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Developing Better Instructors Using the *Principles to Actions* Professional Learning Toolkit

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Learning to Use Effective Mathematics Teaching Practices

Many years ago, there was an article titled *Unlearning to Teach Mathematics*[1] that emphasized how the experiences and beliefs future teachers bring into their preparation courses highly impacts the commitments they make toward their future teaching. Though there have been many advances in knowing what constitutes an effectively taught mathematics class, many preparing teachers have limited to no experience with those techniques and envision their future classroom continuing the *status quo*—typically a teacher-centered focus of instruction. Are the efforts of mathematics education courses helping these future teachers unlearn how to teach mathematics?

In the training of teachers for the classroom, there has been an ongoing question of how to help future teachers move from the "teacher-centered" focus of instruction to a more "student-centered" focus of instruction. The National Council of Teachers of Mathematics published a series of resources called the *Principles to Actions Professional Learning Toolkit*[2] that provides classroom videos that allow the opportunity to view "student-centered" lessons that promote recommended teaching practices for mathematics. In Spring 2020, a collaboration of mathematics teacher educators committed to sharing at least five of these videos in their mathematics courses for future elementary teachers. Their goal was to answer the question: Does exposure to video examples of student-centered mathematics instruction in elementary

[1]D. L. Ball, "Unlearning to teach mathematics," *For the learning of mathematics* 8, no. 1 (1988): 40-48.
[2]Principles to Actions Professional Learning Toolkit," National Council of Teachers of Mathematics, accessed April 23, 2023, https://www.nctm.org/PtAToolkit/.

classrooms contribute to students' commitment to this type of instruction? The future teachers completed a pre/post survey to measure their commitment toward using student-centered type instruction in their future mathematics classes. This article shares the results of these efforts, communicating what commitments future elementary teachers made toward effective mathematics teaching practices and what factors brought about those commitments.

Connections to Prior Research

Hart et al.[3] provide a review of research related to experiences of prospective elementary teachers in mathematics content courses that are influential to developing productive dispositions for teaching mathematics. Their review generally shows that experiencing alternative approaches to instruction (e.g., problem-based learning, working in groups, exploring various approaches, and considering children's thinking) helps to shift, in varying degrees, elementary prospective teachers' beliefs away from teacher-centered instruction toward a more student-centered instruction. They suggest that more inquiry is needed on "specific experiences prompting EPT [elementary prospective teacher] change."[4] Even when beliefs about effective pedagogy are shifted, prospective elementary teachers often revert to teacher centered instruction when they enter schools where this is the predominant mathematics pedagogy. "Letting go of traditional perspectives on mathematics and its teaching and learning engrained over many years as students in mathematics classrooms is an arduous process and fraught with resistance."[5] Swars et al.[6] noted that new teachers are often hesitant to implement reform beliefs within a culture of a traditional school setting. They did note some maintenance of more student-centered pedagogies

[3] L. C. Hart et al., "A review of research on affect of elementary prospective teachers in university of mathematics content courses 1990-2016," *School Science and Mathematics* 119, no. 1 (2019): 3-13.
[4]Hart et al., "A review of research," 11.
[5]Hart et al., "A review of research," 11.
[6]S. Swars et al., "A longitudinal study of elementary pre-service teachers' mathematics beliefs and content knowledge," *School Science and Mathematics* 107, no. 8 (2007): 325-335.

when the prospective elementary teachers worked with cooperating teachers who used those methods in their field placements. The focus of this project provided a specific type of experience to encourage reformed beliefs in effective mathematics pedagogy (using the *Principles to Actions Professional Learning Toolkit* videos and resources) which also exposed students vicariously to classrooms where the methods were being effectively used. The hope is that these experiences could bring about commitments to effective pedagogy that will overcome the resistance experienced when entering the workforce in traditional school settings.

