Using Professional Learning in Practice: The Case of Novice College Instructors

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We report on findings from a mixed methods study on preservice elementary teacher learning outcomes as a result of being enrolled in courses where their instructors were participating in professional development designed for those new to teaching content courses for future teachers. The study contributes to the current sparse literature within the RUME community on student performance as a result of professional learning opportunities for mathematics faculty. Results indicate improved undergraduate learning outcomes among preservice teachers when instructors engaged in a professional short-course that both fostered growth of instructors' own Mathematical Knowledge for Teaching (MKT) for teaching undergraduates and provided instructors with opportunities to learn about and support prospective teachers' development of MKT (for teaching children).

Keywords: professional development, mathematical knowledge for teaching, teaching for robust understanding

There have been many calls in the last decade to devote time and effort to the professional development (PD) of faculty in mathematics departments who teach the courses for future K-8 teachers (Flahive & Kasman, 2013; Masingila et al., 2012; Masingila & Olanoff, 2022). Indeed, Greenberg and Walsh (2008) noted that mathematics faculty regularly seek professional support in the work of teaching prospective teachers. To the best of the authors' knowledge, there have been two documented efforts in the literature to meet the needs of this call. Castro Superfine and colleagues (2013, 2014) have discussed the design model for their NSF funded *Mathematical Knowledge for Teaching Teachers* (MKTT) project, while we (Jackson et al., 2020) elaborated on the design features of our NSF funded *Professional Resources and Inquiry into Mathematics Education* (PRIMED) *for K-8 Teacher Education* project. In the former, the use of a research-based curriculum by experienced teacher educators was associated with large learning gains by undergraduates (Castro Superfine et al., 2013). However, the work did not include explicit attention to investigating prospective teacher learning outcomes as a result of faculty participation in professional development or include instructors who were new to teaching future teachers. This report aims to provide at least a partial snapshot of the relationships among *novice* instructor PD and undergraduate learning. The study is part of a larger (PRIMED) project. Here we share results of examining measures of particular target outcomes – related to mathematical knowledge for teaching – among participating faculty and their undergraduate students.

Theoretical Foundations

Mathematical Knowledge for Teaching and Its Assessment

The types of knowledge required of mathematics teachers have emerged from several decades of research and development that have grown from seeds sown by Shulman (1986). In 2008, Ball and colleagues described *mathematical knowledge for teaching* (MKT). As initially conceptualized, MKT consists of *subject matter knowledge* and *pedagogical content knowledge.* Subject matter knowledge included *common content knowledge*, *specialized content knowledge*, and *horizon content knowledge*. In particular, common content knowledge is used in everyday activities by teachers and others such as mathematicians, engineers, or homemakers. By comparison, specialized content knowledge is the knowledge that is specific to the task of teaching. Within pedagogical content knowledge, there are *knowledge of curriculum*, *knowledge of content and students*, and *knowledge of content and teaching*. Knowledge of curriculum includes awareness of the content and connections across standards and texts . Knowledge of content and students blends knowledge for doing mathematics with knowledge for unpacking it in ways relevant to how students think about, know, or learn (Hill, et al., 2008). Knowledge of content and teaching is a knowledge of teaching moves for making unpacked meanings accessible to students.

The Learning Mathematics for Teaching (LMT) instrument developed by Hill, Schilling, and Ball (2004) is a validated and reliable tool for assessing MKT development. The instrument assesses common and specialized content knowledge in different domains of K-8 mathematics including number and operations; in addition, some items assess knowledge of content and students. Though the instrument was initially validated for the purposes of measuring MKT among in-service teachers, in recent years it has been used to measure MKT development in courses for future teachers (Flake, 2014; Namakshi et al., 2022). A sample released item from the LMT instrument assessing specialized content knowledge is shown in Figure 1.

3. Imagine that you are working with your class on multiplying large numbers. Among your students' papers, you notice that some have displayed their work in the following ways:

Student A	Student B	Student C
35 x 25 125 +75 875	35 x25 175 +700 875	35 x 25 25 150 100 +600 875

Which of these students would you judge to be using a method that could be used to multiply any two whole numbers?

