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Implementing Equitable Practice-Based Teacher Education to Advance Rural STEM Teacher Candidates' Pedagogical and Content Knowledge

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Abstract

This longitudinal three-year study explored implementation of practice-based teacher preparation incorporating high-leverage teaching practices to advance PCK. Participants included teacher candidates (n = 45) who completed elementary science and mathematics methods courses at a rural Midwestern university. Students engaged in teaching rehearsals to explore STEM concepts and equitable teaching practices. Data from surveys and student reflections revealed an increase in teacher candidates' perceptions of their knowledge and competence of teaching science and math content equitably.

Introduction

Teacher Preparation Programs (TPPs) are tasked with building well-started beginners, advancing novice teacher candidates' current content conceptual knowledge while also preparing them with strategies and methods to teach those content areas. In essence, TPPs develop students' burgeoning pedagogical content knowledge (PCK), first developed by Shulman (1986, 1987), and provide opportunities to advance student PCK from beginning to advanced novice status through foundations and methodology courses prior to student teaching. As Darling-Hammond and colleagues (2005) highlighted, TPPs cannot completely develop PCK, but should be designed in such a way to prepare PCK readiness in STEM fields that will continue to develop with novice teachers into the beginning stages of their career (Akerson et al., 2017).

In examination of practice in teacher education, the researchers discovered a disconnect from what was previously covered in methods courses and the transferability of that knowledge to teaching experiences for teacher candidates. Students were learning theoretical applications of best practices but struggled to enact those practices in their field placements. The TPP at this Midwestern university relies on a variety of assessments to analyze teacher candidate PCK readiness, such as teacher performance assessments, state-wide teacher examinations, traditional coursework, portfolio reviews, and classroom mentor teacher feedback. An analysis of the latter provided the launching point for this research, as mentor teachers noted students knew the theoretical underpinnings of best practices, but needed more development of how to use those pedagogical practices in a classroom full of diverse students and needs. Moreover,

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conversations with teacher candidates revealed perceptions of personal identity confidence and competence struggles with mathematics and science learning; thus, leading to challenges with teaching these subject areas. Regularly, the researchers heard at the beginning of the semesters, *I am not good at math*or *I was terrified of science classes.* These conversations were supported by the work of other researchers who discovered that teacher candidates have underdeveloped science conceptual knowledge (Carrier et al., 2017) and are lacking confidence in their math skills (Bekdemir, 2010) which historically has led to aversion to teaching those subjects. Overcoming the math/science reluctance while balancing how to teach these subjects was a critical part of this research on how to assist teacher candidates to develop their personal PCK.

Additionally, teacher candidates revealed their limited previous knowledge or models of working with diverse students. Many remarked that their previous K-12 learning was in fairly homogeneous settings whereas their field placements included diverse classroom settings reflective of the changes in population demographics in the state. Currently, the population of the state has 22% people of color (Minnesota Compass, 2023) with projections for future demographics suggesting the statewide diversity rate for school-aged population will be nearly 37% in 20 years, highlighting the rapid change of diversity (Palmer &Tchourumoff, 2021). However, some counties in the state, like those in which the university is situated and by which it is surrounded, have greater percentages of diverse students. In addition to racial and ethnic identities, teacher candidates are also challenged by working with students for whom English is not their first language who also have a myriad of other categories of diversity (Wright, 2019). Currently, 9.2% of K-12 students are considered English Language learners (Minnesota Department of Education, 2023) with projections for upwards of 25% of public-school students being language learners in two years (Piazza et al., 2020). Collectively, teacher candidates must not only know content knowledge and pedagogical best practices but also how to build relationships and personalize learning for a variety of students.

