

A REVIEW OF 25 YEARS OF RESEARCH: ELEMENTARY PROSPECTIVE TEACHERS IN UNIVERSITY MATHEMATICS CONTENT COURSES

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The purpose of this review was to examine the 25-year period of research on elementary prospective teachers (EPTs) in mathematics content courses since publication of the Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989). Analysis included an extensive electronic search and a manual search of 11 well-respected journals. Twenty-four studies met the inclusion criteria. Nineteen of the 24 studies occurred in the context of a reform pedagogy. Results showed positive changes in EPTs' affect were possible, but these shifts were sometimes difficult to come by and encountered resistance from the EPTs. Some studies showed an increase in EPTs' content knowledge, while others did not achieve the desired effects. Results show further study of EPTs' content knowledge is warranted. Implications for course learning experiences and suggestions for future research are offered.

Keywords: Mathematical Knowledge for Teaching, Teacher Education-Preservice, Teacher Beliefs, Teacher Knowledge

Introduction

Similar to many countries, in the U.S. most elementary teachers are prepared as generalists during initial teacher preparation, ultimately assuming positions in schools requiring the teaching of all subjects. Such all-purpose preparation has led to a corpus of elementary teachers needing improved knowledge for effectively teaching mathematics with understanding and proficiency at the level of rigor and depth depicted by the *Common Core State Standards for Mathematics* (CCSI, 2010). The significance of mathematical knowledge should not be underestimated, since teacher knowledge has been linked to teaching effectiveness and ultimately student learning (Hill, 2010). Wu's (2009) assertion rings true: "The fact that many elementary teachers lack the knowledge to teach mathematics with coherence, precision, and reasoning is a systemic problem with grave consequences" (p. 14). Accordingly, considerable resources and efforts have been devoted to both understanding this knowledge and determining efficacious ways of building it (e.g., Ball, Hill, & Bass, 2005). Many institutions of higher education have added specialized mathematics content courses for elementary prospective teachers (EPTs) that according to the Conference Board of the Mathematical Sciences (CBMS, 2012) should be grounded in the perspective that teachers should study the mathematics they teach in depth and from the viewpoint of the teacher.

Such mathematics courses hold challenges specific to elementary teachers, who often have negative affect toward mathematics, including dislike and avoidance (Bekdemir, 2010), and a propensity to espouse traditional, procedural views on what it means to know and do mathematics and on how it is learned (CBMS, 2012). These difficulties are compounded by the perspective of some EPTs who think they do not need to learn more mathematics, as their experiences thus far have provided them sufficient content knowledge needed for teaching in the elementary classroom. Given this increasing awareness of the need for improved mathematical knowledge of elementary teachers via specialized mathematics courses, coupled with constraints particular to this population, research on EPTs in university mathematics content course experiences is critical.

Purpose of the Review

The purpose of this review is to examine the research on EPTs in mathematics content courses since publication of the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). Specifically, the review examines empirically based articles published from 1990 to 2014 (25 years) with EPTs as participants, who were completing university courses identified as mathematics content courses. We review past research in order to present the state of knowledge on the mathematical preparation of EPTs and also to highlight areas research has left unresolved. We provide summary findings and contributions of the body of work, implications for elementary teacher preparation, and suggestions for future research.

Method

The pool of articles in this review was determined through several cycles of appraisal and scrutiny using a comprehensive search strategy aimed at identifying all available studies. Criteria for initial inclusion were that the study must have: (a) been published between 1990 and 2014, (b) included EPTs in an initial certification program as participants, and (c) occurred in a university mathematics content course/university math for teachers content course/or university course that simultaneously focused on mathematics content and teaching methods as the context. A university course solely focusing on mathematics teaching methods was excluded, as were studies in yearbooks and conference proceedings.