Figure 1 Sample Item from LMT Instrument (Hill et al. 2004)

Teaching for Robust Understanding

Teaching for Robust Understanding (TRU, Figure 2) is a research-based framework designed to attend to particular aspects of instruction (Schoenfeld, 2016). The framework was developed for research and has proven useful in practice. The TRU framework is used to explore the attributes of equitable and robust learning environments that support each student in becoming a knowledgeable, flexible, and resourceful disciplinary thinker. The TRU framework is a powerful tool because it provides a working definition of *effective mathematics instruction* that includes attention to equity along with language for describing characteristics of classroom activity. Given the centrality of educational equity in the PRIMED project, the TRU framework served a dual purpose: as a resource to guide participants in examining their own and peers' responsiveness to prospective teachers in curricular and instructional choices, and as a resource for the developers in the design, development, implementation, and evaluation of the PRIMED short-course itself.

The Mathematics	Cognitve Demand	Equitable Access to Content	Agency, Ownership, and Identity	Formative Assessment
The extent to which the mathematics discussed is focused and coherent, and to which connections between procedures, concepts and contexts (where appropriate) are addressed and explained. Students should have opportunities to learn important mathematical content and practices, and to develop productive mathematical habits of mind.	*The extent to which students grapple with and make sense of central mathematical ideas and their use. Students learn best when they are challenged in ways that provide room and support for growth, with tasks that are not low level but not impossible. The level of cognitive demand should be conducive to what has been called productive struggle.*	*The extent to which classroom activity structures invite and support the active engagement of all of the students in the classroom with the core content being addressed by the class. Classrooms in which a small number of students get most of the "air time" are not equitable, no matter how rich the content: all students need to be involved in meaningful ways.*	*The extent to which students are provided opportunities to "walk the walk and talk the talk" – to contribute to conversations, to build on others' ideas and have others build on theirs – in ways that contribute to their development of agency (the willingness to engage), their ownership over the content, and the development of positive identities as thinkers and learners.*	*The extent to which classroom activities elicit student thinking and subsequent instruction responds to those ideas, building on productive beginnings and addressing emerging misunderstandings. Powerful instruction "meets students where they are" and gives them opportunities to deepen their understandings.*

Figure 2: Teaching for Robust Understanding (TRU) Framework, Schoenfeld (2016)

Effective Design and Implementation of PD for Instructors of Future Teachers

Castro Superfine and Li (2014) discussed features of high quality professional development that they considered effective for teacher educators:

(1) Participants should be engaged in learning that is grounded in the content of teaching and learning. In particular, it must pay special attention to the MKT that is used in the work of teaching undergraduates who are preservice K-8 teachers *in addition to* bringing awareness to the instructional challenges of teaching MKT (for K-8 teaching).

(2) The PD must create the possibility of cognitive disequilibrium. That is, instructors are challenged to think about what they believe future elementary teachers need to know about MKT and why. They must also reflect on how future teachers learn about MKT.

(3) Participants must be provided with opportunities for collaboration in order to form a professional community of practice. Thus, effective PD allows for the mutual sharing of ideas and lessons learned from the work of teaching future teachers.

(4) Learning opportunities and tasks within the PD must be embedded in or directly related to the particular specialized work of teaching future teachers. PD tasks are situated in the actual work that instructors do every day in their own local institutional contexts.

