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Connecting MASTERS Project: Mathematics and Science Teaching Excellence in Rural Schools

Abstract

This study examined the effects of a focused professional development program for teachers in rural schools on math content knowledge and persistence measured by outcomes on the Math Assessment. Scores for all participants were analyzed (n = 37). A marked improvement was seen in the math content knowledge of teachers from the pre-assessment to the post assessment. Teachers increased their scores by 17% on the Math Assessment. The most salient result of the present study pertained to the number of answers that were scored a zero meaning they were left blank with no attempt to answer. Noteworthy is the fact that there was a total of 23 scores of zero in the pre-assessments and only 5 scores of zero in the post assessments.

Keywords

STEM, Mathematics Education, Professional Development

Connecting MASTERS Project: Mathematics and Science Teaching Excellence in Rural Schools

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Introduction

Rural schools across the nation are challenged to provide their students with the foundational knowledge and skills to enter STEM careers. The causes identified in a 2014 report, *Work to Do: The Role of STEM Education in Improving the Tri-State Region's Workforce,* (Campos Research Strategy, 2014) indicate a shortage of students who are prepared for high-level STEM coursework, teachers experienced in teaching STEM, and shrinking education budgets that diminish STEM-specific professional development. Teachers in rural schools endure professional isolation and lack access to high quality professional development opportunities.

In rural Kansas, limited opportunities for ongoing teacher education, particularly in STEM (Science, Technology, Engineering and Mathematics) fields, is a concern that ranked high among the districts' teachers that completed self-assessments for the MASTERS project. Many also admitted lacking confidence in carrying out integrated STEM curricula. In addition, they all reported challenges regarding standards of education. The Kansas College and Career Ready Standards (KCCRS) in mathematics and science require that teachers make content accessible for their students and that students acquire a deep level of understanding.

Teachers from the districts that partnered with the MASTERS program did not have the capacity or the support to make the curricular changes that the STEM fields and KCCRS required. These high-need school districts, located more than an hour away from any state university, became the target of this integrated STEM and standards education program. The focus was on helping teachers create meaningful experiences for students to connect with math concepts and to develop a mindset to help them persevere through challenges.

In the Connecting MASTERS Project, the goal was to engage teachers in professional development that was designed for intense and relevant learning with the following strategies: immersion in KCCRS mathematics and science learning, lesson development, book study, examining student work and analyzing errors, identifying common misconceptions, and coaching.

The very specific purpose of the present study was to investigate the relationship between teacher participation in this focused professional development program and performance on the Math Assessment.

Method

Setting

The Teachers College at Emporia State University (ESU), Pittsburg State University (PSU), and the Southwest Plains Regional Service Center (SWPRSC) partnered with rural high-needs elementary schools to provide needed professional development. A two-week summer institute was led by ESU and PSU faculty experienced in the Kansas College and Career Ready Standards (KCCRS) in mathematics and science and the instructional strategies that promote student learning in STEM subjects. The summer institute was held in two separate sites, Western and Southeastern. A SWPRSC Instructional Coaching Consultant and a Project Coach assisted with facilitating the summer institute and engaged in activities with the project participants. While professors and coaches were present at each site, participants were also connected with teachers, faculty and STEM content through video transmissions.

Identified Needs

During initial planning meetings, and through conversations with teachers and administrators in the participating schools the most pressing need expressed was to address the complete lack of training provided to district teachers to improve their STEM curriculum development and classroom integration. Limited discretionary funds have led to a decrease in district-funded professional development, and only broader education topics have been emphasized at the district level. The introduction of one-to-one or mobile technology in many of the classrooms came with little content-focused pedagogical training, thus exacerbating the difficulties of teachers untrained in STEM curriculum and in how to leverage technology to improve student learning experiences.