One of the challenges in documenting changed commitments in students' views of effective mathematics pedagogy is an objective tool to measure that change. A study by Pourdavood and Liu[7] on pre-service mathematics teachers' beliefs noted the importance of collecting both quantitative and qualitative data for research related to developing instructional strategies in teachers. They emphasize that "qualitative data could provide valuable information on different factors that influence the change process that occurs in PSTs [pre-service teachers]"[8] providing details that numbers simply cannot show. "Mixed methods research benefits from the strengths of both quantitative and qualitative research and therefore provide a better perspective for understanding, analyzing, and interpreting the complexity of teacher change and mathematics education reform in general."[9] In keeping with these recommendations, this study utilized both quantitative data from Likert-type questions in a pre/post survey and open-ended questions which were analyzed using a coding scheme. One of the open-ended questions asked the prospective elementary mathematics teachers to describe the teaching strategies he/she would

[7]R. G. Pourdavood and X. Liu, "Pre-service elementary teachers' experiences, expectations, beliefs, and attitudes toward mathematics teaching and learning," *International Journal of Learning, Teaching and Educational Research* 16, no. 1 (2017): 1-27.
[8]Pourdavood and Liu, "Pre-service elementary teachers' experiences," 10.
[9]Pourdavood and Liu, "Pre-service elementary teachers' experiences," 25.

use in teaching equivalent fractions. The coding of this description benefited from a type of continuum suggested by Bull[10] that provided a range of teaching strategies with teacher-centered methods at one end and learner-led classrooms at the other extreme.

Method

Students taking a mathematics course for elementary education in Spring 2020 took nearly identical pre- and post-course surveys with questions adapted from Swan[11] and the Wisconsin Center for Education Research,[12] providing a snapshot of their plans for teaching mathematics. The survey consisted of 3 parts: (1) an open ended question where the student described the instructional strategies he/she would use in teaching a lesson on equivalent fractions, (2) a series of questions describing various instructional techniques allowing students to answer on a scale of anticipated use in their mathematics classroom (almost never, sometimes, half of the time, most of the time, almost always), and (3) an additional list of instructional activities where students indicated the amount of time used in that activity over the course of a school year (none; little—less than 10% of instruction time for the school year; some—10-25% of the instruction time for the school year; moderate—26-50% of the instruction time for the school year; and considerable—more 50% of the instruction time for the school year). An additional open-ended question was added to the post-survey: "Please describe how any views you have about teaching math in the elementary classroom have changed over the last semester

[10]Bernard Bull, "A 9-Stage Continuum of Teacher-Centered to Learner-Led Classrooms & Communities," Etale – Exploring Futures & Innovations in Education with Dr. Bernard Bull, November 17, 2019, accessed December 18, 2020, etale.org/main/.
[11]M. Swan, "Designing and using research instruments to describe the beliefs and practices of mathematics teachers," *Research in Education* 75, no. 1 (2006): 58-70.
[12]"Survey of Instructional Practices, Teacher Survey, Grades K-12, Mathematics," Wisconsin Center for Education Research, 2021, accessed February 8, 2021, http://programs.ccsso.org/content/pdfs/K12mthSurvey31407.pdf

and what has brought about that change."[13] Although the surveys were elicited from students at two different universities, only students from one of the universities complied, with twenty-three completing the pre-survey and twenty-seven completing the post-survey. The pre- and post-surveys could be linked by a code created by the student. Only fifteen of the surveys were paired using this code.[14]

The instructors who participated in the study agreed to supplement the curriculum of their mathematics for elementary teachers classes in Spring 2020 with at least five of the classroom videos available through the *Principles to Actions Professional Learning Toolkit*. The classes connected to those who completed the survey consisted primarily of topics from geometry and measurement. Prior to requirements to leave campus due to the pandemic, students worked in groups with a variety of upper elementary grade activities modeled as they reviewed the mathematics concepts. When the *Principles to Actions* recordings were used, students first worked through the activity associated with the *Principles to Actions* video. They then watched the video in class and answered reflection questions afterward. After leaving campus due to the pandemic, the course was provided asynchronously. Students still completed upper elementary activities associated with the concepts (e.g. Geogebra constructions, Math Playground activities, activities provided in their course pack). The *Principles to Actions* videos were watched individually and students still submitted written reflections on the classroom episodes.

Results: Quantitative Data

[13]Copies of the survey instruments are available from the author. A link to a copy of the post-survey is available here: https://docs.google.com/forms/d/e/1FAIpQLScVRsXISTSiUdPKF3F4-3UkZFdDzHdo86hKwf3D8-yp3pgTUw/viewform.
[14]It was noted that the students who completed the survey were typically in their third year of study while those from the university that did not complete the survey were in their first year.

