Title:

Co-teaching and the PrimeD framework: Radicals and Rational Exponents

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Abstract (< = 500 characters)
This study examined the application of a co-teaching model to the PrimeD framework. Two teachers and a teacher educator collaborated to develop, implement, evaluate, and study a unit on radical expressions, equations, and functions in 3 high school algebra 2 classes. Results indicated that this approach to PD can be a powerful way to support the professional growth of teachers and teacher educators alike.

Additional Information:

Equity (500 char)
This study resulted in professional growth of teachers with regard to empowering students to lead the development of knowledge around concepts and procedures, developing and critiquing strategies and ideas. This approach to teaching mathematics helped the teachers transcend racial divides to give every student in their classes a voice and opportunity to contribute to their own learning and that of others.

Descriptors
Secondary, Teacher Knowledge, Teacher Practice, Teacher Education, Algebra/Algebraic Reasoning, Qualitative

Co-teaching and the PrimeD framework: Radicals and Rational Exponents

This study examined the application of a co-teaching model to the Professional Development: Research, Implementation, and Evaluation (PrimeD) framework (Driskell et al., 2016; Saderholm et al., 2017; Figure 1). The research questions for the present study were:

1. How can the application of a co-teaching model to the PrimeD framework support the professional growth of teachers?
2. How can the application of a co-teaching model to the PrimeD framework enhance the professional growth of teacher educators?

Conceptual Framework

PrimeD divides professional development (PD) into four phases: design and development, implementation, evaluation, and research. PrimeD applies principles of improvement science (e.g., Bryk, Gomez, Grunow, & LeMahieu, 2015; Langley et al., 2009) and characteristics of effective PD (e.g., Desimone, 2009; Garet et al., 2001; Guskey, 2000; Loucks-Horsley et al., 2010; Sztajn, 2011) to provide a robust structure to address well-defined PD goals in K-12 settings. PrimeD calls for a formal, explicit, cyclic connection between PD activities and classroom implementation in ways that drive innovation in the classroom while using classroom experiences to drive whole group activities and inspire future directions.

Engaging Teachers as Partners in PD

PrimeD encourages activities in which teachers participate as partners rather than mere recipients of knowledge (Jones & O'Brien, 2014; Loucks-Horsley et al., 2010; Philippou et al., 2015). PrimeD uses networked improvement communities (NICs) to engage teachers in PD activities as partners and leaders in ways that drive meaningful and directed collaborative endeavors that not only become an important component of the PD, but also contribute to the evolution of the learning experience.