To be best equipped to effectively teach all students, including those unlike themselves, PCK development is critical for teacher candidates. Teacher identity and efficacy as defined by pedagogical content knowledge understanding serves as the theoretical framework for this research. Earlier researchers suggested that teacher preparation programs develop frameworks to assist teacher candidates with growth in both content knowledge and best practices for teaching said content (Ball & Bass, 2000; Ball et al., 2008; Ejiwale, 2013; Ignatz, 2005), and others suggest PCK be a necessary element of teacher education (Annetta & Shymansky, 2006). “The confluence of conceptual understanding merging content knowledge, pedagogical strategies appropriate to the content, and knowledge of child development was introduced by Shulman (1986) as pedagogical content knowledge (PCK)” (Noles Stevens, 2020, p. 36). Later the definition expanded to stress that teachers possess a robust and flexible understanding of content, deep enough to teach others (Ball et al., 2000). Pedagogical content knowledge can be described as a continuum from novice introduction to seasoned veteran and develops over time (Williams & Lockley, 2012). Teacher educators, specifically methods instructors, build foundations of initial PCK readiness and foster development to continue throughout the entirety of a career (Kind, 2009; Zembal-Saul et al., 1999).

Recognizing the needs identified by both classroom mentor teachers and teacher candidates, the researchers evaluated current teacher education reform efforts and research to address critical course design elements for instruction shifting towards practice-based teaching. The researchers, along with another colleague, participated in a multi-year graduate certificate learning sequence through the University of Michigan’s TeachingWorks program, focused on practice-based teaching with emphasis on using high-leverage practices (HLP) (TeachingWorks, 2023a). Departmentally, a shift to practice-based teaching models using high-leverage practices was implemented to strengthen the theory and practice taught in methods courses to the realities of present-day and future teaching (Dalinger et al., 2020; Darling-Hammond, 2017). Practice-based education focuses on novices learning how to teach through exercises working with peers and instructors in methods courses prior to clinical placements for content

(Forzani, 2014). Of particular importance, PBT focuses on elevating teacher education to improve teaching to meet and adapt the diverse and evolving current and future needs of students (Matsumoto-Royo & Ramfrez-Montoya, 2021). Practice-based teaching focuses on assisting teacher candidates to learn relevant knowledge of high-leverage practices and provides opportunities in courses to practice those core skills and dispositions to know when and how to use them effectively (Ball & Forzani, 2009; Davis & Boerst, 2014). Sometimes used interchangeably in the literature, core practices and high-leverage practices refer to the professional level teaching that is the ultimate goal of developing PCK. According to the TeachingWorks organization, whose supposition is great teachers are taught, explains

high-leverage practices are the fundamentals of teaching. These practices are used constantly and are critical to helping students learn important content. The high-leverage practices are also central to supporting educators to identify, understand, and begin to disrupt patterns of injustice in the classroom while reinforcing students' social and emotional development through equity and inclusion. (TeachingWorks, 2023b)

The shift to practice-based teaching centers on the improvement of teaching by building beginners through research-based best practices that address the complexity of teaching as well as support improving student achievement (Ball & Forzani; 2009; Grossman et al., 2018). The use of high-leverage practices addresses the realization that most beginning teachers face that PCK growth is more than just learning about teaching and requires continual professional development to move beyond novice status (Annetta & Shymansky, 2006; Hurlburt & Krutka, 2020). Across research, high-leverage practices are core skills that occur frequently in classroom teaching and are ones that allow teacher candidates to begin to master as an element of burgeoning PCK (Grossman et al., 2018) through teaching enactments, such as peer run-throughs and coached rehearsals,with peer and instructor feedback in methods courses. The process of merging practice-based teaching requires a process of decomposition of each high-leverage practice whereby teacher candidates work to segment each element in order to practice in incremental steps prior to reassembling the HLP in its entirety.

High-leverage practices are core skills that occur frequently in classroom teaching and are ones that allow teacher candidates to begin to master for their PCK development (Grossman et al., 2018) through teaching enactments, such as peer run-throughs and coached rehearsals in methods courses. Providing opportunities to practice learning to teach can be pivotal to later classroom success (Mansfield, 2012). High-leverage practices also allow teacher candidates to practice with content that they may find challenging conceptually. Within this research, three specific high-leverage practices - eliciting and interpreting student thinking, modeling content, and leading a group discussion - were selected as they highlight constructivist thinking prevalent in best practices from professional teaching organizations for science and mathematics (National Council of Teachers of Mathematics [NCTM], 2014;National Science Teachers Association[NSTA], 2023).

