to reduce the number of items from an initial item pool and modify the content of items from a more contextually-grounded approach, and Phase three presents the assessment of the nomological validity of the PT-PET scale. Chapter five presents a discussion about the dissertation and its implications.

CHAPTER 2. LITERATURE REVIEW

2.1 Teacher Knowledge

Over the past decades, numerous frameworks have been suggested over the past decades, in order to understand what constitutes teacher knowledge and how teacher professional knowledge might be interconnected to classroom practice (e.g., Calderhead, 1996; Clandinin, 1985; Elbaz, 1983; Shulman, 1987; Rovegno, 2003). The approach to teacher knowledge used in this study follows the concept of Clandinin and Connelly's (1995) metaphor, *professional knowledge landscape*, in which teacher knowledge is defined as "a sense of expansiveness and the possibility of being filled with diverse people, things, and events in different relationships" (pp. 4-5). That is, the definition of teacher knowledge applied in this study would encompass both personal (i.e., individual, practical, know-how of individual teachers) and social (i.e., academic, codified, propositional knowledge) dimensions of knowledge production.

Traditionally, learning to teach has been considered as part of formal education where teacher candidates are expected to receive verified information presented by education professors and duplicate the actions of experienced teachers during apprenticeship with less emphasis on teacher candidates' own reflection (Zeichner, 1993). In this view, teachers were generally expected to develop knowledge about how to maintain classroom conditions and utilize supports and interventions to help students improve their behaviors at a desired level. In contrast, teacher knowledge has also been defined as “nonpropositional” (Munby, Russell, & Martin, 2000), “knowing-in-action” (Schön, 1983, 1987), “personal, practical, and experiential” (Clandinin, 1985), and “classroom-oriented” (Elbaz, 1983). In one of the earlier studies of the professional knowledge landscape, Elbaz (1983) identified three types of practical knowledge about teaching that teachers may develop from classroom experience: rule of practice, practical principles, and images, and further argued that teacher knowledge should be investigated within authentic work contexts, suggesting that teacher knowledge is experiential, purposeful, value-laden, and oriented to classroom practice (Elbaz, 1991). In the same vein, Clandinin (1985) indicated that “personal practical knowledge is viewed as tentative, subject to change and transient, rather than something fixed, objective, and unchanging” (p. 364), and further, described learning to teach as the interpretation and reconstruction of classroom experiences (Clandinin & Connelly, 1995).

To examine this nature of teacher knowledge and its relationship with theory, some scholars have suggested the concept of “craft knowledge” (Munby et al., 2000). Leinhardt (1990) defined craft knowledge as “the wealth of teaching information that very skilled practitioners have about their own practice. It includes deep, sensitive, location-specific knowledge of teaching; unfortunately, it also includes fragmentary, superstitious, and often inaccurate opinions” (p. 18). Calderhead (1996) described craft knowledge as the knowledge that teachers acquire primarily through their own teaching practices rather than through their formal learning. Schön (1983, 1987) described the development of teacher knowledge with emphasis on both “reflecting-in-action” and “reflecting–on-action” that includes both practical and propositional knowledge. In other words, when learning to teach something new, teachers, as reflective practitioners, should adjust both their subject matter knowledge and craft knowledge, and this process requires “more than simply mapping new subject matter knowledge onto existing procedural routines” (Calderhead, 1991, p.271).

Shulman (1986, 1987) argued that traditional research on teaching has overemphasized managerial aspects of teaching, while underemphasizing the complex relationship between content knowledge and pedagogy; and then suggested seven categories of teacher knowledge including content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge (PCK), knowledge of learners, knowledge of contexts, and knowledge of educational ends. Although all of three categories were essential elements for successful teaching, Shulman (1987) indicated “among these categories, pedagogical content knowledge is of special interest it identifies the distinctive bodies of knowledge for teaching” (p.8), because it is “the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that makes it comprehensible for others’’ (1986, p. 9). That is, PCK is considered to include alternative representations of subject matter and a particular process of pedagogical reasoning to meet the needs of learners (McKewan & Bull, 1991). Rovegno (2003) also suggested that teacher knowledge is complex, practical, personal, and situated because it is applied within, shaped by, and, in turn, shapes practice. This means that the ability to teach is constructed over time and through experience and thus teachers should be flexible and reflective in identifying solutions to teaching problems.

In recent decades, scholars have argued that teacher knowledge is neither transmitted from external authorities, nor implicit know-how from direct experience, but rather exists in the interaction between practitioners and communities (e.g., Desimone, 2009; Horn & Little, 2010; Kroll, 2005; Levine, 2011; Levin & Marcus, 2010; Miller, 2008; Nelson & Slavit, 2008; Prestridge, 2009). Brown, Collins, and Duguid (1989) called for closer attention to the contextual nature of teacher knowledge based on an epistemology of situated cognition, arguing that teacher professional development is an enculturation process through social interaction among a group of practitioners. In a similar fashion, Craig (2004) described that, like all knowledge workers, “teachers negotiate meaning for their stories of experience” and “take different stories and different versions of their stories to different people in different knowledge communities for interpretation” within “knowledge communities” (p. 2). Within this context, teacher knowledge is seen as being situated in contexts, and their cognition as being socially situated and distributed (Putnam & Borko, 2000). For a conceptual integration of social influences into teacher knowledge framework, Shulman and Shulman (2004) indicated that teacher’s knowledge construction occurs simultaneously and interactively through personal reflection nested in the community of practitioners. From this socio-cultural perspective, Birchak, Connor, and Crawford (1998) described a collaborative group of practitioners where participants are “responsible for sharing and thinking together; not an occasion to come and hear a presentation” (p.6). Within this group, teachers are expected to identify their teaching problems, describe their problem-solving processes, justify their solutions, and evaluate whether and how to make positive impacts in their schools. This approach has been also used in teacher preparation programs in order to help teacher candidates collaboratively develop their pedagogical content knowledge: for example, pre-service teachers plan a lesson together, demonstrate teaching and/or observe colleagues teaching it, and discuss and critique the lesson to improve it (Birchak et al., 1998).

In a more recent attempt to investigate this collaborative nature of teacher knowledge development, emerging professional development models suggest that meaningful, sustained transformations in classrooms are enhanced by allowing teachers to engage in locally situated, inquiry-based, longitudinal, and collaborative communities of practice. Given these emerging trends, Cordingley, Bell, Evans, and Firth, (2005) conducted a review of research that focused on the impact of school-based collaborative professional development on teacher practice, and concluded that collaborative professional development produced changes in teachers' practice, attitudes, beliefs, and student achievement. As an initial attempt to understand the nature of pre-service and practicing teachers' beliefs about teaching knowledge, Fives and Buehl (2010) revealed that individuals view teaching as coming from a variety of sources: for example, formal preparation, formalized bodies of information, observational and vicarious experience, interactive and collaborative experiences, enactive experiences, and self-reflection. Interestingly, Fives and Buehl (2010) indicated that practicing teachers were more likely to view knowledge as "coming less from authority and more from one's own experience and active construction of meaning" (p. 489), while questioning formal education and formalized bodies of knowledge. Butler and Schnellert (2012) investigated how collaborative, inquiry-oriented professional learning communities might contribute to educational change efforts.

Recently, some scholars investigated the effects of the technology integration into teacher professional development (e.g., Ertmer, 2005; Ertmer et al., 2012; Glazer, Hannafin, Polly, & Rich, 2009; Kopcha, 2012; Polly & Hannafin, 2011). With the examination of how knowledge flows among teachers, Hew and Hara (2007) investigated what motivates or hinders teachers to share knowledge online: and addressed four main motivators for sharing knowledge in online communities of teachers: (a) collectivism (i.e., teachers share knowledge to increase welfare of a community), (b) reciprocity (i.e., teachers share knowledge to pay it forward), (c) personal gain (i.e., while sharing knowledge, teachers can gain new knowledge), and (d) altruism (i.e., teachers share knowledge in empathy with other teachers' struggles). Looi, Lim, and Chen (2008) indicated that emerging technology provides new opportunities for teachers' professional growth and identity formation, while suggesting further studies of how such communities can be built and sustained. Hur and Brush (2009) described online communities of teachers where teachers share both knowledge and emotion and further promote self-esteem and confidence about teaching profession. In a more structured approach with a focus on the effect of technology integration on classroom practice, Kopcha (2010) found that teachers progressed through mentoring to teacher-led communities of practices that supported more student-centered uses of technology.

In sum, the literature on teacher knowledge reflects the complex, multidimensional, and collaborative nature of being a professional teacher. It also suggests that teacher knowledge may be developed through several dualities in terms of locus of source and locus of process: such as formal vs. informal (Fives & Buehl, 2010), declarative vs. procedural (Russell & Munby, 1991), personal vs. collaborative (Butler vs.

Schnellert, 2012), and so on. Particularly, it was found that there is a growing trend towards the use of technology for collaborative teacher professional development. As student teachers progress, they may confront situations that require them to resolve the tensions between knowledge from external authorities and that is developed through reflective experience. Therefore, understanding teachers' personal epistemologies and the relationships between such beliefs and other factors influencing collaborative teacher professional development may contribute to the development of effective teacher preparation programs and continuing professional development programs.

2.2 Personal Epistemology

Epistemology is a branch of philosophy defined as "the study or a theory of the nature and grounds of knowledge especially with reference to its limits and validity" (Merriam-Webster Online dictionary). Epistemology is primarily concerned with how we come to know what we know. Hofer (2002) noted that epistemology involves investigations about the origin, limits, methods, and justification of human knowledge, while personal epistemology reflects how an individual thinks about knowledge and knowing from a psychological and educational perspective. This means that research on personal epistemology concerns an individual's epistemological beliefs (i.e., beliefs about the nature of knowledge and knowing). Hofer and Pintrich (1997) detailed that "personal epistemology would include cognitions and beliefs about the certainty of knowledge (objectivist versus relativist/multiplist views), the simplicity of knowledge (simple, concrete versus complex, contingent, context-dependent), the source of knowledge (external authorities versus personal voice), and justification for knowing (criteria for making knowledge claims, use of evidence, use of reasoning)" (p. 390).

2.2.1 What Constitutes Personal Epistemology?

Not surprisingly, there is little agreement about what constitutes personal epistemology, but Pintrich (2002) categorized various research paradigms into three broader approaches: developmental (e.g., epistemological development), cognitive (e.g., epistemological beliefs and epistemological metacognition), and contextual (e.g., epistemological resources). These three approaches are described next.

2.2.1.1 Developmental Approach to Personal Epistemology

The early literature generally examined how an individual's epistemological beliefs become more *sophisticated* over time and how education contexts influenced the development of those beliefs (Alexander, 1997). William G. Perry (1970) was the first psychologist to empirically examine college students beliefs about knowledge in his longitudinal, phenomenological study. He found that Harvard liberal arts students progressed through nine sequential positions about the nature of knowledge and knowing. He explained "this progression is from thinking to meta-thinking, from man as knower to man as critic of his own thought" (p. 71). Table 1 describes Perry's scheme and the transitions between them.

Table 1

Perry's (1970) Scheme

	Position	Knowledge	Knowing
Dualism	1 – Basic Dualism	Knowledge is absolute truth in black-and-white terms.	Students receive absolute and unquestioned information from external authority (e.g., parent, teacher, church).
	2 – Multiplicity Pre-legitimate	Knowledge is typically right or wrong (we-right-good vs. they-wrong-bad).	Different perspectives and beliefs are acknowledged, but are simply wrong.
Multiplicity	3 – Multiplicity Legitimate but Subordinate	Some knowledge is uncovered and temporarily (right, wrong, and "not yet known")	Authority provides the source of answers or the source of ways to find the answers.
	4 - Multiplicity	Some knowledge is right or wrong, but most is not yet known.	Authorities are the source of ways to think. (We'll never know for sure)
Contextual Relativism	5 – Contextual Relativism	Most knowledge is contextual and subjective (the most significant transition).	Students learn methods to critically evaluate their disciplines (self-consciousness of being an active maker of meaning). Meta-cognition begins.
Commitment within Relativism	6 – Commitment Foreseen	Knowledge is not absolute but students take a role for making judgments (qualitative shifts from intellectual to ethical)	Students take responsibility for making a commitment based on their values.
	7, 8, and 9 – Commitment within Relativism	Commitments regarded as an affirmation of one's own identity which was required within a relativistic world	Students consider legitimate alternatives after experiencing genuine doubt.

Note: Adapted from Perry (1970).

Moore (2002) grouped these nine positions into four broader categories: dualism, multiplicity, contextual relativism, and commitment within relativism. Students at the *Dualism* level (Position 1 and 2) tend to perceive instructors as authority figures who provide the answers to students. At the *Multiplicity* level (Position 3 and 4), students begin to acknowledge legitimate uncertainty in the world, so that they can appreciate an intellectual world in which multiple perspectives exist with expert proponents supporting each perspective. The movement toward *Contextual Relativism* (Position 5) is the most significant transition within Perry's scheme. In this fundamental transition, students gain a vision of a world that is essentially relativistic and context-bound, with a few right/wrong exceptions and more importantly, they start to consider themselves to be *active makers of meaning*. At the final level, *Commitment within Relativism*, students tend to value some beliefs more than others and define one's identity in a contextually relativistic world. Perry noted that the changes in this last position are not structured changes like previous positions, but there has been little additional research done on this issue. As the seminal work of the uni-dimensional and stage-like views of change, Perry's scheme demonstrated that as students' progress towards more complex forms of thinking; they may also experience changes in their conceptions of knowledge, their roles as learners, and their expectations of instructors.

Following Perry (1970), many researchers have contributed to research on personal epistemology based on the uni-dimensional conceptualization (e.g., Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; King & Kitchener, 1994; Kuhn, 1991). There has been criticism that Perry conducted his study with a group of elite college students who were white males studying at Harvard University during 1950s. In response to this issue, Belenky et al. (1986) examined 'ways of knowing' of a diverse group of women across a broad range of contexts. These female participants were not limited to the formal education system. Through an extensive interview with 135 women from academic and non-academic backgrounds, they described five different lens from which women view the world of knowledge and authority: *received knowing* (similar to

Perry's dualism), *subjective knowing* (similar to Perry's multiplicity), *procedural knowing* (similar to Perry's relativism), and *constructed knowing* (similar to Perry's commitment within relativism). Although Belenky et al. (1986) emphasized the source of knowledge compared to Perry's study, their study did not provide a valid method to assess the gender-related nature of the findings because of the use of the exclusive female sample.

Baxter Magolda (1992) developed the Model of Epistemological Reflection (MER) through a five-year longitudinal study with both male and female college students to examine gender-related patterns. The MER assumes that epistemological development is socially constructed, context-bound, fluid, and constituted by multiple realities, including *absolute knowing* (knowledge is certain and absolute), *transitional knowing* (knowledge is partially certain and partially uncertain), *independent knowing* (knowledge is uncertain and alternative views can be justified), and *contextual knowing* (knowledge is judged based on evidence) (Duell & Schommer-Aikins, 2001). Similar to the limitation of Perry's study, her sample consisted of mostly white and middle-class participants.

King and Kitchener (1994) developed the Reflective Judgment Model (RJM) to understand the processes used in argumentation through a ten-year, longitudinal and cross-sectional interview study with individuals from age groups ranging from high school students to middle-aged adults. The Reflective Judgment Model includes three stages according to the person's view of knowledge and concept of justification: such as *pre-reflective* (similar to Perry's dualism), *quasi-reflective* (similar to multiplicity and relativism), and *reflective stage* (similar to Perry's commitment within relativism). Although these authors made a unique contribution in its elaboration of the upper levels of Perry's scheme, only trained raters are able to utilize the reflective judgment interview, creating a barrier to wider use.

Similarly, Kuhn (1991) interviewed individuals in their teens, 20s, 40s, and 60s to investigate the connection between epistemic theories and real-world reasoning beyond academic knowledge. She identified three distinct, epistemological views related to the certainty of knowledge: *absolutists* (e.g., knowledge is certain and absolute), *multiplists* (e.g., all views are equally valid), and *evaluatists* (e.g., knowledge is uncertain, but viewpoints can be compared and evaluated). Kuhn's work is noteworthy for its elaboration of the connection of epistemic theories to real-world reasoning and its explanation.

As summarized in Table 2, some common trends are evident in these uni-dimensional models that followed Perry's scheme. First, they explored the changes of individuals' beliefs over time, which are associated with age and educational experiences. This stage-like view of change uses the terms *naïve* and *sophisticated* to refer to the range of personal epistemologies (Pintrich, 2002). Second, they used qualitative methods through interviews and open-ended questions, yet such interviews and questions did not explicitly focus on epistemological beliefs. Rather, they fundamentally sought to understand students' perceptions of college-learning experiences. Third, they did not examine the relationship between epistemological beliefs and learning outcomes, though they noted educational implications of their studies about the impact of such beliefs. Last, all researchers suggested a series of developmental stages of epistemological beliefs (Buehl & Alexander, 2006). Among these uni-dimensional models, research questions may be categorized: how individuals interpret their educational experiences (Baxter

Magolda, 1992; Belenky et al., 1986; Perry, 1970), and how epistemological assumptions influence thinking and reasoning processes, focusing on reflective judgment (King & Kitchener, 1994) and skills of argumentation (Kuhn, 1991).

Table 2

Summary of Uni-dimensional Models of Personal Epistemology

Model	Intellectual and Ethical Development	Women's Ways of Knowing	Epistemological Reflection	Reflective Judgment	Argumentative Reasoning
Author	Perry (1970)	Belenky et al. (1986)	Baxter Magolda (1992)	King & Kitchener (1994)	Kuhn (1991)
Subjects	I: 31 UG* II: 67 UG* (4yr study)	90 females from academic institutions; 45 females from family agencies	101 UG* (12yr study)	Secondary, UG*, GR* non-student adults	160 from 10s, 20s, 40s, & 60s
Context	The majority were white, elite, and male college students	Similar to Perry's male focused model, but no comparison between genders	Not different between genders, but gender-related patterns emerged	Social science students scored higher than others.	Relationships of Epistemic beliefs and real world problems
Stages	• Dualism • Multiplicity • Relativism • Commitment within relativism	• Silence • Received knowing • Subjective knowing • Procedural knowing • Constructed knowing	• Absolute knowing • Transitional knowing • Independent knowing • Contextual knowing	• Pre-reflective • Quasi-reflective • Reflective	• Absolutists • Multiplists • Evaluatists

2.2.1.2 Cognitive Approach to Personal Epistemology

Another prominent approach to research on personal epistemology uses a multi-dimensional conceptualization of epistemological beliefs. While the developmental approach uses a uni-dimensional conceptualization of epistemological beliefs, the cognitive approach focuses on how personal epistemology consists of independent, multidimensional structures of beliefs that influence and are influenced by learning (Hofer, 2004). Schommer-Aikins (previously Schommer) pioneered the *multi-dimensional conceptualization* to explore how individuals' epistemological beliefs influence comprehension and cognition for academic tasks in classroom learning (Schommer, 1990). To capture the multi-dimensionality of personal epistemology, she developed the Schommer Epistemological Questionnaire (SEQ) that hypothesized a five-factor structure, including (a) *the stability of knowledge*, ranging from tentative to unchanging; (b) *the structure of knowledge*, ranging from isolated fragments to integrated concepts, (c) *the source of knowledge*, ranging from handed down by authority to gleaned from observation and reason, (d) *the speed of knowledge acquisition*, ranging from quick-all-or-none learning to gradual learning, and (e) *the control of knowledge acquisition*, ranging from fixed at birth to life-long improvement (Schommer, 1990).

However, Schommer's subsequent studies for validity suggested a simpler construct structure. For example, the psychometric tests in her first three studies showed that the four-factor structure has a better fit instead of the initially proposed five-factor structure, including simple knowledge, certain knowledge, innate ability, and quick learning (Schommer, 1990, 1993; Schommer, Crouse, & Rhode, 1992). In terms of the relationship between epistemological beliefs and other learning variables, she found that students with higher achievements had more sophisticated beliefs and girls were less likely to believe in quick learning and fixed ability (Schommer, 1993).

Accumulating evidence for the validity of the SEQ, Schommer-Aikins established a theoretical framework describing the epistemological belief system (Schommer, 1994). The main principles of this framework are (a) personal epistemology may be conceptualized as a multi-dimensional system of beliefs; (b) those beliefs are more or less independent and thus cannot be assumed that beliefs will mature in synchrony; (c) epistemological beliefs are better interpreted as frequency distributions rather than continuums; (d) epistemological beliefs may have both direct and indirect effects on learning and performance; (e) epistemological beliefs may have both domain general and domain specific qualities; and (f) epistemological belief development or change is influenced by experience.

To examine the reliability, validity, and utility of the SEQ within a variety of settings, Schommer-Aikins extended the range of study subjects to include middle school students; however, the results indicated that the previous four-factor structure was not a good fit; instead, a three-factor structure including the stability of knowledge, the speed of learning, and the ability to learn, seemed to be a better fit than other types of structures (Schommer-Aikins, Mau, Brookhart, & Hutter, 2000). In 2005, Schommer-Aikins, Duell, and Hutter used the same items with middle school students and found a four-factor structure which differed from the structure they established in 2000. The new four-factor structure included two existing factors, 'quick learning' and 'certain knowledge,' and two new labels, 'studying aimlessly' and 'omniscient authority.' The previous two studies revealed that students' beliefs in learning were related to their GPAs and their domain-specific epistemological beliefs.

As shown in Table 3, the Schommer's Epistemological Questionnaire (SEQ), as one of the most prevalent instruments in the literature on multi-dimensional personal epistemology, has been validated at multiple educational levels. According to the research populations, she suggested a three-factor model (middle school students) or a four-factor model (college students). Because of methodological limitations of the previous uni-dimensional models, the SEQ has attracted a great amount of attention from researchers in this field.

Table 3

Schommer's Epistemological Questionnaire (SEQ)

Author(s), Year, Subjects	Instrument	Analysis	Factor Labels (No.of items/subsetsa, α)	Results
Schommer (1990) 266 UG*	*Schommer Epistemological Questionnaire* (SEQ) • 63 items • 5-point scale • 15-20 min to administer • 5 hypothesized factors o Structure of knowledge o Certain knowledge o Source of knowledge o Control of knowledge acquisition o Speed of knowledge acquisition	• Principal Factor Analysis using 12 subsets • Varimax and oblique rotation • Varimax reported • Extraction - λ(Eigenvalue) > 1 • Selecting items with factor loadings > .50 • 55.2 % variance explained	• Simple knowledge (3 subsets) • Certain knowledge (1 subset) • Innate ability (3 subsets) • Quick learning (1 subset)	Belief in quick learning predicted oversimplified conclusions, poor performance on the mastery test, and overconfidence in test performance. Belief in certain knowledge predicted inappropriately absolute conclusions
Schommer, Crouse, & Rhode (1992) 424 UG*	SEQ (Schommer, 1990) • 63 items • 5-point scale • 15-20 min • 5 hypothesized factors o Simple knowledge o Certain knowledge o Omniscient authority o Innate ability o Quick learning	EFA • Principal factor analysis of 12 subsets • Varimax rotation • λ > 1 results in 3 factors • λ>.96 results in 4 factors • 54.2 % variance explained CFA • Applied 4-factor structure from Schommer (1990) and compared it to	3-factor solution: • Innate ability • Simple knowledge • Certain knowledge 4-factor solution from EFA: • Simple knowledge • Certain knowledge • Quick learning • Externally controlled learning 4-factor solution from CFA: • Factors not explicitly	Regression analyses indicated that the less students believed in simple knowledge, the better they performed on the mastery test and the more accurately they assessed their comprehension. A path model indicates that study strategies may mediate epistemological effects.

		the 3-factor (1992) that emerged with eigenvalue greater than one criteria • 3 factors: GFI=.911; AGFI=.864 • 4 factors: GFI=.938; AGFI=.899 • Reported that the 4-factor Shommer (1990) model provided the best fit	labeled but Experiment 2 uses labels from Schommer (1990) • Simple knowledge • Certain knowledge • Innate ability • Quick learning	
Schommer (1993) 1182 secondary students (9^{th} – 12^{th})	SEQ • Adapted (i.e., slight rewordings) for high school students based on pilot study • Number of items: not reported • 5-point scale • 15-20 mins	EFA • Principal factor analysis of 12 subsets • Varimax rotation • Extraction- $\lambda > .98$ • Selecting items with factor loadings > .5 • 53.5 percent of variance explained CFA • Compare the fit of a 3-factor model and a 4-factor model • 4-factor model reported to fit better but fit statistics were not reported	• Simple knowledge • Certain knowledge • Fixed ability • Quick learning • αs reported as ranging from .45–.71 but not associated with specific factors	Differences in epistemic beliefs between genders and grades were found. Belief in simple knowledge, certain knowledge, and quick learning decreased across the school years. Fewer girls believed in quick learning and fixed ability. Less belief in quick learning explains higher GPA.

Schommer-Aikins, Mau, Brookhard, & Hutter (2000)
 	
1269 middle school students (7^{th} – 8^{th})
	A short-version SEQ for middle school students
	• 30 items
	• 5-point scale
	• 15-20 mins
		CFA
		• AMOS
		• Split sample
		• Poor fit for the 4-factor model
		  o GFI=.87; CFI=.67; $\chi 2/df$=2.91; RMR=.088
		  o Items removed based on the above fit statistics and low loadings
		• 3 factors modified model
		  o GFI=.982; CFI=.978; $\chi 2/df$ =1.61; RMR=.038
		• 3 factors Replicated model
			The 4 factor structure did not result in a good fit, so they deleted items with small factor loadings and without correlation with other items. The new model resulted in three factors:
			• Stability of knowledge, (2 subsets)
			• Speed of learning (4 subsets)
			• Ability to learning
				Students who believed in more gradual learning and incremental ability had higher GPA. No significant difference was found between genders.

		o GFI=.982; CFI=.978; $\chi 2/df = 1.98$; RMR=.044	(5 subsets)	
Schommer-Aikins, Dull, & Hutter (2005) 1269 middle school students (7th – 8th)	SEQ – Middle School Verision • 30 items • 5-point scale • 15-20 mins	EFA • Conduct factor analysis of 30 items. • Extraction (factor loadings, scree plot) • Varimax rotation • 40.35 % variance explained • Loadings> .3	• Quick learning (10 subsets, .77) • Studying aimlessly (7 subsets, .55) • Omniscient authority (2 subsets, .55) • Certain knowledge (2 subsets, .36)	Beliefs in quick learning and studying aimlessly were related to beliefs about math and math confidence. Both general and domain-specific epistemic beliefs explain students' GPA.

Note: Abstracted from each study *UG: undergraduates.

Since Schommer's initial work, other researchers have used the SEQ to develop new measures of multi-dimensional beliefs by adding new items (e.g., Jehng, Johnson, & Anderson, 1993; Schraw, Dunkle, & Bendixen, 1995) or by creating different factor structures (e.g., Hofer, 2000). For example, Jehng and his colleagues (1993) added items to the SEQ that represented a new aspect of knowledge (i.e., beliefs about the regularity of the learning process), and removed the existing factor and subsequent items (i.e., simple knowledge). As a result of context-modification and in utilizing Confirmatory Factor Analysis (CFA) for their initial 61-item instrument, their finalized instrument comprises 32-items that incorporate constructs of: (a) certainty of knowledge, (b) omniscient authority, (c) rigid learning (orderly process in Jehng et al., 1993), (d) innate ability, and (e) quick learning.

Table 4

Jehng's Epistemological Questionnaire (JEQ)

Author	Instrument	Analysis	Factor Labels	Results
Jehng, Johnson, & Anderson (1993) 398 UG* & GR*	*Jehng Epistemological Questionnaire* (JEQ) • Selected items from SEQ and Spiro's measure (1989) • 61 items • 7-point scale	Selected 34 items out of 41 by using inter-item correlation value CFA • LISREL • 5-factor model for 34 items • GFI=.93; $\chi 2$ (517)=571.44	• Certainty of knowledge • Omniscient Authority • Orderly Processes • Innate ability • Quick learning	Students in social sciences and graduates were more likely to believe that knowledge is uncertain; best acquired from independent reasoning; and learning is not an orderly.

Note: Abstracted from Jehng et al. (1993). *UG: undergraduates, *GR: graduates.

Using this 34-item JEQ, the authors compared students across disciplines and academic levels and concluded that students from the arts and social sciences were more likely than business and engineering students to believe that knowledge is uncertain and best acquired from independent reasoning, and that learning is not an orderly process. In terms of different academic levels, results showed that graduate students were more likely than undergraduates to believe that knowledge is uncertain and best acquired from independent reasoning, and learning is not an orderly process.