The five-member research team engaged in several cycles of examination to arrive at the final collection of articles. The first round was an electronic search that cast a broad net for evidence of the initial inclusion criteria. The electronic databases explored were ERIC, PSYCH Info, Academic Search Complete, Professional Development Collection, and Psychology and Behavioural Sciences Collection using combinations of the following key words: elementary education, elementary teachers, mathematics, undergraduate, mathematics courses, pre-service teachers, prospective teachers, content courses, and early childhood education. Review of abstracts from this search yielded a total of 54 publications. Simultaneously, a targeted, manual review of abstracts in 11 journals considered to have high scholarly regard in the fields of mathematics education and teacher education were examined. These included *American Educational Research Journal*, *Cognition and Instruction*, *Educational Studies in Mathematics*, *Elementary School Journal*, *Journal of Mathematical Behavior*, *Journal of Mathematics Teacher Education*, *Journal of Research in Mathematics Education*, *Journal of Teacher Education*, *School Science and Mathematics*, *Teachers College Record*, and *Teacher and Teaching Education*, which gleaned a total of 40 articles. After eliminating duplicate articles between the electronic database and targeted journal searches the pool for the next round was 89 articles.

Because the original search cast a wide net that focused only on the content of abstracts, the second round of examination focused on the entirety of the article and involved in-depth scrutiny of each manuscript. All 89 manuscripts were carefully reviewed by at least two researchers using a rubric that applied the initial inclusion criteria. In addition to the criteria listed above, to be included the work had to: (a) be research-based, i.e., the report presented research question(s) or purpose(s); (b) provide a review of relevant research and/or theoretical frame; (c) include a description of methods, including participants, context, data collection, and data analysis; (d) present results; and (e) give some interpretation or discussion. These research-based elements were created drawing from *Standards for Reporting on Empirical Social Science Research in AERA Publications* (AERA, 2006). In addition, we noted in the review if a pedagogical approach or method was indicated. In order to establish agreement on the meaning of the components of the rubric, each member of the research team independently read and examined two pre-determined articles (one qualitative and one quantitative) before convening as a group to consider and discuss consistency of interpretation and application of the rubric across the studies. Three typical reasons for exclusion from the final pool

were studies (a) that failed to meet all the research elements criteria, (b) that appeared to have content course contexts but were in fact methods courses, and (c) that involved participants other than EPTs. Of the 89 articles in this round, 24 qualified for the final pool. Journals represented and number of studies in each included *American Educational Research Journal* (1), *Educational Research for Policy and Practice* (1), *Educational Studies in Mathematics* (4), *International Journal of Mathematical Education in Science and Technology* (1), *Issues in Teacher Education* (1), *Journal for Research in Mathematics Education* (1), *Journal of Mathematical Behavior* (5), *Journal of Teacher Education* (1), *Mathematics Education Research Journal* (1), *Mathematics Teacher Education and Development* (1), *School Science and Mathematics* (7).

Summary Findings

We sorted the studies using four distinctive categories from the review rubric: research method, context, purpose/focus, and pedagogical approach of the instruction. A brief overview of each follows.

When considering **research method**, five studies involved quantitative methods only, nine studies included qualitative methods only, and ten studies involved some combination of qualitative and quantitative methods. Clustering by years is shown in Table 1.

Table 1: Clustering by year of the study and research method

	1990-1994	1995-1999	2000-2004	2005-2009	2009-2014
Quantitative				3	2
Qualitative	2	1	2		4
Mixed		2	1	2	5

With respect to **context**, 18 of the studies data collection occurred within one mathematics content course (which may have been collected across multiple sections of the same course). In the six remaining studies, context for data collection occurred in a variety of settings including a comparison of EPTs who completed a content course and those who did not, a study of four integrated content/methods courses, and studies that looked at more than one content course.

When classified by the **purpose/focus** of the study, twelve studies examined affective factors of the EPTs such as beliefs, attitudes, motivation, and identity. Ten studies investigated various forms and concepts of mathematical knowledge of the EPTs. One study explored both affective factors and mathematical knowledge. The last study examined the development of classroom norms and mathematical justification. A classification by years and focus is shown in Table 2.