The surveys completed by the students allowed for a view of their perception of their future mathematics classroom. Students rated instructional techniques and activities by the anticipated regularity in their classrooms. The scales were quantified in order to compare pre- and post-results. After considering the initial outcomes the researchers realized that it would be beneficial to compare the changes observed from the student surveys to see if the students moved closer to the goals for effective mathematics teaching. Consequently, members of the Association of Mathematics Teacher Educators in Indiana were asked to complete the survey in order to define goal results for effective mathematics teaching practices. These results were then used for comparison with the results from the student surveys.

After running two sample t-tests and paired t-tests on the data, several instructional techniques and activities indicated statistically significant change (p-values < 0.05) in the pre-service teachers and approached the effective mathematics teaching practice goals. Table 1 shares these instructional techniques and activities. Note that approaching goals for effective mathematics teaching practice may mean more or less time for a particular teaching technique, depending on the type of strategy. Also, the 2-sample t-test incorporated all of the survey results where the paired test was limited to those surveys that provided correct coding to allow for the pairing of the surveys.

Statistically Significant for both the 2 Sample t-test and the Paired t-test
• The teacher is surprised by ideas that the students develop during a lesson.
• Students explain their reasoning or thinking in solving a problem by using several sentences orally or in writing.
Statistically Significant for the 2 Sample t-test only
• The textbook or worksheets guide the instruction.

• Students invent their own methods.
• Topics are taught separately.
• The teacher jumps between topics.
• Students watch the teacher demonstrate how to do a procedure or solve a problem.
• Students complete computational exercises or procedures from a textbook or a worksheet.
• Students work in pairs or small groups on mathematics exercises, problems, investigations, or tasks.
• Students solve non-routine mathematical problems (e.g., problems that require new or non-formulaic thinking).
• Students make estimates, predictions, or hypotheses.
Statistically Significant for the Paired t-test only
• Students maintain and reflect on a mathematics portfolio of their own.
Statistically significant defined as p-value < 0.05

Table 1. Instructional Techniques and Activities that Showed Significant Change in Emphasis

The three instructional techniques that demonstrated the most significant change toward the suggested effective mathematics teaching practices were (12) the teacher is surprised by ideas that the students develop during the lesson (increased expectation), (39) students explain their reasoning or thinking in solving a problem by using several sentences orally or in writing (increased expectation), and (14) the textbook or worksheets guide the instruction (decreased expectation). (The survey item number is indicated in parentheses.) According to Swan's research,[15] item 12 ("teacher surprise") represents student-centered behavior, item 14 ("textbook guided") represents teacher-centered behavior, and item 39 ("explain thinking") is a

[15]Swan, "Designing and using research instruments."

constructivist teaching method, often found in student-centered classrooms. All three of these strategies were modeled both in the *Principles to Actions* classroom videos and in the class taken by the pre-service teachers. As has been seen in other studies where effective mathematics teaching strategies are modeled in the classroom, these students communicated significant change toward student-centered instructional approaches that are emphasized by *Principles to Actions.*[16]

Results: Qualitative Data

(1) Use traditional methods (worksheet - drill)
(2) Show using visual representations (pie charts)
(3) Discussion - Student Discourse
(4) Engage students in creating visual representations (more teacher directed)
(5) Exploration (student focused)

Table 2. Codes for Lesson Descriptions

In both the pre- and post-surveys, students were asked to describe a lesson they would teach on equivalent fractions. Four researchers read through the responses and independently created categories to summarize the instructional style. The researchers then reviewed their categories together, to develop a consistent coding scheme for the lesson descriptions. The coding scheme (see Table 2) represented a sort of continuum from teacher-centered, transmission-based teaching to student-centered, constructivist-based teaching (as much as we can define a "continuum" in education where there are so many influencing factors and variables). "'Teacher-centered practice' is conceptualized as the teacher transmitting knowledge to students, while 'student-centered practice' is conceptualized as taking students' individual

[16]Swan, "Designing and using research instruments."

processes for knowledge-building into account through instruction designed to be flexible to student needs."[17] The researchers independently used the coding scheme to code the responses and then compared results to determine a final score for each response.

