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Developing Teaching Expertise in K–5 Mathematics

Examining the Effects of a Blended, Practice-Based Math Professional Development Model on Teachers' Confidence and Knowledge

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The Developing Teaching Expertise @ Mathematics (Dev-TE@M) project is focused on developing elementary teachers' knowledge and teaching skills, and ultimately, improving their students' learning. The Dev-TE@M, based at the University of Michigan's School of Education, has developed three practice-based professional development modules designed to be housed within interactive online Learning Management Systems. Each module consists of ten 90-minute face-to-face meetings and activities teachers can complete in a collaborative online environment in between meetings. The modules, which utilize artifacts from teachers' own classrooms, address (a) the mathematics elementary teachers need to know, (b) their students' ways of thinking about mathematics, (c) the accompanying instructional skills and strategies needed to promote understanding for all students and (d) practices for learning from one's own teaching (Figure 1 displays a sample professional development activity).

- Module 1: Representing and Comparing Fractions in Elementary Mathematics Teaching
- Module 2: Supporting Reasoning and Explanations in Elementary Mathematics Teaching
- Module 3: Geometric Measurement and Spatial Reasoning in Elementary Mathematics Teaching

Although all of the modules address these four areas, Module 1 and Module 3 focus on a particular content area. Module 2 focuses on facets of mathematical practice rather than on a specific content area.

Figure 1. Sample Dev-TE@M Professional Development Activity

Pascal's Triangle: Partner Work

```
            1
          1   1
        1   2   1
      1   3   3   1
    1   4   6   4   1
  1   5  10  10   5   1
1   6  15  20  15   6   1
```

- What patterns do you see in the triangle?
- What "rules" do these patterns follow?
- If these patterns continue, what numbers would be in the seventh row? How do you know?

As you discuss the questions, consider:

- Whether your explanations:
  - Have a clear purpose
  - Have a logical structure
  - Use representations and language clearly and carefully
  - Have a focus on the meaning and an orientation to the listener(s)
- How you and your partner are using the Pascal's triangle representation in your explanations

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Evaluation Design

American Institutes for Research (AIR) is conducting an external evaluation of the project, and this brief presents findings from Modules 1, 2, and 3. The evaluation is designed to answer the following questions:

1. Were the critical components of each module implemented as intended and with high levels of participant engagement?
2. Did teachers gain confidence and knowledge from participating in the modules?

STUDY TEACHER CHARACTERISTICS

- Female: 87%
- Teaching experience: 10 years
- Trained through traditional teacher preparation program: 91%
- Took two or fewer courses in mathematics: 40%
- Took two or fewer courses in math methods: 69%
- Had 15 or fewer hours of mathematics PD: 77%
- Had 15 or fewer hours of math methods PD: 81%

The study team collected a number of different types of data to answer these questions. To measure implementation and participant engagement in the modules, the team analyzed self-report data from participants and facilitators, video recordings of the face-to-face meetings, and archival data from the collaborative online meetings. A survey and knowledge inventory were used to measure teacher confidence and knowledge.

A total of 798 teachers and 51 facilitators volunteered to participate in Modules 1, 2, and 3: 532 teachers and 28 facilitators in Module 1, 244 teachers and 15 facilitators in Module 2, and 22 teachers and 8 facilitators in Module 3.

The teacher sample was predominantly female (87%) and had approximately 10 years of teaching experience. The teachers tended to be trained through traditional preparatory programs (91%) and had some prior college coursework in mathematics and math methods. Approximately 40% of the teachers had taken two or fewer college math courses, and 69% had taken two or fewer courses in math methods. For the school year in which teachers participated in the Dev-TE@M project, most of the teachers did not participate in other intensive professional development (PD) programs. Just over 77% of teachers reported participating in fewer than 15 hours of PD focused on mathematics and math methods.

> *The teachers that I worked with seemed to gain a lot from watching their own and each other's videos.—Facilitator*

Table 1 compares some of the characteristics of the teacher sample from the study with the overall population of U.S. teachers. The study sample was more likely to be female and less experienced than the national population.

There were no significant differences in certification between the two groups: More than 90% had standard or regular teaching certificates.

Table 1. Characteristics of Teachers in the Study Sample and the National Population

	Study Sample (%)	National Population (%)	Difference (%)
Female	86.8	76.1	10.6*
Experience	10.2	13.8	3.5*
Regular or standard certification	91.3	91.3	0

Note. The estimates for overall are from the 2011–12 Schools and Staffing Survey.
* The difference between teachers in the study sample and the national population is statistically significant at the .05 level, two-tailed test.