Whereas the four points above address the design and development aspects of effective PD, Guskey (2000) highlighted the critical stages involved in evaluation of PD (Figure 3). In Level 1, evaluation focuses on participants' experience of the PD. Participants are questioned in surveys, interviews, and/or focus groups about how useful they feel the experience was and of what use the PD was to them professionally. In Level 2, the focus is on measuring the knowledge and skills that instructors gained as participants in the PD – specific learning goals are outlined before the PD together with a plan for assessing those goals and assessments typically include things such as pencil-and-paper instruments, reflections, journals, discussion boards, portfolios. At Level 3, evaluation turns attention to the local contexts within which participants operate professionally; common questions at this level attend to how change was (or was not) supported at the departmental/college/university levels. In Level 4, evaluation examines if and how the knowledge and skills from the PD are actually applied in the instructors' professional practice – evidence occurs through such things as direct observations, documented instances in reflective journals or portfolios, and interviews with participants and/or their supervisors. At Level 5, evaluation considers if and how participation in the PD impacted student learning outcomes – indicators of student achievement may include cognitive aspects such as performance in things like course grades, assessment scores, or scores from standardized tests. However, affective and psychomotor outcomes are also commonly measured in lieu of/in addition to cognitive skills by examining such things as student attitudes and beliefs, dispositions, and classroom behaviors.

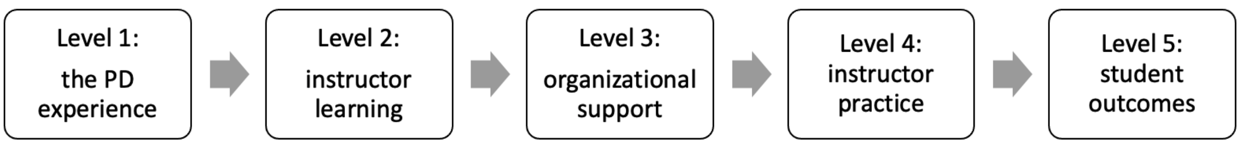


Figure 3: Five Critical Levels of PD Evaluation (Guskey, 2000)

The emphasis in the current study was to dig into the connections among **Levels 2, 4 and 5**. In particular, the aim in this report is to illustrate how the PRIMED design – which had the four principles documented by Castro Superfine and Li (2014) and incorporated use of the TRU framework – had downstream effects on Levels 2, 4 and 5. In this vein, the research question this study addressed was: *What is the nature of relationships among participation in PRIMED activities, college instructors' mathematical knowledge for teaching, and that of their students?*

Methods

For the PRIMED project, each participating college instructor agreed to complete various research tasks and agreed to include assignments in their courses through which their students completed assessments of the mathematical knowledge needed for teaching grades K-8 (the LMT). Instructors (n=15) and undergraduates (n=476) providing data for the study were from 12 different institutions of higher education (2 public community colleges, 7 master's granting [6 public, 1 private], 3 doctorate-granting [2 public, 1 private]).

The PRIMED design and learning goals are briefly described here (see Jackson et al., 2020 for a detailed description). The PRIMED professional learning experience was through the Canvas online course management system and was a hybrid: two of the five modules (Module 2 and Module 5) included both asynchronous and live online activity-based work by instructor teams from different colleges and universities; the other three modules were sets of self-paced asynchronous web-based activities completed by instructors individually with asynchronous discussion board interaction and the option of online meetings of the instructor teams. The short-course included assessments of instructor learning in each module. Participant teams rarely met in real time during the asynchronous modules and tended to check-in with each other by email or through the online discussions in Canvas.

Performance on the LMT was used as one of the outcome measures for Guskey's Level 2 (of instructors) and for Level 5 (of undergraduates). Participants who fully engaged in the short course completed three lesson experiments in which they enacted PD principles as part of their instruction using task-based active learning techniques. In addition to surveys, the project team collected artifacts from the course such as online discussion board posts about lesson experiment efforts by instructors, in-module assessments, and intake/exit interviews with each individual participant.

Results

For Guskey's Level 4 effects we examined details related to the second of the three lesson experiments. For Levels 2 and 5 we looked at gains on the LMT among the undergraduate future teachers (students) and level of PRIMED participation of instructors.

