



Reform-based Mathematics Teaching Practices for Teacher Candidates' Professional Development

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Abstract

K-6 teacher candidates in the USA are required to meet three mathematics criteria, (1) attainment of conceptual understanding, (2) correctness of procedure fluency and (3) an understanding of mathematics reasonings and problems-solving from Educative Teacher Performance Assessment [edTPA], which is the most popular assessment for initial certification/licensure teacher candidates in the U.S.A. Research demonstrated that teacher candidates' can be enhanced to better prepare for reform-based mathematics teaching. The purpose for designing this study was to examine how K-6 teacher candidates' professional development transferred to reform-based mathematics teaching that align with three edTPA criteria. The study implemented the mixed methods with 15 K-6 teacher candidates participating in both quantitative and qualitative research activities. Data were collected from participants' final assessment portfolios to evaluate candidates' teaching effectiveness, The study also conducted semi-structured verbal interviews with candidates' math lesson design, reformed-based mathematics teaching, and the role of self-efficacy in doing reform-based teaching. Results indicated that candidates face multiple challenges in transferring from skill-repeated (traditional) math teaching to reasonings-developed (reform-based) math pedagogy. Teacher candidates agreed that from traditional to reform-based mathematics teaching benefits their teaching effectiveness. Methods for facilitating reform-based teaching in mathematics via professional development is discussed.

Keywords: K-6 teacher candidates' assessment, reform-based mathematics teaching, elementary mathematics edTPA, teacher candidates' self-efficacy

1. Introduction

The reformed-based teaching paradigm, based on research-based methods, supports changes in perspective from teacher-centered to student-centered learning. MacIsaac and Falconer (2002) wrote that effective teachers may or may not, depending upon circumstance, tune their pedagogy to research-based methods. Thus, teacher preparation faculty members must support reformed-based teaching by advocating, demonstrating, and providing feedback on

adoption of learner-based perspectives. Researchers (Gabriele & Joram, 2007; Polly et al, 2020) have demonstrated the efficacy of such reforms in producing increments in K-12 students' learning and attitude. In addition, such supports increase teacher candidates' self-efficacy (Sawyer, 2017). To make sure that teacher candidates have maximized teaching self-efficacy, many states adopted edTPA (2024) to assess candidates' performance and, indirectly, their sense of self-efficacy. Teacher candidates represent, or fail, to demonstrate their self-efficacy by employing research-supported methods, in the present case, reformed-based teaching paradigm.

1.1. edTPA and pre-service teacher candidates' self-efficacy

About two decades ago, education policy makers in the U.S.A. expressed concern about the validity of teacher and, by extension, candidate efficacy (National Center for Education Statistics, United States, 2009). In the past, each state in the United States has its own teaching certification/licensure requirements. However, after two decades of searching and evaluating approaches, many states have turned to SCALE's Educative Teacher Performance Assessment (edTPA, 2024). Some states officials (e.g. State of Minnesota) even situate the edTPA as a K-12 initial licensure requirement.

Teacher candidates express varying perceptions of their status as rising new teachers (Darling-Hammond & Bransford, 2005). Normally, teacher candidates build on self-efficacy when they successfully perform a given task in a field placement and receive their mentor's constructive feedback. Using Bandura's (1977) model, one may invoke "self-efficacy" that teacher candidates come to believe that they have the skills with which to successfully perform a given task and, perhaps even more importantly to successfully engage in problem-solving when they encounter a teaching or planning dilemma. Teacher candidates may invoke four elements in development their self-efficacy; these are (1) mastery experiences, (2) vicarious experiences, (3) verbal persuasion, and (4) physical/emotional arousal. All these elements are presented in solid, reform-based pre-teaching preparation and furthermore are at least indirectly assessed via the edTPA.

1.2. The research question of teacher candidate's self-efficacy

The purpose of the study was to examine the following research questions:

1. How do K-6 teacher candidates transfer traditional teaching to reform-based teaching in mathematics?
2. How do K-6 teacher candidates self-efficacy benefits them to implement reform-based mathematics teaching?

2. Related literature review

2.1. Reform-based mathematics teaching

By about 2015, standard-based education had been adopted across most states in the U.S.A. (Karatas et al., 2022). Effective mathematics teaching practices have been largely based on two related sources; first, the process standards promulgated by the National Council for the Teaching of Mathematics (NCTM, 2000); second, standards were also proposed by the National Research Council (NRC, 2001). The two sources reported in the strands of mathematical proficiency under conceptual understanding, procedure fluency, strategic competence, adaptive reasoning, and productive disposition (Karatas et al., 2022). These two sources were used in evaluating candidates' skills in planning for and utilizing "deep"

mathematics learning to improve instructional practices and ensure mathematics success for all students (NCTM, 2014); and represented components that form reform-based teaching practice in the United States (Taylor & Lee, 2021). By deep, I mean that candidate cannot only teach effectively, but that they exhibit an understanding of the theoretical aspect of *why* a certain approach is desirable. In addition, I looked for evidence that in vivo applications were literally or figuratively incorporated into planning and teaching.