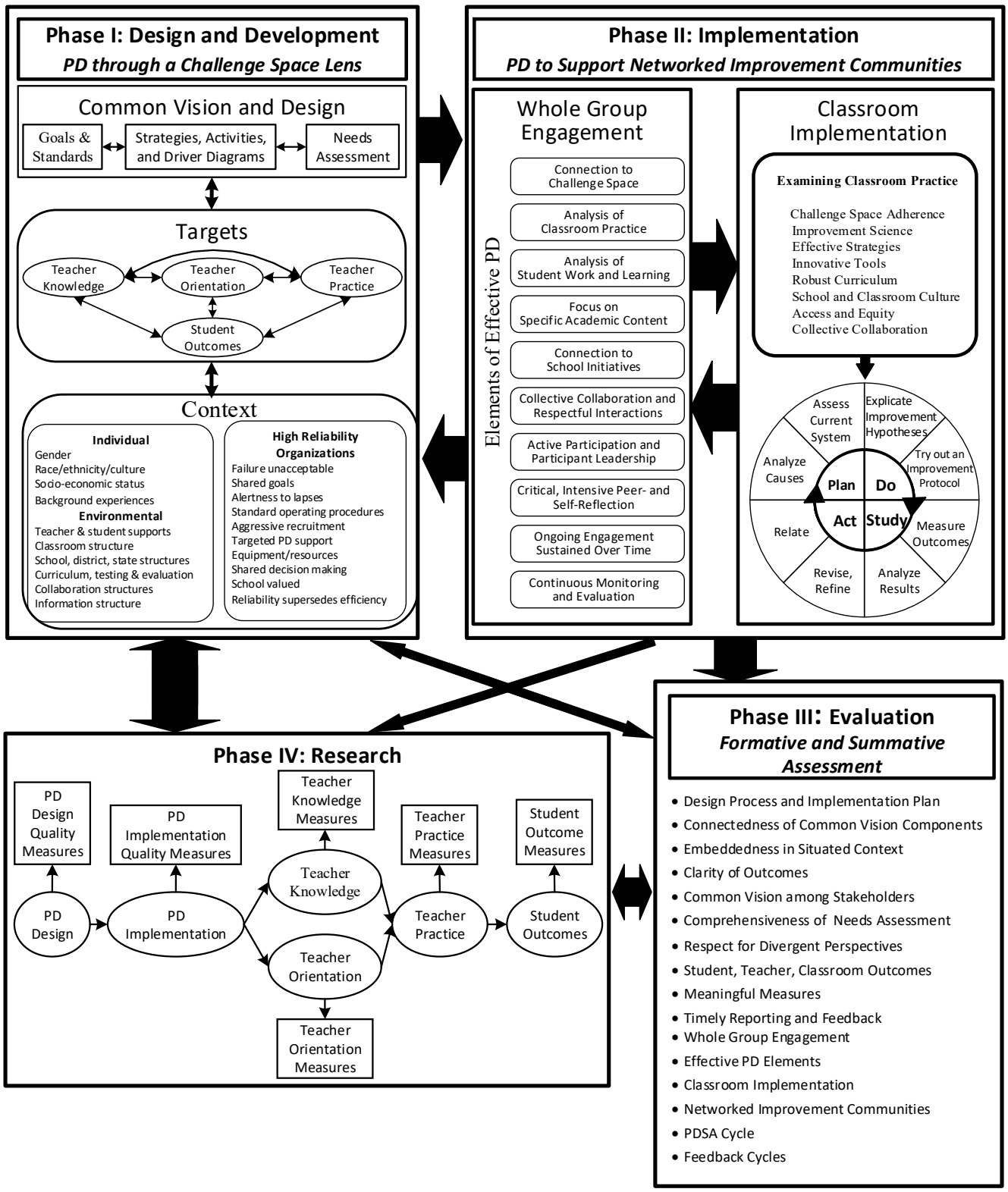

***Figure 1*. Illustration of the PrimeD framework (Driskell et al., 2016; Saderholm et al., 2017).**

The PrimeD framework explicitly encourages essential interactions and relationships among the facilitators, teams, and participants. The development of learning communities at the school and

district levels a critical element of these interactions and relationships. NICs focus on a common aim and seek to develop a deep understanding of a particular problem and collaborating on approaches to solve it. NICs examine approaches to solving a problem through improvement science: developing, testing, and refining interventions. The NIC approach organizes learning communities to effectively integrate interventions into the field at an accelerated pace. In a NIC, all stakeholders, including the teachers, must embrace a common vision about the challenge space and their role in addressing it. To be true to the NIC construct, teachers must be engaged as partners rather than recipients, both through classroom implementation and during whole group engagement.

Collaborating with Former Preservice Teachers

A co-teaching model was applied to PrimeD to engage former preservice teachers in professional development through designing, planning, and implementing a unit of study in collaboration with a teacher educator. In Phase I Design, a unit plan was developed along with a discussion of particular teaching strategies for each lesson (e.g., examples, sequencing of activities, questioning strategies). In Phase II Implementation, classroom implementation occurred before whole group engagement because the classroom trials were designed to form the foundation for subsequent PD. The teacher educator supported classroom implementation of the unit by gathering materials for a unit project and collaborating with each teacher to plan and teach particular lessons in the unit. Evaluation (Phase III) was carried out by each team member and discussed with the whole team. Strategies for the unit were adjusted based on evaluation results and then enacted in subsequent lessons (i.e., connection from PrimeD Phase III to Phase II via Phase I). Each team member maintained a reflection journal and collected student work and feedback to support Phase IV Research.

Methods

This study examined the application of a co-teaching model to the PrimeD framework to support the development of a NIC (Research Question 1) and the growth of teachers and teacher educators (Research Questions 2 and 3). The targets of the program (PrimeD Phase I Targets) were

teacher knowledge, orientation, and practice as well as student outcomes (achievement, reasoning/thinking/explaining, orientation, meta-cognition, & learning behaviors). The study followed an action research design in which teachers were researchers in their own classrooms. Classroom observations, teacher reflection journals, lesson documents, and student work were the data sources for the study.