Findings

Implementation and Participant Engagement

The study's first research question analyzed implementation of the modules. To measure fidelity, staff from the Dev-TE@M first reviewed video recordings of each face-to-face meeting to determine the degree to which planned session activities matched what was delivered. The study team then performed the same set of fidelity analyses on a random subset of the face-to-face meetings. Based on these analyses, which were generally consistent between the Dev-TE@M and the study team, **Modules 1, 2, and 3 were implemented with high fidelity.** Each of the ten 90-minute face-to-face meetings generally followed the planned agenda, and teachers completed the activities in between the face-to-face meetings. Module 1 included activities designed to help teachers deepen their understanding and ability to teach fractions. Teachers were exposed to different ways to represent and compare equivalent fractions and use these representations in the classroom. Special attention was given to how students think about various representations and the underlying concepts. The module carefully used study photos of the public writing space (blackboards, whiteboards, etc.) and other classroom artifacts. Module 2 did not focus on a specific math topic but rather on supporting sound mathematical reasoning and explanations. Teachers learned how to support student reasoning and sense-making in their classrooms, drawing heavily from artifacts of their own classrooms. Module 2 included a video workshop component. Within and across the activities in these modules, the facilitators essentially delivered these activities as planned. Module 3 returned to a focus on a specific math topic: geometric measurement. Teachers engaged with student learning progressions for one-, two-, and three-dimensional measurement. They used these progressions as the basis for considering future instruction and for taking anecdotal notes to capture students' engagement in geometric measurement activities.

> *The [teachers] deepened their knowledge of the concepts presented via reasoning tasks. —Facilitator*

The facilitators also provided feedback on their experiences leading the modules. Overall, the facilitators reported high satisfaction with the quality and usefulness of the professional development materials. They documented specific instances in which teachers appeared to be improving their understanding of both content and pedagogy. Examples included crafting conceptual explanations, appreciating the importance of conceptual coherence, and orchestrating discussions that highlighted student thinking. The facilitators also pointed out that teachers found the analysis of their own practice—including video analysis—to be extremely valuable professionally.

Based on surveys completed at the conclusion of each module by teacher participants and facilitators, as well as the study team's analyses of video recordings of a sample of the face-to-face meetings, the teachers exhibited **high levels of engagement and satisfaction with the module activities**. The survey data indicated that teachers generally found that the session activities helped strengthen their understanding of mathematics and student thinking and to improve specific pedagogical strategies. The video analyses portrayed teachers as actively involved in the learning activities, with few instances of teacher disengagement.

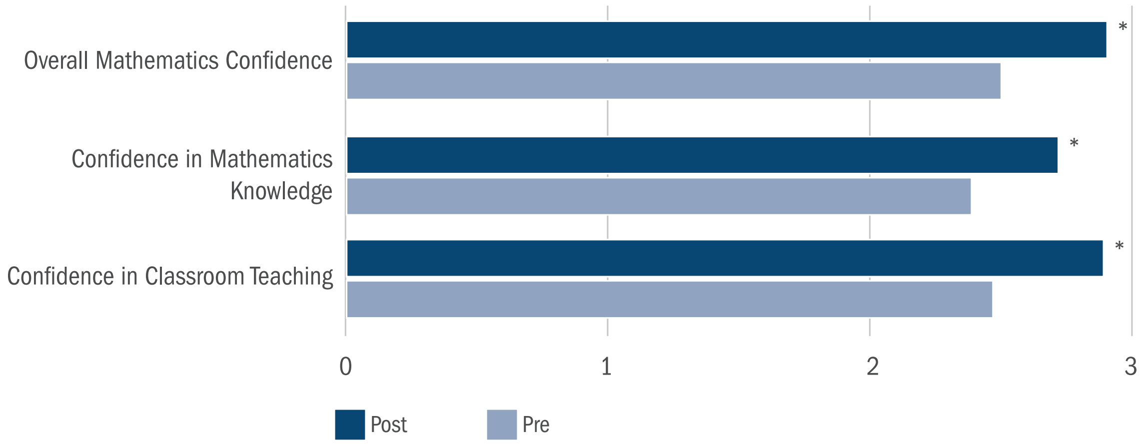
Teacher Confidence

> *Participants gained confidence in sharing their practice, trust in the process of video workshop to capture students thinking and explaining of mathematics, and strategies for getting students to elaborate.—Facilitator*

Because the modules emphasized deepening teachers' knowledge in the context of teaching and included activities in which teachers reflected on their own teaching, teachers reported on the degree to which modules affected their confidence in math teaching, as well as their confidence in learning mathematics. Teachers were assessed on these dimensions at the beginning and end of Modules 2 and 3. In Module 1, teachers were assessed only at the beginning of the module; therefore, an analysis of teachers' confidence uses data only from Modules 2 and 3. The results show that **teachers' confidence significantly improved** during the course of the module.