Reform-based mathematics teaching is defined as the integration of teaching processes, with awareness of students' prior knowledge and where the educator involves students in real-life or symbolic in vivo application (Pfitzner-Eden, 2016). Symbolic applications must be included because P-12 students cannot always be sent into the environment to perform mathematics skills—though this practice is certainly *most* desirable. By “reform”, it means emphasizing mathematics thinking and reasoning rather than *only* memorization and computation, though these elements must also be present in effective instruction (Karatas et al., 2022).

Student-centered curriculum designs (Jong, 2016) to enhance students' conceptual and procedure and mathematics reasoning are the essential aim in reform-based mathematics teaching (Hiebert et al, 2003). Under the essential questions of reform-based mathematics teaching, the teaching events may emphasize problem-solving, mathematics discourse, justification of the answers, and using multiple methods or representation to solve the problems (NCTM, 2014).

2.2. Self-efficacy for reform-based mathematic teaching

Teacher self-efficacy (TSE) provides positive outcomes for teacher candidates and their future students. The levels of teacher candidate's self-efficacy likely improve their performance in conducting reform-based mathematics teaching (Gabriel & Joram, 2007). In fact, self-efficacy is an essential factor in reform-based mathematics instruction because teachers with higher levels of self-efficacy regarding their application of research-supported mathematics instruction methods, exhibit greater levels of application; in short, confident leads to use. Giles et al., (2016) conducted a study of 41 teacher candidates; they reported that teacher candidates performed more positively under conditions of higher self-efficacy and concluding that teacher preparation staffers must apply Bandura's components in their methods sequence.

Pfitzner-Eden (2016) conducted research by using teacher candidates as participants and the first sample (N=359) completed an overaction practicum, and second sample (N=395) completed a teaching practicum, and the research showed the TSE significantly changes in both groups. Teaching is a complex task (e.g., Darling-Hammond & Bransford, 2005) and teacher candidates have little prior knowledge of actual demands and perplexities of the teaching task, the judgement of mastery experiences might only depend on their own student teaching performance and knowledge from their teacher preparation program. Reform-based mathematics teaching provide a direction and goals for them to work on, and on the other hand, teacher candidate assessment, edTPA, required three criteria, which are aligned with reform-based mathematics teaching performance.

2.3. edTPA validity and confidence building

Effective elementary mathematics teachers are required to demonstrate acquisition of planning, teaching and assessment skills and knowledge (NCTM, 2014); these elements are represented in edTPA portfolio via three tasks domains: (1) Planning, (2) Instruction, and (3) assessment. Three criteria of elementary mathematics, conceptual understanding, procedure

fluency, and mathematics reasoning and problem-solving, are aligned with reform-based mathematics teaching expectation, even though some edTPA professional terms (e.g. language function, syntax, discourse etc.) and requirements (e.g. research/theory, learners and environment's assets, short video-filming etc.) may produce performance challenges (DeJanrnette, et al., 2021; Polly et al., 2020). The edTPA assignment during student teaching means that teacher candidates are required to perform, analyze, and justify their reform-based mathematics teaching, presumable in terms of the reformed methods they have learned in order to manage the three criteria. Certainly, to increase edTPA scores, teacher candidates encounter mastery experiences such as those suggested by Bandura (1977), putatively leading to increased confidence (e.g., self-efficacy).

3. Methods

3.1. Setting

The mixed methods of this study were conducted at a comprehensive teaching-driven university in central Minnesota, U.S.A. The unit offered undergraduate B.A. degrees to K-6 elementary education candidates, rendering them eligible for initial licenses. Initial license teacher candidates typically undertake the edTPA (either elementary literacy or elementary mathematics edTPA) in their student teaching semester (the final semester) and submitted it prior to an as a requirement for graduation as completion is a licensure requirement.

3.2. Participants

This study followed three cohorts of undergraduate senior teacher candidates, which are including teacher candidates in 2022 spring, 2022 fall semester, and 2023 fall semester. The totally students in the three cohorts are 87. Out of 87 teacher candidates, 33 teacher candidates agreed to share their edTPA scores for the study, signing the IRB approved letter of consent. Within 33 teacher candidates, 15 of 38 (39.5%) candidates agree to participated in the interview activities. The study did not investigate the reasons that more than half of potential candidates declining to participate; however, they were reacting to added workload of the of the interview; in the future studies, it may plan to look at this more closely. Impressionistically, however, no obvious differences accrued between participants and their non-participating classmates, in terms of grade point level and gender. Thus, the samples can be considered as representative of the population.