Participants

School Districts

The districts involved in MASTERS project were rural school districts, located more than an hour away from any state university. In addition, these districts were all identified as high-need school districts and were selected for this partnership because of: 1) their high populations of economically-disadvantaged students 2) low science and/or math achievement scores on state assessments, 3) previous ESU/PSU collaboration with teachers in these schools, and 4) the mutual interests and benefits in pursuing this project.

All of the high-need school districts have large populations of students qualifying for free and reduced lunch, low-socioeconomic status (low-SES), and students who are English language learners (ELL). **Table I** shows the demographics for the individual school buildings participating in the project. The project served more than 2,000 K-6 students, with approximately 1500 students qualifying for free and reduced lunch (low-SES) and 520 students identified as ELL.

TABLE I: 2016 - 2017 BUILDING DEMOGRAPHIC INDICATORS

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Elementary Schools	1	2	3	4	5	6
Enrollment	355	442	321	251	163	541
Low-SES	96%	86%	62%	45%	50%	73%
ELL	75%	59%	-	-	-	2%

Teachers

The Connecting MASTERS Project was designed to support thirty-seven (37) teachers in rural Kansas in creating a meaningful instructional program that integrates STEM curriculum. Teachers in the four partner school districts did not have the capacity or the support to make the curricular changes required of the KCCRS.

Teachers in the project were asked how many undergraduate or graduate courses they have had in science and math. In science, over 75% indicated they have had only 1-3 science courses; 25% have had 4-5 courses and 5% have had 6-7 courses. Teachers have had more formal instruction in math, with 58% having 1-3 courses, 27% having 4-5 courses and 15% completing 6-7 courses.

Teachers completed two self-assessments. The math survey was adapted from The Mathematics Content and Confidence Self-Assessment, found on the Kansas State Department of Education (KSDE) MSP website, and is aligned to the KCCRS in Mathematics. The revision focused on the clusters within the domains, rather than on each indicator. Teachers were asked to refer to the specific standards for each cluster as they completed the survey. Teacher participants completed the assessments in November 2016. There was a separate survey for teachers at each grade level. **TABLE II** displays the KCCRS mathematics clusters that were identified as areas of need. Areas of need were based on those clusters that received an average rating of 2.75 or below in either content knowledge or confidence teaching.

TABLE II: AREAS OF NEED: TEACHER SELF-ASSESSMENT MATH

Areas of Need: Domains and Clusters	Grade	Content	Teaching
Operations and Algebraic Thinking			
Understand and apply properties of operations and the relationship between addition and subtraction.	1	3.25	2.75
Generate and analyze patterns.	4	2.60	2.80
Analyze patterns and relationships.	5	3.33	2.67
The Number System			
Compute fluently with multi-digit numbers and find common factors and multiples.	6	2.67	3.33
Apply and extend previous understandings of numbers to the system of rational numbers.	6	2.67	3.00
Number and Operations—Fractions			
Build fractions from unit fractions by applying and extending previous understandings of operations on whole	4	2.60	2.60

numbers.			
Understand decimal notation for fractions, and compare decimal fractions.	4	2.40	2.60
Expressions and Equations			
Apply and extend previous understandings of arithmetic to algebraic expressions.	6	2.67	3.33
Represent and analyze quantitative relationships between dependent and independent variables.	6	2.33	1.67
Measurement and Data			
Measure lengths indirectly and by iterating length units.	1	3.00	2.50
Tell and write time.	1	3.25	2.75
Measure and estimate lengths in standard units.	2	2.75	2.75
Relate addition and subtraction to length.	2	2.75	3.25
Solve problems involving measurement and estimation of intervals of time, liquid volumes, and masses of objects.	3	2.75	3.25
Represent and interpret data.	4	2.80	2.60
Convert like measurement units within a given measurement system.	5	3.00	2.67
Represent and interpret data.	5	3.00	2.33
Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.	5	3.00	2.67
Geometry			
Graph points on the coordinate plane to solve real-world and mathematical problems.	5	2.67	2.67
Solve real-world and mathematical problems involving area, surface area, and volume.	6	2.67	3.0
Statistics and Probability			
Develop understanding of statistical variability.	6	2.67	2.67
Summarize and describe distributions.	6	2.00	2.33