In eliciting and interpreting student thinking, teacher candidates learn to develop a repertoire of probing questions to unpack what a student knows about a concept from prior knowledge and later how a student is thinking while processing mathematics and science conceptual and procedural thinking. To help students visualize challenging STEM content, teacher candidates learn to represent procedural processes to explain how to problem solve. In recent years, both mathematics and science educators have shifted to student-centric practices focused on learner discussion to make meaning of new content (Achieve, 2013; NCTM, 2014; National Research Council [NRC], 2012). Teacher candidates must also understand how to frame, orchestrate, orient, and facilitate group discussions where students lead the conversations by sharing their thoughts and ideas regarding scientific and mathematical concepts (TeachingWorks, 2023c).

Purpose of the Study

The purpose of this study was to explore teacher candidates' development of pedagogical content knowledge to determine ways to improve student conceptual understanding of science and mathematics content as well as engage in ways to boost candidates' pedagogical practices. The study focused on the

implementation of practice-based teacher preparation in two methods courses that spanned an academic year for three years to garner student self-perceptions of their personal PCK development. The courses emphasized teaching STEM concepts using the high-leverage practices of eliciting and interpreting student thinking, modeling of content, and leading a group discussion. The following research questions guided this study:

1. How do teacher candidates perceive their PCK development after participation in practice-based teacher education utilizing high-leverage practices?
2. How do teacher candidates perceive their ability to teach equitably in rural settings after participation in practice-based teacher education utilizing high-leverage practices?

Methodology

The authors conducted survey research using Microsoft Forms over the course of three academic years 2020, 2021, and 2022 with three different cohorts of teacher candidates at a rural Midwestern university. Selection criteria for participants included only early childhood or elementary majors who completed both fall elementary mathematics methods and the spring elementary science methods course and who completed all surveys (pre-math, post-math, and post-science) associated with the research study. Forty-five qualified candidates out of 69 students met the criteria for selection in the study. In both methods courses, the teacher educators selected a unit of study in which to engage in an iterative practice-based teaching cycle of introduce, prepare, enact, and analyze based on the work of the University of Michigan's Teaching Works protocols (2023). In mathematics, the unit selected was fractions, and in science, the transfer of electrical energy (battery and bulb experiment) was chosen. In both courses, the researchers collaboratively planned the instruction to include introducing high-leverage teaching practices, preparing scripts to practice teaching content equitably using peer run-throughs and coached rehearsals, enacting incorporating HLPs in their field experience, and student self-analyzing their competence and confidence with enacting eliciting and interpreting student thinking and leading a group discussion. The field experience teaching high-leverage practice enactments were based on student field placement by subject area. In mathematics, teacher candidates conducted both a small and large group discussion, and in science, the students all completed an eliciting and interpreting student thinking for the battery and bulb experiment with a third through fifth grade student as well as leading a group discussion before and after investigation based on their targeted grade band. Analysis of survey data included computation of aggregated means and standard deviations for survey questions from all participants across the two semesters using a fall math pre survey and post survey and a science post survey. The intentional decision not to include a science pre survey was based on the fact that teacher candidates had only two weeks difference between the end of fall semester and the beginning of spring semester.

The self-perception survey included seven questions with Likert-scale responses ranging from 1 representing *not at all* to 5 representing *extremely*. At the end of the two semesters of instruction each year, teacher candidates were asked to answer six open-ended questions on Google Jamboard to gather qualitative responses on teacher candidate self-perceptions of their personal PCK development. Open-ended responses asked teacher candidates to share their perceptions of what they deemed most important in teaching with an emphasis on the following areas: knowing content, eliciting and interpreting student thinking, leading a group discussion, disrupting inequity, and advancing equity and justice in the classroom. A step-wise thematic analysis using Nowell et al.'s (2017) protocol was conducted to arrive at common themes within participant responses. At the conclusion of each semester, the researchers reviewed the results of the Microsoft Form surveys and Google Jamboards to uncover teacher candidate perceptions of their developing PCK, based on responses to open-response questions. All data from the Microsoft Forms were stored in Microsoft Excel spreadsheets and the Google Jamboards were shared among the researchers and stored as a collaborative document.

Findings

Table 1 presents the descriptive statistical analysis to answer the research questions.