Participants. Two high school mathematics teachers and a teacher educator collaborated to develop a unit of study for rational expressions, equations, and functions for three algebra 2 classes. The two high school mathematics teachers were former preservice teachers in the teacher educator's university teacher preparation program. Teacher A was in her third year of teaching; Teacher B was in her fourth year of teaching. Both teachers taught in the same large suburban high school and had taught in that school since completing their teacher preparation program. Teacher A taught two algebra 2 classes, both of which were "co-taught" classes, meaning that the class had a high number of students identified as having special needs and a special education teacher helped teach the classes. One of the classes also had two students who were supported during class by a para-educator. The para-educator engaged in lessons alongside her two students, coaching them through the activities and assignments. These two classes had approximately 30 students each with approximately 60% attendance on any particular day. Teacher B taught one algebra 2 class, which was an honors class with typically high-achieving students. This class also had approximately 30 students.

Racial diversity. Racial diversity may have played a factor in the project. The two teachers, teacher educator, and para-educator were White, and the special education co-teacher was Asian. By contrast, the students in Teacher A's classes were largely African American and Hispanic. Teacher B's class consisted of White, African American, Hispanic, and Asian students. The disparity in race between the teachers and students was a consideration in the design of the unit. For example, the strategies chosen for the unit were designed to empower students and give them a voice in how

activities occur. Students were positioned as researchers throughout the unit and presented their findings as the culminating activity.

Results

This study examined the application of a co-teaching model to the PrimeD framework to support the development of a NIC (Research Question 1) and the growth of teachers and teacher educators (Research Questions 2 and 3). PrimeD Phase I consisted of the development of a challenge space for the PD. The overall challenge was to identify key teacher knowledge, beliefs, and practices needing to be addressed by the PD to empower students to take a leadership role in their learning of the mathematics. The strategy for meeting this challenge was to co-plan, teach, and study (evaluation and research) a unit of study with the teachers. Phase II Implementation consisted of the planning process (whole group meetings in PrimeD) and enactment of the unit (classroom implementation in PrimeD). The planning and enactment activities provided data to address all three research questions.

Planning Process

The planning process began with an examination of the district curriculum for algebra 2 to determine the target content. The teacher educator originally suggested the idea of co-teaching a lesson to Teacher B, the more experienced of the two teachers, as a way for him to try out the co-teaching model on a small scale as recommended by Karp and Bush (2017). The initial conversation with Teacher B revealed how the project is a mutual learning experience for both teachers and teacher educator, not just for the teachers:

> *[Teacher B] immediately suggested including [Teacher A], which I hadn't thought of at all. It didn't have anything to do with [Teacher A], it was just that [Teacher B] and I had worked together on other projects since she had graduated, so I sort of already knew what to expect for working with her. I realized pretty quickly that I was thinking too small in several ways. I was thinking about just teaching a lesson together and having some follow-up conversations and using those to put together a useful PD.*

She was thinking about being a teacher leader and empowering her fellow teachers. She was immediately thinking about how she and [Teacher B] could take this work back to their planning teams and improve the overall math instruction in the school. She didn't just want to teach a robust lesson either. She wanted to make the mathematics come alive, which made me begin thinking at the unit level and phenomena-first teaching. I realized that working with an individual teacher might have some advantages in some cases, but getting teachers to work collaboratively would be far more powerful. I knew about NICs before; I just hadn't thought about applying them here (Teacher Educator reflection).

The inclusion of Teacher A marked a critical point in the design of the project. Teacher A brought a great deal of insight into the unit design and implementation. Her classes were also starkly different from Teacher B's, which meant that the classroom implementation phase would make any findings about students more generalizable.

The two teachers and teacher educator mapped out the unit, planned strategies, and tested ideas. The group examined the algebra 2 curriculum and decided to pick a unit that happened after PARCC testing was complete. Both teachers were concerned that if they tried something new, and students scored lower than usual on the district's interim benchmark assessments, they could score lower in their performance evaluations. They agreed that the target unit should be radical expressions, equations, and functions. Very few district and school resources were available for that unit, making the unit plan potentially more desirable to other teachers in the school. The team originally wanted to plan and implement another unit (rational functions, expressions, and equations), but insufficient time to plan the second unit collaboratively narrowed the scope to only the first unit.

The team wanted the unit to foster conceptual understanding with connections to authentic contexts. The teacher educator suggested a phenomena-first approach, which was tentatively agreed to by the teachers, pending the identification of a robust phenomenon. They found an idea in the CORD

(2011) Algebra 2 textbook, “Measuring mold.” In this activity, students measured the area of mold on a piece of bread throughout the unit. They used mathematical modeling to examine the best function to model the growth rate. Including this project in the unit meant that the radical functions would be considered in relation to other functions the students had already studied, reinforcing and enhancing their understanding of the other functions, radical functions, and functions in general.