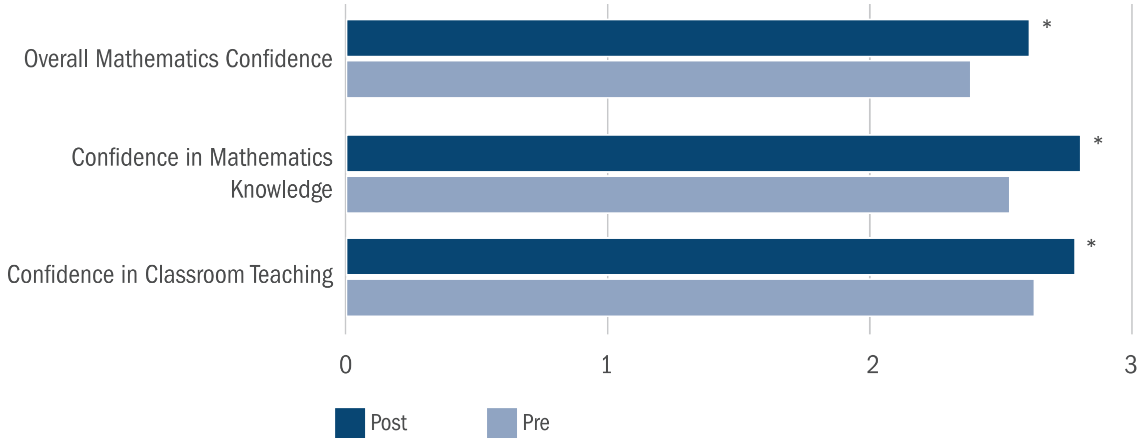
Figures 2 and 3 illustrate the improvement in teachers' confidence in Modules 2 and 3, respectively. The study found that teachers' confidence in both mathematics and math teaching increased from less than confident to more than confident on a 4-point scale. This difference was statistically significant in a multilevel model that controlled for teacher characteristics, such as experience and math background.[1]

Figure 2. Teachers' Confidence in Math and Math Teaching, Pre- and Post-Module 2 (Reasoning and Explanations)



* The difference from pre to post is significant at $p < .05$.

Figure 3. Teachers' Confidence in Math and Math Teaching, Pre- and Post-Module (Geometric Measurement)



* The difference from pre to post is significant at $p < .05$.

Teacher Knowledge

The other part of the study's second research question examined teachers' understanding of math knowledge in the context of teaching. Teachers were assessed on these dimensions at the beginning and end of each module. The results show that **teachers' knowledge significantly improved** during the course of the module.

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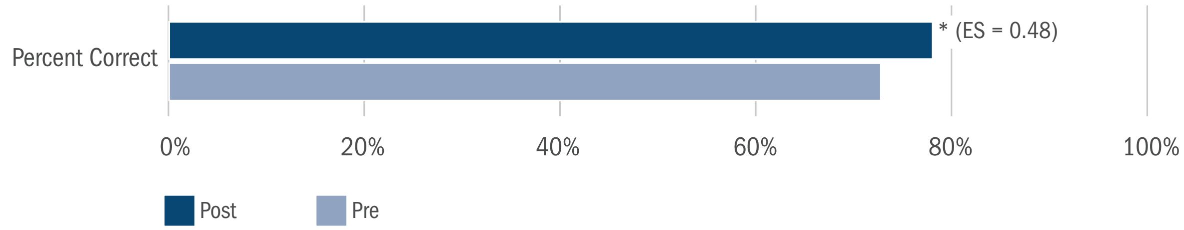
[1] To test whether the change in any outcome is significant from pre to post intervention, a model of the following form is used: $Y_{it} = \beta_0 + \beta_1 Post + \sum \beta_X Covariates + \varepsilon_{ij}$ where Y_{it} represents the outcome of interest for a teacher i at pretest (t = 1) and posttest (time = 2) including mathematics knowledge, teachers' report on student activities in class, teachers' confidence in classroom teaching, teachers' confidence in mathematical knowledge, and teachers' overall mathematics confidence. *Post* is an indicator for posttest (post = 1 if t = 2), and *Covariates* represent the covariates to be used in the analyses including years of experience, professional development activities, number of courses taken in college, past year activities, and use of commercial math textbooks. Models were run in a stepwise manner starting with an unconditional model to a model with full set of covariates. The results across different model specifications were consistent. Therefore, the results from the unconditional model was reported to increase the power of the analyses.

Figures 4 through 6 illustrate the improvement in teachers' knowledge in each module. In Module 1, participating teachers' knowledge scores improved from 69% correct to 75% correct (see Figure 4), which was statistically significant in a multilevel model that controlled for teacher background characteristics.