Table 2: Clustering by year of the study and focus

	1990-1994	1995-1999	2000-2004	2005-2009	2009-2014
Affective	1	2	2	2	5
Cognitive	1		1	3	5
Other		1		1	

Finally we clustered by **pedagogical approach** used in the courses. We termed the pedagogy as reform when it aligned with pedagogy described by NCTM in the *Principles and Standards for School Mathematics* (2000) and/or the *Principles to Action* (2014). Any study that generally described EPTs learning through means such as peer or small group interactions, classroom discourse, modeling and representations, and/or problem solving tasks involving reasoning and sense making, among other elements, was considered to involve reform. Nineteen of the 24 studies were

identified as reform. In the remaining five studies, the pedagogical approach was either not described or was not clear.

Extended Analysis of Courses Involving Reform Pedagogy

Within the nineteen studies identified as using reform pedagogy in the courses, we found, among others, descriptors such as: the instructor acts as a facilitator; students work in small groups; students present their ideas to the class; manipulatives are used; and problems are used to build conceptual understanding, reasoning, and sense-making. Some studies included significant details about the instruction, while others were less forthcoming. In either case, the salience of this instructional focus is evident based on the large portion of the twenty-four studies that involved reform pedagogy (79%). Within these nineteen studies, ten focused on affective factors. Five of the ten examined change that occurred over a course or courses and four were descriptive. Seven of the nineteen studies focused on content knowledge, specifically its development. One of the nineteen examined affective factors and content knowledge, one compared two groups (one having a reform course and one that did not), while the remaining study focused on constructing classrooms norms and mathematical justification within a reform approach.

Studies Not Categorized as Using Reform Pedagogy

Three of the remaining five studies addressed specific areas of mathematics content (i.e., the associative property, order of operations, and polygons), but not within a reform course. All three of these studies were descriptive, relating EPTs' understandings. The two remaining studies explored affective factors. One studied the relationship between motivation to learn mathematics and attitudes toward mathematics and the second conducted a collective case study using data from two previous studies in which the researchers contrasted the EPTs and instructors' perspectives, looking for common themes and relationships. Table 3 displays reform and other instructional approach clustered by year.

Table 3: Clustering by year of the study and pedagogical approach

	1990-1994	1995-1999	2000-2004	2005-2009	2009-2014
Reform	2	3	2	4	8
Other			1	1	3

As evidenced in Tables 1-3, research on the mathematical preparation of EPTs has increased over the last 10 years, has predominantly employed a reform approach to instruction, and as noted earlier, was primarily done within a single course or sections of a single course. Quantitative only methods were employed least.

Space limitations prevent a detailed accounting of each of the 24 studies¹ in this paper. However, some additional summary findings are worthy of mention.

- Several studies across the time frame (e.g., 1996, 2004, 2007, 2014) using both qualitative and quantitative methods and occurring within a single course employing a reform pedagogical environment revealed EPTs generally developing positive affective stances.
- While positive impact of reform pedagogies was reported, there was also evidence of mixed results where EPTs showed some reform perspectives, but continued with some traditional perspectives (e.g., 1993, 2004, 2011, 2014).
- Some studies that employed reform approaches showed little to no change in the overall content knowledge of the EPTs (e.g., 1994, 2007, 2008).

Wood, M. B., Turner, E. E., Civil, M., & Eli, J. A. (Eds.). (2016). *Proceedings of the 38th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Tucson, AZ: The University of Arizona.

Discussion

It is noteworthy that only 24 studies across the past 25 years were identified as meeting the inclusion criteria. Eleven of these studies (46%) were published during the last five years of the period of review, showing a recent increase in attention on the mathematical preparation of EPTs. This upturn is heartening, but given the importance of elementary teachers having a deep and flexible knowledge of elementary mathematics and that courses taken during teacher preparation offer the best opportunity for development of this knowledge, more inquiry is warranted.