Evidence of Undergraduate Learning from Lesson Experiment Reporting

In the second lesson experiment, which occurred about halfway through the short-course, instructor participants were asked to search the practice literature in teams (of 2 or 3) for a task that had already been developed and implemented in a course for future K-8 teachers. After locating the task, each team agreed on two of the TRU dimensions to pay particular attention to while implementing the task in their own classes. The participants were asked to observe each other and debrief about the observation as each partner implemented the task. Each team was given the prompts below to document their experiences about the entire process:

Before the Lesson Prompts:

1. Which TRU framework dimensions have you selected? What do you hope to learn about yourself as an instructor by paying attention to those dimensions?
2. What is the task you have chosen? Say a little about why you chose it.
3. In terms of the selected TRU dimensions, what do you anticipate will be your greatest challenge with the lesson? How do you plan to address that challenge?

After the Lesson Prompts:

4. How was thinking about the two TRU dimensions challenging? How was it useful/beneficial?
5. How might paying attention to the TRU framework inform future task selection? Implementation?
6. [Bonus question!] Did any of the students get stuck at some point? What did you do or say to help them advance? Would you do the same thing in the future? Why or why not?

Notice that the prompts were written to have the participants actively reflect on their practice, implementing the recommendations set by Castro Superfine and Li(2014). The lesson experiment itself was structured within the work that they did as instructors, another aspect that followed the recommendations.

For the sake of space, we report here on the responses of one participant Sheila (a pseudonym) to demonstrate aspects of her own professional learning as well as that of her future teacher students. Sheila chose a task titled "Maren's Garden" in which the undergraduates in her class had to determine how many gardens could be planted with 4 bags of soil if each garden required ¾ of a bag of soil. Sheila also asked students how much soil would be left. In the Maren's Garden activity, students were asked to solve the problem in two different ways, one of which had to include pictures/diagrams. Sheila indicated that she was aware that future teachers might find it challenging to make sense of what the fractional part of the answer represented in terms of the context of the problem (i.e., that the 1/3 in the answer 5 1/3 referred to a unit of a garden rather than a bag of soil). Sheila indicated in the first prompt that she had chosen to focus on Cognitive Demand and Agency because she wanted the future teachers to make connections with their previous procedural knowledge of fraction division. For prompt 5, Sheila answered:

> Paying attention to the TRU framework will help me to choose tasks that give students opportunities to make connections between concepts or skills that they already know. For example, in the task I selected (which required students to compute $4 \div 3/4$ in more than one way), we were able to compare/contrast solution methods and even provide a reason why multiplying by the reciprocal made physical sense in the problem!

In answering the prompt 6, Sheila noted that:

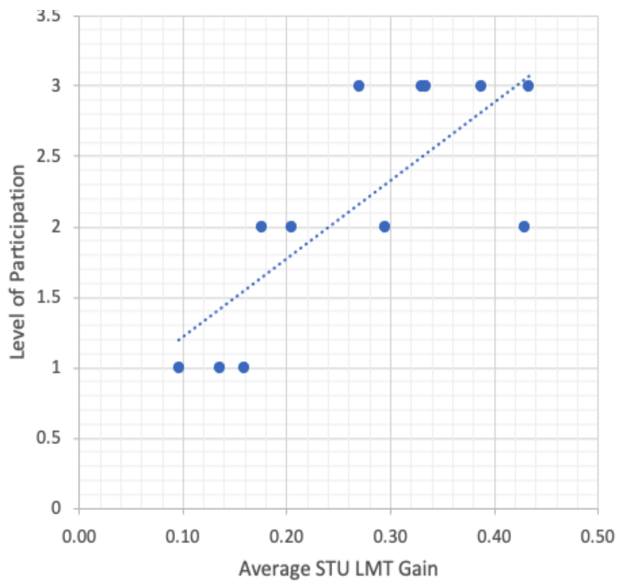
> Yes, students got stuck, and it was a great opportunity for learning! They got stuck when comparing their answers from two methods (one of which had to be visual). In the visual method, it was found that 4 bags of soil divided among gardens that each required 3/4 of a bag of soil meant that 5 full gardens could be made with 1/4 bag of soil remaining. Using the calculation, however, $4 \div 3/4 = 4 \times 4/3 = 16/3 = 5\ 1/3$. Students were puzzled why the calculation showed a left over part of 1/3 compared to the picture, which showed ¼.
>
> I asked them to think about what the fractional part represented in each case and then gave them some time to think about this. In the end, some of the groups realized that the calculation was counting gardens and so the 1/3 represented part of a garden, not a bag of soil. I would do this activity again and implement it in the same way.