Table 1 *Survey Results*

Question	Math presurvey		Math postsurvey		Science postsurvey	
	M	*SD*	*M*	*SD*	*M*	*SD*
1. How skilled are you at this point in making sense of what students are saying?	3.53	0.63	3.64	0.68	3.64	0.61
2. How skilled are you at this point in probing students' thinking without putting words in their mouths (eliciting & interpreting)?	2.98	0.75	2.98	0.62	3.58	0.78
3. How skilled are you at this point in facilitating a group discussion?	3.80	0.94	3.31	0.76	3.51	0.79
4. How knowledgeable are you at this point in explaining the various strategies to compare fractions to determine the largest fractions(in building collective knowledge with the battery and bulb phenomena)?	2.73	0.84	3.22	0.95	3.87	0.69
5. How skilled are you at this point in explaining and modeling mathematical (scientific) ideas to others?	3.20	1.01	3.36	0.83	3.29	0.76
6 How skilled are you at this point in building relationships with students?	3.87	0.92	4.31	0.67	4.04	0.93
7. How skilled are you at this point in taking concrete actions to address forms of social injustice and inequities in your work with children?	3.13	0.73	3.13	0.66	3.33	0.71
Overall	3.34	0.83	3.44	0.74	3.59	0.74

Note.n = 45. Scale - 1 = *Not at All*, 2 = *Slightly*, 3 = *Moderately*, 4 = *Very*, 5 = *Extremely*.

Overall, teacher candidates' perceptions increased in six of the seven questions addressed by the survey; one fell slightly. The areas that increased minimally over the course of two semesters for three years of implementation of practice-based teacher education were self-perceptions of their ability to make sense of what students are saying (M = 3.53 to M = 3.64), explaining and modeling scientific and mathematical concepts (M = 3.20 to M = 3.29), building relationships with students (M = 3.87 to M = 4.04), and taking concrete actions to address social justice and inequities in teaching (M = 3.13 to M = 3.33). Two areas increased moderately including eliciting and interpreting student thinking (M = 2.98 to M = 3.58) and how knowledgeable students perceived their abilities to explain preselected STEM content (M = 2.73 to M = 3.87). Students' perceptions of their ability to facilitate a group discussion decreased over the course of their methods year (M = 3.80 to M = 3.51). Longitudinally, teacher candidates perceived themselves to be slightly skilled in the areas surveyed at the beginning of the year (M = 3.34) prior to instruction using high-leverage teaching practices in practice-based methods courses and at the conclusion of the year students moved toward having moderate perceptions of their pedagogical and content knowledge (M = 3.59). Given these statistics, the researchers concluded that teacher candidates perceive their PCK development as slightly to moderately improved after participation in two semesters of practice-based teacher education utilizing high-leverage practices. Furthermore, teacher candidates also perceived a slight increase in their ability to teach equitably in rural settings after participation in practice-based teacher education utilizing high-leverage practices.

Responses to the open-ended questions supported the quantitative findings in the survey. The initial observations of teacher candidates' qualitative responses noted an increase from themath presurvey to the science postsurvey of elements necessary for effective teaching using high-leverage teaching practices. In the next step, an inductive reasoning approach was utilized to develop codes from participant responses. The initial codes generated from the data identified the following: knowing content, building relationships, making connections, diverse learners, and inclusive learning that advances equity. Table 2 shares the identified codes along with frequencies of occurrence.

Table 2 *Identified Codes*

Identified codes	Frequency
Knowing Content	35
Building Relationships	23
Making Connections	18
Diverse Learners	11
Inclusive Classroom Environments	23