Additionally, in a survey given in November 2016, teachers responded to the statement, “List any concepts/processes that are the most difficult for your students to grasp or perform.” Responses related to mathematics included the following:

- Interpreting and analyzing data, and reporting findings.
- Recording data in graphs
- Problem solving on their own
- Critical thinking skill

Treatment Procedures

The project involved 37 teachers and 6 building principals and assistant principals in the professional development activities. Teachers attended a two-week summer institute for 60+ hours of content focused professional development. Principals and teachers were involved in the book study intervention during the school year. Teachers and principals signed a commitment to participate in the MASTERS project, including support for classroom coaching sessions.

The key strategies of the project included: content-laden summer institutes in two locations; support for instructional change through a dual coaching model and video-taping of select lessons; book studies with administrator involvement; and ongoing maintenance of content and strategies through a web-based learning management system (CANVAS) for participants, continued support from IHE (Institutes of Higher Learning) faculty, and sharing products in an open educational resource website (OER).

Summer Institutes.

TABLE III displays the content and schedule of the 2017 summer. The morning schedule was from 8:30 – 12:00 M-F, a working lunch from 12:00 – 1:00 M-TH, and the afternoon schedule was from 1:00 – 4:00 M-TH, totaling 33.5 hours each week.

TABLE III: CONTENT SCHEDULE FOR YEAR ONE SUMMER INSTITUTE

	Week One	**Week Two**
8:30	**STEM Focused Content Study**	
Mon	Unpacking Elementary Science and Next Generation Science Standards – Concepts, Progressions and Practices	Integration of STEM Content in Elementary Classrooms – Study of Common Points of Contact
Tues	Unpacking Mathematics Standards and KSDE Standards Revision – Concepts, Progressions and Practices	Using Mathematical Models and Computational Thinking to Solve STEM Problems
Wed	Mathematics - Focus on Fractions and Application to STEM Problems	Formative Assessments: Analyzing Assessments for Student Misconceptions
Thurs	Elementary Engineering – Innovative Strategies to Teach Measurement	Technology Integration within Science and Mathematics
Fri	Using Mathematical and Scientific Thinking to Solve Problems	SAMR Model Integrated Within Elementary Science and Mathematics
11:00	Lesson Planning on Content of the Day *(On Half-Day Fridays - Debrief on Content of the Week and Reflections)*	
12:00	Working Lunch Sessions *Presentations by Industry Leaders / Conversations In Lesson Planning*	
1:00	**Extensions in STEM Content Pedagogy**	
Mon	Observing Students and Methods to Determine How They Demonstrate the Mathematical and Science Practices	Mathematics and Science Integration Strategies: Downfalls, Time Constraints, and Avoiding Barriers
Tues	Improving Student Inquiry of Mathematical and Science Concepts	Designing a School-wide Mathematics and Science Day for Elementary

	& Questioning Skills	Students
Wed	Teaching Students How to Use Their Math and Science Voice	Curriculum Material Analysis – STEM Stopping Points and Going Back to Needs Assessment
Thurs	Formative Assessments in Mathematics and Science - Designing Assessments to Guide Instruction	Vertical Professional Learning Communities Involvements: Enhancing intrastate collaboration efforts
2:30 M-TH	**Book Study –** *Mathematical Mindsets: Unleashing Student' Potential through Creative Math, Inspiring Messages and Innovative Teaching*	**Book Study –** *Teaching Math, Science, and Technology in Schools Today Guidelines for Engaging Both Eager and Reluctant Learners*
3:30	*Debrief of Daily Topics / Reflections*	*Debrief of Daily Topics / Reflections*

The professional development morning sessions provided teachers with critical content knowledge by examining the KCCRS in math and science and applying content to STEM integrated problems. Teachers worked through hands-on activities and developed personalized lesson plans incorporating strategies appropriate for their students. In the afternoons, teachers were provided with specific content pedagogy strategies designed to strengthen their lesson planning and classroom instruction, and engaged in book studies. For each teacher, $145 of resource materials was purchased for the summer institute.