3.3. Data collection and analysis

The elementary mathematics edTPA scores were collected from the 33 participants for answering the first research question: How K-6 teacher candidates transfer traditional teaching to reform-based teaching in mathematics. A descriptive statistic is used to report and analyze the three criteria, conceptual understanding, procedure fluency, and mathematics reasoning. The verbal interviews were hosted after participants completed and received their edTPA scores. Fifteen participants provide their perspectives about reform-based mathematics teaching experience in their field and how their self-efficacy support them to do reform-based teaching and prepare for their edTPA assessment. The qualitative data were analyzed presented the second research question: How K-6 teacher candidates' self-efficacy benefits them to implement reform-based mathematics teaching. The interview data is analyzed by coding process. Some main coding themes are "student-centered learning", "reasoning development", "play-based, game-based or inquiry-based teaching" and "self-efficacy."

4. Results and Discussions

4.1. The quantitative data results and discussions

Table 1 includes the 33 teacher candidates' mean scores in the three tasks of edTPA tasks. Note that edTPA materials report interrater reliability scores of from .64 to .81 for the fifteen rubrics three domain entries in Table 1 below. These reasonable reliability indices are probably generated via the rigorous training and assessment completed by those scoring the edTPA (edTPA, 2024).

Conceptual understanding, procedure fluency, and mathematics reasoning and problem-solving criteria in elementary mathematics edTPA were collected over three semesters from rubrics developed for scoring the edTPA; because the materials are copyrighted, I did not provide them here. However, roughly, the rubrics represent the candidate's ability to (a) explain the methods selected under the three; (b) the smoothness of the descriptions provided, and (c) the degree to which candidates imbedded reasoning and problem-solving into the three domains (edTPA, 2024).

Table 1: The 33 participants' descriptive statistics (average scores are represented below)

Rubrics Within Tasks ¹	Planning task	Instructional task	Assessment task	Total ²
Conceptual understanding	3.5	3.5	2	9
Procedure fluency	4	4.5	2	10.5
Mathematics reasoning and problem-solving	3	3	2	8
Total	10.5	11.0	6	

¹Source: (N=33 from Spring 2022 to Spring 2023)

²The sum of rubrics scores across Task domains.

To the degree that values across Tasks are comparable (a state of affairs supported by edTPA publications), candidate proved most proficient in delivering instruction (11.0 of 15), and lowest on the assessment rubrics (6 of 15). Within three criteria, procedure fluency showed the highest performance and mathematic reasoning and problem-solving, the lowest. For those unfamiliar with the edTPA, it is worth noting that evaluators score the instructional Task largely via in-situ performance with a video recording provided. I would add that the relationship between scores shown in Table one was remarkably similar across the three semesters.

Another way to understand these results is that teacher candidates tended to perform well in their teaching focused on procedure correctness and enhancing student fluency as a priority. Teacher candidates perform well in real teaching scenarios and reform-based planning (based on the documents cited above), but many struggles with assessing student learning in light of the reformed-based teaching promulgated for the profession.

The researcher of this study interpreted these data from my experience as meaning that candidates need to improve their assessment strategies in order to know how to guide students in focusing on critical thinking as a reform-based mathematics teaching requirement. IThe researcher of this study should note here that national edTPA data demonstrates that assessment remains difficult for candidates across edTPA tools (they differ by subject matter) nationally—meaning that difficulties with assessment either accrue to the instrument or to the objective difficulty of assessment as a skill domain—not to the program represented by these candidates. My observations tend to support the latter interpretation; that is, assessment, as measured via the edTPA is **objectively and developmentally** difficult for novice educators. Perhaps it remains natural for novice educators to concentrate on the delivery of instruction. Also, in the classes, the researcher of this study has noticed that, as assessment is technically

difficult—an advanced topic as it were, my candidates tend to go through the motions rather than really delving into the importance of assessment in planning and guiding instruction. Perhaps knowledge and skills related to assessment ought to be put off until teachers have gained more perspective via teaching. It also remains possible that teacher candidates boasting minimal in situ teaching experience, can better navigate planning and instruction from textbook learning in their methods sequence while struggling with assessment.