In a similar fashion, Schraw et al. (1995) developed a more compact but reliable instrument, the Epistemic Belief Inventory (EBI). The EBI contains a total of 28 items representing the five factors: (a) certain knowledge, (b) simple knowledge, (c) omniscient authority, (d) quick learning, and (e) fixed ability. Using the EBI, Schraw and his colleagues examined the relationships between epistemological beliefs and moral reasoning according to the types of problem solving (e.g., well-defined and ill-defined problems). Results showed that epistemic beliefs were related to performance on the ill-defined tasks but not the well-defined tasks.

Table 5

Schraw et al.'s Epistemic Belief Inventory (EBI)

Author	Instrument	Analysis	Factor Labels (No. of Items/α)	Results
Schraw, Dunkle, & Bendixen (2002) Study I: 212 UG* StudyII: 124 UG* & GR*	*Epistemic Belief Inventory* (EBI) • 5-factor from Schommer (1990) • 28 items • 5-point scale	EFA • Principal Factor Analysis of 32 items • Extraction- $\lambda > 1$ • Oblique and varimax rotations conducted, varimax reported • Item selection: loadings >.3 and cross-loadings <.3 • Study I: 64% variance explained • Study II: 60 % variance explained	Fixed Ability (I: 5, .87; II:4, .84) Certain Knowledge (I: 3, .76; II: 4, .76) Omniscient Authority (I: 3, .76; II: 3, .71) Simple Knowledge (I: 2, .67; II: 2, .63) Quick Learning (I: 3, .74; II: 3, .73)	Well-defined and ill-defined problems require separate cognitive processes and epistemic beliefs play an important role in ill-defined problem solving.

Note: Abstracted from Schraw et al. (2002). *UG: undergraduates, *GR: graduates.

Unlike the JEQ and the EBI, Hofer (2000)'s Domain-Focused Epistemological Beliefs Questionnaire (DFEBQ) was not based on the SEQ. Prior to the development of the DFEBQ, Hofer and Pintrich (1997) conducted a critical and comprehensive review of the previous studies and instruments (e.g., Belenky et al., 1986; King & Kitchener, 1994; Kuhn, 1991; Perry, 1970; Schommer, 1990) and then identified several theoretical and methodological issues. They proposed that there are two general areas to represent the core aspects of personal epistemology theories: such as *nature of knowledge* and *nature of knowing*. Nature of knowledge involves two factors: (a) certainty of knowledge and (b) simplicity of knowledge, while nature of knowing involves two other factors: (c) source of knowledge and (d) justification for knowing.

Table 6

Hofer's Discipline-Focused Epistemological Beliefs Questionnaire (DFEBQ)

Author	Instrument	Analysis	Factor Labels (No. of Items/α)	Results
Hofer (2000) 326 UG*	*Discipline-Focused Epistemological Beliefs Questionnaire* (DFEBQ) • 27 items • 5-point scale • Separately administered for psychology and science • 4 hypothesized factors o Certainty of knowledge o Simplicity of knowledge o Source of knowledge o Justification of knowing	EFA • Principal Components and maximum likelihood factoring of items • Extraction- λ > 1; scree plot • Oblique and varimax rotations conducted, varimax reported • Loadings >.4 • Reported cross-loadings greater than .3	Psychology • Certainty/simplicity (89, .74) • Justification for knowing: personal (4, .56) • Source of knowledge: authority (4, .51) • Attainability of truth (2, .6) Science • Certainty/simplicity (89, .81) • Justification for knowing: personal (4, .61) • Source of knowledge: authority (4, .64)	Strong disciplinary differences were found within an individual. Compared with knowledge in psychology, knowledge in science is more certain and unchanging. For science, students were more likely to regard authority and experts as the source of knowledge, more likely to believe truth is attainable by experts, and less likely to regard personal knowledge and firsthand experience as a basis for justification.

			• Attainability of truth (2, .75)	

Note: Abstracted from Hofer (2000). *UG: undergraduates.

Although other beliefs about learning, teaching, and intelligence suggested by some of the previous studies may be related to these four factors, Hofer and Pintrich (1997) claimed that these additional beliefs are relatively peripheral to personal epistemology theory, and thus "the domain of epistemological beliefs should be limited to individuals' beliefs about knowledge as well as reasoning and justification processes regarding knowledge" for conceptual clarity (p. 116). In addition, they emphasized that the issue of domain specificity may need to be explicitly tested in empirical research, assuming that academic domains differ in structure and content. Based on this review, Hofer (2000) developed the 27-item Domain-Focused Epistemological Beliefs Questionnaire (DFEBQ). Using factor analysis techniques, she finalized the DFEBQ with the four factors: certainty/simplicity of knowledge, personal justification for knowing, authority as a source of knowledge, and the attainability of the truth. To test its validity, she used the DFEBQ to compare two academic domains: science and psychology, as shown in Table 6. Since then, the DFEQB have been used to guide the development of additional instruments (*Bråten* & *Strømsø*, 2005; Karabenick & Moosa, 2005).

Buehl, Alexander, and Murphy (2002) created the Domain-Specific Belief Questionnaire (DSBQ) that contained a total of 22 items to assess personal epistemology within two distinct domains, such as mathematics and history. While Hofer's DFEBQ contained 11 items for domain-generality (e.g., "Most words have one clear meaning") and 16 items for domain-specificity (e.g., "In this subject, most work has only one right answer"), the DSBQ was developed based, in part, on the SEQ and contained 11 items per domains (e.g., "Students who are good at math have to work hard" versus "Students who are good at history have to work hard"). Using the DSBQ, they examined domain specificity and found that students' beliefs about schooled knowledge do show specificity when mathematics, a more well-structured domain, is compared to history, a more ill-structured domain.

Table 7

Buehl et al.'s Domain-Specific Beliefs Questionnaire (DSBQ)

Author	Instrument	Analysis	Factor Labels (No. of Items / α of Study II&III)	Results
Buehl, Alexandar, & Murphy (2002) Study I: 181 UG Study II: 633 UG Study III: 523 UG	*Discipline-Specific Beliefs Questionnaire* (DSBQ) • Study I: 81 items • Study II: 50 items • Study III: 22 items • 10-point scale	Study I: EFA • Principle axis factoring of 44 items • Extraction- $\lambda > 1$ and scree plot • Varimax and oblimin rotation • 33.30 % variance explained • Loadings > .40 Study II: CFA • Revised items given to new samples • Assessed a 4-factor domain-specific model • CFI=.93, GFI=.94, AGFI=.92, SRMR=.05, RMSEA=.05, $\chi 2$ (184)=426.40 Study III: CFA • Confirmed 4-factor model fit with a third dataset • CFI=.88, GFI=.91, AGFI=.88, SRMR=.06, RMSEA=.05, $\chi 2$ (184)=521.60	• Integration of Information and Problem-Solving in Mathematics (6, .74/.69) • Need for Effort in Mathematics (5, .68/.72) • Integration of Information and Problem-Solving in History (6, .75/.65) • Need for Effort in History (5, .61/.58)	Students believed more effort is needed to acquire knowledge in mathematics than history and that knowledge in mathematics is more integrated with knowledge in other areas than is true for history. But there was neither significant interaction between gender and domain, nor main effect of gender.

Note: Abstracted from Buehl et al. (2002). *UG: undergraduates.

Wood and Kardash (2002) reported that they failed to reproduce the expected factor structure of SEQ as well as that of JEQ, suggested by the developers. They interpreted that many researchers using Schommer's Epistemological Questionnaire (SEQ) may tend to analyze the 12 subsets, instead of the total 63 items, and this could add unexpected variability to each factor. Moreover, there are several problematic items that seem too general or a bit irrelevant to the nature of knowledge (e.g., I don't like movies that don't have an ending).

Table 8

Wood & Kardash Epistemological Beliefs Survey (EBS)

Author	Instrument	Analysis	Factor Labels (No. of Items/α)	Results
Wood & Kardash (2002) 793 UG* & GR*	Combine SEQ and JEQ • 80 items (58 from SEQ, and 22 from JEQ) • 5-point scale	Removed items through inter-item correlation <.1. 64 items were left. EFA • Principle axis factor of items • Promax rotation • Extraction- λ > 1 and scree plot • 22.05 % variance explained • Item selection- loadings > .35 and cross-loading <.25 • 38 items were left for later analysis	• Speed of knowledge acquisition (8, .74) • Structure of knowledge (11, .72) • Knowledge construction and modification (11, .66) • Characteristics of successful students (5, .58) • Attainability of objective truth (3, .54)	There were significant differences between genders among undergraduate students, while graduate students did not differ on all five factors.

Note: Abstracted from Wood & Kardash (2002). *UG: undergraduates, *GR: graduates.

Therefore, Wood and Kardash (2002) created a new instrument, Epistemological Beliefs Survey (EBS), by combining SEQ and JEQ, conducted internal consistency tests and several different exploratory factor analyses, and finally retained 48 items that represented five factors of personal epistemology: such as (a) speed of knowledge acquisition, (b) structure of knowledge, (c) knowledge construction and modification, (d) characteristics of successful students, and (e) attainability of objective truth. To test the validity of EBS, they also examined gender difference in EBS scores; male and female graduate students in their study did not differ on any of the five factors.

In sum, a cognitive approach to personal epistemology concerns the independence of the multiple components of epistemological beliefs, whereas a developmental approach to personal epistemology proposes a more unitary structure that changes over time (Pintrich, 2002). To some extent, a cognitive approach also assumes the general developmental pattern (i.e. changing from naïve to sophisticated over time) within each of the components. However, there is very little agreement on whether and how variations in the sophistication of beliefs across different dimensions need to be interpreted. For example, if one progresses toward a more sophisticated view of certainty of knowledge but still has a naïve view of justification for knowing, how should we treat this status developmentally? More investigations on how the different dimensions are coordinated in development are needed.

Recently, several studies have demonstrated that personal epistemologies are related to learning within internet-based environments (Mason, Boldrin, & Ariasi, 2010). Focusing on epistemological beliefs regarding Internet environments, Bråten, Strømsø, and Samuelstuen (2006), developed an instrument to assess students’ beliefs about the nature of knowledge obtained from the Internet (i.e., what they believe knowledge is on the Internet) and knowing (i.e., how they come to know on the Internet), based on Hofer and Pintrich's (1997) model. From a series of instrument validation processes, they found students’ Internet-specific epistemological beliefs play a critical role in Internet-based learning activities, such as searching and evaluating reliable and valid information.

Factor analyses revealed the two-factor structure of *Internet-specific Epistemological Beliefs Questionnaire* (ISEQ), including *General Internet Epistemology* and *Justification for Knowing*.

Table 9

Bråten et al.'s Internet-specific Epistemological Beliefs Questionnaire (ISEQ)

Author	Instrument	Analysis	Factor Labels (No. of Items/α)	Results
Bråten et al. (2006) 157 UG*	Combine Hofers' DFEBQ • 36 items • 10-point scale	Removed items through inter-item correlation <.1. 28 items were left. EFA • Promax rotation • Extraction- λ > 1 and scree plot • 47 % variance explained • Item selection- loadings > .40 and cross-loading <.20 • 19 items were left for later analysis	• General Internet Epistemology (14, .9) • Justification for Knowing (4, .7)	Students who considered the Internet to be a good source of accurate facts were reportedly more likely to use Internet-based sources when doing their coursework. Students holding the Internet to be a good source of true factual knowledge or believing that Internet-based knowledge claims can be accepted without critical evaluation somewhat more likely to prefer online feedback and contributions to face-to-face discussions.

Note: Abstracted from Bråten (2006). *UG: undergraduates.

Factor 1, General Internet Epistemology, consisted of 14 items dealing with beliefs concerning the certainty and simplicity of Internet-based knowledge, as well as with beliefs concerning the Internet as a source of knowledge. The four items assigned to Factor 2, Justification for Knowing, concerned the critical evaluation of knowledge claims encountered on the Internet through the use of multiple sources, reasoning, and prior knowledge activation. Using ISEQ, Bråten and his colleagues conducted a variety of studies focusing on students' Internet-specific epistemological beliefs as they related to their evaluation of the qualities of information obtained from the Internet and justifying their claims based on those evidences (e.g., Andreassen & Bråten, 2013; Bråten, Britt, Strømsø, & Rouet, 2011; Bråten et al., 2006; Strømsø & Bråten, 2010).

2.2.1.3 Contextual Approach to Personal Epistemology

There have been two distinct issues in understanding what fosters epistemological development or how epistemological beliefs are altered: (a) domain-generality versus domain-specificity and (b) context-independent versus context-dependent. The first issue has discussed among researchers, since Hofer (1999, 2000) published the first multidimensional instrument of domain-specific epistemological beliefs. For defining domains, school subject areas or disciplines have mostly focused on: science (e.g., Conley et al., 2004; Elder, 2002; Hofer, 2000; Karabenick & Moosa, 2005; Lin, 2002), mathematics (e.g., Buehl et al., 2002; Buehl & Alexander, 2005; Hofer, 1999), psychology (e.g., Hofer, 2000), and history (e.g., Buehl et al., 2002; Buehl & Alexander, 2005). For example, Lampert (1990) found that the majority of students believe that mathematics is associated with certainty (e.g., getting the right answer quickly). Similarly, Schoenfeld (1992) found that students believe that the teacher is the source of mathematics knowledge; therefore justification for knowing comes from the teacher or the field. In the field of science education, Carey and Smith (1993) indicated the difficulties of teaching a constructivist approach to science was due to the common sense of epistemology among students and teachers.

The second issue is whether personal epistemology takes the form of stable, unitary beliefs or fine-grained, context-sensitive resources. Pointing out the inconsistencies in students' epistemologies, Hammer (1994) argued that student personal epistemologies as measured by a standardized survey may not reflect their epistemic reasoning about physical phenomena within the context of the course. Perhaps students' "practical epistemologies" (Sandoval, 2005) come to be more sophisticated than the survey detects. Hammer and Elby (2000, 2001, 2002, 2003, & 2010) investigated college students' beliefs about *Structure of Physics Knowledge* and beliefs about *Learning Physics*, suggesting domain-specificity with high levels of contextual variation. Their research has suggested fundamentally different views that the contexts may not reflect the general developmental pattern of becoming more sophisticated; rather, personal epistemology can be viewed as context-specific epistemological resources, instead of developmental stages, beliefs, or theories. In this view, students hold multiple epistemological stances that can be activated or deactivated depending on the domain, the specific learning context, and the socio-cultural settings (Hammer & Elby, 2002). Therefore, how classroom context shapes the nature of knowledge and knowing within a specific domain is more predictive and explanatory than research on stage-based personal epistemology (Louca, Elby, Hammer, & Kagey, 2004).

Jonassen (1997) described individual epistemic beliefs as one of the important factors influencing the validity of alternative solutions when solving ill-defined problems. Because ill-defined problems typically do not have one single solution, students are expected to construct their own arguments against alternative solutions by developing personal position statements about their preferred solutions (Jonassen, Strobel, & Gottdenker, 2005). In doing so, they are likely to build their mental models of the problem, which is important to support their justification and decisions for chosen actions

(Jonassen, 2000). Jonassen and Strobel (2006) asserted that a set of epistemic beliefs may take a crucial role, when students are "observing the effects of their interventions; constructing their own interpretations of the phenomena and the results of the manipulation; and sharing those interpretations with others" (p. 1).

The aforementioned studies have focused on the relationship of epistemic beliefs and the dynamic nature of problem spaces for learners. However, Pintrich (2002) criticized that it is still not clear "how development should be conceptualized in terms of both intra-individual and inter-individual variations in the nature of contexts over time" (p. 402); and suggested that a contextual approach may need to be further explored from a longitudinal perspective in order to trace the nature of developmental change in personal epistemology.

2.2.2 How Do We Measure Personal Epistemology?

There is the diversity of research designs, measurement methods, and analytic strategies employed in the literature of personal epistemology. Yadav et al. (2011) pointed out some challenges in measuring personal epistemology: there is a need for more robust and diverse measures and clearer conceptualizations of the constructs that comprise personal epistemology. The literature shows early research theorizing personal epistemology considered epistemological beliefs as broad and general and focused on developmental changes as stage-like by using qualitative interviews in analysis (e.g., Baxter Magolda, 1992; Kuhn, 1991; Perry, 1990). These descriptive studies using qualitative longitudinal interview data can provide rich and complex understandings of individuals' reasoning about the nature of knowledge and knowing, by establishing a framework of development change using emergent themes from data (e.g., Baxter Magolda, 1992; Fives & Buehl, 2008; Kuhn, 1991; Perry, 1970).

They, however, were criticized for time and cost-consuming. In addition, these earlier studies assumed students conceptualize personal epistemology in a fairly uniform fashion, whereas most of the current studies tend to rely on the possibility of multiple dimensions that are somewhat independent of each other and prefer more objectively scored, Likert-scale, items when administering a large-scale survey (e.g., Schommer, 1990; Schraw et al., 1995). As demonstrated earlier in this chapter, several standardized instruments were developed and examined by more narrowly defining each of beliefs that have its own development path across time. Due to the convenience and efficiency of the self-reported measures of personal epistemology, such instruments have been widely used and formed the fundamental basis of recent personal epistemology research (Buehl, 2008). However, some empirical studies using standardized instruments have showed incongruence between beliefs and practices. For example, Olafson and Schraw (2006) found that none of the practicing teachers in their study indicated support for the realist position, yet all of their final products were coded as 'realists', indicating that there might be differences between practitioners' and researchers' conceptualizations of the beliefs of interest. DeBacker, Crowson, Beesley, Thoma, and Hestevold (2008) argued that the three most widely used existing instruments – such as, the Epistemological Questionnaire (SEQ, Schommer, 1990), the Epistemic Beliefs Inventory (EBI, Schraw et al., 2002), and the Epistemological Beliefs Survey (EBS, Wood & Kardash, 2002) - have shown poor construct validity with large error components. Many of the initial studies explored broader topics that are not solely epistemological in nature (e.g., argumentation or intellectual development; Kuhn, 1991; Perry, 1970), while more recent studies assessed knowledge-specific beliefs. For example, Schommer-Aikins (1990, 2004), Hammer (1994), Elby (2001), and Wood and Kardash (2002) argued that beliefs about self, learning, classroom instruction, and domain-specificity are part of personal epistemology (e.g., beliefs about quick learning, innate ability, or successful students). In contrast, Hofer and Pintrich (1997) and Sandoval (2005) argued that only knowledge-specific dimensions should be considered in personal epistemology for conceptual clarity.

To deal with the aforementioned methodological issues, Debacker, et al. (2008) emphasized the need for careful examination of constructs based on more rigorous theoretical evidences of personal epistemology. Particularly, further empirical and theoretical research may be needed to converge on a definition of personal epistemology with cognitive structures (i.e., beliefs about knowledge and beliefs about learning or intelligence). Recently, researchers have suggested the combination of diverse measures from quantitative and qualitative approaches (Bendixen & Rule, 2004; Pintrich, 2002; Yadav et al., 2011). For example, a researcher can use open-ended questionnaires as a contextually grounded approach "in a more nuanced way at different levels of granularity" (Yadav et al., 2011, p. 34). Then, such results can be replicated by using standardized measures with a larger sample to confirm belief structure.

With regard to the population of participants sampled, personal epistemology has been assessed using a diversity of participant-related variables, such as age, gender, education level, academic majors, ethnic culture, and so on. For example, studies found that students' beliefs about knowledge become more sophisticated with age and education based on the assumption of the developmental nature of personal epistemology (e.g., Jehng et al., 1993; Schraw et al., 1995); students' epistemological beliefs may also differ according to their academic majors (Hofer, 2000; Paulsen & Well, 1998). Evidence of potential gender differences in epistemological beliefs have been found, but inconsistencies in emergent patterns have been also observed (Buehl, 2003). There is another increasing trend to investigate the role of culture in epistemological beliefs, especially within Asian countries (Chan & Elliot, 2002; Youn, 2000). These studies noted that researchers should be cautious about administering the existing instruments in international contexts, especially those that were designed for samples collected from the United States or other Western countries. For example, Qian and Pan (2002) found that the factor structure identified in the United States showed low reliabilities with data collected from China; thus current instruments may need to be modified to examine cultural differences in personal epistemology.

Taken together, there is a need to develop more reliable and valid instruments focusing on the population of interest. The important challenges for this study are (a) how we can promote teachers' beliefs about the nature and the process of teaching knowledge and (b) how we can examine the differences in such beliefs "across individuals who are entering a teacher education program, completing a field experience, entering the classroom as a novice teacher, and persisting in the teaching profession" (Fives & Buehl, 2010, p. 503).

2.2.3 How Can We Promote Epistemological Awareness?

Pintrich (2002) argued that "epistemological development is a function of internal psychological mechanisms as well as contextual facilitators and constraints" (p. 403). Research has situated personal epistemology within metacognitive processes, which is activated and/or altered during conceptual change learning (e.g., Kendeou, Muis, & Fulton, 2010; Mason & Gava, 2007; Mason & Boldrin, 2008; Muis & Duffy, 2013; Muis & Foy, 2010; Muis, Kendeou, & Franco, 2011; Murphy & Mason, 2006; Stathopoulou & Vosniadou, 2007). Particularly, these studies examined how contextual factors from specific forms of instruction to promote personal epistemology (Bendixen & Rule, 2004; Hofer, 2004; Tsai, 1998, 1999). For example, King and Kitchener (2002) investigated how students justify their beliefs when faced with ill-structured problems by wrestling with questions about the limits, certainty, and criteria for knowing. They called this status of epistemic cognition "reflective judgment" (Dewey, 1938), when students realize that some ill-structured problems cannot be solved with certainty. Similarly, Kuhn and Weinstock (2002) examined epistemological thinking through investigations into real-world cognitive activities such as juror decision making; and found that epistemological beliefs have intrinsic implications for critical thinking. They found that there was very little progression toward the evaluativist[2] level of epistemological understanding with an increase in age and experience; rather intellectual climate and values may promote social tolerance and acceptance from an evaluativist perspective. Jonassen, Strobel, and Gottdenker (2005) suggested model-based reasoning, which helps students externalize their ideas, and visualize and test their own hypotheses. Models, as epistemic resources, consist of the representations of "the spatial and temporal relations and causal structures connecting the events and entities depicted" (p. 18); and thus modeling supports a deeper

[2] As shown in Table 2 earlier, evaluativist, as the last position of Kuhn's Argumentation Reasoning framework, is considered to understand that knowledge is constructed, but that some knowledge is "better" than others so as to determine which knowledge can be the "best" evidenced based knowledge; while subjectivist, as the middle position in it, may value personal opinions, but still knowledge remains largely unexamined (Kuhn 1991; Kuhn & Weinstock, 2002).

level of conceptual engagement. Jonassen and Johannes (2006) contended that learners, as epistemic agents, should be given opportunities to initiate meaning making and knowledge construction.

As part of specific forms of instruction to promote personal epistemology, the impact of technology-integrated instruction on students' epistemological beliefs, comprehension, and achievement has been increasingly investigated. Hofer (2004) claimed that students searching Web information should be engaged in metacognitive processes, such as epistemic monitoring, judgment, and self-regulation. Students are likely to ask themselves: "Is this information credible?" "Is it certain?" "What is the evidence that supports this information?" "Is this aligned with my own experiences?" or "How can I know enough to justify my knowledge related to this information?"

As an initial attempt, Jacobson and Spiro (1995) compared the effects of two different types of hypermedia tutorials (Minimal Hypertext/Drill versus Thematic Criss-Crossing Hypertext) to examine cognitive flexibility theory, and included a measure of epistemological beliefs. Results showed that students with 'simple knowledge' epistemological beliefs were more likely to struggle with the nonlinear and multidimensional nature of an ill-defined hypertext system. Jonassen et al. (2005) argued that computers allow to build external representations of what students are learning, as "the most potentially powerful and engaging methods for fostering and assessing conceptual change" (p. 16). It is also argued that computer-based modeling tools may help students construct their models of domain knowledge through epistemic reflection.

Later, two research groups, Mason and colleagues and Bråten and colleagues, produced research outcomes that demonstrated that students' epistemic monitoring and judgments influence web search strategies, argumentative reasoning, and decision-making (Bendixen, 2010). Mason and Boldrin (2008) investigated how students' epistemic judgments evolve and influence their learning about science concepts and understanding the nature of scientific inquiry through debate and argumentation on the Web. Similarly, Mason, Boldrin, and Ariasi (2010a, 2010b) examined the role of epistemic reflections about the credibility of online resources, the simplicity/complexity and certainty/uncertainty of online knowledge, as well as the justifications supporting it. Mason, Boldrin, and Ariasi (2011) revealed that most epistemic reflections used for online learning were about the source of knowledge: for example, the evaluation of the credibility of websites and the justifications for specific claims with supportive evidence from multiple credible sources. As a cross-sectional study, Mason, Boscolo, Tornatora, and Ronconi (2013) examined the relationships between epistemic beliefs, achievement goals, self-beliefs, and actual achievement in science. Results from structural equation modeling revealed that students' epistemic beliefs about the development of scientific knowledge had a direct effect on the actual achievement of domain knowledge, whereas beliefs about the justification of scientific knowledge had a direct and an indirect effect via achievement goals (e.g., mastery, performance-approach, and performance-avoidance goals) on scientific knowledge.

The notable contribution of Bråten's research group is the scale development of the Internet-specific Epistemological Questionnaire (ISEQ) with the dimensions of the Hofer and Pintrich (1997) framework as a point of departure. In 2005, Bråten, Strømsø, and Samuelstuen developed this instrument to assess learners' beliefs about the nature of web-based knowledge and the process of knowing to predict learners' attention to and evaluation of source information on both offline and online measures. Based on these results, Strømsø and Bråten (2010) investigated the role of personal epistemology in the regulation of Internet-based learning. They assessed the degree to which students believed that the Web contains correct and detailed facts about course-related topics. Results showed that undergraduate students who believed that Web information claims needed to be critically examined against other knowledge sources, reason, and prior knowledge were reportedly more likely to engage in self-regulatory strategies than those who believed that Web information contains correct and detailed facts and does not need to be evaluated, when using the Internet during coursework. With the importance of information literacy on multiple-text comprehension, Bråten, Britt, Strømsø, and Rouet (2011) proposed a framework, specifying how and why different epistemic belief dimensions may be linked to the comprehension and integration of multiple texts. Applying this framework, Bråten, Strømsø, and Samuelstuen (2011) examined how students judge the trustworthiness of different information sources and found that students low in topic knowledge tended to trust less trustworthy sources and failed to choose appropriate criteria when judging the trustworthiness of sources.

In a similar fashion, Barzilai and Zohar (2012) examined the differences of absolutist and evaluativist epistemic perspectives when evaluating website trustworthiness and critical integration of multiple online sources. The results indicated that students' epistemic thinking plays a critical role in online inquiry learning: for example, evaluativists significantly outperformed absolutists in the online resource integration strategy. Barzilai and Eshet-Alkalai (2013) investigated the effect of epistemic thinking (e.g., abolutivist, multiplist, or evaluativist) and the nature of online resources (e.g., conflicting or converging blog posts) in terms of how learners understand, evaluate, and integrate multiple perspectives. They found that conflicting blog posts were more likely to stimulate learners' evaluativist perspectives than converging blog posts, supporting that individual epistemic thinking plays an important role in the comprehension and integration of multiple online sources (Bråten, Britt, Strømsø, & Rouet, 2011). Despite these findings in the literature, whether and how personal epistemologies are related to metacognition (e.g., self-regulated learning) and information literacy within technology-integrated learning contexts are still open questions and thus more empirical work is needed.

In addition to specific forms of instruction, domains are considered as contextual factors that have been synonymous with school subjects (i.e., mathematics, science, reading, social studies) or disciplines (e.g., mathematics, history, chemistry, psychology) in the literature that focuses on epistemological thinking within a domain (Buehl, 2008; Pintrich, 2002). For example, Lonka and Lindblom-Ylanne (1996) found, using Perry's scheme (1970), that more students with dualistic perspectives existed among medical students, while more students with relativist perspectives were common among psychology students. Marra, Palmer, and Litzinger (2000) also used Perry's scheme to examine the impact of a single team-based, project-learning course on first-year engineering students' intellectual development as well as the relationship of their epistemological beliefs, gender, and academic ability. Studies employing a multi-dimensional conceptualization of personal epistemology also examined differences in personal epistemology among various academic majors. Jehng et al. (1993) found that students majoring in "soft" fields (i.e., social sciences, art, or humanities) tend to believe less in the certainty of knowledge, prefer their own reasoning abilities when acquiring knowledge, and are less prone to view learning as an orderly process than students in “hard” fields (i.e., engineering or business). Paulsen and Wells (1998) classified majors into “soft” (e.g., humanities) or “hard” (e.g., engineering), as well as “applied” (e.g., education) or “pure” (e.g., natural sciences), referring to Biglan’s taxonomy of academic disciplines (1973a, b). They found that students in both “pure” and “hard” fields were more likely to believe in the certainty of knowledge, the simplicity of knowledge, or the quickness of learning than students in “applied” and “soft” fields.