Book Study.

The book study group read and discussed Mathematical Mindsets: Unleashing Students' Potential through Creative Math, Inspiring Messages and Innovative Teaching by Jo Boaler. The Adult Numeracy Network's Professional Development Principles state that sound professional development should begin with teachers as mathematics learners and thinkers. Following that principle, in addition to the discussion questions, a Math Task related to the reading was offered each day during the workshop. These were tasks that could certainly be shared with students, but participants were asked to approach the task as a mathematics learner and thinker in order to have their own experience with the excitement of discovering mathematical ideas. Each task was chosen to be accessible and challenging regardless of the math level that is familiar to the participant. Teachers were asked to try to let go of ideas of math that you can and can't do and just work with the activity as it is given. The book study time also included probing discussion questions and short video snippets to complement the reading.

Results

Design

To assess the effectiveness of the treatment on teachers' math content knowledge and persistence a One-Group Pretest-Posttest Design was used. The basic premise behind the pretest–posttest design involves obtaining a pretest measure of the outcome of interest prior to administering some treatment, followed by a posttest on the same measure after treatment occurs.

Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Overall**
Pre-Test	1.32	3.00	2.95	2.73	3.00	1.86	1.81	1.68	2.49	2.95	2.89	2.14	2.11	1.38	1.73	2.27
Post Test	2.08	2.95	2.95	2.95	3.00	2.51	2.51	2.11	2.86	2.97	2.92	2.92	2.46	1.86	2.46	2.65

Math Assessment Development

The Math Assessment (see Appendix A) was developed to create measures of learning to match the math instruction the teachers received during the summer workshops. Rational Numbers, Area, and Volume were the broad themes covered during instruction, with the bulk of the instruction time spent on Rational Numbers. Proportionally, the Math Assessment included 12 questions on Rational Numbers and 3 questions on Area and Volume. The same questions were used for both the pre and post assessments.

Math Assessment Results

A total of 37 participants took both the pre and post assessments. Both cohorts of the grant, Western and Southeastern, took the exact same assessments.

All items for all assessments were scored individually. Numerical values corresponding to each achievement level used for scoring purposes were: Exceeds Expectations (3 points), Meets Expectations (2 points), Falls Below Expectations (1 point), and No Credit (0 points). Finally, the data were aggregated and tabulated. **TABLE IV** shows the Average Scores by Question on the Math Assessment. The pre-assessment was given to all participants on the first day of the workshop. The average score for all participants on the pre-assessment was 2.27.

After instruction the participants took the post assessment. A marked improvement was seen on the post assessment. The average score for all participants on the post assessment improved to 2.65. Scores on 14 of the 15 questions were either improved or the same. Teachers increased their scores from the pre-test to the post-test by 17%.

TABLE IV: Average Scores by Question on Math Assessment

In addition, another significant finding emerged. **TABLE V** shows the Pre-Test Number of 0's per Question and Post-Test Number of 0's per Question.

There was a total of 23 scores of zero in the pre-assessments and only 5 scores of zero in the post assessments. Scores of zero were given only if an item had no answer, no attempt, and no work.

TABLE V: Pre-Test and Post Test Number of 0's per Question

Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**Overall**
Pre-Test	2	0	0	0	0	0	1	0	0	0	0	2	0	8	10	23
Post Test	1	0	0	0	0	0	0	0	0	0	0	0	1	3	0	5

Discussion

We know professional development is most effective when participants are immersed in the activities that they will later teach, building their confidence in addressing potential classroom implementation issues. STEM professional development activities that involve high levels of engagement improve teacher effectiveness and student performance (Darling, 2000). Further, immersion in the curriculum planning activities that support STEM integration leads to a higher level of teacher efficacy (McRel, 2002). Through delivering past STEM professional development programs, ESU faculty have seen teachers' initial hesitancy toward unfamiliar STEM-based activities turn into very strong desire to learn and do more with the experience. In addition, research shows teacher self-efficacy is augmented when teaching and professional development are done, not in isolation, but as a community of learners (Mintzes, 2013). This is best done utilizing multiple groupings and breakout sessions in which teachers are able to build these relationships (Raelin, et al, 2011). The MASTERS professional development program was designed for intense and relevant learning using all of these best practices from research.