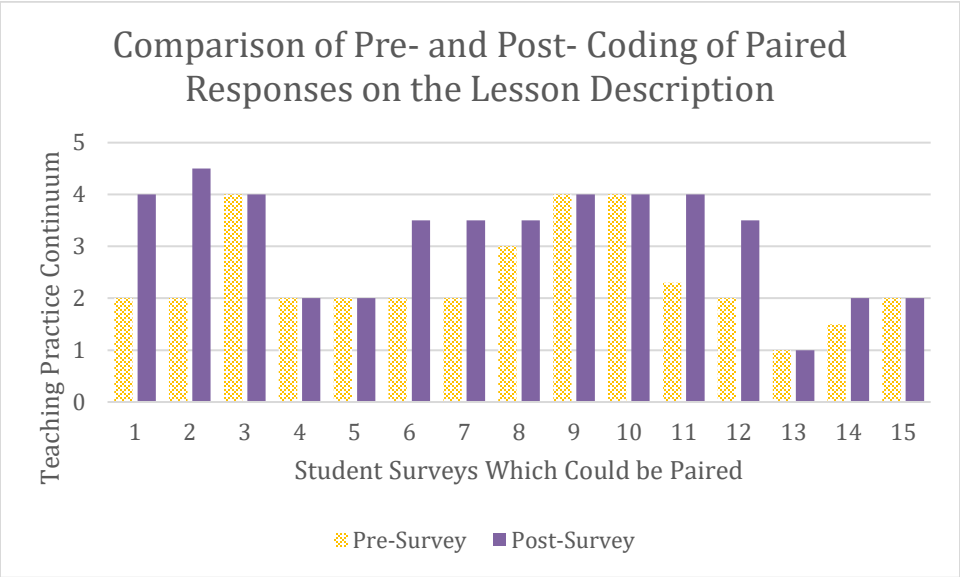

Figure 1. Comparison of Pre- and Post- Coding of Paired Responses on Lesson Description

For the lesson description, all the paired responses either indicated movement towards student-centered classrooms with constructivist views or no change in their classroom focus (see Figure 1). For the pre-survey paired responses the average was 2.45. The post-survey paired response average was 3.33, indicating some increase up the scale. This demonstrates a general movement/trend from more teacher-centered, transmission-based teaching to more student-centered, constructivist-based teaching. The overall pre-survey average was 2.3 and the post-survey average was 3.0, so here, also, there appears to be some increase up the scale in general.

[17]M. B. Carney, J. L. Brendefur, G. R. Hughes, and K. Thiede, "Developing a mathematics instructional practice survey: Considerations and evidence," *Mathematics Teacher Educator* 4, no. 1 (2015): 93-118.

(1) **An emphasis on discourse - questioning**
(2) **Exploration**
Problem Solving
Allow mistakes - productive struggle
Student Centered Emphasis
Create conclusions
(3) **Collaboration** - Working with others
(4) **Emphasize process rather than product**
Why vs how
Reasoning

Table 3. Codes for "Changed Views about Teaching Math in an Elementary Classroom"

In the post-survey an additional open response item asked the pre-service teachers to provide a description of any change in their views of teaching mathematics and to also indicate what may have brought about that change. As with the lesson descriptions, themes were noted in the responses that led to a coding scheme. The categories in Table 3 informed the analysis of the responses.