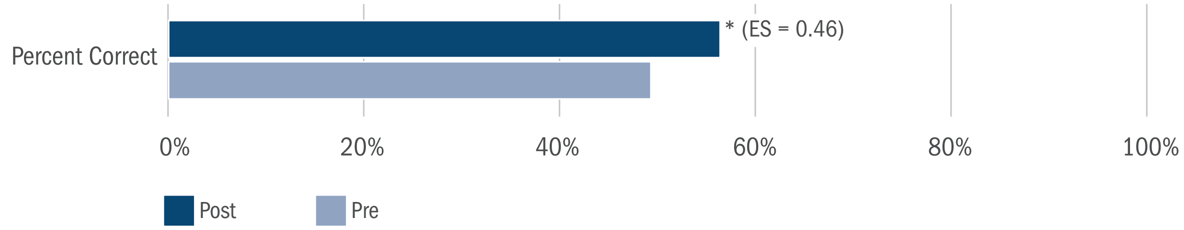
Figure 4. Teachers' Knowledge, Pre- and Post-Module 1 (Fractions)



* The difference from pre to post is significant at $p < .05$.

In Module 2, teachers also improved on the knowledge assessment from pre- to post-administration. Figure 5 shows that teachers moved from 50% to 57% over the course of the module. This difference was also statistically significant using the same multi-level model in Module 1.

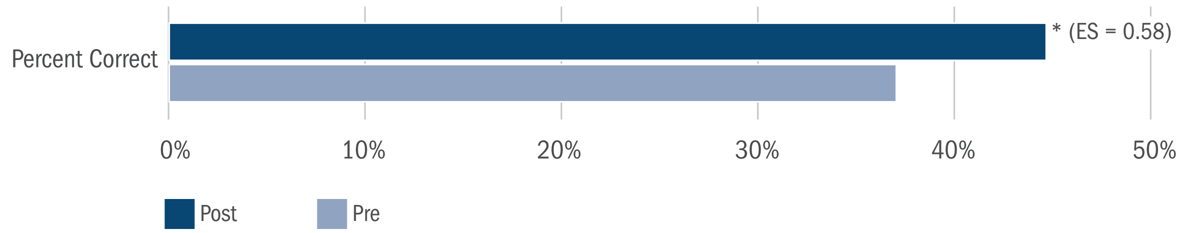
Figure 5. Teachers' Knowledge, Pre- and Post-Module 2 (Reasoning and Explanations)



* The difference from pre to post is significant at $p < .05$.

In Module 3, teachers also improved on the knowledge assessment from pre- to post-administration. Figure 6 shows that teachers moved from 37% to 45% over the course of the module. This difference was also statistically significant using the same multilevel model in Module 1.

Figure 6. Teachers' Knowledge, Pre- and Post-Module 3 (Geometric Measurement)



* The difference from pre to post is significant at $p < .05$.

Contextualizing the Findings

A consistent pattern of positive findings has emerged across the three modules. Each module was implemented by a local facilitator with high levels of fidelity, which is encouraging from usability and feasibility standpoints. By the end of the two Dev-TE@M modules with available data, teachers' confidence in mathematics and classroom instruction significantly improved. For each of the three modules—the two content-focused modules and the one focused on instructional practices—teachers demonstrated statistically significant improvements in math knowledge. Furthermore, the knowledge measures used in this project, which assess teachers' math knowledge in the context of teaching, have been positively associated with student achievement in other studies. The associations are estimated to range from .02 to .05, depending on the study (e.g., see Hill, Rowan, & Ball, 2005; Rockoff, Jacob, Kane, & Staiger, 2011; Garet et al., 2011). Other studies have used a more traditional measure of teachers' math content knowledge but did not observe a positive relationship with achievement. For example, Garet and colleagues (2016) measured teachers' math content knowledge with items from the Northwest Evaluation Association, a test typically given to K–12 students, and found no association (.00) with student achievement.

These results are encouraging; they indicate that teachers' confidence and math knowledge can grow in a relatively short period of time when they participate in these modules. Although this study did not measure teachers' instructional practice, a future project might assess whether teachers' knowledge of math in the context of teaching translated into improved teaching. A classroom observation rubric that is aligned to the Dev-TE@M modules, such as the Mathematical Quality of Instruction (MQI), could be used to answer this question. In fact, certain dimensions of the MQI have been positively associated with student achievement in prior studies (e.g., Blazar, 2015; Hill, Kapitula, & Umland, 2011). Yet like the previously discussed associations between teachers' content knowledge and student achievement, these associations are quite modest (roughly .05).

In sum, designing professional development programs like Dev-TE@M appear to be focused on the right areas, but the field has more to learn about what it would take to boost teachers' knowledge and practice to levels that translate to improved student achievement. Given these modest associations, the effects would have to be large. One idea to increase the impact would be to better integrate pre-service and in-service teacher development programs. Perhaps providing teachers with a more coherent, intensive set of opportunities to develop math knowledge for teaching and practice enacting that knowledge in the classroom could lead to stronger effects. The field should identify other strategies and continue to build from encouraging findings from this and other well-designed, well-implemented projects.

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