4.2. The qualitative data results and discussions

The interview data may better reveal the development of self-efficacy among the 15 candidates. Specifically, I asked them about their perceived efficacy in meeting national standards for reform-based mathematics teaching. In looking at the data, it was discovered that themes reflected reasoning-developed, notions or content reflecting student-centered learning. Discrimination of these themes proved relatively straightforward. For details of the scoring system, please contact the researcher of this study at the e-mail address provided.

4.2.1. Conceptual understanding

In meeting the national reforms, teacher candidates are required to concentrate on building students' critical thinking and to make contain of elementary students' level of conceptual understanding (certainly as assessment-heavy task). Most of teacher candidates adopted the play-based, game-based, or project-based teaching methods emphasized in our program from the recommended textbook (Van de Walle et al., 2022). These methods seemed to help candidates ask different but salient questions.

I need to ask students “why” so students can show me their conceptual understanding evidence orally. ...It is very important for me to learn how to effectively ask students questions so students can use their own word to describe their understanding. (quoted from the participant five, coded as of reasoning development).

Math games are so helpful for students play and develop their conceptual understanding. I ask them questions like “how do you win the game?” or “why do you think you are on the right track?”, ... These help me to know [that] they [putatively elementary students] have learned the concept of fractions and can explain why her fraction is greater than her opponent. (quoted from participant eight, coded as of student-centered learning).

4.2.2. Procedure Fluency

How educators motivate students to learn mathematics is one of the important elements in reform-based mathematics teaching. Methods of inculcating skills, which tend to reflect result-driven processes. To make certain that students enjoy doing the repeated steps correctly and answers are correct as well, most of teacher candidates appreciated game-based strategies, which fit the reform-based teaching cited in the literature review.

I love reform-based teaching because students have fun to use dice (or number cards) to make different fractions and compare which fraction is greater. The more they play, the better fraction concept is used in the game. For example, I gave them a geo-board and ask them to find 10 different kinds of “half ($\frac{1}{2}$)” shown via the geo-board. They are so interest to explore different “ $\frac{1}{2}$ ” [combinations] when they have “equal area” conceptual understanding. (quoted from participant twelve, coded as of game-based teaching).

I asked students to tell me three different ways (but not standard algorithm) to get the sum of $46 + 78$. In the beginning, my students are kind of confused [by] what I meant.

When I give them a hint (not answer), they begin to find like $40 + 70$ get 110; and $6 + 8$ get 14; and then $110 + 14$ get 124. After that, they practiced similar questions (from iPad games) by using their own ways becoming more fluency. I have to say [that] they loved it and feel meaning in [their] math lessons. (quoted from participant two, coded as of play-based engagement).

4.2.3. Mathematics reasoning and problem-solving

In meeting reform-based teaching requirements, teacher candidates are required to generate mathematical and numerical reasoning from their students, thus supporting problem-solving. It was found that for teacher candidates, it proved difficult collect examples of elementary students' mathematics reasoning. Perhaps because examples of such behaviors are seldom found in the teachers' guides provided in schools. However, when some teacher candidates "deeply" adopted inquiry-based approaches, they proved able to generate such examples.

Questions from textbooks normally just repeat the same skills (same kinds of questions) over and over. However, I don't know how to assess their conceptual understanding under math games. Students still need to answer workbook questions. Those questions just repeat, repeat, and repeat without any "why" questions or "how" questions. I feel [that] students enjoy playing math games I provide and don't like to do their workbook at all. (quoted from participant two, code as of reasoning development)

To meet reform-based mathematics teaching, I design my measurement [in my] math lesson to be inquiry-based. Under the five Es' process [Engage, Explore, Explain, Elaborate, and Evaluate], students represent how they measure the area of the classroom by how many steps they walked in one wide side and length side. I see my inquiry questions are so important to guide them think their own way, so my students know how to provide their mathematics reasoning in the whole group presentation. (quoted from participant eleven, coded as of inquiry-based assessment).

4.2.4. Self-efficacy is the key to support reform-based mathematics teaching

The researcher of this study asked teacher candidates to identify factors supporting their efforts to adopt the reform-based mathematics teaching via the methods sequence. Via this query, the researcher hoped to identify aspect of self-efficacy. In other words, what factors help them become more confident in applying student-centered ideas in their planning and instruction?

I belief I can do it and do it well by getting a lot of teaching experience during my students teaching time. Honestly speaking, the edTPA is way beyond my brain and so many people including some current teachers provide negative comments about edTPA. However, I want to get high score on the edTPA so I can smoothly apply for my MN K-6 teaching license. I truly believe I can do it because I know reform-based mathematics teaching very well from you. (quoted from participant seven, coded as of self-efficacy).