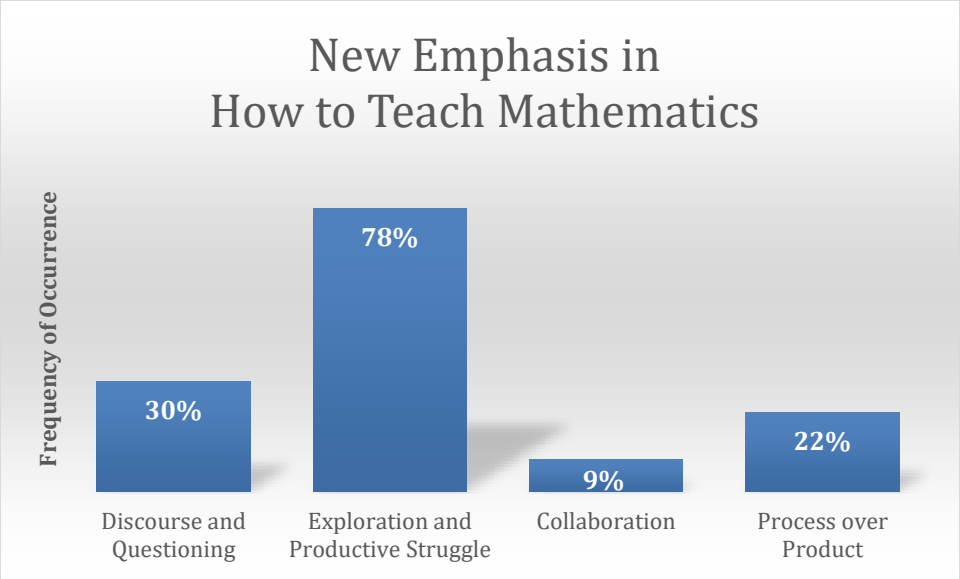

Figure 2. Student Perceived Changes in How They Will Teach Mathematics

The frequency of each of the categories is shown in Figure 2. Clearly category 2, "Exploration and Productive Struggle," was described by the pre-service teachers the most frequently as a description of how their views of teaching mathematics had changed. The *Principles to Actions* materials and the in-class instruction both emphasized these teaching practices. One responder said that she had been most impacted by "all the hands-on activities we did in class to help us understand the concepts better" (response 7). Another student said, "[the instructor] modeled how to promote exploration and discovery through the tasks he gave us as he challenged us to figure things out for ourselves by not just giving us the answer or formula" (response 11). This theory is most clearly seen in this pre-service teacher's response:

> I have really started considering the idea of guiding students to explore on their own through asking questions. I usually would have thought it was helpful to give them some information to guide them, but I can do the same process with questions instead and although it may take longer, it is more likely to stay in their minds when they approach the same types of problems in the future. This change occurred in my thinking because of a lot of the activities we engaged in during the course, as we were asked to explore things as we were guided only with questions. It was frustrating at some points, but the success of solving a difficult problem was so much more rewarding. (Response 16)

The productive struggle and problem-solving that this pre-service teacher talks about were clearly modeled quite well in the course and made a positive impression on her. Thus, as

exploration, productive struggle, and hands-on learning were so well incorporated into the daily classes throughout the semester, this category came up frequently in the pre-service teachers' responses. Many of them were especially impressed by the idea of allowing students to struggle with problems until they arrive at their own conclusions/formulas/answers because the pre-service teachers themselves experienced deeper learning when their instructor had them do this. They also observed this modeled in classrooms with young children in the *Principles to Actions* videos, making the teaching practice relevant to their future teaching.

Category 1, "Discourse and Questioning," was also a common description of change in instructional focus, occurring in one of every three responses. Here is one response:

> There is a need for students to have productive struggle and conversation/discourse when learning math. I think what brought about this change was all the hands-on activities we did in class to help us understand the concepts better, as well as the reflections that were done in class…where we watched a video, had the script, and were able to discuss it. Just like in learning math concepts, learning how to teach math we need…the discourse on how to teach math. (Response 7)

This student learned the benefit of math discourse through actual practice in class as well as through the videos and reflections written. Another student says, "Math should be more exploration, hands-on, collaborative, and facilitated with lots of thought-provoking questions. After being in [my practicum experience], working in my math group in class, and also watching and writing the math reflections, I now see the importance of these things!" (response 12). Again, the student emphasizes the in-class experiences and the *Principles to Actions* videos with reflections as fundamental for developing new commitments toward teaching mathematics.

Category 4, "Emphasizing Process over Product, Why vs. How," was usually connected to an emphasis on "deeper learning" gained by students when this was the instructional focus. For example, response 9 says, "I have learned that it is important for students to see why concepts and formulas make sense. Even better, the students should be given the opportunity to create a formula for a concept, and by them creating the formula, they will have a deeper

understanding for the concept." Another example, response 15, says, "My views have changed in the sense that I want to make my math students understand why things work instead of just how they work. I want to help them understand the why because that will help them understand the concepts." Thus, we see here that these pre-service teachers moved towards the Effective Mathematics Teaching Practice of using and connecting mathematical representations, for in this practice, "effective teaching of mathematics engages students in making connections among mathematical representations to deepen understanding of mathematics concepts and procedures and as tools for problem solving."[18]

While category 2, "Collaboration" developed as a code prior to the independent coding, very few responses actually received this final code. While collaboration may be implied by areas such as discourse and even exploration, the responses didn't indicate this emphasis. Since these students were required to complete the final half of their semester in an asynchronized online format due to the COVID-19 pandemic it is possible that collaborative instructional techniques were less impacting than the other emphases.