Collectively, a growing body of research has suggested that contextual factors can simultaneously constrain or prompt change in individual’s epistemological beliefs as part of a fundamental developmental structure (Hofer & Pintrich, 1997; King & Kitchener, 1994). Further studies are needed to identify the various instructional elements as well as the mechanisms that promote personal epistemology as well as domain-specific epistemological advances.

2.3 Personal Epistemology and Teacher Education

2.3.1 Teachers’ Personal Epistemology and Teaching

Research on teachers’ beliefs has mainly been concerned about beliefs about teaching and students’ learning (Ertmer, 1999, 2005; Kane, Sandretto, & Heath, 2002); however, currently teachers’ beliefs about the nature and justification of knowledge have drawn interests from researchers (Bråten, 2010). Clearly, recognizing a link between personal epistemology and teaching practice is important to identify how different epistemological beliefs influence, and in turn are influenced by, curricular and pedagogical decisions in classroom contexts.

When examining in-service teachers' personal epistemologies, many studies have demonstrated that there was a consistency between personal epistemology and teaching practices. Bronwlee (2011) presented previous studies, showing that constructivist teaching is related to a sophisticated level of personal epistemology (i.e., evaluativist epistemology), whereas transmission teaching is characterized by a naïve level of personal epistemology (i.e., absolutist epistemology). This means that teachers with sophisticated beliefs about knowledge and knowing are more likely to encourage students to engage in higher-order thinking rather than reproducing knowledge. As an initial attempt, Brownlee (2001) examined how personal epistemology and teaching practices were related among novice teachers: for example childcare teachers with evaluativistic personal epistemologies tended to describe child-centered, constructivist approaches to teaching. Schraw and Sinatra (2004) also demonstrated that teachers with more sophisticated personal epistemology are like to be much more flexible with teaching strategies and engage more with their students. From an extensive literature review, Maggioni and Parkinson (2008) concluded that there may be reciprocal relationships between teachers' epistemological cognition, epistemological beliefs, and specific interventions for explicit reflection on epistemological beliefs (e.g., calibration). Kang (2008) found that teachers with relativist views about science (e.g., science knowledge is tentative) were likely to establish teaching goals that are consistent with educational reform in science (e.g., helping students develop critical thinking skills). Based on Hofer's framework (2000), Weinstock and Roth (2011) found that teachers' relativistic epistemologies promoted teacher perspective-taking, higher student autonomy, and multiple viewpoints. Tabak and Weinstock (2011) employed Kuhn's developmental model of *Argumentative Reasoning* that includes three stages from absolutist to multiplist and to evaluativist stances. They showed how classroom interaction affects epistemological socialization: for example, recitation fostered absolutist views, whereas inquiry fostered evaluativist views.

In terms of pre-service teachers' personal epistemologies and teaching practices, most studies have investigated the relationship between personal epistemology and teaching beliefs instead of teaching practices (Kang, 2008). Brownlee (2001) found a critical link between more sophisticated levels of personal epistemology and child-centered, constructivist teaching practices among pre-service teachers. Brownlee (2004) also indicated that pre-service teachers with relativist beliefs were more likely to view teaching through constructivist perspectives, where teachers take a role of facilitator to promote students' knowledge construction through conceptual change. Yadav and Koehler (2007) found that pre-service teachers' epistemological beliefs influenced their teaching conceptions including how they interpret exemplary teaching practices. For example, they found that pre-service teachers viewing knowledge as certain and unambiguous tended to focus more on identifying mistakes and correcting errors in student work, whereas those viewing knowledge as more complex and integrated were more likely to provide opportunities for students to revise their work. Using a mixed-method approach with Hong Kong pre-service teachers, Cheng, Chan, Tang, and Cheng (2009) revealed that "a large number of the pre-service teachers believed that learning effort was needed for successful learning, were of the view that knowledge evolved over time, and believed it was important to critique knowledge, particularly experts' knowledge" (Brownlee et al., 2011, p.13).

However, some studies indicated that personal epistemology and teaching practices are not always consistent. Although constructivist approaches to teaching are considered to be good practice, many teachers may be challenged by these teaching contexts and so stick to traditional, teacher-centered instruction (Many, Howard, & Hoge, 2002). Windschitl (2002) noted that “classroom teachers are finding the implementation of constructivist instruction far more difficult than the reform community acknowledge” (p.131). Schraw, Olafson, and VanderVeldt (2011) noticed that some experienced teachers in their sample tended not to adjust their beliefs about knowledge and knowing as the result of short-term interventions. Lee and Tsai (2011) also found that the more experienced science teachers tended to show inconsistencies between their beliefs about the nature of science knowledge and science teaching practices; and interpreted that this situation resulted from the transition between traditional teacher-centered and constructivist orientation in Taiwan. Studies on pre-service teachers’ personal epistemologies have shown similar results: pre-service teachers held sophisticated beliefs about knowledge, but still held the view of teaching and learning from a traditional perspective (Cheng et al., 2009, Fives, 2011). Findings indicated that pre-service teachers seem to feel more familiar with a teacher-centered approach, because a constructivist approach may be challenging in classroom contexts, while a naïve level of personal epistemologies may help them establish their own professional competences that will foster their early teaching practices (Fives & Buehl, 2010). Therefore, it should be considered that teachers’ personal epistemologies are “a major component of the classroom climate” (Bendixen & Corkill, 2011, p.100); and thus supportive environments for constructivist approaches to teaching are as important as various opportunities for explicit reflection of teachers' personal epistemologies (Windschitl, 2002).

2.3.2 Teachers' Personal Epistemology and Learning

Research efforts in personal epistemology have explored how such beliefs influence learning strategies and learning outcomes in pre-service teachers (Bronwlee & Berthelsen, 2006; Chan, 2003; Muis, 2004). For example, Chan (2003) indicated that pre-service teachers with preferences toward external sources of knowledge tended to use surface learning approaches, while those with preferences for learning efforts and meaning making were more likely to use deep learning approaches. Similarly, Ravindran, Greene, and DeBacker (2005) suggested that a more sophisticated personal epistemology was related to mastery goals and meaningful approaches to learning; and Bråten and Strømsø (2006b) found that students with absolutist views of knowledge were less likely to use mastery goals in their learning.

With regard to the relationship between personal epistemology and learning outcomes, research has shown somewhat inconsistent findings. *Bråten* and *Strømsø* (2006a) found that students with sophisticated personal epistemologies showed better comprehension when multiple contexts offered conflicting information, while Bråten, Strømsø, and Samuelstuen (2008) found that students with sophisticated personal epistemologies (e.g., climate change knowledge could be constructed) did not do as well as those with naïve personal epistemologies (e.g., climate change knowledge could be transferred from authority). Peng and Fitzgerald (2006) also found that naïve beliefs in *Structure of Knowledge* (i.e. knowledge is certain and simple) were related to understanding of texts, while sophisticated beliefs in *Fixed Ability* (i.e. intelligence is not innate, but fixed) were related to difficulties with problem solving. About this issue, Brownlee et al. (2011) noted "how various dimensions of personal epistemologies may differentially influence learning outcomes in terms of text comprehension as a learning outcome" (p. 9).

In sum, previous studies indicate that teachers' personal epistemologies may influence teaching practices as well as learning strategies and outcomes. Thus, it is critical to understand how to promote sophisticated beliefs about knowledge and knowing within teacher education.

2.3.3 How Can We Promote Teachers' Personal Epistemology?

Given the influence of personal epistemology on teaching practices, teacher educators need to consider how to promote pre-service teachers' sophisticated beliefs about knowledge for engaging students in knowledge construction that allows multiple ways of knowing (Yadav, Herron, & Samarapungavan, 2011). Kang (2008) noted, "Teacher education courses should provide teachers with opportunities to engage in inquiry and explicit discussion on underlying epistemological issues" (p. 495). In other words, these inquiry-oriented courses need to be designed to allow pre-service teachers to explicitly reflect on their own beliefs and explore multiple ways of knowing (Brownlee, 2001).

For this purpose, researchers have examined the effects of specific instructions designed to encourage pre-service teachers' explicit reflection on their personal epistemologies at a metacognitive level. For example, Abd-El-Khalick and Akerson (2009) found a strong link between pre-service teachers' metacognitive awareness and understandings of the nature of science knowledge during the specific instruction designed to teach them to use metacognitive strategies during learning processes. Some researchers have suggested “relational pedagogy” in teacher education, which is a social constructivist perspective on the development of epistemological beliefs (Baxter Magolda, 1993). Relational pedagogy emphasizes the relationship between the *knowers* and the known from a social constructivist perspective, while previous frameworks of personal epistemology mostly focused on the internal relations (i.e. the relationship between the knower and the known). Relational pedagogy holds the view that knowledge is constructed individually as well as socially through interactions with social and learning contexts; and thus it values students as knowers and allows them to reflect in a variety of ways through supported and protected classroom discussions (Baxter Magolda, 1996). Therefore, relational pedagogy has been used as a basis for an intervention program design in teacher education, in which pre-service teachers can explore different beliefs and alternative teaching practices that may conflict with their existing beliefs (Cheng et al. 2009). For example, Brownlee, Purdie, and Boulton-Lewis (2001) designed an intervention program in which pre-service teachers were required to reflect on their epistemological beliefs using personal diaries. They found that students who experienced these reflective practices showed a statistically significant shift to more sophisticated epistemological beliefs than those in a tutorial program. Similarly, several studies found that pre-service teachers described more sophisticated relational epistemological beliefs over time, when the intervention program focused on constructivist instruction that emphasized explicit discussion and collaborative reflection on conflicting issues (e.g., Bendixen & Cockill, 2011; Brownlee, 2004; Marra & Palmer; 2011; Tillema, 2011).

Since Jacobson and Spiro's (1995) study on the impacts of technology integration on personal epistemology, Internet-based intervention programs also have been used as an *epistemological* tool (Tsai, 2004), in order to help students critically evaluate web sources and explore the nature of knowledge and knowing through the Internet. For example, Ren, Baker, and Zhang (2009) investigated the effects of wiki-textbook writing on pre-service teachers' epistemological beliefs. Using the EBI (Schraw et al., 2002), they found that there was a significant difference in one factor of personal epistemology *Certainty of Knowledge* (i.e. viewing knowledge as fixed or more fluid) among the traditional and Wiki-based programs. This is the initial study to integrate wikis in a teacher education program and investigate its effect on pre-service teachers' epistemological beliefs. More recently, Andreassen and Bråten (2013) examined the relationship between teachers' self-efficacy on evaluation of information quality and their reliance on relevant source features when judging the trustworthiness of websites. The findings indicated that teachers' source evaluation self-efficacy beliefs uniquely predicted their use of website information (i.e., information about products and producers), when judging their trustworthiness. These findings noted that further empirical studies are needed about this topic.

2.4 Potential Variables Influencing Personal Epistemologies

A newly developed scale with good psychometric properties should relate to other variables in a way that theory predicts its relationships – for example, how target variables correlate with other variables in a specific direction. Following is a list of potential theoretical antecedents of personal epistemologies of teaching. It is important to note that this list was not intended to be an exhaustive list of antecedents, but may provide insights to locate personal epistemologies of teaching within the nomological position of the variables.

2.4.1 Perceptions of Teacher Educators' Pedagogical Practices

Teachers use a variety of pedagogical practices designed to encourage students to develop justification for knowledge (Henessey et al., 2013). Teachers' pedagogical practices enable students to "determine whether or not sources are valid and credible; estimate the adequacy of the information, [and] test the validity of the information'' (NCSS, 2010, p. 164). In other words, teachers provide their students with models for "how the ideas build on, or connect with, other ideas, thus enabling them to develop new understanding and skills'' (NCTM, 2000, p. 14). Several studies demonstrated empirical evidence that teachers' personal epistemologies have an impact on the epistemic climate of their classrooms, indicating that teachers' pedagogical practices influenced their perception of content knowledge, their preferences regarding instructional approaches, and their understanding of the student as a learner (e.g., Johnson et al., 2001; Howard et al., 2000, 2011).

In this sense, university teachers' pedagogical practices may be geared to actually helping to advance student personal epistemologies. They may face situations demanding explicit demonstration of their conceptions of teaching when preparing their students for the teaching profession (Ben-Peretz, 2001). Jonassen, Marra and Palmer (2003) noted that pedagogical practices can affect students' epistemological development, and in turn, students' epistemological level can indicate the success of certain pedagogical activities. This study supports the position that the intersection of pedagogical activities and personal epistemologies may provide faculty with insights on how what they do as teacher educators interacts with and potentially enhances or retards students' personal epistemologies. Therefore, Henessey et al.'s framework of epistemic practices (2013) was employed which includes two opposite approaches to pedagogical practices, such as foundationalism and reliabilism. For foundationalists, knowledge consists of basic beliefs that are non-inferential, infallible, indubitable, incorrigible, and hierarchical in nature (Fumerton, 2000; Moser, 1995); and foundationalism-based pedagogical practices are generally "transmitting new facts that build based on basic understandings" (Henessey et al., 2013, p. 507). In contrast, reliabilists believe that knowledge can be justified only if it was produced through a reliable cognitive process. Therefore, reliabilism-based pedagogical practices focus more on "justifying understandings with observable evidence" (Henessey et al., 2013, p. 507). Although Henessey et al. (2013) noted that reliabilism should not be treated to be superior to other methods for justification, generally teachers who demonstrate teaching practices based on reliabilism may use authentic or real-world examples and require their students to explain how their new understandings can be verified through evidence collected, seeking ways to foster deeper learning in their students (Chambliss, Alexander, & Price, 2012).

2.4.2 Perception of Information Quality

Perceptions of the quality of information have been considered as one of the critical determinants influencing participants' contribution to group performance using collaborative tools for knowledge construction (Flanagin, Park, & Seibold, 2004). Generally, information quality has been measured in three related areas: information content, information format, and physical environment associated with information, determining if information is accurate, current, relevant, secure, valid, and complete

(Jeong & Lambert, 2001). Lim (2009) demonstrated that perception of information quality was important for students to participate in knowledge construction and sharing, as epistemic activities, within Wikipedia. Particularly, positive impressions of information quality provided by others can be a manifestation of anticipated outcomes through interactions in a group. Whitmire (2003, 2004) examined the relationship between personal epistemology, reflective judgment, and information-seeking behavior, indicating that undergraduates who viewed knowledge as evolving and integrated exhibited the ability to handle conflicting information sources and to recognize authoritative information sources. Rieh (2002) developed a model of judgment of information quality and cognitive authority, suggesting that users evaluate information quality in terms of characteristics of sources (e.g., URL domain, reputation, author, and credentials). This study defined Perception of Information Quality as whether information is accurate, verifiable, reliable, well-written, and presents views fairly without bias (Lim, 2009); and examined how such perceptions interact with personal epistemologies of teaching.

2.4.3 Knowledge Sharing Self-Efficacy

Hsu, Ju, Yen, and Chang (2007) described knowledge sharing self-efficacy as perceived capabilities for "authoring knowledge content, codifying knowledge into knowledge objects by adding context, contributing personal knowledge to the organizational database, sharing personal knowledge in formal interaction with or across teams or work units, or in informal interactions among individuals" (p. 155). Wang and Noe (2010) recently reviewed qualitative and quantitative studies of individual-level knowledge sharing during the organization learning process, emphasizing that organizational culture has a direct effect on employees' knowledge sharing behavior as well as an indirect effect through influencing managers' attitudes toward knowledge sharing. Lin, Lin, and Huang (2008) investigated knowledge sharing and creation within an online teacher professional development program, suggesting that information quality is one of the critical factors influencing teachers' participations in collaborative lesson plan development via knowledge sharing and creation. Following Chen and Hung (2010), knowledge sharing self-efficacy was defined as “one's confidence in an ability to provide knowledge that is valuable to others” (p. 228). That is, knowledge sharing self-efficacy is confidence in one's capabilities to provide valuable and useful information to others and respond to questions or issues posted by others. In this study, knowledge sharing self-efficacy was examined if one is confident in providing valuable knowledge and responding or adding comments to others' opinions (Chen & Hung, 2010); and how such confidence may impact personal epistemologies of teaching.

2.4.4 Information Evaluation Self-Efficacy

Information evaluation, as a core component of information literacy, is the judgment and analysis of accuracy, relevance, effectiveness, and authority of information (Fitzgerald, 2000; Webber & Johnson, 2000). Hofer (2004) pointed out that Web search is a process involving a number of epistemological perspectives, such as judgments with metacognitive monitoring. For example, students filter information based on its credibility and validity and then make a range of judgments based on practical needs and cognitive authority. Similarly, Kienhues, Stadtler, and Bromme (2011) investigated whether and how conflicting and consistent Web-based information affects personal epistemology and decision making, indicating that the types of information (e.g., conflicting versus consistent) differently affect sophisticated personal epistemologies. They emphasized the importance of experiencing epistemic doubt about the accuracy and completeness of existing knowledge, as the heart of information literacy, in order to develop sophisticated epistemological beliefs. Information evaluation self-efficacy was defined as one' confidence in evaluating the qualities of information, based on Bandura's concept of self-efficacy (Bandura, 1986, 1987). In this study, information evaluation self-efficacy was examined to determine if one is confident evaluating the quality of information and the credibility of cognitive authorship (Lim, 2009); and how such confidence may affect personal epistemologies of teaching.

2.4.5 Significance of the Study

Intellectual growth is central to the goal of higher education. As college students experience epistemic doubt that results from critical thinking, they undertake a developmental progression in which they progressively shift from their belief in the omniscience of authorities to viewing knowledge as the production of negotiation through collaborative investigation and ultimately take increasing responsibility for their own learning. Chai and Lim (2011) argued that "teachers are expected to be mediators and knowledge brokers and provide guidance, strategic support, and assistance to help students with diverse needs to assume increasing responsibilities for their own learning" (p. 3). Therefore, in this study, I have argued that teacher education programs need to encourage pre-service teachers' intellectual development, particularly focusing on the role of epistemological beliefs (i.e. personal epistemology) on argumentation performance, when solving ill-structured diagnosis-solution problems.

Despite a growing body of literature on personal epistemology and teacher education, Yadav et al. (2011) contended that there is a clear need to develop more robust and diverse measures of teachers' personal epistemologies by rethinking the dimensions/constructs of such beliefs. This issue can be dealt with from the discussion about domain-generality versus domain-specificity in personal epistemologies. Almost all studies of teachers' personal epistemologies have used existing instruments designed to assess domain-general knowledge. In addition, despite the efforts to use diverse qualitative measures (e.g., interviews; essays; vignettes; concept maps), there has been less effort devoted to the development of a robust multi-item standardized measure to assess individual conceptualizations of the nature of knowledge and knowing in teaching. Schraw, Brownlee, and Berthelsen (2011) argued that lack of universal measurement design principles within personal epistemology research may lead to some disconnections between personal epistemology and teaching practices. Similarly, Guerra-Ramos, Ryder, and Leach (2010) found inconsistences between science teachers' responses about the nature of science and their actual teaching practices in class. For example, the participating teachers tended to give naïve responses to direct questions, but seemed to use more sophisticated levels of science knowledge in classroom situations. To reduce this apparent gap, Guerra-Ramos et al. (2010) designed a follow-up semi-structured interview protocol, including questions and tasks that teachers are likely to link to their professional practice. The results showed that the teachers could extend and justify their responses to pedagogically relevant question about the nature of science. Guerra-Ramos et al. (2010) concluded "adopting only academic normative criteria without combining them with more pedagogically oriented approaches leads to a very limited perspective on teachers' ideas about science, with limited relevance for their professional practice" (p. 300). As such, it is important to develop richer and more contextually validate measures designed to assess personal epistemologies.

Therefore, this study aims to develop a reliable and valid instrument to assess teachers' personal epistemologies of teaching. In addition, the structural model was used to examine the intersections of personal epistemology, pedagogy, and knowledge construction, in order to inform what should be included in teacher education programs designed to promote epistemological development. Using the proposed scale in this study, teacher educators and researchers can easily administer it to a large sample size and establish generalizability based on findings. In addition, they can establish a foundation to identify the nature of the relationship between teachers' epistemological beliefs and teaching practices, as well as better understand how to promote teachers' sophisticated beliefs through specific intervention programs. More importantly, the examination of the structural relationships between personal epistemologies and other variables allows an important step towards understanding the effects of critical knowledge sharing on personal epistemology in teacher education.

CHAPTER 3. METHODS

Effective measurement is vital to drive the progress of scientific research as a central component of empirical research investigating the relationships between latent variables (Crook, Shook, Madden, & Morris, 2009; Reynolds, 2010). Therefore, reliable and valid instruments contribute to the academic legitimacy of a research field. The goal of Chapter 3 is to detail the procedure of instrument development and validation by utilizing a sequence of steps that is consistent with the suggestions of several seminal methodologists in scale development (e.g., DeVellis, 2011; Flynn & Pearcy, 2001; Netemeyer, Bearden, & Sharma, 2003; Spector, 1992). The author particularly took great care to apply advanced psychometric techniques with technological advances in computers. Given that many existing measures in personal epistemology research are self-report measures, a self-report measure was developed for *Pre-service Teachers' Personal Epistemologies of Teaching Scale* (PT-PETS). Figure 1 graphically presents the development procedure used in this study.

3.1 Step 1: Construct Definition

The first step of any scale development is to determine what is being measured, relying on its definition and content domain (DeVellis, 2011). The extensive literature review presented in Chapter 2 allowed the author to delimit the theoretical domain of the

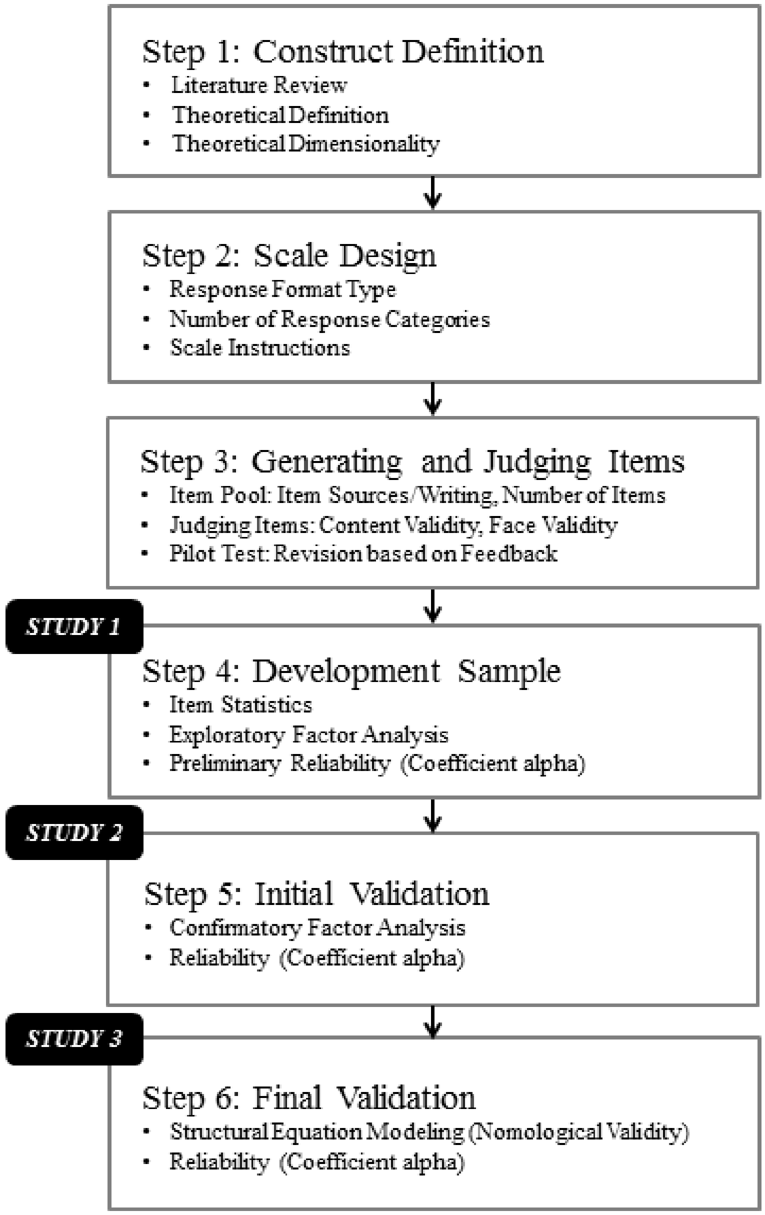

Figure 1. Scale Development Procedure

construct by determining what is included or excluded from this domain. Accordingly, the nature of learning was excluded to strengthen the construct validity of the proposed scale, although it may be highly correlated with the nature of knowledge as the target construct in this study. This exclusion was supported by the suggestion of Netemeyer and his colleagues (2003), indicating, “When extraneous factors or domains of other constructs are included, more than one construct underlies the total score, and construct validity is threatened” (p. 90). Likewise, the clear specification of the boundaries was carefully examined in the first step.

3.2 Step 2: Scale Design

Two basic issues were considered to determine the format of items: such as (a) dichotomous (e.g., true-false scoring) versus multi-chotomous (e.g., Likert-type, semantic differential) scale points and (b) wording of the response scale points (e.g., strongly disagree-strongly agree) (DeVellis, 2011; Netemeyer et al., 2003). As described in Chapter 2, the formats of the six existing instruments varied, including five-point (e.g., Schommer, 1990; Schraw et al., 2002), six-point (e.g., Jehng et al., 1993), seven-point (e.g., Kardash & Scholes, 1996; Kardash & Howell, 2000; Wood & Kardash, 2002), and ten-point formats (e.g., Buehl et al., 2002; Bråten et al., 2005). A variety of researchers (e.g., Fisher, 2000) have indicated the advantages and disadvantages of including a middle “uncertain” or “neutral” category; however, the author decided to push students to take a clearer stand by using a six-point Likert scale without the middle category (Boone, Townsend, & Staver, 2011).

(A)	Strongly Agree with (A)	Moderately Agree with (A)	Somewhat Agree with (A)	Somewhat Agree with (B)	Moderately Agree with (B)	Strongly Agree with (B)	(B)
Learning to teach is a process in which I read relevant information…							Learning to teach is a process in which I personally construct understandings...

Figure 2. A Sample Item with a 6-point Likert Scale

In addition to the use of these multi-dichotomous scales, semantic differential items were generated that were bipolar in nature (i.e., naïve versus sophisticated personal epistemologies, absolutist versus relativist personal epistemologies). As shown in Figure 2, verbal labels were used for each of the two opposite statements to reduce positivity bias and improve reliability: for example, strongly agree with (A), moderately agree with (A), and somewhat agree with (A) (Tourangeau, Rips, & Rasinki, 2000).

3.3 Step 3: Generating and Judging Items

Using a deductive approach, the initial item pool was generated for each of the constructs determined in the first step. As shown in Table 10, six existing personal epistemology scales from different studies were reviewed to create a representative sample of the targeted construct that exhibit content validity. Face validity was also considered in terms of ease of use, proper reading level, clarity, as well as response formats. Two experts in the field of teacher education and five pre-service teachers offered insights into representation of the construct and how to measure it, thus strengthening face validity.

Table 10

Personal Epistemology Instruments from the Literature

Author	Instrument	Items	Scale	Finalized Constructs
Schommer (1990)	Schommer Epistemological Questionnaire (SEQ)	63	5-point Likert Scale	▪ Simple Knowledge ▪ Certain Knowledge ▪ Innate Ability ▪ Quick Learning
Jehng, Johnson, & Anderson (1993)	Jehng et al.'s Epistemological Questionnaire (JEQ)	61	7-point Likert Scale	▪ Certainty of Knowledge ▪ Omniscient Authority ▪ Orderly Process ▪ Innate Ability ▪ Quick Learning
Schraw et al. (1995)	Epistemic Belief Inventory (EBI)	28	5-point Likert Scale	▪ Fixed Ability ▪ Certain Knowledge ▪ Omniscient Authority

				▪ Simple Knowledge ▪ Quick Learning
Hofer (2000)	Discipline-Focused Epistemological Beliefs Questionnaire (DFEBQ)	27	5-point Likert Scale	▪ Certain/Simple Knowledge ▪ Justification for Knowing: Personal ▪ Source of Knowledge: Authority ▪ Attainability of Truth
Wood and Kardash (2002)	Epistemological Beliefs Survey (EBS)	38	5-point Likert Scale	▪ Speed of Knowledge Acquisition ▪ Structure of Knowledge ▪ Knowledge Construction and Modification ▪ Characteristics of Successful Students ▪ Attainability of Objective Truth
Bråten, Strømsø, & Samuelstuen (2005)	Internet-specific Epistemological Beliefs (ISEQ)	19	10-point Likert Scale	▪ General Internet Epistemology ▪ Justification for Knowing

Note. Instruments are ordered by the year of publication.