The third and fourth steps involved a deeper qualitative analysis to identify themes and to identify the connectivity between and overlapping from the codes. Through this process, several areas, such as inclusive learning environments and diverse learners, appeared connected in multiple student responses, and as such, a theme of inclusive learning environment was created to address teacher candidate belief that one of the most important elements of effective teaching and learning was creating inclusive learning environments for all students based on the individual students' diverse backgrounds. A teacher candidate succinctly described her beliefs of inclusive classrooms as *providing a space for students to learn and grow and be their best where they feel comfortable, welcomed, valued, and seen*. Another student described how inclusive classrooms enrich learning for all students, by explaining the necessity of teachers to *understand that all students may have a different cultural and religious background and to use this* [understanding] *to guide the investigation so they* [students] *can fully learn.* A second theme emerged that included knowledge of content taught and the ability to make connections with that content and the world outside the classroom. For example, one teacher candidate responded that one of the most important aspects of teaching mathematics was *making sure the students understand the WHY behind their answers, not just focusing on getting the right answer*. Another student explained *knowing your content allows you to entirely and confidently lead your lessons and discussions and allows students to higher think.* A third student discerned *giving students experiences that make the learning relatable will make it so that everyone is equal and can make an investigation have connections to their lives.* The final, and perhaps most noted, theme by participants was the necessity of building relationships with students to better accommodate the two previous themes. Participant responses indicated that by building relationships, they (as future educators) would better understand how to create inclusive classrooms and how to meet the educational needs for students in order to more effectively teach the content. One student summarized her takeaways as *the most important part of teaching is building relationships with your students, it is important to make connections with your students so they can trust you and your teaching.* Encapsulating this theme, another student remarked *building relationships and life lessons that students can take with them. It is, of course, important to teach the content, but I believe that will come easier if you take the time to build the relationship first*. Thus, the final themes summarizing participants' biggest takeaways for developing PCK and teaching equitably were building relationships, knowledge of content and making connections, and creating inclusive classrooms for diverse learners.

Discussion

In this study, teacher candidates' perception of their PCK development moved from *slightly* to *moderately* skilled. This increase is similar to the findings of other researchers. Mansfield (2012) suggested mastery of skills comes from a series of experiences with collaboration and active engagement, and Williams and Lockley (2012) and Avrimidou and Zembal-Saul (2010) contend pedagogical content knowledge is

developed over time and experience, beginning in teacher preparation programs. Further, Avrimidou and Zembal-Saul (2010) aver that PCK development is challenging, thus, the participants slight improvement is reflective of the hard work of learning to teach effectively.

Initially, participants perceived their ability to lead a group discussion as moderately skilled, but after decomposing the nuanced elements to conduct this high-leverage practice equitably while also advancing content knowledge, their self-perception dropped. Comments from teacher candidates noted that the skills needed to effectively lead discussions were much more involved than they previously believed. One teacher candidate commented, *prior to unpacking the decomposition for leading a group discussion, I never realized all the moves my classroom mentor teachers were mentally making while leading students in discussions. I now know I have a lot of work to do.* However, despite the drop of self-perceived ability, many students noted that the process of learning STEM concepts became more meaningful to them with several teacher candidates noting *if math had been taught this way when I was in elementary school, it would have made more sense to me.* In alignment with the state's shift to new science standards, some teacher candidates noted that through leading group discussions, they were able *to allow multiple students ideas to be shared to help the whole class see the patterns emerging with lighting a light bulb.* Despite the lowered self-perceptions, most teacher candidates expressed strong desires to continue practicing leading group discussions to advance their PCK and student understanding, which aligns with the professional teaching expectations outlined by national mathematics and science teaching organizations (Achieve, 2013; NCTM, 2014; NRC, 2012). Another commonly noted item by teacher candidates was participating in the practice-based teaching cycle where they were required to write a detailed script identifying probing questions and preparing to respond to student ideas they might encounter strengthened their lesson plan writing. Participants shared that the process was both rigorous and intense but furthered their perceptions of their overall PCK. One candidate commented, *Oh my goodness! I am so glad we have written out these scripts. I know this is going to help me with my lesson planning and teaching for the edTPA.*

Davis and Smithey (2009) noted that changes in teacher education programs help teacher candidates expand PCK readiness to usable teaching skills in the classroom. Regarding eliciting and interpreting student thinking, participants in this study showed they needed more than a semester to show growth. No change was perceived after the first semester of engaging in a practice-based teaching cycle with their skill at interpreting student thinking, but after a second semester of learning, teacher candidates perceived moderate improvement in their ability to probe student thinking and to make sense of what learners were communicating. Teacher candidates noted that by actively engaging with the content, they were better able to flexibly understand said content (Ball & Bass, 2000) and thus, their ability to ask a wider variety of questions developed over the course of the two semesters which was similar to the findings of Menon and Sadler (2017) and Davis and Smithey (2009) that engagement with children in content and practice enabled a deeper understanding of how children learn.