Conclusions

As has been observed in other studies, providing coursework that emphasizes effective mathematics teaching practices helps pre-service elementary teachers develop commitments toward those teaching strategies. The students in this study benefited from instruction that was guided by the Effective Teaching Practices as presented in *Principles to Actions*.[19] The instructor modeled those techniques and the *Principles to Actions* classroom videos allowed students to see the same teaching practices used with elementary-aged children. In the quantitative data, the pre-

[18]National Council of Teachers of Mathematics, *Principles to Actions: Ensuring Mathematical Success for All* (National Council of Teachers of Mathematics, 2014), 24.
[19]National Council of Teachers of Mathematics, *Principles to Actions*.

service elementary teachers showed significant change toward measures of instructional techniques that are indicated as effective mathematics teaching practices according to mathematics teacher educators. The teaching strategies indicating the most significant growth emphasized students developing their own conclusions or strategies prompting teacher surprise and students explaining their reasoning and thinking. These strategies are similar to the effective teaching practices shared in *Principles to Actions*[20] that emphasize students engaged in problem solving and reasoning, students making connections, students engaging in discourse, and the teacher posing purposeful questions. The instructional strategy of using the textbook or worksheets to guide instruction showed a significant decrease in importance among the pre-service teachers as the students learned the value of working in groups and with hands-on activities.

The students communicated their growth in a similar manner through descriptions of a lesson to teach equivalent fractions where pre-survey descriptions tended to be more teacher-centered and post-survey descriptions communicated a more student-centered focus. The pre-service teachers' self-assessment of their growth, as shared in the post-survey, also indicated a commitment toward student-centered instructional practices. Not surprisingly, the themes that became apparent in the responses paralleled several of the effective teaching practices noted in the *Principles to Actions* materials such as "productive struggle," "questioning," and "discourse." Even with half of the course instruction given online during forced stay-at-home requirements from the COVID-19 pandemic, the pre-service teachers described their changes in instructional commitments as coming both from their experiences within the course and the experiences related to the *Principles to Actions* videos and reflections.

[20]National Council of Teachers of Mathematics, *Principles to Actions*.

The results of this study are similar to many noted by Hart, et. al.[21] They note that a number of different pedagogical approaches applied to mathematics content classes for teachers (e.g., problem-based learning, working in groups, etc.) encourage a shift in beliefs from more teacher-centered to more student-centered approaches to teaching. The pre-service teachers in this study experienced instruction that was guided by the *Principles to Actions*[22] "Effective Mathematics Teaching Practices" both in classroom experiences and in videos of those practices used in elementary classrooms.

One of the concerns with the shift in beliefs is a maintained commitment to those teaching practices when the elementary pre-service teachers have their own classroom. "Changes seen in EPTs [elementary pre-service teachers] during courses may not carry over to the practicing teacher."[23] Swars[24] found a maintenance of new pedagogical commitments in student teaching due in part to alignment of teaching strategies used in the university content classroom with successful modeling of those teaching practices by cooperating teachers in field placements. For many programs, finding cooperating teachers in field placements who mirror the effective mathematics teaching strategies used in the university courses is not a possibility. One benefit provided by the *Principles to Actions* videos is that students are able to see and reflect on the use of the "Effective Mathematics Teaching Practices" by teachers in *real* elementary classrooms. While this study does not have data to document a maintenance of commitment to change as the pre-service teachers enter their own classrooms, there is hope that the exposure to classrooms modeling effective teaching strategies, as shared in the *Principles to Actions* videos, will provide

[21]Hart et al., "A review of research."
[22]National Council of Teachers of Mathematics, *Principles to Actions*.
[23]Hart et al., "A review of research," 11.
[24]Swars et al., "A longitudinal study."

these teachers with a vision for effective teaching in their future classrooms that may develop as they gain greater confidence in their teaching.

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