There is no agreement about the actual number needed for an initial item pool for a single construct; instead, guidelines vary according to the types of construct (i.e., unidimensional versus multidimensional). DeVellis (2011) suggests that generating a pool twice the size of the resulting scale will suffice for narrowly defined constructs, while Robinson, Shaver, and Wrightsman (1991) recommend up to 250 items for the initial pool of multidimensional constructs. Generally, an over-inclusive rather than under-inclusive pool for initial items is recommended, particularly when the pilot sample is one of convenience and not necessarily entirely representative of the population of interest (Netemeyer et al., 2003).

To judge the content and face validity of the items in the initial pool, a panel of three experts and five members of target population assessed the degree to which items represent the construct's definition and domains by using a three-point rating scale (i.e., not representative, somewhat representative, and clearly representative). According to Hardestry and Bearden (2004), (a) items were retained if at least fifty percent of the judges rated the items as "clearly representative" (B) in case that any judge rated an item as “not representative” the items were retained only when two out of the three expert judges rated the item as “clearly representative” (Appendix A). The experts also provided written comments in terms of item writing (e.g., wording clarity, wording redundancy, and positively/negatively worded items). The panel of experts included three faculty members from teacher education, whereas the target population consisted of five undergraduate students in the College of Education.

3.4 Step 4: Development Sample (Study 1)

3.4.1 Sample

The purpose of Study 1 was to examine the initial factor structure of the proposed scale through the purification of the items included. This step included item statistics, exploratory factor analysis, and preliminary reliability tests. Item statistics were analyzed to determine which items should be deleted or retained, in combination with the content and face validity. Exploratory factor analysis was conducted to parsimoniously evaluate the dimensionality of a set of variables by revealing the smallest number of interpretable factors (Brown, 2006; Thompson, 2004). Preliminary reliability tests provided evidence about the internal consistency of the scale. Participants were solicited from 202 pre-service teachers, enrolled in a required 3-credit educational technology course in Fall 2012, at a large Midwest University, which has a culturally rich racial and ethnic representation. The demographic data of this sample, such as age, gender, ethnicity, major, and school year, were reported. Regarding sample size for exploratory factor analysis, there are various rules recommended. For example, Gorsuch (1997) suggested that the number of participants for a pilot test should be in the 300 range, whereas Clark and Watson (1995) suggested that 100 to 200 participants will suffice. DeVellis (2011) recommended that a scale developer have a sample size five to ten times the total number of items on the final scale. Comrey and Lee (1992) suggested the following guidance: 100 = poor, 200 = fair, 300 = good, 500 = very good, 1,000 or more = excellent. However, Costello and Osborne (2005) indicated, “Strict rules regarding sample size for exploratory factor analysis have mostly disappeared. Studies have revealed that adequate sample size is partly determined by the nature of the data” (p. 4). In this study, it was concluded that a total of 200 participants may be sufficiently large to evaluate the dimensionality of the scale proposed in this study.

3.4.2 Exploratory Factor Analysis

Exploratory factor analysis (EFA) was conducted using SPSS 20.0 (Statistical Package for Social Sciences) for two purposes: (a) to reduce the number of items in the proposed instrument until the remaining items maximized the explained variance as well as the reliability of the instrument; and (b) to identify possible primary (latent) factors in the instrument (Brown, 2006; DeVellis, 2011; Netemeyer et al., 2003). The procedural aspects of EFA include: (a) factor extraction, (b) factor selection, (c) factor rotation, and (d) interpretation of the resulting factors.

There are several different methods of EFA extraction, including principal components analysis, weighted least squares, alpha factor analysis, maximum likelihood, image factor analysis, canonical factor analysis, and so forth (Thompson, 2005). Brown (2006) noted, “For EFA with continuous indicators, the most frequently used factor extraction methods are maximum likelihood (ML) and principal factors (PF)” (p. 21). PF assumes that the scores on measured variables are perfectly reliable, whereas ML assumes multivariate normal distribution of the variables. Because scores are never perfectly reliable, the literature suggests ML instead of PF, when satisfying the distributional assumption. ML basically allows the research to create factors that reproduce the relationships among variables in the population, versus in the sample. Moreover, it provides a variety of fit indices, indicating how well the factor structure fits the data. Thus, after testing a normal distribution assumption, ML was used for the factor extraction in this study.

To determine the number of factors, the four psychometric criteria, such as (a) the Kaiser-Guttman rule (i.e., the eigenvalue-greater-than-one rule), (b) the scree plot, (c) the number of items that substantially load on a factor, and (d) the amount of variance being explained by an extracted factor in relation to the total variance explained by the entire factor solution (Costello & Osborne, 2005; Netemeyer et al., 2003; Thompson, 2005). Note that eigenvalues represent the amount of variance. If an eigenvalue is less than 1.0, the variance explained by a factor is less than the variance of a single item. The scree test also uses the eigenvalues to create a graph, demonstrating the last crucial decrease in the amount of the eigenvalues. Both the eigenvalue rule and the scree plot have broad appeal because of their simplicity and objectivity (Brown, 2006).

Once the number of factors is determined, the extracted factors are rotated in order to enhance their interpretability (i.e., maximize high loadings, minimize low loadings). The fit of the EFA solution is not affected by rotation – that is, the communalities of orthogonal and oblique are the same in EFA (Brown, 2006). More importantly, factor rotation can “produce a solution with the best simple structure” (Brown, 2006, p. 31). There are two rotation techniques: orthogonal (e.g., varimax) and oblique (e.g., promax) rotation. Oblique rotation allows factors to correlate, whereas orthogonal keeps factors uncorrelated. In other words, oblique technique may be appropriate (in most cases) for social science research to examine the degree to which multiple dimensions correlate (Netemeyer et al., 2003). Thus, oblique rotation method (e.g., promax) was used for this study, in order to account for the potential correlation, or lack of correlation, among factors.

In terms of factor selection and item purification, Brown (2006) suggests that factors with loadings no less than .40 but no greater than .90 and/or factors with a small number of items (less than three salient loading items) should be eliminated, to better interpret the resulting factor structure. Accordingly, the author carefully reviewed the meaningfulness and interpretability of selected factors as well as eliminated both poorly defined factors and poorly behaved items.

3.4.3 Item Statistics

Netemeyer et al. (2003) argued that EFA criteria need to be used in tandem with other criteria, such as reliability and item-based statistics (e.g., corrected item-to-total correlations, average inter-item correlations, and item variances). Therefore, such statistics were considered for item purification in this study. Generally, the literature suggests item-to-total correlations of .50 or greater and inter-item correlations of .30 (Hair, Black, Babin, Anderson, & Tatham, 2006; Robinson et al., 1991). However, Netemeyer et al. (2003) indicated that item-to-total correlations of .35 or greater can be accepted if face and /or content validity warrant it. In addition, item means around 4.0 were desired on a six-point Likert scale, assuming that means closer to the extremes (i.e., six) could decrease the amount of variance among items (DeVellis, 2011). Finally, these statistics were merely guidelines that would result in the item deletion if the item had good face and/or content validity (Netemeyer et al., 2003).

3.5 Step 5: Initial Validation (Study 2)

3.5.1 Sample

The target population of this study was pre-service teachers, 18 years or older, enrolled in a teacher education program. The first dataset was collected from 200 pre-service teachers enrolled in a required 3-credit educational technology course in the spring semester, 2013. However, because of a relatively small sample size for factor analysis (n = 100), additional data were collected from students in the College of Education of the same university, in the fall semester, 2013 (n = 591). It was found that these two different datasets did not differ significantly on any variable (all p's > .05). The demographic information of this sample, such as age, gender, ethnicity, major, and school year, was reported. Data from students who responded inappropriately on the demographic survey or missed some items on the PT-PETS were excluded. As a result, 336 students was remained for data analysis of Study 2. This sample size has enough statistical power for the planned data analyses, including confirmatory factor analysis and structural equation modeling.

3.5.2 Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) was used to confirm a measurement model specified by the previous exploratory factor analysis (e.g., the number of factors and the pattern of indicator-factor loadings). The objective of CFA is to test how well the hypothesized model fits the observed data and minimize the difference between them. Brown (2006) indicated that CFA solutions are generally more parsimonious than EFA ones by reproducing the observed relationships between items with fewer parameter estimates than EFA; and CFA can be also used to examine competing factor structures (Netemeyer et al., 2003). Thus, CFA was conducted using Amos 20 to verify the hypothesized model produced by the EFA with the four criteria suggested by Netemeyer et al. (2003): (a) model convergence and an "acceptable range" of parameter estimates, (b) fit indices, (c) significance of parameter estimates and related diagnostics, and (d) standardized residuals and modification indices.

When the differences can no longer be reduced further, the CFA solution was determined to converge. Maximum likelihood (ML) estimates was used, which includes an iterative process to minimize the differences between an observed covariance matrix and a theoretical matrix. Once model convergence had occurred, model fit was examined to assess "the degree to which the observed covariances in the data equate to the covariances implied by the data" (Brown, 2006, p. 151).

In general, there are two types of fit indices, including absolute and comparative fit indices. Absolute fit indices used in this study included chi-square (χ^2) index, the standardized root mean square residual (SRMR), the Akaike Information Criterion (AIC), and the root-mean-square-error-of-approximation (RMSEA). The chi-square value is the traditional measure for evaluating overall model fit. But, because most models with large sample sizes do not account for all measurement error, a non-significant chi-square is rarely obtained. Therefore, the RMSEA was used to adjust for the model complexity tendency and reject an unacceptable model with a large sample, by measuring the amount of misfit per degree of freedom; thus, ideally, the RMSEA equals zero for models of perfect fit. A RMSEA value of .08 or less is generally considered a good fit (Hu &

Bentler, 1999). The SRMR was also used, which is very sensitive to model mis-specification, whereas being less sensitive to sample size (Hu & Bentler, 1998) and sample data distribution (e.g., normal distribution). Although there is no absolute criterion for a *SRMR* value of *acceptable* fit, generally the smaller the SRMR values the better model fit (e.g., < .05; SRMR = 0 indicates perfect fit), because it means less difference between the sample and reproduced covariance matrices. The AIC defined by Jöreskog and Sörbom (1993) takes model parsimony into account by comparing competing CFA models with different numbers of latent variables. Again, there is no absolute criterion for acceptable fit of AIC; generally, smaller values indicate better fit.

Table 11

Cutoff Criteria for Several Fit Indices

Indexes		Recommended value
Absolute fit		
	$\chi 2$	Ratio of $\chi 2$ to $df \leq 2$ or 3
	Akaike information criterion (AIC)	Smaller the better
Comparative fit		
	Comparative fit index (CFI)	> .90
	Tucker-Lewis index (TLI)	> .90
Other		
	Root-mean-square-error-of-approximation (RMSEA)	< .06 to .08
	Standardized RMR (SRMR)	≤ .08

In contrast to absolute fit indices, comparative fit indices assess whether the CFA model provides a better fit to the data than a null model. As the most common fit indices, the comparative fit index (CFI; Bentler, 1990) and the non-normed fit index (NNFI), which is also known as the Tucker-Lewis index (TLI), were used in this study. The CFI and TLI values of .90 or greater are considered a good fit. In sum, it can be concluded that the “smaller is better” strategy is appropriate for absolute fit indices (e.g., SRMR, RMSEA, AIC), while the “bigger is better” is appropriate for comparative fit indices (e.g., CFI, TLI).

In addition to model fit indices, significance of parameter estimates was applied as criterion for item retention. For example, items that did not load significantly on their associated factors were deleted. The acceptable value for item loadings on their respective factors were from .60 to .90 (Bagozzi & Yi, 1988; Brown, 2006).

Lastly, standardized residuals (SRs) and modification indices (MIs) were also used. The value of SRs reflects differences between the hypothetical covariance matrix and the observed covariance matrix that represent a potential evidence of misfit. Hair et al. (1998) noted that SRs greater than +2.57 indicate statistically significant misfit. The value of MIs means the difference in the chi-square between two models - one model has a fixed parameter, while the other has a freely estimated parameter. In other words, MIs reflect the approximate reduction of the overall chi-square model fit when freeing a parameter with an MI of 3.84 or greater (Hair et al., 1998).

3.5.3 Reliability

Coefficient alpha was used to indicate the internal consistency of the proposed scale because it is a conservative estimate of reliability with less measurement error (Ping, 2004; Streiner, 2003). In general, the value of .70 is considered acceptable (Hair et al., 2006); however, the value of .80 is highly recommended for a newly developed scale (Clark & Watson, 1995).

3.6 Step 6: Final Validation (Study 3)

3.6.1 Structural Equation Modeling

Structural Equation Modeling (SEM) is a statistical methodology that provides researchers with techniques of testing how a set of variables define constructs and how these constructs are related to each other (Byrne, 1998; Schumacker & Lomax, 2004). The benefits of structural equation modeling are the abilities (a) to account for the measurement error and unique variance that cannot be explained or controlled with traditional procedures such as multiple regression analysis, (b) to combine factor analytical and regression techniques, and (c) to test multiple paths of influence simulataneously (Lei & Wu, 2007). Thus, SEM was conducted to provide additional evidence of dimensionality, reliability and nomological validity of PT-PETS. Prior to conducting SEM, all assumptions of SEM were tested, including (a) multivariate normal distribution, (b) large sample, and (c) continuous variables. No assumptions were violated.

In order to conduct data analysis, SPSS 20.0 and Amos 20.0 were utilized. Descriptive statistics were done by using SPSS, both confirmatory factor analysis and structural equation modeling were conducted using Amos. Descriptive statistics including mean, standard deviation of the variables, correlation coefficients were obtained in order to summarize variables of interests: *Perceptions of Teacher Educators' Pedagogical Practices*, *Perception of Information Quality*, *Knowledge Sharing Self-efficacy*, *Information Evaluation Self-efficacy*, and all three factors of the PT-PETS (i.e., *Construction of Teaching Knowledge*, *Contextuality of Teaching Knowledge*, and *Complexity of Teaching Knowledge*).

Jöreskog and Sörbom (1993) suggested three approaches to modeling in SEM; (a) strictly confirmatory strategy: formulating and testing a model with empirical data; (b) alternative model or competing model strategy: proposing alternative models with empirical data against the existing theoretical model; and (c) model generating strategy: specifying a tentative, hypothetical model, seeking a well-fitting model with meaningful interpretations of the relationships among the variables. In this study, data were analyzed by applying “model generating strategy” in order to obtain the best model describing the variables of interest contributing to pre-service teachers’ personal epistemologies of teaching. Several important terms used in SEM are briefly described next.

- *Observed variables* are directly measured, so they are assumed to measure associated latent variables. Squares or rectangles represent observed variables in a model (Kline, 2011). *Latent variables* cannot be directly observed or measured, but are measured by a set of observed variables (Schumacker & Lomax, 2004). They are represented by circles or ellipses in a model.
- *Exogenous latent variable* is a variable used as a predictor or independent variable in a model, assuming to affect other variables. *Endogenous latent variable* is a variable predicted by other latent variables in a model, with at least one arrow leading into it. It can be used as dependent variable, but possibly can affect other variables (Kline, 2011).
- *Path diagram* demonstrates hypothesized directional effects of one variable on another either with a line of a single arrowhead (casual) or with a curved line of two arrowheads (correlational) (Kline, 2011). The *measurement errors* indicate

unmeasured portion of the variance of any observed variable, such as random error or systematic error (Kline, 2011; Schumacker & Lomax, 2004).

- *Measurement model* presents the link between latent variables and their associated observed variables with factor loading values. Prior to SEM, assessment of the measurement model gives information about the reliability and validity of the latent variables (Schumacker & Lomax, 2004). *Structural model* describes the relationships among latent variables. The *structure coefficients* are used to represent the strength and direction of the relationships among them. The relationship between a latent exogenous variable (e.g., independent variable) and a latent endogenous variable (e.g., dependent variable) is denoted by γ (gamma), while the relationship between latent endogenous variables is denoted by β (beta).
- *Direct effect* is the effect between two different latent variables with a unidirectional arrow, while *indirect effect* is a mediating effect between two latent variables without a link. The mediating variable contributes to transmitting the causal effects of prior variables to subsequent ones (Kline, 2011). To present the strength of the relationship between latent variables, standardized path coefficients are used as effect size. Effect size, as the indicator of the practical significance of findings, explain the proportion of variance in the dependent variable accounted by the independent variables; small effects = less than .10, medium effects = .10 ~ .30, and large effects = greater than .50 (Pallant, 2013).

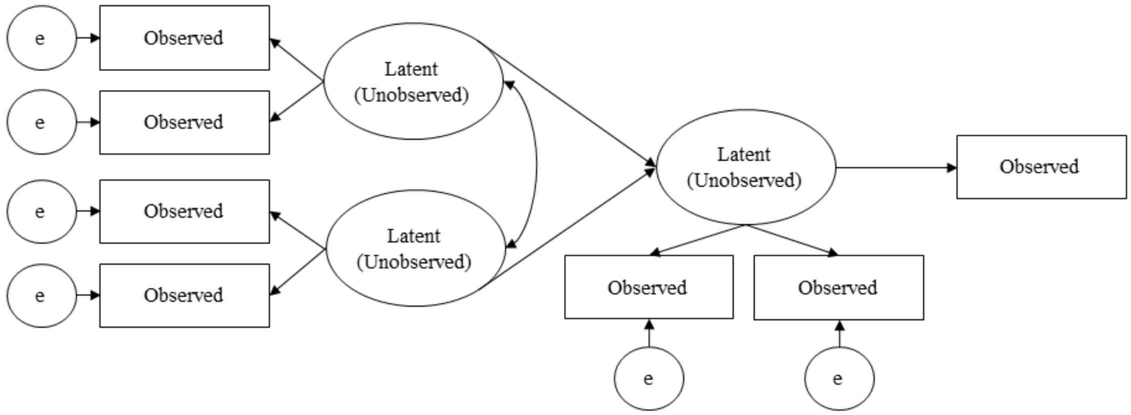

Figure 3. An Example of a Structural Model

Following the two-step procedures of model generation suggested by the literature (Jöreskog & Sörbom, 1993), this study utilized two steps including (a) the establishment and assessment of a measurement model, and then (b) the evaluation of the structural model. The results of the measurement model assessment inform whether an initial hypothetical model needs to be modified or changed before testing.

The goodness of fit criteria were taken as evidence of a global model: for example, chi square ($p > .05$), Comparative Fit Index (CFI; > .90), *Tucker-Lewis index (*TLI; > .90*)*, and Root Mean Square Error of Approximation (RMSEA; < .08). After this, the magnitude and direction of the parameter estimates were examined (Schumacker & Lomax, 2004). Then, total, direct, and indirect effects were examined for testing hypotheses in an initial structural model.

3.6.2 Variable Definitions and Measures

Based on the literature review, *perceptions of teacher educators' pedagogical practices* was selected and defined as one of the most influential variables on pre-service teachers' personal epistemologies of teaching. To assess this variable, the 10 items of

Hennessey, Murphy, and Kulikowich (2013)'s instrument was adopted. The original instrument consisted of 30 Likert-type items about teachers' pedagogical practices designed around each of the three epistemic frameworks, including *Foundationalist*, *Coherentist*, and *Reliabilist* practices. In this study, the 10 pairs of conflicting statements from *Foundationalist* and *Relabilist* perspective were selected that required the respondent to choose between two opposite statements, representing the ends of a continuum of teacher educators' pedagogical practices. Cronbach alphas for each sub-construct from the original studies were .70 (Foundationalist) and .83 (Relabilist).

Table 12

Perceptions of Teacher Educators' Pedagogical Practices (10 items, 6-point Likert scale)

Item	Foundationalist	Reliabilist
1	My instructor provides explanations for new facts that build upon basic understandings.	My instructor emphasizes the importance of aligning thinking with observable evidence.
2	My instructor thinks the premises underlying a topic are central to acquiring knowledge.	My instructor shows that explanations based on observable evidence are more viable than explanations not based on observable evidence.
3	My instructor teaches us to describe how our observations are based on facts that are always true.	My instructor teaches us to provide evidence for our thinking.
4	My instructor teaches us facts that are based on known truths rather than opinion.	My instructor teaches us to explain how our conclusions should be checked by using observable evidence.
5	My instructor teaches us to explain new facts using facts known to everyone.	My instructor asks us to explain how our new understandings can be verified through the collection of data.
6	My instructor teaches us understandings that are evident to everyone.	My instructor teaches us to describe how to collect observations that inform our understandings.
7	My instructor asks us to explain how new information builds upon what is known to be true.	My instructor teaches us to justify our understandings with observable evidence.

8	My instructor uses demonstrations in his/her teaching to reinforce our basic understanding about the content.	My instructor uses demonstrations in his/her teaching to show how reasoning can be confirmed with data collected as evidence.
9	The content my instructor teaches in school is based on a few core concepts.	The content my instructor teaches in school requires us to reason based on evidence.
10	The examples my instructor uses in his/her teaching are derived from a few basic understandings.	The examples my instructor uses in his/her are supported by evidence collected from the natural environment.

As possible theoretically influencing variables, three variables related to knowledge construction and sharing were selected, such as *Perception of Information Quality*, *Knowledge Sharing Self-efficacy*, and *Information Evaluation Self-efficacy*. The eight items of the *Perception of Information Quality* (5 items) and *Information Evaluation Self-efficacy (3 items)*, were adopted and revised from the pre-existing items of Lim (2009)'s instrument, while the three items of *Knowledge Sharing Self-efficacy* were adopted and revised from pre-existing items of Chen and Hung (2010)'s instrument. Cronbach alphas of each sub-construct from the original studies were .90 (Perception of Information Quality), .84 (Information Evaluation Self-efficacy) and .83 (Knowledge Sharing Self-efficacy).

Table 13

Perception of Information Quality, Knowledge Sharing Self-efficacy, and Information Evaluation Self-efficacy (11 items, 6-point Likert Scale)

Factor	No.	Item
Perception of Information Quality (Lim, 2009)	1	Information from online community sites (e.g., forum, blogs, wikis, etc.) is reasonably accurate.
	2	Information from online community sites (e.g., forum, blogs, wikis, etc.) is verifiable elsewhere.
	3	Information from online community sites (e.g., forum, blogs, wikis, etc.) is reliable.
	4	Information from online community sites (e.g., forum, blogs, wikis, etc.) presents views fairly and without bias.
	5	Information from online community sites (e.g., forum, blogs, wikis, etc.) is generally well-written.
Information Evaluation Self-Efficacy (Lim, 2009)	6	I am confident in evaluating the quality of online information.
	7	I am confident in evaluating the credibility of the author(s) of online articles.
	8	I am confident in evaluating the credibility of the sources cited in an online article.
Knowledge Sharing Self-Efficacy (Chen & Hung, 2010)	9	I have confidence in my ability to provide resources and ideas that are valuable to other members in online community sites (e.g., forum, blogs, wikis, etc.).
	10	I have the expertise, experiences and insights needed to provide knowledge valuable for other members in online community sites (e.g., forum, blogs, wikis, etc.).
	11	I have confidence in responding or adding comments to messages or articles posted by other members in online community sites (e.g., forum, blogs, wikis, etc.).

CHAPTER 4. RESULTS

This chapter presents the empirical results of the study described in Chapter 3. According to the sequential nature of scale development, this chapter provides a chronological description of the results of: (a) Development of an Item Pool, (b) Study 1 (Development Sample), (c) Study 2 (Initial Validation), and (d) Study 3 (Final Validation).

4.1 Development of an Item Pool

As described earlier, this study assumes that the construct of personal epistemology should exclude beliefs about learning and intelligence (e.g., innate ability and quick learning), as advocated by Hofer (2000). Therefore, Hofer's *Domain-Focused Epistemological Beliefs Questionnaire* (DFEBQ) was utilized as a primary source to create four preliminary constructs of the *Pre-service Teachers' Personal Epistemologies of Teaching Scale (PT-PETS)*: (a) certainty of teaching knowledge, (b) simplicity of teaching knowledge, (c) source of teaching knowledge, and (d) justification for teaching knowledge, as shown in Table 14.

In terms of the content domain, various aspects of teaching knowledge have been informed by numerous taxonomies and frameworks from the literature (e.g., Elbaz, 1983; Grossman, 1990; Morine-Dershimer & Kent, 1999; Shulman, 1986, 1987; Shulman & Shulman, 2004). However, there is no consensus on the definition of teaching knowledge

(Fives & Buehl, 2010). Therefore, this study defined teaching knowledge as that knowledge which teachers believe is the necessary knowledge for teaching.

Table 14

Four Factors that Constitute the Pre-service Teachers' Personal Epistemologies of Teaching

	Construct	Definition
Nature of Knowledge	Certainty of Teaching Knowledge	Teaching knowledge is viewed as absolute or contextual.
	Simplicity of Teaching Knowledge	Teaching knowledge is viewed as an accumulation of facts or as highly interrelated concepts.
Nature of Knowing	Source of Teaching Knowledge	Teaching knowledge is handed down by external authority or constructed by individuals.
	Justification of Teaching Knowledge	Individual pre-service teachers move through a continuum of dualistic beliefs toward the multiplicity acceptance of opinions to reasoned justification.

Note. Adapted from Hofer (2000).

Once the four hypothesized constructs had been established, an item pool was created for each construct by adapting items from published instruments, as well as generating new items to reflect the nature of teaching knowledge and practices. Because the finalized scale proposed in this study was expected to have around 20 or 30 items (i.e., the four hypothesized constructs with at least 6 items each), it was determined that the item pool should have at least 60 or more items to tap the domain of the *Pre-service Teachers' Personal Epistemologies of Teaching* and exhibit its content validity. The experts and the pre-service teachers helped the author revise 26 items and remove 6 items out of the 60 original items by clarifying unclear terms or eliminating redundant performance indicators. In addition, the experts suggested additional items or made comments about the existing items. Six additional items were removed based on specific written recommendations, indicating that the items were theoretically confounded with other known pre-service teachers' belief constructs. Consequently, a total of 48 out of the 60 items were retained for further evaluation. These 48 items were administered to 8 pre-service teachers. They were asked to provide open-ended feedback via email on each item with regard to item format, item interpretation, response categories, length of the scale, and general impressions of the PT-PETS.

4.2 Study 1: Development Sample (Exploratory Factor Analysis)

The initial validation was designed to empirically examine the factor structure (dimensionality) of the 48 items and purify those items based on its psychometric properties. The EFA allowed the researcher to discover the smallest number of interpretable factors and to explain the correlations among the factors and associated items (Brown, 2006).

4.2.1 Sample

The sample data were inspected for missing data, scores out of specified range of responses, and outliers. Due to the low number of missing items and large sample size, the list-wise deletion method was used to handle missing data. The total number of the respondents was 160 out of the possible 202 subjects. Their demographic profiles were stratified by gender, age, major, student level, race/ethnicity, along with means and standard deviations of the PT-PETS scores for each stratification, as shown in Table 15.

Table 15

Demographic Profiles of the 160 Participants

Category		N	%	M	SD
Gender	Female	116	72.5%	4.67	0.69
	Male	44	27.5%	4.51	0.69
Age	18~22	155	96.9%	4.62	0.69
	23~26	3	1.9%	4.70	1.12
	27~31	1	0.6%	4.42	0.00
	32~	1	0.6%	5.73	0.00
School Year	Freshman	92	57.5	5.11	1.074
	Sophomore	44	27.5	4.98	1.151
	Junior	17	10.6	4.65	.226
	Senior	7	4.4	5.20	.374
Major	Early Childhood Education	11	6.9%	4.60	0.83
	Elementary Education	80	50.0%	4.60	0.67
	Secondary Education	48	30.0%	4.76	0.72
	Others	21	13.1%	4.43	0.57
Specialization	Agricultural Education	11	6.9%	4.53	0.66
	Art Education	5	3.1%	4.91	0.56
	Biology Education	1	0.6%	5.73	0.00
	Chemistry Education	4	2.5%	5.10	0.75
	Engineering/Technology Education	2	1.3%	4.89	1.31
	English Education	15	9.4%	4.70	0.78
	Family and Consumer Science	4	2.5%	4.52	0.41
	Foreign Language Education	1	0.6%	5.42	0.00
	Health Education	6	3.8%	5.04	0.61
	History Education	1	0.6%	4.00	0.00
	Mathematics Education	19	11.9%	4.52	0.69
	Social Studies Education	7	4.4%	4.42	0.56
	Spanish Education	3	1.9%	4.00	1.09
	Special Education	21	13.1%	4.57	0.72
	Others	60	37.5%	4.61	0.66
Race	African American	2	1.3%	5.14	1.20
	Asian	6	3.8%	4.34	0.90
	White	150	93.8%	4.64	0.67
	Multi-racial	2	1.3%	4.00	0.24

4.2.2 Factor Extraction

As shown in Table 16, the normality of PT-PETS item distributions was examined. Results show that all skewness statistics and kurtosis statistics were less than ± 3, indicating a trend of normal distribution (Kline, 2010). This result allowed choosing maximum likelihood (ML) estimation for factor extraction in order to evaluate how well the correlations among the items were predicted by the extracted factors. In addition to ML, Bartlett's test of sphericity, χ^2 (1128, n = 160) = 4627, p <.0001, and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of .901 (>.80) suggested that the data were adequate for common factor analysis (Tabachnick & Fidell, 2001).