Affective Factors

Of the 24 identified studies, 19 were in the context of courses involving reform pedagogy and more than half (10) of the 19 looked at affective factors. Overall, this review found that a reform instructional approach had positive effects and provided opportunities for constructive shifts in affective factors such as beliefs about mathematics, confidence, motivation, and attitudes. Specifically, six studies showed EPTs developed a positive perspective toward a reform approach to instruction, while three revealed a moderate effect and one showed almost no effect. Interestingly, this last study has the oldest publication date (1993), a time when focus on beliefs and affect was in its infancy.

The significant attention on teacher affect in the studies parallels the emphasis in the field of mathematics education over the time period and also provides credence to the assertion this teacher development construct is highly relevant to EPTs. That is, elementary teachers too often have negative affect toward mathematics, including a fear, dislike, and avoidance of the subject, and this propensity needs to be considered, addressed, and examined during university courses with the goal of affecting change. When considering learning experiences prompting change in teacher affect, the studies showed the use of problem-based instruction affording EPTs opportunities to invent their own solution strategies and engage in productive struggle, in addition to an emphasis on peer interactions, were efficacious.

Though course experiences promoted the desired changes in teacher affect to a degree, some studies noted that EPTs enter courses with such deeply rooted, negative affect that change was difficult and too often persisted at some level throughout and after the courses. Letting go of traditional perspectives on mathematics pedagogy learned over many years as students in classrooms was an arduous process and fraught with resistance. Results from two of the descriptive studies on teacher affect, one from the beginning of the time period (Civil, 1993) and one at the end of it (Chamberlin, 2013) support this assertion. We found that while the more recent group showed some change, both groups of EPTs, separated by a generation, exited their mathematics course still holding *some* traditional perspectives on what it means to teach and learn mathematics.

Content Knowledge

Further consideration of the focus of the identified studies showed an increased emphasis on research on content knowledge over the time period. Of the seven studies focusing on specific content knowledge in this group, four studies revealed improved content knowledge in courses involving reform pedagogy, while the remaining three did not achieve the desired effect. A few studies (some within a reform pedagogy and some that were not) focused on examining specific areas of content knowledge (e.g., fractions, nominal categorical data, ratio, polygons, order of operations, associative property of multiplication) that revealed mixed findings of EPTs learning. Research on more areas of elementary mathematics is clearly needed. Several studies lent credence to the importance of EPTs' understanding the relevance and usefulness of the mathematics learned in the courses, including explicit connections to the elementary classroom. However, one study found instructors and EPTs had conflicting viewpoints on such an emphasis (Hart, Oesterle, & Swars, 2013).

The overall shift in attention from affective factors (e.g., teacher affect, etc.) toward content knowledge is depicted in Figure 1. Over the time period 1989-2014, the percentage of studies focusing on content knowledge increased, while studies of affective factors remained relatively constant (Three studies are not included in this total.)

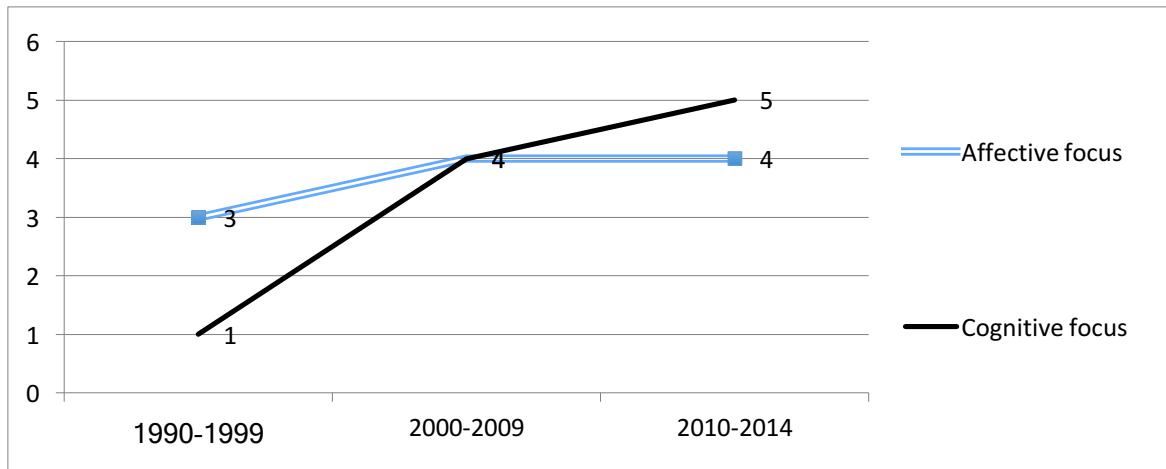


Figure 1: Changes in focus related to the EPTs.