For Sheila, an important part of her job as a teacher educator was to make sure that her students could develop their specialized content knowledge, to make connections between representations (i.e., the symbolic and diagramatic in this case). Sheila found it important to let her undergraduate students explore for themselves in order to become agentic, owners of their own learning. That this was happening was evidenced in her report of the future teachers exploring the distinction between the units involved in the problem.

Association Between Undergraduate Learning and Instructor Participation in PRIMED

The overall mean gain for undergraduates on the LMT was 0.29 standard deviations (sd), indicating they increased knowledge of target ideas. Other research on prospective teacher learning has indicated that one semester of instruction in a carefully designed course by an experienced teacher educator can lead to gains of up to 1sd (Castro Superfine et al., 2013). However, typical instruction when college instructors have professional development to strengthen their teaching has seen gains among their prospective teacher students of around 0.25 sd (Laursen et al., 2015). Here, the instructors were novices with teaching future teachers and had a comparable downstream effect (i.e., the average of 0.29sd across all instructors).

The research team also examined the relationship between an instructor's level of participation and their undergraduate students' average gain on the LMT instrument. Level 1 was assigned to the lowest amount of participation (less than one-third of the short-course activities engaged in/completed). For these instructors the average gain was about 0.13sd. Level 2 indicates moderate participation (up to two-thirds of activities completed; for example, parts of some modules not accessed or missing parts of one or two lesson experiment planning, implementation, or reflection activities). Learning gains among students in the classes of Level 2 participants averaged about 0.28sd. Level 3 indicates high participation in most activities and at least two completed lesson experiments. For the students of Level 3 instructors the average LMT gain was about 0.35sd. Instructors reported on their perceived participation in the exit interview: based upon evidence presented within the course, the research team agreed with all of the participants except for one who ranked herself at Level 2. Compared with the other participants, her engagement was Level 3. As the plot of the regression line in Figure 4 shows, there appears to be a robust correlation between rising average LMT gains and increasing levels of participation (r^2~0.6).



Level of Instructor Participation	Average of Student LMT Gain (sd)
1	0.10
1	0.14
1	0.16
2	0.18
2	0.20
2	0.29
2	0.43
3	0.27
3	0.33
3	0.33
3	0.39
3	0.43

Figure 4. Association and table of values for level of PRIMED participation and student LMT gain.

Conclusions and Future Research

We see from the lesson experiment and LMT data that there was a positive relationship between PRIMED participation and the knowledge for teaching gained by their students. While limited in scope due to the size of the study, we see that instructors implemented their intended lesson experiment curriculum with careful attention to the TRU framework and, as illustrated in the case of Sheila, their future teachers gained specialized content knowledge. The more instructors participated, the more opportunities they had to put into play a Castro Superfine and colleagues' (2013, 2014) action knowledge – an analog of knowledge of content and teaching for teacher educators (see Jackson, et al., 2018).

While certainly not evidence for a causal effect (Yoon et al., 2007), the study reported here contributes to the literature on ways to connect PD impact with undergraduate learning impact. A real challenge for the RUME community is to design and conduct large enough studies (or multiple repetitions of moderate sized studies like ours) to explore robust causal effects. Methods for addressing this challenge are part of ongoing work in educational research at all levels (e.g., Kim et al., 2018; Rosenbaum, 2005).

Acknowledgements

First, our thanks to the hundreds who participated in the PRIMED project. This material is based upon work supported by the National Science Foundation under Grant No. DUE-1625215.

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