Table 16

Descriptive Statistics for PT-PETS (n =160)

Item	Mean	SD	Skew	Kurt
1. Most principles and theories about teaching have changed over time.	5.03	1.075	-1.095	.637
2. Theorists in education would probably come up with different solutions to a teaching problem.	5.10	.973	-1.200	1.645
3. Experts in education understand a specific teaching case in different ways.	5.09	.900	-.803	.171
4. Even the one ideal solution from teaching experts should be questioned.	5.30	.930	-1.631	2.801
5. Even if they are well-studied, no teaching problems could have a certain answer applicable to all situations.	4.94	1.091	-.816	-.074
6. Combining information about teaching and learning across chapters or even across classes is more important than memorizing what the textbooks say.	5.28	1.017	-1.644	2.708
7. Most teaching problems have multiple solutions, even the simplest ones.	5.22	.949	-1.122	.522
8. Possible solutions to a teaching problem can be investigated by reflecting on personal experiences.	4.94	1.050	-.864	.103
9. There is no absolute truth in education.	4.71	1.185	-.790	.197
10. The best way to learn about teaching is to investigate various cases of teaching and then to integrate the different perspectives.	5.14	1.008	-1.486	2.515
11. Students should critically evaluate what the textbooks say.	4.95	.957	-.728	.243

12. Teacher education programs should provide opportunities to work on a variety of teaching cases – each case has multiple solutions.	5.27	.852	-1.042	.720
13. Teaching knowledge will become more integrated and complex over time.	4.71	1.232	-.813	-.012
14. Teaching knowledge is organized as highly integrated concepts.	3.74	1.568	-.240	-.980
15. Teaching knowledge is complex and value-driven.	4.00	1.378	-.307	-.534
16. It is important to give students a chance to re-organize the topics across chapters based on their own framework.	4.29	1.375	-.649	-.187
17. Teaching knowledge should be developed through posing challenging questions and asking 'real-life' solutions.	4.24	1.348	-.380	-.775
18. When solving a teaching problem, the most important thing is to justify my understandings with observable evidence.	3.99	1.445	-.345	-.829
19. The more you know about teaching, the more there is to know.	4.56	1.212	-.702	.161
20. It is important for teachers to stay up-to-date on the current research and practices about teaching.	5.09	1.008	-1.123	1.155
21. The information about how to teach should be presented by showing its relationship with day-to-day life.	4.62	1.228	-.949	.602
22. A good way to understand a textbook is to reorganize the information according to one’s own understanding.	4.81	1.113	-1.022	.920
23. Most key concepts in teaching are different things to different people.	4.89	1.038	-1.119	1.235
24. I prefer to rely on my own experiences or conversations with peers.	4.57	1.325	-.873	.233
25. Students can challenge answers from the teaching experts, even if most accept those answers.	4.53	1.298	-.772	.158
26. Students should evaluate the reliability of information in textbooks.	4.29	1.320	-.391	-.736
27. Although one’s personal experience conflicts with ideas in the textbook, s/he can justify his/her understanding with strong, relevant explanations.	4.78	1.003	-.444	-.372
28. College courses with professional literature (e.g., books, articles) are insufficient to be good teacher and more personal experiences are also needed.	4.51	1.288	-.475	-.665
29. Personal experiences are salient sources of teaching knowledge.	4.52	1.155	-.493	-.174
30. Students should question what the experts know.	4.90	1.077	-.686	-.313
31. How much a person gets at of school mostly depends on the quality of their learning experience.	4.49	1.387	-.853	.064
32. Reflecting on personal experiences is more useful than depending on the knowledge from textbooks, when solving teaching problems.	4.58	1.090	-.521	-.264
33. Teaching knowledge is generated by teachers as a result of their experiences.	3.89	1.383	-.200	-.860

34. Teaching knowledge is constructed through my own experiences.	4.64	1.173	-.766	-.001
35. It is better to find relevant experiences to solve common teaching problems.	4.68	1.141	-.928	.921
36. Development of teaching knowledge is a process of building up your own knowledge based on personal experiences.	4.65	1.245	-.774	-.070
37. I tend to evaluate the accuracy of information given by the instructor.	3.81	1.518	-.453	-.755
38. Forming my own ideas about teaching is more important than memorizing what the textbooks say.	4.49	1.171	-.639	-.240
39. The more you know about teaching, the more there is to know.	4.52	1.223	-.827	.216
40. I try to apply general principles used in similar teaching contexts, but allow for flexibility.	4.44	1.222	-.639	-.321
41. "Teaching wisdom" refers to knowing how to find the solutions to teaching problems.	4.59	1.394	-.966	.140
42. First-hand experience is the best way to learn about teaching and learning.	5.03	1.113	-1.311	1.661
43. There is never one right answer to a teaching problem.	4.45	1.191	-.660	-.006
44. I evaluate any information about teaching obtained from anywhere.	4.44	1.263	-.754	.043
45. Learning to teach is a process in which I personally construct understandings and gain experiences about how to teach.	4.82	1.223	-1.152	1.091
46. Even though someone in authority tells me what to do, I usually question it myself.	3.87	1.575	-.231	-1.050
47. I prefer to rely on my personal knowledge developed through my own teaching experiences.	4.38	1.292	-.729	-.023
48. When I encounter a difficult problem, I try to work it out myself without consultation with anyone.	4.19	1.463	-.526	-.475

4.2.3 Factor Selection

To determine the appropriate number of underlying factors, (1) the Kaiser-Guttman rule (i.e. eigenvalue greater than 1 rule); (2) Cattell's (1966) scree plot; and (3) the goodness-of-fit statistics, such as χ^2 and RMSEA, were used in the current study. As shown in Table 17, four eigenvalues were above 1.0, suggesting a four-factor structure.

Table 17

Total Variance Explained (the eigenvalues > 1.0 rule)

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	
1	16.279	33.914	33.914	15.781	32.877	32.877	10.434
2	4.450	9.272	43.186	3.959	8.248	41.125	10.209
3	2.137	4.453	47.639	1.611	3.355	44.480	5.913
4	1.852	3.859	51.498	1.360	2.833	47.313	5.944
5	1.492	3.108	54.606	.976	2.034	49.347	8.788
6	1.244	2.591	57.197				
7	1.166	2.428	59.625				

Similarly, Figure 4 indicates that eigenvalues curve above a straight line at the fourth factor. However, a much larger change in the eigenvalues occurs at the third factor. This suggests the appropriateness of a three or perhaps four factor solution.

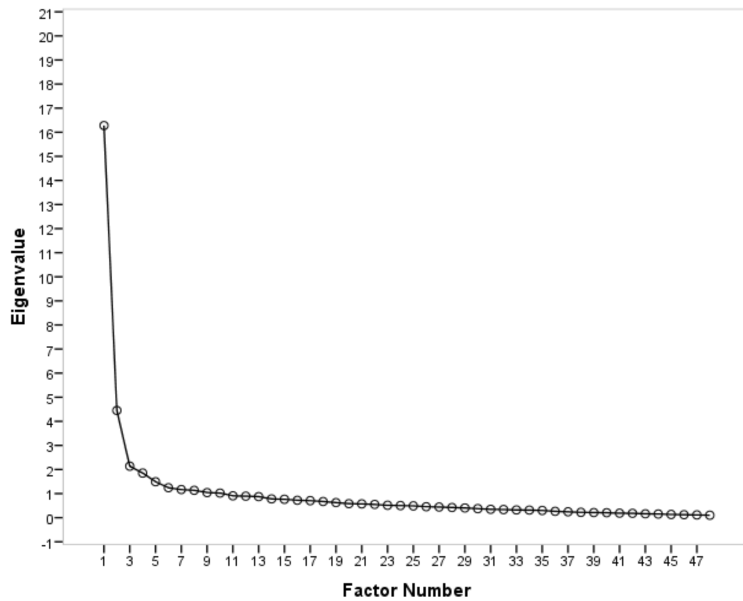

Figure 4. A Scree Test of Eigenvalues from the unreduced correlation matrix

The goodness-of-fit statistics (e.g., χ^2 , RMSEA) also provided information about how well the parameters of the factor model can reproduce the same correlations. Table 18 shows that there is a reduction of over 0.01 between 1-factor to 3-factor model, while there is a reduction of less 0.005 between 3-factor to 5-factor model. This indicates that a three-factor model would be appropriate for the scale.

Table 18

Goodness-of-fit Statistics

	χ^2	df	p	RMSEA	90% C.I.
1-factor model	2609.384	1080	.000	0.094	0.089 - 0.099
2-factor model	1953.831	1033	.000	0.075	0.070 - 0.080
3-factor model	1747.890	987	.000	0.069	0.064 - 0.075
4-factor model	1554.664	942	.000	0.064	0.058 - 0.069
5-factor model	1434.213	898	.000	0.061	0.055 - 0.067

Likewise, all three criteria for the goodness-of-model fit in this study (e.g., eigenvalues, scree plot, and χ^2 and RMSEA values) indicate that the first three factors are the most significant components which represent more than 50% of the variance in pre-service teachers' personal epistemologies of teaching.

4.2.4 Factor Rotation

Since the data suggested a three-factor model of the PT-PETS, three factors were rotated to foster their interpretability. As noted earlier, factor rotation does not affect the fit of factor model (e.g., the number of factors, the combination of items and factors), but allows the researcher to produce the best simple solution, by maximizing factor loadings close to 1.0 and minimizing factor loadings on the remaining factors. In this study, oblique rotation, which assumes the factors to be correlated, was used, because the factors were conceptualized as interrelated aspects of personal epistemology.

To determine which items constitute which factors, the factor loadings of the items for each factor were gauged. According to Steven's (2002) guideline about the relationship between the sample size and cutoff factor loading, items with a factor loading greater than .40 were selected for the designated factor. When an item loaded onto more than one factor (i.e. related to more than one factor, over .30), the item was also excluded to avoid any conceptual uncertainty. This resulted in a three-factor, thirty-item model of the PT-PETS, as shown in Table 19. All 30 items had significant factor loadings onto one of three factors, suggesting each items' unique contribution to one of the factors.

Table 19

Final EFA Results of PT-PETS (Pattern Matrix): 3-factor, 30 items

	Item	Factor Loadings		
		Factor 1	Factor 2	Factor 3
Q45	Learning to teach is a process in which I personally construct understandings and gain experiences about how to teach.	.769		
Q42	First-hand experience is the best way to learn about teaching and learning.	.706		
Q41	"Teaching wisdom" refers to knowing how to find the solutions to teaching problems.	.653		
Q38	Forming my own ideas about teaching is more important than memorizing what the textbooks say.	.647		
Q34	Teaching knowledge is constructed through my own experiences.	.635		
Q39	The more you know about teaching, the more there is to know.	.618		
Q35	It is better to find relevant experiences to solve common teaching problems.	.610		
Q40	I try to apply general principles used in similar teaching contexts, but allow for flexibility.	.587		
Q29	Personal experiences are salient sources of teaching knowledge.	.575		
Q36	Development of teaching knowledge is a process of building up your own knowledge based on personal experiences.	.548		
Q32	Reflecting on personal experiences is more useful than depending on the knowledge from textbooks, when solving teaching problems.	.447		
Q43	There is never one right answer to a teaching problem.	.428		
Q30	Students should question what the experts know.	.412		
Q03	Experts in education understand a specific teaching case in different ways.		.835	
Q02	Theorists in education would probably come up with different solutions to a teaching problem.		.770	
Q04	Most teaching problems have several ideal solutions.		.706	
Q06	Combining information about teaching and learning across chapters or even across classes is more important than memorizing what the textbooks say.		.686	

Q07	Most teaching problems have multiple solutions, even the simplest ones.	.685	
Q05	Even if they are well-studied, no teaching problems could have a certain answer applicable to all situations.	.665	
Q11	Students should critically evaluate what the textbooks say.	.664	
Q10	The best way to learn about teaching is to investigate various cases of teaching and then to integrate the different perspectives.	.639	
Q12	Teacher education programs should provide opportunities to work on a variety of teaching cases – each case has multiple solutions.	.636	
Q08	Possible solutions to a teaching problem can be investigated by reflecting on personal experiences.	.587	
Q01	Most principles and theories about teaching have changed over time.	.513	
Q09	There is no absolute truth in education.	.485	
Q14	Teaching knowledge is organized as highly integrated concepts.		.712
Q15	Teaching knowledge is complex and value-driven.		.682
Q26	Students should evaluate the reliability of information in textbooks.		.584
Q24	I prefer to rely on my own experiences or conversations with peers.		.507
Q18	When solving a teaching problem, the most important thing is to justify my understandings with observable evidence.		.491

Note: Computer program used: SPSS 20. Extraction method: Maximum Likelihood. Rotation: Direct Oblimin (Oblique). Only loadings greater than 0.40 are shown.

The first factor consisted of 13 items that focused on the source of teaching knowing and the justification of teaching knowledge: for example, knowledge coming from an authority source (e.g., textbook, teacher educator, or researcher) or being developed through personal experiences. The second factor was comprised of 12 items that focused on knowledge not being absolute. The third factor includes five items about whether teaching knowledge is an accumulation of facts or comprises highly interrelated concepts.

4.2.5 Item Statistics and Preliminary Reliability

The item-to-total correlations of factor 1, factor 2, and factor 3 revealed values ranging from .54 to .75, from .58 to .72, and from .50 to .62, respectively. Likewise, all the 30 items of the three factors exceeded the prescribed thresholds of .50 for item-to-total correlations and .30 for inter-item correlations (Hair et al., 2006). Item means of factor 1, factor 2, and factor 3 ranged from 4.44 to 5.03, from 4.94 to 5.30, and from 3.74 to 4.57, respectively. Coefficient alpha for factor 1 and factor 2 was .915 and .911; whereas, coefficient alpha for factor 3 was .759. Therefore, the item statistics and the preliminary reliability from the EFA indicates that each factor shows a high level of internal consistency; and these findings led the author to run confirmatory factor analysis using the three-factor structure of the PT-PETS.

4.3 Study 2: Initial Validation (Confirmatory Factor Analysis)

The purpose of the second round of data collection was to examine dimensionality, reliability, and validity by using confirmatory factor analysis. Data were collected from a representative sample of pre-service teacher (n = 336). Referring to Hair et al. (2006) recommendation, a ratio of 10 respondents per item, the sample size was considered acceptable enough. Since the literature indicates that grouping tends to preserve the internal consistency of the measures, the thirty items from three constructs were grouped instead of randomly interspersed (Lam, Green, & Bordignon, 2002; Melnick, 1993).

4.3.1 Sample

As shown in Table 20, participants included 336 pre-service teachers enrolled in a required 2-credit educational technology course either in Spring 2013 or in Fall 2013. The majority of the students were female (76.2%), white (87.2%), first-year (44.9%) students, studying to be elementary (47.3%) or secondary teachers (33.0%).

Table 20

Means and Standard Deviations of the PT-PETS Score by Demographic Profiles of the 336 Participants

Category		N	%	M	SD
Gender	Female	256	76.2%	4.76	0.79
	Male	80	23.8%	4.65	0.90
Age	18~22	304	90.5%	4.72	0.82
	23~26	22	6.5%	4.95	0.54
	27~31	5	1.5%	3.61	1.27
	32~	5	1.5%	5.33	0.47
School Year	Freshman	151	44.9%	4.67	0.83
	Sophomore	80	23.8%	4.73	0.85
	Junior	55	16.4%	4.75	0.87
	Senior	50	14.9%	4.90	0.69
Major	Early Childhood Education	23	6.8%	4.72	0.73
	Elementary Education	159	47.3%	4.69	0.86
	Secondary Education	111	33.0%	4.80	0.81
	Others	43	12.8%	4.70	0.74
Specialization	Agricultural Education	16	4.8%	4.73	0.36
	Art Education	10	2.4%	4.59	0.60
	Biology Education	5	2.4%	4.43	1.21
	Chemistry Education	2	1.2%	5.57	0.37

	Engineering/Technology Education	4	1.2%	4.90	0.13
	English Education	35	9.4%	4.86	0.94
	Family and Consumer Science	7	1.2%	5.01	0.40
	Foreign Language Education	2	0.6%	4.45	0.40
	Health Education	3	8.2%	4.49	0.22
	History Education	14	11.8%	4.24	1.20
	Mathematics Education	33	7.1%	4.76	0.77
	Social Studies Education	40	1.2%	4.68	0.72
	Spanish Education	4	13.1%	4.45	1.61
	Special Education	51	36.5%	4.80	0.77
	Others	110	32.7%	4.74	0.86
Race	African American	5	1.5%	4.37	0.76
	Asian	18	5.4%	4.43	0.82
	White	293	87.2%	4.79	0.89
	Multi-racial	20	5.9%	4.33	0.82

Note: Mean and SD values were obtained by averaging the scores in each item of the revised PT-PETS (30 items). Mean scores could range from 0 to 6.

4.3.2 Overall Goodness of Fit

A confirmatory factor analysis (CFA) was conducted based on the three-factor solution with the 30 items produced from the exploratory factor analysis (EFA) in Study 1. EFA was used to identify the underlying factor structure of the PT-PETS and to remove items that loaded poorly onto the intended factors. CFA was performed to confirm the proposed factor structure of the measurement model that emerged from the sample with addition purification of the scale. The covariance matrix from the specified measurement model (i.e. three factors being predicted by 30 observable indicators) was entered into Mplus 6.12. The comparative fit index (CFI), the Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA) were used to evaluate overall goodness of fit. The results of the initial CFA indicated the three-factor measurement model with 30 items provided a poor fit to the data (See Table 21). First of all, the overall model fit was not great with a $\chi 2$ statistic of 1082.881 (*df* = 402), large enough to reject the null of a good fit. Overall goodness-of-fit indices fell below accepted thresholds: CFI = .886, TLI = .877, RMSEA = .071, and SRMR =.050. This means the 3-factor measurement model with 30 items did not fit well with the whole data, did not produce uniformly interpretable parameter estimates. All of the items loaded significantly on the associated factors ($p < .05$).

4.3.3 Localized Areas of Strain

To improve the model fit significantly, additional purification and refinement were required on poor performing items based on their standardized loadings, significance of loadings, standardized residuals, modification indices, and error variances. This process was undertaken until the desired model fit was achieved. Items 24 and 41 had the lowest R^2 values at .240 and .360 respectively, indicating that both items contributed little to the variance in the model. Therefore they were removed. Standardized residuals (SRs) were less than 1.96 in magnitude, indicating that there were no significant differences between the theoretical covariance matrix and the observed covariance matrix; however, modification indices (MIs) revealed that several items cross loaded on two factors (Items 2, 3, 7, and 12, all of which originally were associated with factor 2; Items 39 and 42 were part of factor 1). The literature suggests that removing cross-loading items helps interpret the factor structure and thus significantly improves the model fit (Anderson & Gerbing, 1988). In accordance with this suggestion, elimination of the cross-loading items resulted in a model that approached an acceptable fit to the data, $\chi^2(249, N = 336) = 576.311, p < .05$; CFI = .923, TLI = .915; RMSEA = .063, and SRMR = .048, all standardized factor loadings were substantial (>.45). MIs also showed that there were many items with correlated errors that generally should be avoided because they suggest an overlap in content coverage (Schweizer, 2010). By far, the largest modification index suggested that the errors of Item 26 (i.e., Students should evaluate the reliability of information in textbooks) and Item 30 (i.e., Students should question what the experts know) be allowed to correlate. In this case, Item 26 was removed from factor 3 instead of allowing its error with Item 30, because it contributed to a better overall model fit than did the removal of Item 30: $\chi^2(186, N = 336) = 395.782$, $p < .05$; CFI = .945, TLI = .938; RMSEA = .058, and SRMR = .042. The same issue was present for Items 29 and 36. The correlated errors between these two items were found; removing Item 29 contributed to better model fit than did removing Item 36: $\chi^2(167, N = 336) = 343.238$, $p < .05$; CFI = .951, TLI = .944; RMSEA = .056, and SRMR = .037 (See Table 22).

Table 21

Initial CFA Results (3-factor model; 30 items)

	Fit Indices	
	$\chi 2$ (df = 402, N = 336)	1082.881
	p-value	.000
	AIC	1265.658
	Comparative fit index (CFI)	.886
	Tucker-Lewis index (TLI)	.877
	Root mean square error of approximation (RMSEA)	.071
	Standardized root mean square residuals (SRMR)	.050

No.	Item	Loadings
	Factor 1	
Q42	First-hand experience is the best way to learn about teaching and learning.	.769
Q45	Learning to teach is a process in which I personally construct understandings and gain experiences about how to teach.	.748
Q32	Reflecting on personal experiences is more useful than depending on the knowledge from textbooks, when solving teaching problems.	.739
Q35	It is better to find relevant experiences to solve common teaching problems.	.736
Q38	Forming my own ideas about teaching is more important than memorizing what the textbooks say.	.733
Q30	Students should question what the experts know.	.703
Q36	Development of teaching knowledge is a process of building up your own knowledge based on personal experiences.	.693
Q40	I try to apply general principles used in similar teaching contexts, but allow for flexibility.	.683
Q29	Personal experiences are salient sources of teaching knowledge.	.679
Q34	Teaching knowledge is constructed through my own experiences.	.675
Q39	The more you know about teaching, the more there is to know.	.668
Q43	There is never one right answer to a teaching problem.	.659
Q41	"Teaching wisdom" refers to knowing how to find the solutions to teaching problems.	.470
	Factor 2	
Q06	Combining information about teaching and learning across chapters or even across classes is more important than memorizing what the textbooks say.	.779

Q12	Teacher education programs should provide opportunities to work on a variety of teaching cases – each case has multiple solutions.	.770
Q04	Most teaching problems have several ideal solutions.	.769
Q07	Most teaching problems have multiple solutions, even the simplest ones.	.769
Q05	Even if they are well-studied, no teaching problems could have a certain answer applicable to all situations	.738
Q10	The best way to learn about teaching is to investigate various cases of teaching and then to integrate the different perspectives.	.730
Q08	Possible solutions to a teaching problem can be investigated by reflecting on personal experiences.	.723
Q03	Experts in education understand a specific teaching case in different ways.	.698
Q01	Most principles and theories about teaching have changed over time.	.697
Q02	Theorists in education would probably come up with different solutions to a teaching problem.	.686
Q09	There is no absolute truth in education.	.648
Q11	Students should critically evaluate what the textbooks say.	.612
	Factor 3	
Q18	When solving a teaching problem, the most important thing is to justify my understandings with observable evidence.	.743
Q15	Teaching knowledge is complex and value-driven.	.737
Q14	Teaching knowledge is organized as highly integrated concepts.	.714
Q26	Students should evaluate the reliability of information in textbooks.	.635
Q24	I prefer to rely on my own experiences or conversations with peers.	.594

Note: Computer program used: Mplus 6.12. Input matrix: covariance. All factor loadings are completely standardized and significant at $p < .05$.

Table 22

Final CFA Results (3-factor model; 20 items)

	Fit Indices	
	$\chi2$ (*df* = 249, *N* = 336)	343.238
	p-value	.000
	AIC	469.238
	Comparative fit index (CFI)	.951
	Tucker-Lewis index (TLI)	.944
	Root mean square error of approximation (RMSEA)	.056
	Standardized root mean square residuals (SRMR)	.037

No.	Item	Loadings
	Factor 1	
Q45	Learning to teach is a process in which I personally construct understandings and gain experiences about how to teach.	.741
Q35	It is better to find relevant experiences to solve common teaching problems.	.737
Q32	Reflecting on personal experiences is more useful than depending on the knowledge from textbooks, when solving teaching problems.	.737
Q38	Forming my own ideas about teaching is more important than memorizing what the textbooks say.	.734
Q30	Students should question what the experts know.	.712
Q40	I try to apply general principles used in similar teaching contexts, but allow for flexibility.	.684
Q36	Development of teaching knowledge is a process of building up your own knowledge based on personal experiences.	.682
Q34	Teaching knowledge is constructed through my own experiences.	.672
Q43	There is never one right answer to a teaching problem.	.647
	Factor 2	
Q06	Combining information about teaching and learning across chapters or even across classes is more important than memorizing what the textbooks say.	.782
Q04	Most teaching problems have several ideal solutions.	.767
Q05	Even if they are well-studied, no teaching problems could have a certain answer applicable to all situations.	.731
Q10	The best way to learn about teaching is to investigate various cases of teaching and then to integrate the different perspectives.	.730
Q08	Possible solutions to a teaching problem can be investigated by	.729

	reflecting on personal experiences.	
Q01	Most principles and theories about teaching have changed over time.	.704
Q09	There is no absolute truth in education.	.663
Q11	Students should critically evaluate what the textbooks say.	.618
	Factor 3	
Q15	Teaching knowledge is complex and value-driven.	.741
Q14	Teaching knowledge is organized as highly integrated concepts.	.722
Q18	When solving a teaching problem, the most important thing is to justify my understandings with observable evidence.	.713

Note: Computer program used: Mplus 6.12. Input matrix: covariance. All factor loadings are completely standardized and significant at $p < .05$.

The first factor was labeled as *Construction of Teaching Knowledge* (Items 30, 32, 34, 35, 36, 38, 40, 43, and 45; 9 items), which is associated with pre-service teachers' beliefs about the nature of the knowing process in teaching, such as source of knowledge (i.e., Authority: Teaching knowledge is handed down by external authority or constructed by individuals) and justification process (i.e., Evaluation: Individuals move through a continuum of dualistic beliefs toward the multiplicity acceptance of opinions to reasoned justification). The second factor was labeled *Contextuality of Teaching Knowledge* (Items 1, 4, 5, 6, 8, 9, 10, and 11; 8 items), which describes individual beliefs about the nature of teaching knowledge, such as certainty of knowledge (i.e. Teaching knowledge is viewed as absolute or contextual). Lastly, the third factor was labeled as *Complexity of Teaching Knowledge* (Items 14, 15, and 18; 3 items), which focuses on whether teaching knowledge is viewed as an accumulation of facts or comprise highly interrelated concepts.

The resulting scale contains 20 items that appear to measure the three aspects of the PT-PETS, which the author labeled *Construction of Teaching Knowledge*, *Contextuality of Teaching Knowledge*, and *Complexity of Teaching Knowledge*. Overall, results support the idea that pre-service teachers' personal epistemologies of teaching are multidimensional and complex.

4.4 Study 3: Final Validation (Structural Equation Modeling)

The purpose of Study 3 was to examine the theoretical relationships between antecedents and outcomes of pre-service teachers' personal epistemologies using structural equation modeling (Amos 20 software). It was designed to assess the nomological validity, as a type of construct validity, of a newly developed scale, the PT-PETS, by investigating the extent to which constructs that are theoretically related are empirically related (Netemeyer et al., 2003). Therefore, two different datasets, such as 1) perceptions of teacher educators' pedagogical practice, 2) perceptions of information quality, and 3) knowledge sharing within online communities, were collected from the same sample as Study 2, in addition to PT-PETS dataset. According to the recommendations from the literature (Anderson & Gerbing, 1988; Jöreskog & Sörbom, 1993; Schumacker & Lomax, 2004), the two-step approach was employed: assessment of measurement models and structural models.

4.4.1 Descriptive Statistics and Correlation among the Variables

To test the normality assumption, the means, standard deviations, skewness and kurtosis for all the measured variables were analyzed together. The means ranged from 3.40 to 4.82, and the standard deviations from 0.86 to 1.12. The absolute values of the skewness ranged from 0.23 to 1.16, while those of the kurtosis ranged from 0.12 to 1.9, indicating normal distribution of the data (Curran,West & Finch, 1996). To check the strength of the relationships among the variables of interest, correlations were also examined and the results showed significant correlations among all of the variables at the alpha level of 0.01 (See Table 23).