Although students initially perceived their abilities to model and explain content as only slightly skilled, this was the area in which the most improvement was seen. Their intentional decision to structure the practice-based teaching cycle on two units of study that historically in the courses were the most challenging for teacher candidates to enact teaching in the field saw a mean gain of +1.14 in teacher candidate self-perception. Ball and colleagues (2008) highlighted that the ability to represent content understanding is a special element of PCK critical to the profession of teaching. The role of teacher preparation programs is then to explore content understandings with embedded pedagogical practices that continue the development of teaching skills (Bursal, 2012; Hanuscin et al., 2011). The design of this study allowed for the creation of inclusive spaces where content merged with pedagogy to enable teacher candidates to investigate and make discoveries of new knowledge and how to best teach to support student understanding (Abrams & Middleton, 2017).

This Midwestern university teacher education faculty has made a conscious effort to better prepare teacher candidates for the rapidly evolving and changing diversity in the state. Although the university is

situated in a rural county, the surrounding area and school districts are comprised of some of the most diverse student populations. As a faculty, the school of education made an intentional focus on incorporating culturally-responsive and inclusive teaching practices and norms in courses. One of the focus areas of this research has been to prepare teacher candidates to teach equitably in rural settings. The teacher candidates and researchers invested in the hard work of developing self-awareness to better build relationships with students as well as take concrete actions to address forms of social injustice and inequities. The researchers' involvement in the TeachingWorks (2023a) program and other culturally-responsive teaching pedagogies helped inform how to address building awareness and equipping teacher candidates with practical skills to advance not only their content knowledge and methods of instruction, but also how to engage with students from a diverse variety of backgrounds. This study showed success in meeting these goals as teacher candidates perceived improvement in both building relationships and addressing social inequities, with building relationships receiving the highest overall mean score (M = 4.04) indicating that candidates perceive a very strong ability to build relationships with students.

In conclusion, after completing two semesters over three years of co-taught practice-based teacher education learning cycles with emphasis on the high-leverage teaching practices of eliciting and interpreting student thinking, modeling of content, and leading a group discussion, teacher candidates self-perceived *slight to moderate* improvement of their PCK development. Teacher candidates' perception grew at a rate appropriate for well-started novices who will continue the work of PCK development throughout their careers as educators. The most significant gains were in modeling STEM content knowledge and in eliciting and interpreting student thinking whereas their highest perceptions were in the necessity to build relationships for equitable and inclusive classrooms.

Recommendations

Given the findings of this survey research, the following recommendations for practice are suggested:

1. Teacher preparation programs should consider incorporating practice-based teacher education learning emphasizing high-leverage teaching practices throughout methods courses.
2. Teacher educators should consider integrating challenging STEM content with practice-based teacher education.
3. Teacher preparation programs should consider the critically important and necessary steps to ensure that practice-based teaching addresses building relationships with all students and addressing forms of social injustice and inequities.

Summary

This survey study explored teacher candidates perceptions of their pedagogical content knowledge in relation to implementing three high-leverage practices, eliciting and interpreting student thinking, modeling of content, and leading a group discussion, after two semesters of co-taught methods instruction over the course of three academic years. Participants included 45 teacher education candidates (elementary and early childhood majors) enrolled in a rural Midwestern university. Survey questions asked about perception of skill level with eliciting and interpreting student thinking and making sense of those ideas, modeling content in specific mathematics and science units, leading a group discussion, building relationships with students, and advancing justice and equity in the classroom. Survey results revealed teacher candidates' perceptions of a slight to moderate improvement in PCK, and qualitative responses supported the survey data with areas of largest growth in building relationships to equitably teach and understand content knowledge to explain effectively.

Recommendations for future practice include that teacher preparation programs consider implementing practice-based instruction with an emphasis on high-leverage teaching practices. Specifically, TPPs should consider the use of practice-based teaching models for subject disciplines, such as STEM, where teacher candidates self-identify a reluctance to teach. Lastly, teacher preparation programs should invest

in ensuring that teacher candidates are taught how to build relationships with all students and how to address forms of inequity in the classroom.

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