I feel [that] doing reform-based mathematics teaching strongly depends on self-efficacy. It is not like the traditional way to get the correct answer and move to the next lesson (presumably a critique of traditional approaches). It involves many strategies to let my students understand [new knowledge] deeply. In addition, students understanding and reasoning need to have evidence as an edTPA requirement. I would like to say that play-based and game-based teaching strategies play key roles

reform-based teaching and meet edTPA requirements. (quoted from participant 11, coded as of self-efficacy).

The interview showed that self-efficacy has the most power to help teacher candidates transfer their teaching style from traditional methods to the reform-based teaching requirements. Even though they understood that the edTPA played a role in assessing their performance in meeting the new national standards, they expressed a preference for replacing edTPA in judging their skills. It derived the firm impression that it was the workload added to their student teaching to which they objected—not assessment per se. All 15 interview participants announce that edTPA provided only cosmetic, and somewhat shallow, evidence for their efficacy. The instrument did not, it seems, add to their sense of self-efficacy.

5. Conclusion

This study directly examined teacher candidates' transfer from traditional mathematics teaching to reform-based mathematics pedagogy. The question was how teacher candidates transfer from reliance on skill-repeated teaching strategies to reasoning-developed pedagogy in teaching mathematics. Three criteria were adapted via the investigation (edTPA, 2024) for assessing candidates' performance. Indirectly, via the study, the role of self-efficacy in exploiting reform-based teaching was explored (e.g., Taylor & Lee, 2021; Jong, 2016; Darling-Hammond & Bransford, 2005; Hiebert et al, 2003). A second part of the study was related to previous studies of self-efficacy in doing reform-based mathematics teaching (Pfitzner-Eden, 2016; Giles et al., 2016; Gabriel & Joram, 2007; Bandura, 1977). Researchers (DeJanrnette et al., 2021; Polly et al., 2020) also investigated candidate performance on the “Elementary Mathematics” edTPA (2024), which plays a role in assessing teacher candidates' reform-based teaching performance and their levels of self-efficacy.

In line with the cited studies, teacher candidates recognized that they faced two significant challenges. First, they need to transfer math teaching strategies from skill-repeated to reasoning-based teaching to enhance students' mathematics understanding. Pre-service teacher candidates, with little real-life pedagogical experience (Darling-Hammond & Bransford, 2005), may require time for significant “real-world” practice of critical thinking-based teaching with feedback from their cooperative teachers. The second challenge, encountered by preservice teachers, is daunting pressure to complete the edTPA and thus licensure requirements (Polly et al., 2020). Even though the essential ideas in the “Elementary Mathematics” version of the edTPA aligned efficiently with reform-based mathematics teaching, teacher candidates perceive the edTPA's requirement as somewhat odious—at least as part of student teaching.

The results of the present investigation suggest that teacher candidates do not consider the edTPA as contributing to self-efficacy performance of reform-based mathematics pedagogy. This study demonstrated that teacher candidates would like to spend more time concentrated on their real teaching experiences than in understanding many requirements in the edTPA Handbook. This result echoes Polly, et al. (2020) findings that “...candidates expressed disproportionate periods of time dedicated to edTPA during student teaching” (p. 392).

Teacher candidates seem to sense that they spend too much time preparing and executing the edTPA and that this “time sink” inhibits their ability to take advantage of national reforms which they see as beneficial to students' learning. Teacher candidates from the horn of Africa, several of whom were represented in the study, faced more challenges than did their mainstream Midwestern counterparts. Two Somalian candidates performed extremely well in adopting reform-based teaching. However, they reported that, in their view, the edTPA

portfolio produced differential hardship. This deserves more attention from policy makers and researchers (see the concerns from DeJanrnette's et al., 2021).

The study indicated that teacher candidates, in building self-efficacy, need to perform the skills associated with reforms in mathematics instruction, under conditions of support and feedback. The results aligned with findings from previous reports (Pfitzner-Eden, 2016; Giles et al., 2016; Gabriel & Joram, 2007). The main facet that builds teacher candidates' self-efficacy (Bandura, 1977) is *master experience* under Bandura's (1977) four facets. Based on the present results, teacher preparation programs may need to increase teacher candidates' real-life teaching experiences in support of their emerging confidence. Effective assessment of teacher candidates' professional development may increase their self-efficacy (Gabriel & Joram, 2007), though interview data indicated that the edTPA per se does not do so.

The purpose of this study was to explore the facilitation of reform-based mathematics instructional models. The study supported the notion that, while a system for assessing and thus supporting reforms in math teaching probably a "social good" the edTPA may not be the best such system—the sheer workload, according to candidates, may have obviated the adoption of reforms. Teacher candidates tend to build self-efficacy by engaging in practice with support.

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