Table 23

Means, Standard Deviations and Correlation Coefficients (n = 336)

			Pearson Correlation Coefficient						
Constructs	M	SD	1	2	3	4	5	6	7
Construction of Teaching Knowledge	4.7080	.91456	-						
Contextuality of Teaching Knowledge	4.8289	.85927	.775**	-					
Complexity of Teaching Knowledge	4.6806	.99641	.693**	.781**	-				
Perceptions of Teacher Educator’s Pedagogical Practices	4.1789	1.11973	.490**	.513**	.567**	-			
Perception of Information Quality	3.3994	1.00856	.157**	.140*	.175**	.214**	-		
Knowledge Sharing Self-efficacy	4.0228	1.04515	.223**	.287**	.277**	.195**	.437**	-	
Information Evaluation Self-efficacy	4.3690	1.02734	.322**	.379**	.346**	.196**	.316**	.710**	-

**Significant at the alpha level of 0.01

4.4.2 Theoretical Model and Hypotheses

A growing number of studies have argued that personal epistemology may play a direct or mediated role in knowledge change, along with other motivational constructs, such as mastery goals, personal interest, values, self-efficacy, and control beliefs (e.g., Mason & Boscolo, 2004; Sinatra et al., 2003; Stathopoulou & Vosniadou, 2004); as well as contextual constructs, such as teacher's pedagogical practices, and classroom environments (e.g., Hammer & Elby, 2002; Tsai & Chuang, 2005; Tsai, 2012). In spite of empirical evidence demonstrating the relationships between teacher's pedagogical practices and students' personal epistemologies (e.g., Conley, Pintrich, Vekiri, & Harrison, 2004; Hofer, 2001) and personal epistemology and knowledge management (e.g., Matthew & Simon, 2012; Tillema & Orland-Barak, 2066), little has been investigated on the cause-and-effect relationships among such variables. Therefore, this study examined whether and how other factors influencing knowledge construction (e.g., *Perception of Information Quality*, *Knowledge Sharing Self-efficacy*, and *Information Evaluation Self-efficacy*) play an indirect role by affecting pre-service teachers' personal epistemologies of teaching, according to types of *Teacher Educators' Pedagogical Practices*, as shown in Figure 5. A formal statement of each hypothesis in the model is provided below with a brief description of the rationale behind such hypotheses. The hypotheses were generated following the flow of the model from antecedents to outcomes.

$\mathbf{H_1}$: Perceptions of teacher educators' pedagogical practices (i.e., Foundationalism versus Reliabilism) are positively related to pre-service teachers' knowledge sharing self-efficacy.

$\mathbf{H_2}$: Perceptions of teacher educators' pedagogical practices are positively related to pre-service teachers' information evaluation self-efficacy.

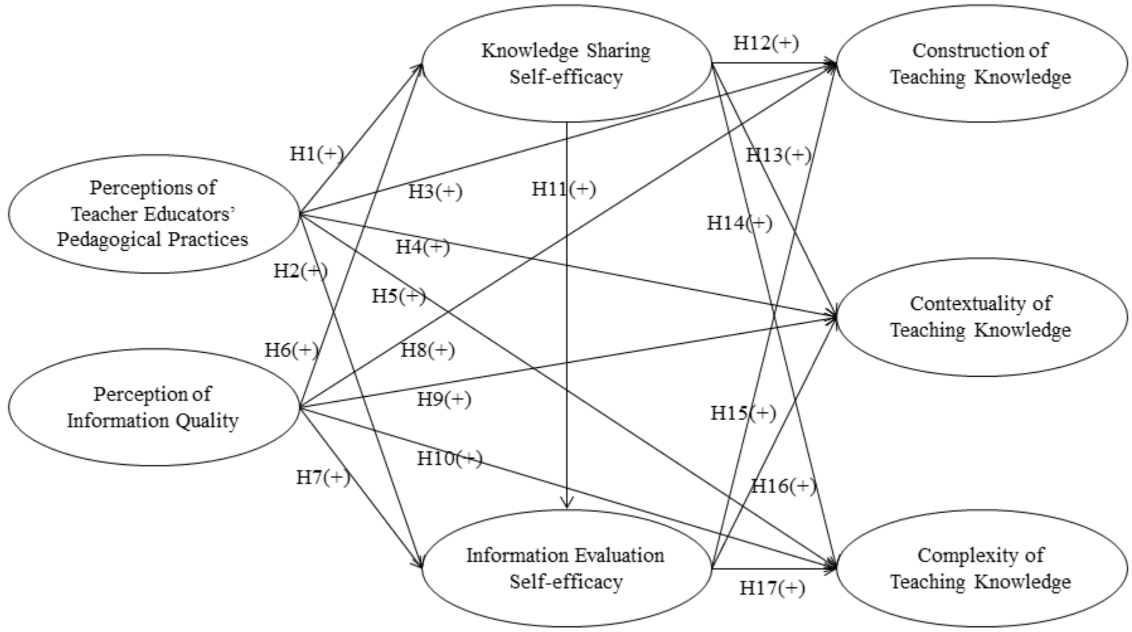

Figure 5. Hypothesized Model

$\mathbf{H_3}$: Perceptions of teacher educators' pedagogical practices are positively related to pre-service teachers' sophisticated beliefs about the construction of teaching knowledge.

$\mathbf{H_4}$: Perceptions of teacher educators' pedagogical practices are positively related to pre-service teachers' sophisticated beliefs about the contextuality of teaching knowledge.

$\mathbf{H_5}$: Perceptions of teacher educators' pedagogical practices are positively related to pre-service teachers' sophisticated beliefs about the complexity of teaching knowledge.

The types of pedagogical practices that a teacher educator chooses to apply in classroom may serve as a model to help their students develop their own justifications of teaching knowledge (Hennessey, Murphy, & Kulikowich, 2013).

$\mathbf{H_6}$: Perception of information quality is positively related to knowledge sharing self-efficacy.

$\mathbf{H_7}$: Perception of information quality is positively related to information evaluation self-efficacy.

$\mathbf{H_8}$: Perception of information quality is positively related to sophisticated beliefs about the construction of teaching knowledge.

$\mathbf{H_9}$: Perception of information quality is positively related to sophisticated beliefs about the contextuality of teaching knowledge.

$\mathbf{H_{10}}$: Perception of information quality is positively related to sophisticated beliefs about the complexity of teaching knowledge.

A pre-service teacher's perception about the credibility of Web information may affect self-efficacies about the knowledge construction process and understandings about the nature of teaching knowledge.

$\mathbf{H_{11}}$: Knowledge sharing self-efficacy is positively related to information evaluation self-efficacy.

$\mathbf{H_{12}}$: Knowledge sharing self-efficacy is positively related to sophisticated beliefs about the construction of teaching knowledge.

$\mathbf{H_{13}}$: Knowledge sharing self-efficacy is positively related to sophisticated beliefs about the contextuality of teaching knowledge.

$\mathbf{H_{14}}$: Knowledge sharing self-efficacy is positively related to sophisticated beliefs about the complexity of teaching knowledge.

From a social constructivism perspective, knowledge creation and sharing are considered to be a dynamic and continuous process of justifying individual beliefs toward the truth. Such process contains the critical evaluation of the credibility of potential knowledge sources. Therefore, if an individual is confident in sharing knowledge sources (e.g., personal teaching experiences, relevant research findings) within online communities, s/he may hold or develop sophisticated beliefs about the nature of teaching knowledge (e.g., knowledge is evolving, highly interrelated, and justified by experiences).

$\mathbf{H_{15}}$: Information evaluation self-efficacy is positively related to sophisticated beliefs about the construction of teaching knowledge.

$\mathbf{H_{16}}$: Information evaluation self-efficacy is positively related to sophisticated beliefs about the contextuality of teaching knowledge.

$\mathbf{H_{17}}$: Information evaluation self-efficacy is positively related to sophisticated beliefs about the complexity of teaching knowledge.

Online searching for information requires metacognitive monitoring that is an underlying activity for understanding new terms or uncertain information. Through this process, an individual may experience changes in beliefs about the nature of teaching knowledge.

4.4.3 Assessment of Measurement Model

In accordance with the two-step procedures of SEM (Anderson & Gerbing, 1988), the measurement model was specified and tested by CFA, prior to testing the full structural model, in order to assess validity and reliability of the latent constructs. Since the initial measurement model that contained seven latent variables loading on 41 indicators, item parceling was used to reduce the total items from different constructs into a smaller number of indicators for each construct. Parceling technique (bundling or grouping items) has recently gained considerable attention in the structural equation modeling (SEM) community (Bandalos, 2008). Item parcel can be defined “as an aggregate-level indicator comprised of the sum (or average) of two or more items, responses, or behaviors” (Little, Cunningham, Shahar, & Widaman, 2002, p. 152). That is, summing or averaging item scores from two or more items of the same scale can be used instead of individual item scores in a SEM analysis. Item parcels are more interpretable and reliable than individual items as latent variable indicators and even more likely to satisfy assumptions of multivariate normal distribution (Marsh, Hau, Balla, & Grayson, 1998; Sass & Smith, 2006). Therefore, parcels were grouped according to the guidelines of Coffman and MacCallum (2005) – items were randomly assigned to parcels per construct and the mean of items were used. As a result, the goodness of fit indices were produced as shown in Table 24, indicating this model has a good fit with the data collected.

Table 24

Fit Statistics for the Measurement Model (n = 336)

	Recommended value	Measurement model
$\chi 2$ / *df*	-	207.447 / 76
Comparative fit index (CFI)	> .90	.945
Tucker-Lewis index (TLI)	> .90	.913
Root mean square error of approximation (RMSEA)	< .08	.072

As shown in Figure 6, the validity of constructs was assessed by factor loadings, which ranged from .594 to .915. Hair et al. (2006) recommended that a factor loading greater than .50 is desirable and indicate a solid factor.

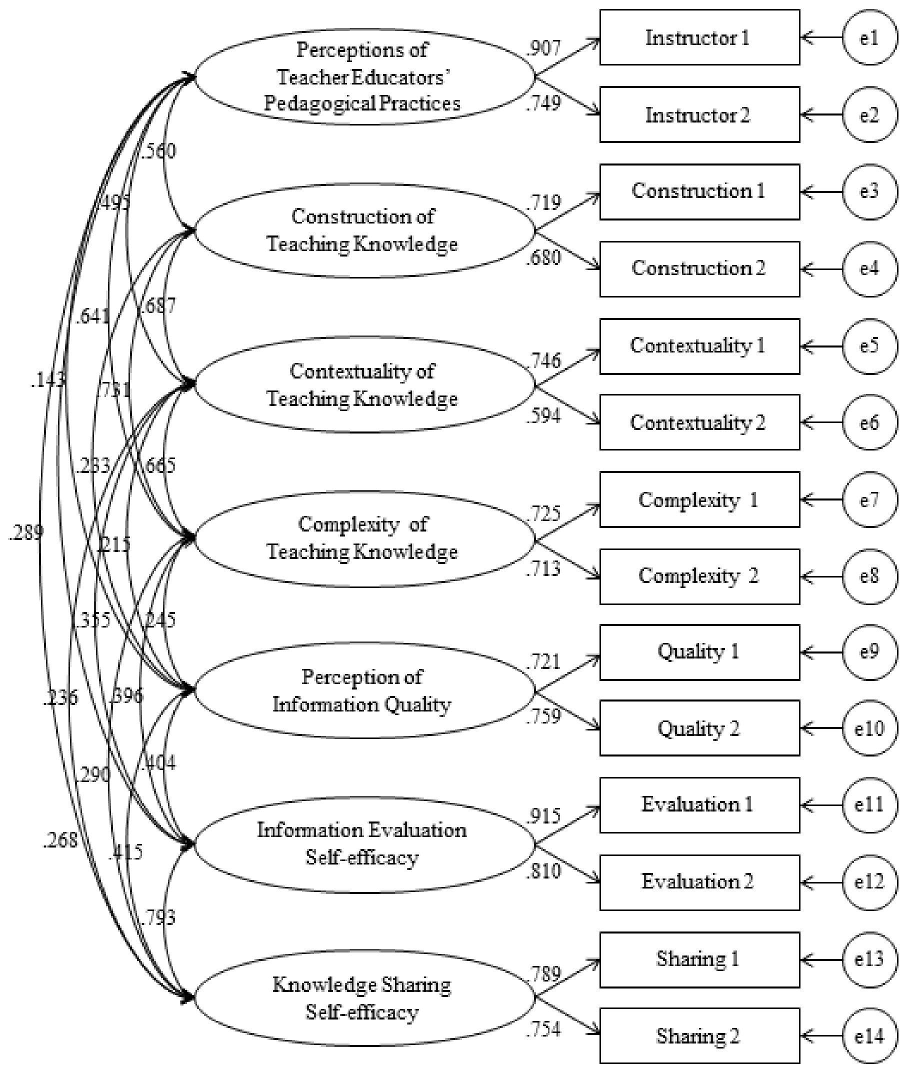

Figure 6. Confirmatory Factor Analysis for Measurement Model

4.4.4 Structural Equation Modeling for Hypothesis Testing

Since the first step of analyses revealed a good-fitting measurement model, the second step was undertaken to test the hypothesized model via structural equation modeling (Amos 20). Table 25 shows that the structural model also demonstrates a very good fit to the data. To test hypotheses, direct effects between constructs were assessed at the alpha level of .05, by examining the strength and direction of the relationships among constructs; for example, the relationships among exogenous and endogenous variables were identified by γ (lowercase gamma), while the relationships among endogenous variables were by β (lowercase beta).

Table 25

Fit Statistics for the Initial Structural Model (n = 336)

	Recommended value	Structural model
χ2 / *df*	-	135.689 / 58
Comparative fit index (CFI)	> .90	.959
Tucker-Lewis index (TLI)	> .90	.935
Root mean square error of approximation (RMSEA)	< .08	.063

From the initial structural model, it was found that the effect of *Perceptions of Teacher Educators' Pedagogical Practices* on pre-service teachers' *Knowledge Sharing Self-efficacy* was statistically significant ($\gamma = .210$, $p < 0.05$), supporting hypothesis 1. In terms of the relationship with the three factors of the PT-PETS, the effect of *Perceptions of Teacher Educators' Pedagogical Practices* on *Complexity of Teaching Knowledge* was statistically significant ($\gamma = .794$, $p < 0.05$), while the effect of *Perceptions of Teacher Educators' Pedagogical Practices* on *Construction of Teaching Knowledge* ($\gamma = .655$, p = .049) and *Contextuality of Teaching Knowledge* ($\gamma = .687$, p = .063) were not. These findings supported hypothesis 5.

The effect of *Perception of Information Quality* on *Knowledge Sharing Self-efficacy* was significant ($\beta = .413$, $p < 0.05$), supporting hypothesis 6; however, there were no significant effects on the other latent variables. The paths between *Knowledge Sharing Self-efficacy* with all the associated endogenous variables were found to have significant values. It shows the positive direct effect of *Knowledge Sharing Self-efficacy* on *Information Evaluation Self-efficacy* (β = .788, $p < 0.001$), but the negative direct effects of *Knowledge Sharing Self-efficacy* on all the three factors of the PT-PETS; *Construction of Teaching Knowledge* (β = -.179, $p < 0.001$), *Contextuality of Teaching Knowledge* (β = -.568, $p < 0.001$), and *Complexity of Teaching Knowledge* (β = -.697, $p < 0.001$). The effect of *Information Evaluation Self-efficacy* on the three factors of PT-PETS showed significantly positive values; *Construction of Teaching Knowledge* (β = .687, $p < 0.001$), *Contextuality of Teaching Knowledge* (β = .458, $p < 0.001$), and *Complexity of Teaching Knowledge* (β = .520, $p < 0.001$).

Based on these findings, insignificant path coefficients were removed from the initial model; and as a result, the modified model demonstrated a good fit, showing a very strong predictive power, as shown above in Table 26. The standardized path coefficients of the modified model appeared in Figure 7.

Table 26

Fit Statistics for the Modified Structural Model (n = 336)

	Recommended value	Structural model
$\chi 2$ / *df*	-	158.021 / 64
Comparative fit index (CFI)	> .90	.950
Tucker-Lewis index (TLI)	> .90	.929
Root mean square error of approximation (RMSEA)	< .08	.066

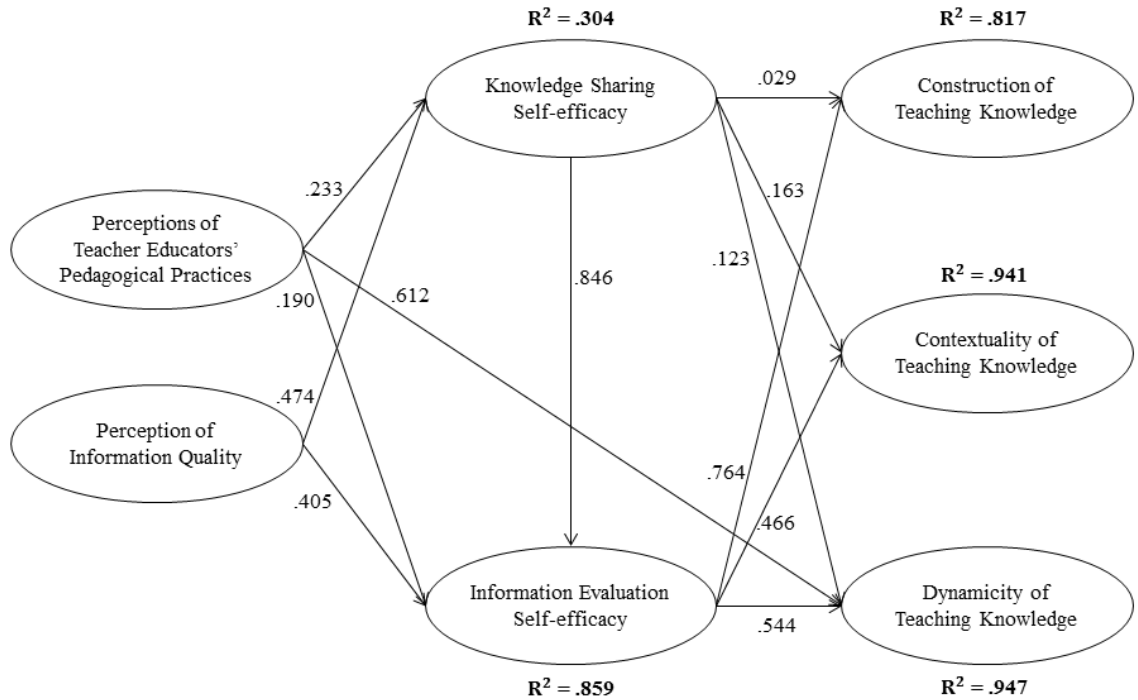

Figure 7. A Modified Model with Standardized Path Coefficients

4.4.4.1 Perceptions of Teacher Educators' Pedagogical Practices and PT-PETS

The results of the modified structural model demonstrates that the effect of *Perceptions of Teacher Educators' Pedagogical Practices* and pre-service teachers' *Knowledge Sharing Self-efficacy* was statistically significant (γ = .233, $p < 0.05$), supporting hypothesis 1. In addition, the significant mediating effect of *Knowledge Sharing Self-efficacy* between *Perceptions of Teacher Educators' Pedagogical Practices* and *Information Evaluation Self-efficacy* was found (β = .244, $p < 0.05$, CI: .085 ~ .402). In terms of the relationship with the three factors of PT-PETS, the direct effect of *Teacher Educators' Pedagogical Practices* on *Complexity of Teaching Knowledge* was statistically significant (γ =.827, $p < 0.05$), supporting hypothesis 5. Overall, *Perceptions of Teacher Educators' Pedagogical Practices* showed the largest total effect on one of the PT-PETS factors, *Complexity of Teaching Knowledge* (γ =.612; see table 27). This finding supports the previous study that the pedagogical practices teacher educators employ in their programs provide pre-service teachers with a model for what counts as teaching knowledge as well as how they can acquire teaching knowledge (Hennessey et al., 2013).

Table 27

Total Effects Establishing Nomological Validity of the PT-PETS

H.	Path		*Direct Effects*	*Indirect Effects*	*Total Effects*
H1	Perceptions of Teacher Educators' Pedagogical Practice	→ Knowledge sharing Self-efficacy	.233	-	.233
H2		→ Information Evaluation Self-efficacy	-	.244*	.190
H5		→ Dynamicity of teaching knowledge	.827*	-	.612
H6	Perception of Information Quality	→ Knowledge sharing Self-efficacy	.474*	-	.474
H7		→ Information Evaluation Self-efficacy	-	.496*	.405
H11	Knowledge Sharing Self-efficacy	→ Information Evaluation Self-efficacy	.846**	-	.846
H12		→ Construction of teaching knowledge	-.164**	.194**	.029
H13		→ Contextuality of teaching knowledge	-.555**	.718**	.163
H14		→ Dynamicity of teaching knowledge	-.631**	.754**	.123
H15	Information Evaluation Self-efficacy	→ Construction of teaching knowledge	.764**	-	.764
H16		→ Contextuality of teaching knowledge	.466**	-	.466
H17		→ Dynamicity of teaching knowledge	.544**	-	.544

4.4.4.2 Perception of Information Quality and PT-PETS

The effect of *Perception of Information Quality* on *Knowledge Sharing Self-efficacy* was significant (β =. 474, $p < 0.05$), supporting hypothesis 6. It was also found the significant mediating effect of *Knowledge Sharing Self-efficacy* between *Perception of Information Quality* and *Information Evaluation Self-efficacy* (β =.496, $p < 0.05$, CI: .222 ~ .774).

4.4.4.3 Knowledge Sharing Self-efficacy and PT-PETS

As hypothesized, *Perceptions of Teacher Educators' Pedagogical Practices* (γ = .233) and *Perception of Information Quality* (β =. 474) were positively related to *Knowledge Sharing Self-efficacy*. The two variables accounted for roughly 30% of the variance in *Knowledge Sharing Self-efficacy* (R^2 = .304)[3]. In addition, the positive effect of *Knowledge Sharing Self-efficacy* on *Information Evaluation Self-efficacy* was found (β = .846, $p < 0.001$), supporting hypothesis 11. Interestingly, the results showed the significantly negative direct effects of *Knowledge Sharing Self-efficacy*, but positive indirect effects on all the three factors of PT-PETS in combination of higher level of *Information Evaluation Self-efficacy*; *Construction of Teaching Knowledge* (β = .194, $p <$ 0.001, CI: .019 ~ .643); *Contextuality of Teaching Knowledge* (β = .718, $p < 0.001$, CI: .219 ~ .843); and *Complexity of Teaching Knowledge* (β = .754, $p < 0.001$, CI: .029 ~ .873).

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[3] R^2: <.10: trivial; .10 - .30: small to medium; .30 - .50: medium to large; >.50: large to very large

4.4.4.4 Information Evaluation Self-efficacy and PT-PETS

The three variables, *Perceptions of Teacher Educators' Pedagogical Practices* (γ = .233), *Perception of Information Quality* (β =. 474), and *Knowledge Sharing Self-efficacy* (β = .846) together explained 85.9% of the variance in *Information Evaluation Self-efficacy* (R^2 = .859). Also consistent with the hypotheses, the effect of *Information Evaluation Self-efficacy* on the three factors of PT-PETS showed significantly positive values; *Construction of Teaching Knowledge* (β = .764, $p < 0.001$), *Contextuality of Teaching Knowledge* (β = .46, $p < 0.001$), and *Complexity of Teaching Knowledge* (β = .544, $p < 0.001$), supporting hypotheses 15, 16, and 17. Therefore, *Information Evaluation Self-efficacy* was considered as a strong predictor of personal epistemologies of teaching. The explanatory power of the model is evident in the R^2 values for the three factors of the PT-PETS, *Construction of Teaching Knowledge* (R^2 = .817), *Contextuality of Teaching Knowledge* (R^2 = .941), and *Complexity of Teaching Knowledge* (R^2 = .947). Therefore, the two variables, *Perceptions of Teacher Educators' Pedagogical Practices* (γ = .233) and *Information Evaluation Self-efficacy* (β = .764) are very strong predictors of the three factors of the PT-PETS.

Overall, the construct of personal epistemologies of teaching performs as expected in the hypothesized model, confirming the nomological validity of the scale as a measure of pre-service teachers' personal epistemologies of teaching.

CHAPTER 5. DISCUSSION

The main purpose of this study was to develop a reliable and valid instrument to assess pre-service teachers' personal epistemologies of teaching. The research questions were as follows:

1. To what extent can a reliable measure of *Pre-service Teachers' Personal Epistemologies of Teaching Scale (PT-PETS)* be developed?
2. To what extent can evidence of internal structure validity be identified for the newly developed PT-PETS?
3. What are the relationships between pre-service teachers' personal epistemologies of teaching and their perceptions of knowledge sharing and information evaluation in a conceptual nomological net?

This study first reviewed the literature related to development and validation of teachers' beliefs about the nature of teaching knowledge. Constructs such as teachers' beliefs about the nature of teaching knowledge and the nature of knowing in teaching that are related to knowledge evaluation and construction were discussed. In addition, potential antecedents and mediators of PT-PETS were explored and discussed. Finally, current measurement practices of validity standards were explored to guide the process of the development and validation of the PT-PETS.

Next, data were collected twice in one-year interval to answer the three research questions. 496 undergraduate students in the College of Education at a large Midwestern university participated in this research. The number of participants for Study 1 was 160 (first dataset) and 336 (second dataset). The research data consisted of 372 females (74.35%) and 124 males (25.65%). Of the respondents, 93.7% (N = 459) were between ages 18 and 22, and 6.3% (N = 37) were 23 or older. Overall, 44.9% (N = 223) of the respondents were freshmen, 23.8% (N = 118) were sophomores, and 31.3% (N = 155) were juniors or seniors.

To answer the research questions, exploratory factor analyses (Study 1), confirmatory factor analyses (Study 2), and structural equation modeling techniques (Study 3) were used. The following presents the findings from each of the three studies, the limitations of the research, the implications and suggestions for future research, and a brief conclusion. In Study 1, the factor structure of PT-PETS was examined based on the psychometric properties of the scale. The scale development process began with the generation of 48 items through an extensive literature review and experts review. Such items were inserted into an exploratory factor analysis. An iterative purification process produced a three-factor structure for the PT-PETS. Factor loadings of selected items on corresponding factors ranged from .412 to .835 across the constructs, indicating that the three factors had sound factor loadings. The three factors of the scale indicated acceptable preliminary reliability (coefficient alpha): Factor 1 α = .915, Factor 2 α = .911, and Factor 3 α = .759. Overall, the corrected item-to-total correlations for each item with the three factors of the PT-PETS ranged from .50 to .75. In addition, the corrected item-total correlation for each item to the whole scale ranged from .47 to .70. The objectives of

Study 1 were achieved and the researcher was ready to conduct Study 2, in order to enhance the interpretability of the three factors. In Study 2, the dimensionality, reliability, and validity of the PT-PETS from the EFA results were re-examined to confirm the 3-factor structure with 30 items. However, the CFA results showed that this initial model of the PT-PETS indicated a poor model fit: $\chi^2(402, N = 336) = 1082.881$, $p < .05$, CFI = .886, TLI = .877, RMSEA = .071, and SRMR =.050. Therefore, using the modification indices as a guide, the initial PT-PETS was improved with item reduction from 30 to 20 item; and then, the modified model fit turned out to be better: $\chi^2(167, N = 336) = 343.238$, $p < .05$; CFI = .951, TLI = .944; RMSEA = .056, and SRMR = .037. The first factor was named the *Construction of Teaching Knowledge* because this 9-item factor corresponds to pre-service teachers' conceptualizations of teaching knowledge, such as knowledge source and justification. The second factor was named the *Contextuality of Teaching Knowledge* because this 8-item factor measures whether pre-service teachers view knowledge as absolute or contextual. The third factor was named the *Complexity of Teaching Knowledge*. The 3 items in this factor were developed to ask whether pre-service teachers view of teaching knowledge as an accumulation of facts or as highly interrelated concepts justified by observation.

Collectively, the findings did not support the hypothesis that the PT-PETS would retain a clear 4-factor structure suggested by Hofer (2000). The two hypothesized factors under the heading of the nature of knowledge, such as 'source of knowledge' and 'justification for knowing', were consolidated into one factor, the *Construction of Teaching Knowledge*. These findings are consistent with previous empirical studies. For example, when Schommer-Aikins et al. (2000) administered the 4-factor structure of

SEQ to 7^{th} and 8^{th} grade students, she found that a 3-factor structured was supported with that population. Similarly, Qian and Alvermann (1995) identified a 3-factor solution of SEQ with high school students. In both studies, the 2 factors, the Certainty and Simplicity of Knowledge, were not differentiated by their participants, indicating that age and/or educational level may cause variation in the types of belief factors (Buehl, 2008). Therefore, given the potential differences in belief dimensions across age, education, and professional experience levels, additional research is needed to understand how beliefs about the nature of teaching knowledge emerge and develop throughout the course of a teaching career as well as how such beliefs interact with formal or informal education experiences.