This general trend aligns with the recognition of the need for elementary teachers to have well-developed mathematical knowledge, coupled with the efforts to define the mathematical knowledge needed for teaching (MKT).

Potential Implications

As more and more institutions of higher education require specialized mathematics content courses for EPTs, this analysis revealed certain elements of reform pedagogy generated positive changes. EPTs must have time and opportunities to think about, discuss, and explain mathematical ideas, coupled with a focus on mathematics as a sense making activity. Further, it is imperative EPTs perceive the relevance of the mathematics they are learning to their future profession. Emphasizing problem solving and other mathematical processes (Lubinski & Otto, 2004) and also studying children's thinking (Philipp et al., 2007) are effective mechanisms for promoting learning and change.

Different institutions of higher education include varying mathematics topics in their content courses for EPTs. Regardless of the specific content, an emphasis on problem solving, reasoning, and justification promotes EPTs' learning and change. For example, Liljedahl (2005) suggests that through posing problems, allowing substantial time for working on problems immediately after being assigned, providing time to revisit already assigned problems, working with peers in small groups, and engaging in a reflection about problems can positively transform EPTs' mathematical affect.

Further, while the ostensible purpose of a mathematics content course for EPTs is to learn mathematics, there are strong reasons to incorporate study of children's mathematical thinking into coursework (Philipp et al., 2007). Instead of trying to interest EPTs in mathematics for the sake of mathematics itself, providing connections to something to which they are fundamentally concerned, children, prompts motivation, learning, and change. Studying children's thinking challenges EPTs' beliefs about mathematics and leads to the recognition that their own mathematical understandings are insufficient for teaching elementary mathematics. Such an emphasis also helps EPTs appreciate how important it is for them to know the content for their future roles as teachers. The relevance of the mathematics they are learning to their chosen career path is evident.

Suggestions for Future Inquiry

Considerable challenges exist for reaching the desired goals for EPTs in mathematics content courses. In general, the findings of this analysis showed positive changes in teacher affect and content knowledge are possible within a reform approach to instruction. But, these changes were sometimes difficult to come by and often encountered resistance from the EPTs. Given the paucity of studies, more inquiry is needed, particularly on the aforementioned means of prompting learning and change (e.g., a focus on problem solving, studying children's thinking, etc.). In addition, longitudinal study over several courses or an entire teacher preparation program is warranted. Further, the sustainability of changes in EPTs as they graduate and become responsible for their own classrooms, and how or if such changes translate into classroom practices, are worthy of study. We note that some longitudinal studies may exist but were not the focus of this review. Likewise, EPTs' individual characteristics or capabilities should be examined in relation to change, given the findings of one study revealing mainly high mathematical achievers in the course significantly changed their beliefs (Emenaker, 1996), in contrast with the results of Philippou and Christou (1998), who found change was not-correlated with any of the individual characteristics tested, including mathematical performance.

As a final note, one concern from this review is the significant number of the original 89 studies that failed to incorporate all the elements of quality research and therefore were not considered to meet the criteria for this project. It is imperative that future research on the mathematics education of both elementary prospective and practicing teachers attains a level of rigor that will inform the field of mathematics education in a trustworthy and legitimate way. After 25 years of research in this area, we are still limited in definitive evidence of how to make a difference with this population of learners.

Endnotes

¹Full citations for the 24 papers mentioned in this paper will be available at the presentation and can be obtained by emailing the first author.

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