Both teachers were excited to try out the unit but wanted to make sure the teacher educator would help teach key lessons related to the phenomenon throughout the unit. He therefore led the teaching of the unit introduction, review of the multiplicative structure of exponents, simplifying radical expressions and rewriting radical expressions in different forms, and graphing radical functions. The teachers led the data collection process and all other lessons in the unit.

Unit Enactment

All lessons in the unit were situated within the context of modeling the growth rate of the mold on bread. For example, an examination of parameters in the graph of a radical function was connected to sample mold growth data. Students explored parameter changes using sliders in Geogebra™ to decide how parameter changes influence the shape of the graph generally, then they adjusted the parameters to approximate a best fit to the sample mold data. Connections to regression equations and fit statistics were discussed. The enactment of the unit led to aha moments for both teachers.

Teacher A had focused her practice on providing explicit instruction to support her students with special needs. The opening up of the conceptual space in her classrooms was eye-opening for both her and her students. Students in her class were excited about learning mathematics to a degree they had not been before. This open conceptual space also led to some issues that caught the teachers by surprise. The district benchmark assessments generally focus on getting correct answers to problems, and the problems were generally written so that there was only one correct answer. The students struggled, for example, with rewriting radical expressions in multiple forms, so the class developed a single, default method for simplifying. This method worked until the class encountered

problems that didn't conform to the single method. When they began exploring the connections between forms (e.g., $\sqrt[3]{a^5}, a\sqrt[3]{a^2}, a^{\frac{5}{3}}, a \bullet a^{\frac{2}{3}}$), a student exclaimed in the middle of class, "Wait! You mean that all four of these forms mean the same thing???!!!" In a follow-up discussion, the teacher stated, "I've never thought about the content that way."

Teacher B had more experience than Teacher A and began her enactment after Teacher A had completed hers. Teacher B's enactment was therefore informed by lessons learned by Teacher A. Students in Teacher A's class developed procedural understanding much quicker than Teacher B's students, so better questioning and anticipation of misconceptions despite procedural skill was needed to foster deep conceptual understanding. As with Teacher A, Teacher B tended to focus on correct answers and processes without consistently opening up the conceptual space.

> *I thought I was doing a good job with wait time and perseverance, and then [Teacher Educator] came in to co-teach and walked the students through the graphing area of 2 lesson. Wow! I have work to do with wait time and letting students struggle. He was so patient with them and did not give lots of hints or help. It made it that much more exciting for Marque, who is usually one of my struggling learners in that class, when he was first to come up with the solution. If I were on my own, I would probably have robbed Marque of that opportunity to feel successful. [Teacher Educator] also asked the kids to give each other the gift of discovery by NOT sharing their solutions, and that was great too. So many students participated and kept trying until they figured it out. So, while my wait time has improved from my first year of teaching, it still needs work. I need to work on letting things feel uncomfortable for a bit and letting someone in the class figure it out. I know some of this is feeling pushed by the curriculum. I feel like I still need to "cover" so many things before the final exam, but better for students to truly* ***learn*** *one or two things than for me to quickly cover 4 or 5 things that most of them will promptly forget* (Teacher B reflection).

Teacher B had begun to recognize productive struggle and its value in her classes, especially for students who struggle. Throughout the unit, Teacher B and Teacher Educator focused on giving

students opportunities to lead the development of knowledge around concepts and procedures, developing and critiquing strategies and ideas.

The teacher educator also learned from this project. Because both teachers had been preservice teachers in his university preparation program, he considered ways to better support future cohorts' ability to open up the conceptual space for their students. This reflection led to changes in the structure of the mathematics methods course and field experiences. The co-teaching project also provided an opportunity to put education research/theory (e.g., Skemp (1976/2006) relational understanding) into practice, enhancing his understanding of the challenges inherent in putting theory to practice in multiple contexts. For example, the district benchmark exams increased the need to show quick, nearly-immediate growth in student learning, which places a great deal of stress on teachers seeking to enhance their practice.

Importance of the Research

These preliminary results show that the application of a co-teaching model to the PrimeD framework can be a powerful way to support the professional growth of teachers and teacher educators alike. The study indicated that standardized testing may inhibit teachers' willingness to try new teaching strategies. The study resulted in professional growth of teachers with regard to empowering students to lead the development of knowledge around concepts and procedures, developing and critiquing strategies and ideas. This approach to teaching mathematics helped the teachers transcend racial divides to give every student in their classes a voice and opportunity to contribute to their own learning and that of others. This approach to PD can provide a powerful strategy for advancing the knowledge and understanding of teachers and teacher educators regarding mathematics practice.

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