The purpose of Study 3 was to provide additional confirmation of dimensionality, reliability, and validity through the examination of nomological validity of the PT-PETS using structural equation modeling (SEM). A theoretical model was established based on the literature review of the integrated approach toward personal epistemology, information evaluation, and knowledge sharing. This hypothetical model contained potential antecedents (e.g., perceptions of teacher educators' pedagogical practices, perception of information quality) leading to pre-service teachers' motivations related to information literacy (e.g., knowledge sharing self-efficacy, information evaluation self-efficacy), ultimately leading to the development of personal epistemologies of teaching as outcome measures. After establishing that all assumptions were met, the measurement model was assessed and the structural model was validated using a two-step procedure suggested by Anderson and Gerbing (1988). First, the measurement model confirmed the validity of the employed scales, indicating that significant links existed between the seven latent variables (i.e., Perceptions of Teacher Educator's Pedagogical Practices, Perception of Information Quality, Knowledge Sharing Self-efficacy, Information Evaluation self-efficacy, and the three factors of PT-PETS, such as Construction of Teaching Knowledge, Contextuality of Teaching Knowledge, and Complexity of Teaching Knowledge); and their associated observed variables: $\chi^2(76, N = 336) = 207.447$, $p < .05$; CFI = .945, TLI = .913, and RMSEA = .072. Next, the structural equation model was examined to demonstrate how the hypothesized relationships among these seven latent variables were supported by the data. The various model fit indices produced a good fit to the data: $\chi^2(58, N = 336) = 135.689$, $p < .05$; CFI = .959, TLI = .935, and RMSEA = .063. The results of hypothesis testing provide greater support for the association of pre-service teachers' personal epistemologies of teaching and their perceptions of knowledge construction within online communities, as described next.

5.1 Perceptions of Teacher Educators' Pedagogical Practices and PT-PETS

Hennessey et al. (2013) described that teachers who hold a foundationalist view of epistemic justification tend to transmit facts and skills that are already known within a hierarchically structured system of discipline knowledge, while teachers who hold a reliabilist view are more likely to encourage students to justify their understandings with observable evidences from a contextual and historical analysis. In this study, *Perceptions of Teacher Educator's Pedagogical Practices* appeared to be positively correlated to pre-service teachers' *Knowledge Sharing Self-efficacy* and their beliefs about *Complexity of Teaching Knowledge*. That is, the more teacher educators explicitly articulate a reliabilist view of epistemic justification in their teaching practices, the more they help students understand the complex nature of teaching knowledge, and the more confidence students have in providing knowledge that are valuable to others and responding to shared knowledge by others.

From the CFA results, the factor *Complexity of Teaching Knowledge* contains 3 items representing that teaching knowledge is viewed as highly interrelated concepts based on relative, contigent, and contextual findings from reality, rather than as an accumulation of separate, knowable facts (Schommer, 1990). Since relativism-based pedagogical practices focus on the knowledge produced through “a reliable cognitive process or a history of reliable cognitive processes” (Hennessey et al., 2013, p. 504), teacher educators applying such an approach tend to ask their students to provide observable evidence from their own perspectives to justify their understandings toward a specific phenomenon. This approach may lead to a deeper level of epistemological reflection on what students believe they know, realizing the complicated and dynamic nature of teaching knowledge.

These results are consistent with empirical findings that students’ beliefs about the complexity of knowledge are related to the types of learning strategies they use when studying (e.g., Hofer, 2000; Sinatra & Kardash, 2004), as well as their academic achievements (e.g., Hofer, 2000; Schommer, 1993). In addition, a growing body of research focusing on how teachers’ personal epistemologies affect their teaching and other interactions with students also supports the findings from the current study (e.g., Brownlee, 2001; Brownlee et al., 2011; Lee & Tsai, 2011; Maggioni & Parkinson, 2008; Muis & Foy, 2010; Tabak & Weinstock, 2011; Yadav et al., 2011). Bell and Linn (2002) indicated that teachers with naïve personal epistemologies are less likely to promote higher levels of epistemological activities in their classrooms. They argued that when teachers provided students with opportunities to learn about the problematic nature of scientific knowledge construction, leading explicit investigation of epistemological issues with others, students' understandings of the nature of scientific knowledge improved. Weinstock and Roth (2011) reported a positive relationship between teachers' personal epistemologies and their teaching behaviors, which is important to support student' autonomy in individual knowledge acquisition and social knowledge construction. Strømsø and Bråten (2013) emphasized, "university teachers should attempt to facilitate the development of students' personal epistemology" (p. 64), by challenging students explicitly reflect on their own epistemic justification process and by exposing them to contradicting information about central issues in the subject (Qian & Alvermann, 2000). For this purpose, Strømsø and Bråten (2013) suggest faculty training programs designed to encourage university teachers to calibrate their teaching beliefs and personal epistemology by exposing them to cases – ideally from their own teaching practice – where the contradicting belief systems exist in terms of ways of teaching and learning.

5.2 Perception of Information Quality and PT-PETS

Hypotheses 6 to 10 examined how pre-service teachers' *Perceptions of Information Quality* produced from online communities affected their confidences toward knowledge sharing and information evaluation. It is generally agreed that the higher the quality of information acquired from peers, the higher the satisfaction perceived by participants, following engagement in knowledge construction within online communities (Patel, Pettitt, & Wilson, 2012). This study revealed that pre-service teachers' perception of Web information quality may positively affect knowledge sharing self-efficacy. That is, pre-service teachers who perceive Web information as accurate and credible resources tend to be more confident sharing diverse resources within online communities. Moreover, the positive perception of Web information may lead to increased *Information Evaluation self-efficacy* via the mediating role of *Knowledge Sharing Self-efficacy*. That is, when pre-service teachers feel they can obtain more accurate and credible information from others within online communities, they tend to feel more confident not only to share knowledge with others, but to evaluate information received from others. *Perception of Information Quality* had no significant direct effect on the three factors of the PT-PETS, but a significant direct effect on *Knowledge Sharing Self-efficacy* and a significant indirect effect on *Information Evaluation self-efficacy*. Thus, it could potentially affect the three factors of the PT-PETS via the causal relationship between *Knowledge Sharing Self-efficacy* and *Information Evaluation self-efficacy*, which is crucial to improve teachers' problem-solving confidence (Lin, 2007).

5.3 Knowledge Sharing Self-efficacy and PT-PETS

Not surprisingly, *Knowledge Sharing Self-efficacy* was found to positively correlate with students' levels of confidence in evaluating Web information quality. However, results also indicated that higher levels of knowledge sharing confidence were related to more naïve level of understanding about the nature of teaching knowledge. Specifically, the higher pre-service teachers' confidence in providing and sharing opinions, experiences, or knowledge about teaching with others, the less they embraced the sophisticated nature of teaching knowledge (e.g., evolving, contextual, or value-laden). Instead, they tended to hold beliefs about the certainty, simplicity, and authority of teaching knowledge. This negative relationship was unexpected but might be explained by the degree of self-efficacy being self-reported by pre-service teachers, as addressed in the limitation section. A follow-up qualitative approach might be useful to fully explore the interaction between perceptions of knowledge sharing and conceptualizations of the nature of knowledge which might have not been deeply observed by this exploratory study only using a quantitative approach. Another possible explanation for this unexpected finding could be that the items used in this study focused on external knowledge sharing behaviors, such as providing resources or ideas and giving feedback, which does not provide a complete picture of knowledge sharing's role in promoting epistemological awareness. Then, what else should be considered?

The results of this study revealed the importance of information evaluation self-efficacy, when identifying boundary conditions that determine the direction and magnitude of self-efficacy effects on personal epistemology. As described in Table 27, the negative direct effects of *Knowledge Sharing Self-efficacy* on *Personal Epistemologies of Teaching* were overcompensated by the positive indirect effects induced by increasing *Information Evaluation Self-efficacy*. That is, the strong positive indirect effects of *Information Evaluation Self-efficacy* countered negative direct effects of *Knowledge Sharing Self-efficacy*, developing the sophisticated beliefs about the nature of teaching knowledge.

These results are echoed in a study by Kammerer, Bråten, Gerjets, and Strømsø (2013), indicating that students' uncritical adoption and sharing of Web information caused decreased explicit reflection on the complicated nature of knowledge provided by the Internet and less attention to the sources of information (e.g., website address and author information). They concluded that naïve epistemic trust in the Web may hinder students from "the epistemic challenges involved in managing the wealth of information and evaluating the different types of information sources available on the Web" (p. 1200). Thus, the findings of this study indicate that *Information Evaluation Self-efficacy* could play a crucial role in promoting pre-service teachers' personal epistemologies through critical knowledge sharing experiences.

5.4 Information Evaluation Self-efficacy and PT-PETS

The importance of information evaluation in developing sophisticated personal epistemologies was corroborated by its direct effects on the three factors of the PT-PETS (hypotheses 15, 16, and 17). It shows that higher levels of *Information Evaluation Self-efficacy*, are related to higher levels of epistemological understandings about teaching knowledge. Many studies revealed that undergraduate students are not making judgments and subsequent decisions appropriately when choosing resources for knowledge construction (Davis, 2002, 2003; Ebersole, 2000; Maughan, 2001). As the opportunities to obtain, share, and recreate information within online communities become more available, promoting students to evaluate information resources becomes more important. In addition to sophisticated personal epistemologies, pre-service teachers are expected to enter the profession with the required skills to perform a useful search, recognize valuable resources, and synthesize information into their new conceptualizations that correspond to teaching objectives. Lazonder and Rouet (2008) indicated that personal epistemology, as one of several individual variables influencing the quality of information problem solving, may shape, and be shaped by, the capabilities of information evaluation, through the activation of representations about knowledge and knowing. Therefore, it is necessary to provide pre-service teachers with diverse hands-on activities to critically examine information quality as well as actively share information with others, pursuing the development of personal epistemologies of teaching.

Overall, the results of this study shed some light on the role of pre-service teachers' personal epistemologies of teaching as a reflective activity in the context of critical knowledge construction. More importantly, a reliable and valid measure of pre-service teachers' personal epistemologies of teaching was developed that contains good psychometric properties.

5.5 Limitations and Future Research

There are several limitations to be considered while interpreting the results of this study. One obvious limitation of the research is that personal epistemologies of teaching were measured using a self-report survey instrument. Although the purpose of this study was to develop a self-report instrument designed to measure the construct, there was no examination with different types of measures, such as interviews, essays, journals, or concept maps that have been used to qualitatively characterize epistemological viewpoints. Particularly, direct observation is preferable for knowledge construction behavior selection and treatment monitoring. Thus, the integration with other measurements should be considered to fully verify the convergent validity of the measurement method employed in this study.

Another limitation is that the scale was administered with convenience samples of pre-service teachers. Specifically, the data for confirmatory factor analysis and structural equation modeling was collected twice in one semester interval due to a small sample size of the first dataset. Although there were no significant differences between the responses of participants, future research will have to verify that the scale proposed by this study is generalizable with different sample populations.

Finally, it is important to note that the structural relationships between personal epistemology and knowledge construction is not a comprehensive or exhaustive model including all possible antecedents and outcomes in terms of teachers' personal epistemologies. Additional constructs and measurements need to be used to fully evaluate the nomological validity of the PT-PETS. Additionally, longitudinal investigations of the changes in personal epistemologies are recommended to determine whether pre-service teachers develop more sophisticated personal epistemologies over time and how other factors in reality support or hinder its development.

5.6 Implications

The newly developed instrument, *Pre-service Teachers' Personal Epistemologies of Teaching Scale*, can be a valuable instrument to investigate and reflect on the understandings and beliefs of pre-service teachers about *the nature of knowing* and *the process of knowing* in teaching. There are three immediate implications from this study to understand the interactions between personal epistemology and teaching practices.

First, the results of this study indicate that pre-service teachers' personal epistemologies of teaching can be regarded as one of the critical dimensions of learner analysis for teacher preparation programs. A variety of cognitive factors, such as learning styles and motivation, has been investigated as factors to stimulate and support knowledge construction in teacher education (Mason, Gava, & Boldrin, 2008; Pintrich, Marx, & Boyle, 1993, Sinatra, 2005). However, personal epistemology had less attention. Given that constructivist teaching is associated with more sophisticated personal epistemologies, such as the complex and evolving nature of knowledge (Feucht, 2011; Tillema, 2011), it is crucial that teacher education programs help students develop sophisticated understandings about teaching knowledge in preparation for effective teaching (Schraw et al., 2011; White, 2000). In addition, the investigation with other factors related to critical knowledge construction may offer several interesting insights about what factors shape and facilitate the development of pre-service teachers' personal epistemologies and how such changes improve teaching practices in classroom. Specifically, *Information Evaluation Self-efficacy* was found as the best predictor of pre-service teachers' sophisticated personal epistemologies (R^2 = .859). Therefore, teacher educators need to provide explicit instructions designed to help their students evaluate sources of information used to construct knowledge with others.

Second, the primary methodological implication is that teacher educators may regard this instrument as a diagnostic tool, in order to explicate their students' implicit views about teaching knowledge, aiming to implement instructional interventions that can challenge such implicit, routinized thinking of knowledge construction. In the most current collection of contemporary epistemological research in teacher education, Schraw et al. (2011) stressed the need "to improve the measurement of epistemological phenomena, by codifying definitions and how these phenomena are assessed" (p. 278), from a domain-specific perspective. Prior to this study, no scale existed to measure this construct, without the integration of the concept of either learning or self-efficacy, which hindered empirical investigation of the construct and its relationship with other constructs related to teachers' professional knowledge construction. Thus, the development of this scale with satisfying psychometric properties may provide teacher educators and researchers with opportunities to theoretically and empirically examine epistemological phenomena experienced by teachers or teacher candidates. Obviously, these efforts may benefit the conceptual and practical understandings of the relationship between personal epistemology and teaching practices (Brownlee et al., 2011; Schraw et al., 2011).

Last, the overall construction of a descriptive model of pre-service teachers' knowledge construction may offer a set of guidelines to promote teacher epistemological change during teaching training. Previous studies have used a variety of strategies, such as modeling and evaluation on practical strategies (Brownlee et al., 2011; Tabak & Weinstock, 2011), collaborative reflection on dilemmas or conflicts (Marra & Palmer, 2011; Tillema, 2011), diaries, journals, and explicit discussion in classroom (Bendixen & Cockill, 2011). Collectively, instructional interventions promoting individual reflection and group discussion on authentic teaching cases with dilemmas or conflict issues may be particularly effective to help students develop sophisticated personal epistemologies. This pedagogical approach will enable pre-service teachers to not only collaboratively produce teaching knowledge, but also continuously reflect on their ways of thinking in teaching. Of special importance, according to the results of the structural model analyses, is to facilitate students' critical reflection on the quality of information (e.g., accuracy, credibility, validity) collected by themselves or produced by others prior to generating a set of potential solutions.

5.7 Conclusion

The ideas of this study originated from the assumption that knowledge must be constructed by learners by constantly involving their experiences, practices, interactions, and ways of thinking; and thus students should be given opportunities to investigate how they construct their knowledge and what conditions influence knowledge construction. The goal of teacher education is not to indoctrinate teacher candidates into one or any fixed ways of learning, constructing truths, and making meanings, but to educate them to critically think about their teaching and skillfully perform. Therefore, it is the prime responsibility of teacher educators to create the conditions and the environments that allow for competing, complementing, and/or interacting diverse intellectual views, thoughts, and ideologies. However, research indicates that teacher education programs do not support the development of more sophisticated personal epistemologies needed for effective teaching, and thus most teachers tend to enter the profession with relatively naïve personal epistemologies (Brownlee et al., 2011; Schraw et al., 2011; White, 2000). In addition, there is a need to develop more reliable and valid scales to examine how pre-service teachers' personal epistemologies of teaching interact with a broad range of cognitive, affective, and behavioral variables related to teaching practices (Yadav et al., 2011).

In response to this call, this research sought to develop a *psychometrically* sound instrument to assess pre-service teachers' personal epistemologies of teaching, based on Hofer's definitions of *the nature of knowing* and *the process of knowing*. Through psychometric evaluation, the author proposes the *Pre-service Teachers' Personal Epistemologies of Teaching Scale* (PT-PETS), which has 20 items using a 6-point Likert type response format. The PT-PETS contains three constructs: *Construction of Teaching Knowledge* related to the process of teaching knowledge, and *Contextuality of Teaching Knowled*ge and *Complexity of Teaching Knowledge* related to the nature of teaching knowledge. In addition, this study demonstrates nomological validity of the PT-PETS by examining the relationship with factors influencing teachers’ knowledge construction. Therefore, the author contends that pre-service teachers’ personal epistemologies of teaching is an explanatory variable that may support research that explains teachers’ professional knowledge construction; as well as facilitate practices attempting to promote constructivist teaching approaches in teacher education programs .

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APPENDICES

Appendix A Expert Review

Instruction: The following survey contains statements about beliefs about the nature of teaching knowledge and the process of knowing. Please rate each statement twice, once for category and once for your confidence about your category decision. In other words, the first rating indicates category the statement most closely fits. Use the following definitions and put the category number in the box. The second rating asks you how confident you are with your first rating. Please place a checkmark (V) on the appropriate box that best describes your thought. In addition, you are extremely welcome to leave your comments about any additional factors and/or items that you would like to suggest below.

Definitions of Sub-Factors

1. Certainty of Teaching Knowledge: Teaching Knowledge is viewed as absolute or contextual.
2. Simplicity of Teaching Knowledge: Teaching Knowledge is viewed as an accumulation of facts or as highly interrelated concepts.
3. Source of Teaching Knowledge: Teaching Knowledge is handed down by external authority or constructed by individuals.
4. Justification of Teaching Knowledge: Individual pre-service teachers move through a continuum of dualistic beliefs toward the multiplicity acceptance of opinions to reasoned justification.

(A) Naïve	(B) Sophisticated	Factor (1~4)	Confidence		
			Very Sure	Pretty Sure	Not Sure
Most principles and theories about teaching and learning are unchanging.	Most principles and theories will change over a period of time.				
All theorists of teaching and learning would probably come up with the same solutions to problems.	All theorists of teaching and learning would probably come up with different solutions according to the context.				
All teaching and learning experts understand a specific teaching case in the same way.	All teaching and learning experts understand a specific teaching case in different ways.				
Most teaching problems have only one ideal solution.	Even the one ideal solution from teaching experts should be questioned.				
…	…	…	…	…	…

Appendix B IRB Approval Letter

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HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	PEGGY ERTMER BRNG 3144
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	03/18/2013
Committee Action:	**Exemption Granted**
IRB Action Date:	03/15/2013
IRB Protocol #:	1303013368
Study Title:	Development and Validation of Pre-service Teacher's Personal Epistemology of Teaching Scale (I

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(2) .

If you wish to make changes to this study, please refer to our guidance **"Minor Changes Not Requiring Review"** located on our website at http://www.irb.purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms page of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without

proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 1

- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Categories 2 and 3

- Surveys and questionnaires should indicate
  - only participants 18 years of age and over are eligible to participate in the research; and
  - that participation is voluntary; and
  - that any questions may be skipped; and
  - include the investigator's name and contact information.
- Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
- When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 6

- Surveys and data collection instruments should note that participation is voluntary.
- Surveys and data collection instruments should note that participants may skip any questions.
- When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.

Appendix C Recruitment Email

Subject Heading: Want to win a $20 Amazon gift card? Survey Invitation!

Hello,

My name is Ji Hyun Yu. I am a Doctoral Candidate under the direction of Dr. Peggy A. Ertmer in the Department of Curriculum and Instruction at Purdue University. I am currently working on my dissertation, which aims to develop and validate a new instrument to assess pre-service teachers' beliefs about the nature of teaching knowledge referred to as "Pre-service Teachers' Personal Epistemology of Teaching". We will investigate the role of pre-service teachers' personal epistemology on their perceptions of knowledge sharing in online communities.
If you are 18 years of age or older and a student of College of Education, I would greatly appreciate your thoughts and perspectives. If you decide to participate in this study, please click on the link below and you will be directed to the online survey.

https://purdue.qualtrics.com/SE/?SID=SV_d51DgUPZInKmFjn

The survey should take you approximately 10 minutes to complete. Your responses will be kept confidential and will only be viewed by the investigators. At the end of the survey, there will be an opportunity to enter a lottery drawing of a **$20 Amazon gift card** by submitting your email address. This will be awarded at the completion of the study, which will be **September 13, 2013**. The chance of winning will be **1 in 25, or better**. Your responses will remain anonymous even if you participate in the drawing. A separate data file will be used to store your email address and responses so there will be no way of connecting yours survey responses to your email address. Thank you in advance for your time and participation! Please feel free to pass on this link to other people who might be eligible. If you have any questions about this study, feel free to contact me at yu45@purdue.edu .

Sincerely,

Ji Hyun Yu,
Ph.D Candidate
yu45@purdue.edu

Peggy A. Ertmer,
Professor of Learning Design and Technology
pertmer@purdue.edu

Appendix D Initial PT-PETS for EFA

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TBPK Survey: Each of the following items contains two opposing statements about knowledge for teaching and learning. Please select the degree to which statement matches how you think. There is no right or wrong answer, and we just want to know how you think. Your responses are anonymous and confidential.

- **ONLY ONE OPTION ON EACH ITEM (OR LINE) CAN BE SELECTED.**
- For example, if you think that you are moderately agree with the statement at the left side:

(A)	Strongly Agree with (A)	Moderately Agree with (A)	Somewhat Agree with (A)	Somewhat Agree with (B)	Moderately Agree with (B)	Strongly Agree with (B)	(B)
Most teaching problems have only one ideal solution.	○	●	○	○	○	○	Even the one ideal solution from teaching experts should be questioned.

- TBPK Survey 1 out of 5

(A)	(B)
Most principles and theories about teaching and learning are unchanging.	Most principles and theories of teaching and learning will change over a period of time.
All teaching and learning theorists would probably come up with the same solutions to problems.	Teaching and learning theorists would probably come up with different solutions, based on their contexts.
Teaching and learning experts would all understand a specific teaching case in the same way.	Teaching and learning experts would understand a specific teaching case in different ways.
Most teaching problems have only one ideal solution.	Most teaching problems have several ideal solutions.
Most teaching problems have a single certain absolute answer applicable to all situations if they are well studied.	No teaching problems could have a certain absolute answer applicable to all situations, even if they are well studied.
Memorizing what the textbooks say about teaching and learning is more important than combining information across chapters or even across classes.	Combining information about teaching and learning across chapters or even across classes is more important than memorizing what the textbooks say.
Most teaching problems have one best solution no matter how difficult they are.	Most teaching problems have multiple solutions, even the most simple and complex ones.
Answers to questions about teaching and learning can be found from what is already known.	Answers to questions about teaching and learning change as experts gather more information.
The most important part of teaching and learning is absolute truth.	The most important part of teaching and learning is understanding 'big ideas' and developing new theories.
The best way to learn key topics about teaching and learning is to account for various phenomena using one single perspective.	The best way to learn key topics about teaching and learning is to examine various phenomena integrating different perspectives.
If a phenomenon appears inconsistent, it is because an absolute truth has not yet been found.	When a phenomenon appears inconsistent, multiple perspectives should be used.
Teacher education programs should provide experience to work on teaching problems that has one precise answer.	Teacher education programs should provide experience to work on teaching problems that allow to evaluate alternative and new information.

>>

- **ONLY ONE OPTION ON EACH ITEM (OR LINE) CAN BE SELECTED.**
- For example, if you think that you are moderately agree with the statement at the left side:

(A)	Strongly Agree with (A)	Moderately Agree with (A)	Somewhat Agree with (A)	Somewhat Agree with (B)	Moderately Agree with (B)	Strongly Agree with (B)	(B)
Most teaching problems have only one ideal solution.	○	●	○	○	○	○	Even the one ideal solution from teaching experts should be questioned.

- TBPK Survey 2 out of 5

Knowledge about teaching and learning will become simplified over time.	○	○	○	○	○	○	Knowledge about teaching and learning will become more integrated and complex over time.
It is best to break complex topics into parts and to study them separately.	○	○	○	○	○	○	Breaking down complex topics into separate parts is often misleading because most elements tend to interact and affect each other.
Knowledge about teaching and learning is simple, consistent, and orderly.	○	○	○	○	○	○	Knowledge about teaching and learning is complex, conflicting, and disorderly.
It is difficult for students to learn from a textbook unless you start at the beginning and master one section at a time.	○	○	○	○	○	○	It is important to give students a chance to re-organize the topics across chapters based on their own frameworks.
Learning to teach should be organized around key facts.	○	○	○	○	○	○	Learning to teach should be organized around challenging questions that arise from authentic contexts.
To solve a teaching problem, it is important to discover all the facts.	○	○	○	○	○	○	To solve a teaching problem, it is important how we look at the facts.
Theories about teaching and learning are easy to understand because they contains so many facts.	○	○	○	○	○	○	The more you know about teaching and learning theories, the more there is to know.
Because core knowledge to be good teacher has been already established, no change will occur.	○	○	○	○	○	○	Because core knowledge to be good teacher will change to varying degrees, it is important to stay up-to-date on the current research and practices.
The information about how to teach should be presented in a straightforward fashion.	○	○	○	○	○	○	The information about how to teach should be presented by showing its relationship with day-to-day life.
A really good way to understand a textbook is to memorize the facts in an orderly fashion.	○	○	○	○	○	○	A really good way to understand a textbook is to re-organize the information according to your own understanding.
Most key concepts in teaching and learning have one clear meaning.	○	○	○	○	○	○	Most key concepts in teaching and learning mean different things to different people.
Learning to teach will be most effective when I am told explicitly what I should learn and how I should learn.	○	○	○	○	○	○	Learning to teach will be most effective when I am left with a lot of flexibility regarding what I should learn and how I should learn.

>>

- **ONLY ONE OPTION ON EACH ITEM (OR LINE) CAN BE SELECTED.**
- For example, if you think that you are moderately agree with the statement at the left side:

(A)	Strongly Agree with (A)	Moderately Agree with (A)	Somewhat Agree with (A)	Somewhat Agree with (B)	Moderately Agree with (B)	Strongly Agree with (B)	(B)
Most teaching problems have only one ideal solution.	○	●	○	○	○	○	Even the one ideal solution from teaching experts should be questioned.

- TBPK Survey 3 out of 5

Sometimes you just have to accept answers from the teaching experts , even if you don't understand them.	○	○	○	○	○	○	Sometimes you can challenge answers from the teaching experts, even if most accept those answers.
You can believe most things you read in textbooks.	○	○	○	○	○	○	You can criticize what you read in textbooks.
If your personal experience conflicts with ideas in the textbook, the book is probably right.	○	○	○	○	○	○	If your personal experience conflicts with experts' opinions, you can support your arguments with relevant evidence.
College courses with professional literature (e.g. books, articles) are sufficient to be good teacher.	○	○	○	○	○	○	College courses with professional literature (e.g. books, articles) are insufficient to be good teacher and more personal experiences are also needed.
Accumulated findings from research are salient sources of knowledge for effective teaching.	○	○	○	○	○	○	Reflection on one's experiences with others in school are salient sources of knowledge for effective teaching.
It is good to help students accept what the experts think.	○	○	○	○	○	○	It is good to encourage students to evaluate what the experts think.
How much a person learns in school mostly depends on the quality of the teacher.	○	○	○	○	○	○	How much a person learns in school mostly depends on the quality of their learning experiences.
Relying on the facts presented in textbooks is most useful when trying to solve teaching problems.	○	○	○	○	○	○	Relying on the "know-how" shared in professional teacher communities is most useful when trying to solve teaching problems.
Teachers should control the sequence of students' learning activities.	○	○	○	○	○	○	Students should be allowed to control the sequence of their learning activities.
Knowledge about teaching and learning is generated by traditional university-based researchers.	○	○	○	○	○	○	Knowledge about teaching and learning is generated by experienced teachers.
Using the answer keys in the textbooks is most useful when trying to solve teaching problems.	○	○	○	○	○	○	Using similar experiences or relevant cases is most useful when trying to solve teaching problems.
Knowledge construction is a slow process of collecting information.	○	○	○	○	○	○	Knowledge construction is an evolutionary process of building your own knowledge.

>>

- **ONLY ONE OPTION ON EACH ITEM (OR LINE) CAN BE SELECTED.**
- For example, if you think that you are moderately agree with the statement at the left side:

(A)	Strongly Agree with (A)	Moderately Agree with (A)	Somewhat Agree with (A)	Somewhat Agree with (B)	Moderately Agree with (B)	Strongly Agree with (B)	(B)
Most teaching problems have only one ideal solution.	○	●	○	○	○	○	Even the one ideal solution from teaching experts should be questioned.