After the MASTERS project the participants showed a marked improvement on the Math post assessment. The average score for all participants on the post assessment improved from 2.27 to 2.65. Scores on 14 of the 15 questions were either improved or the same. Teachers increased their scores from the pre-test to the post-test by 17%.

The most salient result of the present study pertained to the number of answers on the Math Assessment that were scored a zero meaning they were left blank with no attempt to answer. Noteworthy is the fact that there was a total of 23 scores of zero in the pre-assessments and only 5 scores of zero in the post assessments. This suggests that a focused professional development program for teachers in rural schools improves math content knowledge and persistence. This gain in confidence has been shown to influence goal-setting, motivation, and attitude toward STEM (Bandura, 1993), and teacher attitude has been shown to greatly affect student STEM performance, (Osborne, et. al, 2003).

Recommendations and Conclusions

Based on the findings of this research study, a well-planned program of support and professional development appears be a major factor in the marked improvement of math content knowledge and persistence of rural elementary teachers. Future research should examine academic outcomes of students of teachers that participated in the MASTERS Project.

Additional research about student learning and development in mathematics is also necessary. New insights could provide valuable information for specific pedagogical content training to be used in professional development courses.

In the final analysis, students stand to gain the most by having teachers who are prepared and supported in their teaching endeavors. To be sure, addressing the issues with teacher content knowledge and persistence in STEM fields is an arduous task involving many variables and certainly more than one solution. Collaboration with members of the education community about ways to address concerns and solutions should be an ongoing endeavor.

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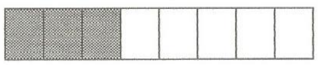
Fractions and Measurement Number______________________

As you solve the prolems leave all of your work.

1) Write 3 questions that a physical or pictorial representation of a fraction must clearly answer.

Write the fraction that represents the shaded area.

2)



3) A 5–minute egg is cooked for what fraction of an hour?

Arrange the fractions in ascending order. Or, if the fractions are equivalent, answer "Equivalent".

4) $\frac{3}{4}, \frac{5}{8}$

5) $\frac{3}{4}, \frac{6}{8}$

Tell whether the fractions are equivalent or not equivalent and how you know that.

6) $\frac{4}{7}$ and $\frac{23}{26}$

7) $\frac{4}{5}$ and $\frac{23}{24}$

Rewrite the fraction in simplest form and tell how you know that.

8) $\frac{70}{84}$

Order the numbers from least to greatest and describe your process.

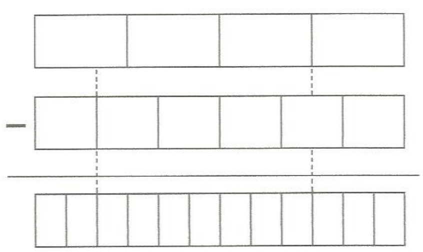
9) $\frac{3}{4}, \frac{5}{6}, \frac{2}{3}$

Write in the required form.

10) $\frac{13}{6}$; mixed number

11) $3\frac{4}{5}$; a single fraction

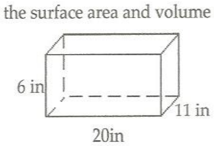
12) What subtraction fact do you think is illustrated by the fraction–strip model?



Solve the problem.

13) Mel plans to fence his small yard for his new puppy. The yard is a 20 yd by 25yd ft rectangle. Fencing costs $10 per 5 yd section. What is the cost of the fence?

14) Find the surface area and volume of the rectangular solid.



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