- TBPK Survey 4 out of 5

I don't usually evaluate the accuracy of information given by the instructor.	○	○	○	○	○	○	I tend to always evaluate the accuracy of information given by the instructor.
Memorizing what the textbooks say is more important that forming my own ideas about teaching and learning.	○	○	○	○	○	○	Forming my own ideas about teaching and learning is more important than memorizing what the textbooks say.
If you study hard enough, you can find the truth to almost everything.	○	○	○	○	○	○	The more you know about a topic, the more there is to know.
I usually try to find out general principles and follow them when I deal with new teaching cases.	○	○	○	○	○	○	I usually try to apply general rules used in similar teaching contexts, but allow for a lot of flexibility.
Teaching wisdom is accumulated knowledge about teaching and learning.	○	○	○	○	○	○	Teaching wisdom is not knowing the solutions, but knowing how to find the solutions.
Memorizing abstract principles is the best way to learn about teaching and learning.	○	○	○	○	○	○	First-hand experience is the best way to learn about teaching and learning.
It should be determined whether someone's answer to a teaching problem is right.	○	○	○	○	○	○	There is really no way to determine whether someone has the right answer for teaching problems.
Mostly I accept, without question, what I am told about teaching and learning by experts.	○	○	○	○	○	○	I evaluate whether information that I find about teaching and learning seems logical.
Learning to teach is a process in which I read the information, record it in memory, and retrieve it appropriately.	○	○	○	○	○	○	Learning to teach is a process in which I personally construct understandings and gain experiences about how to teach.
When someone in authority tells me what to do, I usually do it.	○	○	○	○	○	○	Even though someone in authority tells me what to do, I usually question it myself.
I prefer to rely on knowledge generated by those who specialize in research on teaching.	○	○	○	○	○	○	I prefer to rely on knowledge generated as the results of teaching experiences.
When I encounter a difficult problem, I try to ask someone in authority about what to do.	○	○	○	○	○	○	When I encounter a difficult problem, I try to work it out myself without consulting my teachers.

>>

TBPK Survey 5 out of 5: The following is intended to provide researchers with fundamental demographic information about you. All information will be used for research purposes only and will be kept confidential. Your participation is voluntary and appreciated.

Your PURDUE email:

[ ]

Gender:

- ○ Female
- ○ Male

Age range:

- ○ 18-22
- ○ 23-26
- ○ 27-32
- ○ 32+

Major:

- ○ Early Childhood Education
- ○ Elementary Education
- ○ Secondary Education
- ○ Other [ ]

Area of Specialization:

- ○ Ag Education
- ○ Art Education
- ○ Biology Education
- ○ Chemistry Education
- ○ Engineering/Technology Education
- ○ English Education
- ○ Family and Consumer Science
- ○ Foreign Language Education
- ○ Health Education
- ○ History Education
- ○ Math Education
- ○ Social Studies Education
- ○ Spanish Education
- ○ Special Education
- ○ Other [ ]

Year in College:

- ○ Freshman
- ○ Sophomore
- ○ Junior
- ○ Senior
- ○ Other

Ethnicity:

- ○ Hispanic
- ○ Non-Hispanic

Race:

- ○ American Indian/Alaskan Native
- ○ Native Hawaiian or other Pacific Islander
- ○ Black or African American
- ○ Asian
- ○ White
- ○ Multi-racial

Within your **Monday class period** of EDCI 27000, the class assembled together in:

- ○ WTHR 104
- ○ HICKS 2B 848

Please make sure every question is answered.
Thank you very much for your time!

Appendix E Modified PT-PETS for CFA

PURDUE
UNIVERSITY

PT-PETS Survey (1/4): Each of the following items contains two opposing statements in terms of teaching knowledge. Imagine that you teach your subject matter (e.g. science, math, technology, history, economics, etc.) and select the degree to which statement matches how you think. There is no right or wrong answer, and we just want to know how you think. Your responses are anonymous and confidential.

ONLY ONE OPTION ON EACH ITEM (OR LINE) CAN BE SELECTED.
For example, if you think that you are moderately agree with the statement at the left side:

(A)	Strongly Agree with (A)	Moderately Agree with (A)	Somewhat Agree with (A)	Somewhat Agree with (B)	Moderately Agree with (B)	Strongly Agree with (B)	(B)
Most teaching problems have only one ideal solution.	○	●	○	○	○	○	Even the one ideal solution from teaching experts should be questioned.

Learning to teach is a process in which I read relevant information, record it in memory, and retrieve it appropriately.	○	○	○	○	○	○	Learning to teach is a process in which I personally construct understandings and gain experiences about how to teach.
Memorizing abstract principles is the best way to learn about teaching and learning.	○	○	○	○	○	○	First-hand experience is the best way to learn about teaching and learning.
"Teaching wisdom" refers to accumulated knowledge about teaching and learning.	○	○	○	○	○	○	"Teaching wisdom" refers to knowing how to find the solutions to teaching problems.
Memorizing what the textbooks say is more important than forming my own ideas about teaching.	○	○	○	○	○	○	Forming my own ideas about teaching is more important than memorizing what the textbooks say.
Teaching knowledge is generated by traditional university-based researchers.	○	○	○	○	○	○	Teaching knowledge is constructed through my own experiences.
If you study hard enough, you can get to the truth in teaching.	○	○	○	○	○	○	The more you know about teaching, the more there is to know.
It is better to study the answer keys in the textbooks to solve common teaching problems.	○	○	○	○	○	○	It is better to find relevant experiences to solve common teaching problems.
I try to find out general rules and follow them when I deal with new teaching cases.	○	○	○	○	○	○	I try to apply general principles used in similar teaching contexts, but allow for flexibility.
Accumulated findings from research are salient sources of teaching knowledge.	○	○	○	○	○	○	Personal experiences are salient sources of teaching knowledge.
Development of teaching knowledge is a process of collecting information from research studies.	○	○	○	○	○	○	Development of teaching knowledge is a process of building up your own knowledge based on personal experiences.
Depending on the knowledge from textbooks is more useful than reflecting on personal experiences, when solving a teaching problem.	○	○	○	○	○	○	Reflecting on personal experiences is more useful than depending on the knowledge from textbooks, when solving teaching problems.
There is usually one right answer to every teaching problem.	○	○	○	○	○	○	There is never one right answer to a teaching problem.
Students need to learn what the experts know.	○	○	○	○	○	○	Students should question what the experts know.
All experts in education understand a specific teaching case in the same way.	○	○	○	○	○	○	Experts in education understand a specific teaching case in different ways.
All theorists in education would probably come up with the same solutions to a teaching problem.	○	○	○	○	○	○	Theorists in education would probably come up with different solutions to a teaching problem.

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PURDUE UNIVERSITY

PT-PETS (2/4):

Please select the degree to which statement matches how you think. There is no right or wrong answer, and we just want to know how you think. Your responses are anonymous and confidential.

Most teaching problems have only one ideal solution.	Most teaching problems have several ideal solutions.
Memorizing what the textbooks say about teaching and learning is more important than combining information across chapters or even across classes.	Combining information about teaching and learning across chapters or even across classes is more important than memorizing what the textbooks say.
Most teaching problems have one best solution no matter how difficult they are.	Most teaching problems have multiple solutions, even the simplest ones.
Most teaching problems, if they are well-studied, have a single certain answer applicable to all situations.	Even if they are well-studied, no teaching problems could have a certain answer applicable to all situations
Students should simply accept what the textbooks say.	Students should critically evaluate what the textbooks say.
The best way to learn about teaching is to gather information and organize it in a straightforward manner.	The best way to learn about teaching is to investigate various cases of teaching and then to integrate the different perspectives.
Teacher education programs should provide opportunities to work on a variety of teaching cases – each case has one precise answer.	Teacher education programs should provide opportunities to work on a variety of teaching cases – each case has multiple solutions.
Possible solutions to a teaching problem can be gained from what the authorities say.	Possible solutions to a teaching problem can be investigated by reflecting on personal experiences.
Most principles and theories about teaching are unchanging.	Most principles and theories about teaching have changed over time.
There is an absolute truth in education.	There is no absolute truth in education.
Teaching knowledge is organized as isolated, distinct pieces of information.	Teaching knowledge is organized as highly integrated concepts.
Teaching knowledge is simple, consistent, and orderly.	Teaching knowledge is complex and value-driven.
Students can believe most things they read in textbooks.	Students should evaluate the reliability of information in textbooks.
I prefer to rely on what professors or experts say about teaching.	I prefer to rely on my own experiences or conversations with peers.
When solving a teaching problem, the most important thing is to understand core concepts that are always true.	When solving a teaching problem, the most important thing is to justify my understandings with observable evidence.

>>

PT-PETS (3/4):

The following statements ask you about your instructor's teaching practices. Please select the degree to which statement matches what you observed in class. There is no right or wrong answer, and we just want to know how you think. Your responses are anonymous and confidential.

My instructor provides explanations for new facts that build upon basic understandings.	○ ○ ○ ○ ○ ○	My instructor emphasizes the importance of aligning thinking with observable evidence.
My instructor thinks the premises underlying a topic are central to acquiring knowledge.	○ ○ ○ ○ ○ ○	My instructor shows that explanations based on observable evidence are more viable than explanations not based on observable evidence.
My instructor teaches us to describe how our observations are based on facts that are always true.	○ ○ ○ ○ ○ ○	My instructor teaches us to provide evidence for our thinking.
My instructor teaches us facts that are based on known truths rather than opinion.	○ ○ ○ ○ ○ ○	My instructor teaches us to explain how our conclusions should be checked by using observable evidence.
My instructor teaches us to explain new facts using facts known to everyone.	○ ○ ○ ○ ○ ○	My instructor asks us to explain how our new understandings can be verified through the collection of data.
My instructor teaches us understandings that are evident to everyone.	○ ○ ○ ○ ○ ○	My instructor teaches us to describe how to collect observations that inform our understandings.
My instructor asks us to explain how new information builds upon what is known to be true.	○ ○ ○ ○ ○ ○	My instructor teaches us to justify our understandings with observable evidence.
My instructor uses demonstrations in his/her teaching to reinforce our basic understanding about the content.	○ ○ ○ ○ ○ ○	My instructor uses demonstrations in his/her teaching to show how reasoning can be confirmed with data collected as evidence.
The content my instructor teaches in school is based on a few core concepts.	○ ○ ○ ○ ○ ○	The content my instructor teaches in school requires us to reason based on evidence.
The examples my instructor uses in his/her teaching are derived from a few basic understandings.	○ ○ ○ ○ ○ ○	The examples my instructor uses in his/her are supported by evidence collected from the natural environment.

>>

PT-PETS (4/4):

The following items ask you about your perceptions of knowledge sharing in an online community. Please rate your agreement with how well the following statements describe what you think. There is no right or wrong answer, and we just want to know how you think. Your responses are anonymous and confidential.

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Somewhat Agree	Moderately Agree	Strongly Agree
Information from online community sites (e.g. forum, blogs, wikis, etc.) is reasonably accurate.						
Information from online community sites (e.g. forum, blogs, wikis, etc.) is verifiable elsewhere.						
Information from online community sites (e.g. forum, blogs, wikis, etc.) is reliable.						
Information from online community sites (e.g. forum, blogs, wikis, etc.) presents views fairly and without bias.						
Information from online community sites (e.g. forum, blogs, wikis, etc.) is generally well-written.						
	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Somewhat Agree	Moderately Agree	Strongly Agree
I am confident in evaluating the quality of online information.						
I am confident in evaluating the credibility of the author(s) of online articles.						
I am confident in evaluating the credibility of the sources cited in an online article.						
I have confidence in my ability to provide knowledge that other members in online community sites (e.g. forum, blogs, wikis, etc.) consider valuable.						
I have the expertise, experiences and insights needed to provide knowledge valuable for other members in online community sites (e.g. forum, blogs, wikis, etc.).						

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Somewhat Agree	Moderately Agree	Strongly Agree
I have confidence in responding or adding comments to messages or articles posted by other members in online community sites (e.g. forum, blogs, wikis, etc.).	○	○	○	○	○	○
Sharing knowledge with members in online community sites (e.g. forum, blogs, wikis, etc.) will increase my solving- problem capability.	○	○	○	○	○	○
Sharing knowledge with members in online community sites (e.g. forum, blogs, wikis, etc.) will rapidly absorb and react to new information regarding the area.	○	○	○	○	○	○
Sharing knowledge with members in online community sites (e.g. forum, blogs, wikis, etc.) will be effective in my job and improve my performance.	○	○	○	○	○	○

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Your college email address:

Gender:

- Female
- Male

Age range:

- 18-22
- 23-26
- 27-32
- 32+

Major:

- Early Childhood Education
- Elementary Education
- Secondary Education
- Other

Area of Specialization:

- Ag Education
- Art Education
- Biology Education
- Chemistry Education
- Engineering/Technology Education
- English Education
- Family and Consumer Science
- Foreign Language Education
- Health Education
- History Education
- Math Education
- Social Studies Education
- Spanish Education
- Special Education
- Other

Area of Specialization:

- Ag Education
- Art Education
- Biology Education
- Chemistry Education
- Engineering/Technology Education
- English Education
- Family and Consumer Science
- Foreign Language Education
- Health Education
- History Education
- Math Education
- Social Studies Education
- Spanish Education
- Special Education
- Other

Year in College:

- Freshman
- Sophomore
- Junior
- Senior
- Other

Race:

- American Indian/Alaskan Native
- Native Hawaiian or other Pacific Islander
- Black or African American
- Asian
- White
- Multi-racial

Please make sure every question is answered.
Thank you very much for your time!

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Appendix F The Final Version of PT-PETS

Factor 1: Construction of Teaching Knowledge

No.	*Naïve*	*Sophisticated*
1	Learning to teach is a process in which I read relevant information, record it in memory, and retrieve it appropriately.	Learning to teach is a process in which I personally construct understandings and gain experiences about how to teach.
2	It is better to study the answer keys in the textbooks than to find relevant experiences, when solving common teaching problems.	It is better to find relevant experiences to solve common teaching problems.
3	Depending on the knowledge from textbooks is more useful than reflecting on personal experiences, when solving a teaching problem.	Reflecting on personal experiences is more useful than depending on the knowledge from textbooks, when solving teaching problems.
4	Memorizing what the textbooks say is more important than forming my own ideas about teaching.	Forming my own ideas about teaching is more important than memorizing what the textbooks say.
5	Students need to learn what the experts know.	Students should question what the experts know.
6	I try to find out general rules and follow them when I deal with new teaching cases.	I try to apply general principles used in similar teaching contexts, but allow for flexibility.
7	Development of teaching knowledge is a process of collecting information from research studies.	Development of teaching knowledge is a process of building up your own knowledge based on personal experiences.
8	Teaching knowledge is generated by traditional university-based researchers.	Teaching knowledge is constructed through my own experiences.
9	There is usually one right answer to every teaching problem.	There is never one right answer to a teaching problem.

Factor 2: Contextuality of Teaching Knowledge

No.	*Naïve*	*Sophisticated*
10	Memorizing what the textbooks say about teaching and learning is more important than combining information across chapters or even across classes.	Combining information about teaching and learning across chapters or even across classes is more important than memorizing what the textbooks say.
11	Most teaching problems have only one ideal solution.	Most teaching problems have several ideal solutions.
12	Most teaching problems, if they are well-studied, have a single certain answer applicable to all situations.	Even if they are well-studied, no teaching problems could have a certain answer applicable to all situations.
13	The best way to learn about teaching is to gather information and organize it in a straightforward manner.	The best way to learn about teaching is to investigate various cases of teaching and then to integrate the different perspectives.
14	Possible solutions to a teaching problem can be gained from what the authorities say.	Possible solutions to a teaching problem can be investigated by reflecting on personal experiences.
15	Most principles and theories about teaching are unchanging	Most principles and theories about teaching have changed over time.
16	There is an absolute truth in education.	There is no absolute truth in education.
17	Students should simply accept what the textbooks say.	Students should critically evaluate what the textbooks say.

Factor 3: Complexity of Teaching Knowledge

No.	*Naïve*	*Sophisticated*
18	Teaching knowledge is simple, consistent, and orderly, rather than complex and value-driven.	Teaching knowledge is complex and value-driven.
19	Teaching knowledge is organized as isolated, distinct pieces of information, rather than as highly integrated concepts.	Teaching knowledge is organized as highly integrated concepts.
20	When solving a teaching problem, the most important thing is to understand core concepts that are always true.	When solving a teaching problem, the most important thing is to justify my understandings with observable evidence.

VITA

VITA

Ji Hyun Yu
Purdue University

RESEARCH

My program of inquiry focuses on investigating how conceptualizations of knowledge and the knowing process (i.e. personal epistemology) influence someone's performance in learning, knowledge construction and problem-solving. I also focus on refining a framework that guides research and development in technology-enhanced learning environments. My research areas include the following:

- Personal epistemology, information literacy, and knowledge construction
- Metacognition and learning analytics
- Scientific research collaboration within virtual organizations
- Teacher competency modeling for teaching engineering in K-12 settings
- Engineering design-based learning and engineering identity formation

Skills: E-learning design/development/implementation/evaluation, competency-based training, research methodology, program evaluation, scale development, and validation techniques (i.e., psychometric tests using SPSS, Amos, HLM, and Mplus)

EDUCATION

Ph.D. Purdue University, West Lafayette, IN
Specialization: Learning Design and Technology
Dissertation: Development and Validation of Pre-service Teacher Personal Epistemology of Teaching Scale (PT-PETS) (Chair: Dr. Peggy A. Ertmer)
2008 - present

M.A. Ewha Woman's University, Seoul, Korea
Specialization: Educational Technology
2001-2003

B.A. Ewha Woman's University, Seoul, Korea
Specialization: Philosophy and Sociology in Education, Multimedia
Teacher Certification in Secondary Social Studies, Ministry of Education, Korea
Lifelong Educator License, Ministry of Education, Korea
1996-2001

PUBLICATIONS

Journal Articles

Yu, J., & Strobel, J. (in preparation). Participatory game design for first-year engineering students: Engineering identity, engineering design self-efficacy, and sustainable engineering knowledge. To be submitted to *International Journal of Engineering Education.*

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Yu, J. (2006). Development of Augmented Reality (AR) application system in e-learning environments. *Proceedings of the E-Learn International Conference 2006*, Honolulu, Hawaii.

Park, B.H., **Yu, J.** (2006). An exploration of the educational value of the Augmented Reality (AR) technology, *Proceedings of the Korean Association for Educational Information & Media International Conference 2006*. Seoul. Korea. [All authors in alphabetical order]

Yu, J. (1996). A practical proposal for the improvement of Korean University Entrance Exam (Korean SAT). *Proceeding for a Public Hearing on the Reform of Korean Educational System*. Ministry of Education. Seoul, Korea.

Book Chapters

Chen, X., Choi, J. H. & **Yu, J.** (2012). Applying social network analysis and social capital in personal learning environments of informal learning. In V. Dennen and J. Myers (Eds.) *Virtual Professional Development and Informal Learning via Social Networks*. New York, NY: IGI Global. [all authors in alphabetical order]

Chen, X., Choi, J.H., **Yu, J.**, & Newby, T. (2012). Teaching assistants' community of practice in facilitating pre-service teachers' online learning in a blended course. In H. Yang and W. Shuyan (Eds.) *Cases on Formal, Non-Formal, and Informal Online Learning: Opportunities and Practices*. New York: IGI Global. [all authors in alphabetical order, except last]

HIGHLIGHTS OF PROFESSIONAL EXPERIENCE

R&D Project Manager of Samsung CREDU Corporation , Seoul, Korea (2006 – 2007)

- **Mobile Learning**: the WiBro (Wireless Broadband Internet) learning service
  - Role: Project Manager
  - The goal of this project was to launch a new business model for mobile learning in the B to C market. I established business strategies and an instructional framework for WiBro learning that fits the business training field, and I delivered mobile learning programs.
- **Virtual Reality**: Augmented Reality (AR) Learning System
  - Role: Project Manager, Instructional Designer
  - This project was a government-funded project (Korea Electronics and Telecommunications Research Institute) and the goal was to develop an Augmented Reality Learning System to embed in the standardized curriculum of elementary science education. I designed and developed the AR-supported Learning Environment (storyboard, 3D modeling, animation, natural feature tracking, and the final AR system) using facilitation strategies, and I conducted a pilot test on the effects of the AR Learning System using quantitative and qualitative methods.
- **Social Networking Sites**: Learning Blog for iMBA
  - Role: Project Manager
  - I developed a learning blog for iMBA students, which was designed to support individual learning progress and social activities using Web 2.0 functions. This blog was evaluated as an effective learning tool to create a knowledge-based community of practice by the students and instructors.

HR Consultant for Samsung CREDU Corporation, Seoul, Korea (2005 – 2006)

- **Title : Competency Analysis and HRD Strategy Formulation**
  - Client: Supreme Prosecutor's Office, Ministry of Justice of the Republic of Korea
  - Outcomes: Talent Model, Competency-based Curriculum, Training Curriculum
- **Title : HR Consulting for Small and Medium Enterprises**
  - Client: Korean Ministry of Labor of the Republic of Korea
  - Outcomes: Human Capital Strategy, Job Analysis, Competency-based Curriculum, HR Strategies using Balanced Scorecard (BSC) model
- **Title : The Model Business of National Lifelong Education**
  - Client : Korean Ministry of Education of the Republic of Korea

    - Outcomes: A series of online degree programs for the National Credit Bank System
- **Title : Organizational Culture & HRD Strategy Formulation**
    - Client : CJ Development Co., Ltd., Seoul, Korea
    - Outcomes: Change Management Strategies, Competency-based Curriculum

Lead Instructional Designer for Samsung CREDU Corporation, Seoul, Korea (2003 – 2004)

- Partnered with Samsung Human Development Center for Talent People training
- Developed and refined the CREDU 5 Step Blended Learning Model
- Instructional Development Projects
    - Change Management programs for public officials of the Ministry of Education
        - ✓ Role: instructional designer, training facilitator
        - ✓ This e-learning program taught strategic change management skills for corporate transformation and change using a variety of authentic cases.
    - GE Work-out programs customized for public officials of the Ministry of Labor
        - ✓ Role: instructional designer, training facilitator
        - ✓ This blended learning course taught GE's legendary work-out program, which included effective assessment and decision making tools. Lesson activities ranged from case studies and online discussions to action planning.
    - Training programs for plant project managers of Samsung Engineering & Construction
        - ✓ Role: instructional designer, training facilitator
        - ✓ This blended course, as part of a certificate program, taught plant project managers of Samsung Engineering & Construction. Lesson activities ranged from case studies, online discussions, and action planning, to 360 degree evaluation.
    - The 7 Habits of Highly Effective People (Korean)
        - ✓ Role: instructional designer, training facilitator
        - ✓ This blended course taught the basics of the 7 Habits of Highly Effective People (Stephen Covey). Lesson activities ranged from case studies, online discussions, and 1:1 coaching, to 360 degree evaluation.

Policy Planning Consultant for Samsung CREDU Corporation, Seoul, Korea (2004 – 2007)

- Provided internal consulting service to the president of CREDU, who was a member of the Educational Consulting Committee as well as the president of the Korea e-Learning Industry Association
- Established and released Annual e-Business Strategies entitled, "e-Learning Vision Report Korea" to e-Business enterprises, academic societies, and government agencies (2004-2007)
- Planned and supervised e-Learning Annual Forum (2004-2007)
- Conducted the annual global benchmarking on future learning technology
  - I/ITSEC International Conference 2005 (Florida, USA)
  - E-Learn International Conference 2006 (Hawaii, USA)
  - International Benchmarking Tour 2006 (Tokyo University, Fujitsu, and NTT)

TEACHING

University Courses

2013-present **[EDCI 577] Strategic Assessment and Program Evaluation**
- **Co-instructor with Dr. Marisa Exter**
- Facilitated weekly discussions, group activities, and individual projects

2013-present **[**EDCI 528] Human Performance Technology
- **Co-Instructor with Dr. Marisa Exter**
- Co-developed the instructional materials and teaching strategies to fit into online learning environments

2013-present **[**EDCI 569] E-Learning by Design
- **Co-Instructor with Dr. Marisa Exter**
- Co-developed the instructional materials and teaching strategies to fit into online learning environments

2012-2013 **[**EDCI 568] Educational Applications of the Internet Using Digital Tools to Support 21st Century Learning
- **Co-Instructor with Dr. Peggy Ertmer**
- Co-developed the instructional materials and teaching strategies to fit into online learning environments

2008-2010 **[EDCI 270] Introduction to Educational Technology and Computing**
- **Assistant Instructor** under the direction of Dr. Timothy Newby
- Lectured, prepared, and supervised undergraduate lab sessions

  - Developed instructional materials and evaluated student learning outcomes
  - Facilitated weekly discussions, group activities, and individual projects

HR Training Programs

Yu, J. (2007). Augmented Reality System for Education. Korea Education and Research Information Service (government agency), Seoul, Korea.

  - Delivered trends and issues in Virtual Reality research and practice
  - Introduced the government funded 3D Augment Reality learning system. Reported on the 3-year pilot test results

Yu, J. (2007). Building a Learning Community using Web 2.0 tools for iMBA faculty members, students, and staff. Sungkyunkwan University, Seoul, Korea.

  - Taught how to use Learning Blogs to iMBA students, faculty, and staff
  - Delivered implementation strategies for Learning Blogs embedded in LMS

Yu, J. (2006). Learning Theories for E-Learning Design. Samsung CREDU Corporation, Seoul, Korea.

  - Taught learning theories and e-learning trends and issues to novice instructional designers, LMS developers, and marketers
  - Developed instructional materials and evaluated trainees' assignments and reflections

Yu, J. (2006). Global Benchmarking of E-Learning System. Samsung CREDU Corporation, Seoul, Korea.

  - Delivered benchmarking results and trends and issues in e-Learning business
  - Addressed strategies to improve the current instructional design approaches, LMS system, and marketing approaches. Developed instructional materials and evaluated trainees' action plans

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GRANT WRITING EXPERIENCE

National Science Education Research in Engineering Education

- *Investigation of EPICS as a High School Pathway into Engineering.*
- Purdue University PI: C. Zoltowski; Co-PI: M. E. Cardella, M. Exter, W. C. Oakes ($305, 098)

Spencer Education Foundation

- *A Psychometric Instrument to Measure the Personal Philosophy of Engineering*
- Purdue University PI: J. Strobel. ($25, 000)

HONORS & AWARDS

AECT/NSF Early Career Symposium recipient 2013

- An academic merit based award given to early career faculty and advanced doctorate students in Learning Design and Technology program for excellence in research (Association for Educational Communications & Technology, $1,400)

Frank B. DeBruicker Graduate Award 2012

- An academic merit based award given to one graduate student in the Learning Design and Technology program for excellence in research (Purdue University, 2012-2013, $1,000)

Graduate Research Assistant for NSF GSE Project

- Received a Research Assistantship (Summer 2012-Summer 2013)
- Title: Examining Engineering Perceptions, Aspirations, and Identity Among Young Girls
- PI: Dr. Brenda, M. Capobianco; Co-PI: Dr. Heidi, A. Diefes-Dux

Graduate Research Assistantship in NSF VOSS Project

- Received a Research Assistantship (Spring 2010-Spring 2012)
- Title: Transforming Loose Networks into Sustainable Interdisciplinary Virtual Organizations.
- PI: Johannes Strobel; Co-PI: David F. Radcliffe

College of Education Graduate Student Travel Award

- Fall 2009, Fall 2010, Fall 2011, Fall 2012, Fall 2013

ISPI University HPT Case Study Competition

- Received an award for Top 3, s*ponsored by International Society of* Performance Improvement Conference (ISPI) 2011

Ross Graduate Fellowship at Purdue University

- Outstanding Ph.D. students (Fall 2008- Spring 2012)

AECT Design and Development Showcase Certificate

- Received the certificate sponsored by the Design and Development Division of the Association for Educational Communications and Technology (AECT)

Samsung CREDU e-Learning Courseware Design Award

- Received an award for outstanding business training programs

Samsung CREDU Best Employee Award

- Received an award for best performers

National Undergraduate Thesis Award Winner

- Received an award for Top3 Thesis in Social Sciences
- *Title: The relationship between teachers' perception of student-centered learning and teaching behavior in the classroom: A qualitative study*
- *Ministry of Education, Korea*

PROFESSIONAL AFFILIATIONS

- Association for Educational Communications and Technology (AECT), 2008-present
- American Educational Research Association (AERA), 2008-present
- American Society for Engineering Education (ASEE), 2010-present
- European Society for Engineering Education (SEFI), 2011-present
- National Association for Research in Science Teaching (NARST), 2012-present
- Purdue Association of Educational Technology (PAET), 2008-present