Evaluation of Math Masters 2004-05
Summary Report

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SCALE RET Working Paper

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Abstract

The Math Masters project offered four content related courses and three pedagogy courses to 58 middle school teachers throughout 2004-05. Pre and post-test results showed that participating teachers had statistically significant gains in all four content courses. Each course enhanced teachers' learning with effect sizes ranging from .58 to .91. Qualitative data from content and pedagogy courses also indicate that the courses met their goals and that teachers learned both important math content and related instructional strategies.

Summary Report

The Math Masters project brings together the Madison Metropolitan School District (MMSD), three other south-central Wisconsin school districts, SCALE, and the University of Wisconsin-Madison to provide a program of teacher professional development for middle school mathematics teachers. UW-Madison STEM faculty members have provided four content related courses to teachers throughout 2004-05. The four courses concentrated on key areas of standards-based mathematics: statistics and probability, algebraic relationships/number operations, geometry, and measurement. In addition to content courses, teachers participated in three pedagogy courses where they received content-specific pedagogical instruction and other forms of instructional support and modeling to help them create standards-based mathematics classrooms and effectively utilize the "Connected Mathematics Project" (CMP) curriculum. Our study of Math Masters has been a joint effort between the SCALE RET targeted studies researchers and MMSD. In this summary report, we present the findings on teachers' content knowledge gains from the four Math Masters courses, and review results of the three pedagogy courses.

Four Content Courses & Teachers' Content Knowledge Gains

The main topics for the four content courses appear in Appendix A. Teacher participation in each courses was as follows:

- Thirty-seven teachers participated in the first course on statistics and probability. Twenty-eight teachers were from MMSD.

- Twenty-five teachers participated in the second course on algebraic relationships/number operations. Eighteen teachers were from MMSD.

- Sixteen teachers participated in the third Math Masters course on geometry. Eleven teachers were from MMSD.

- Fourteen teachers participated in the fourth course on measurement. Eleven teachers were from MMSD.

Overall, 58 different teachers participated in the four courses, 46 (79.3%) from MMSD. Six teachers took all four content courses, 5 took three courses, 12 took two, and 35 took one course. About 44% had bachelor's degrees and 56% graduate degrees, with only 5 (8.6%) teachers with degrees in other fields in addition to education (math, computer science, economics, biology, and linguistics). They ranged in experience teaching math from 1 year to over 21 years, and in teaching CMP from 0 to 6 years (note teacher background information was gathered from participants in courses 2, 3, and 4 only).

Pre-tests were given to participating teachers at the first session of each course. The same test was given as the post-test at the last session. The tests were developed by Brian Sniff in conjunction with the UW STEM faculty course instructors to assess both general knowledge of related content and understanding of specific content to be covered in the course. All responses to pre and post-tests were rated twice.

Participating teachers showed statistically significant gains in all four courses. We summarize these findings for all participants below, but note here that the sub-sample of MMSD teachers also showed statistically significant gains in all four courses. Full reports on each course, including the pre/post-tests and specific results for MMSD teachers, are available at https://workspace.wcer.wisc.edu/gm/folder-1.11.7066. Results are summarized in Figure 1.

Figure 1. Pre and post-test results for Math Masters content courses

Content Course	Participants	Average Gains	% of participants with overall gains
Statistics and probability	37	4.08	86%
Algebraic relationships/ number operations	25	3.32	88%
Geometry	16	3.47	75%
Measurement	14	3.82	93%

Course 1, statistics and probability. The possible range of scores on each test was 0-24. Pre-test scores ranged from a low of 5 (3 participants) and a high of 24 (1 participant), with a mean score of 13.81 (*SD* = 4.56). Post-test scores ranged from 11 (1 participant) to 24 (2 participants), with a mean of 17.89 (*SD* = 3.60). Average gain for the whole group was 4.08. Individual participants showed gains ranging from -1 (3 participants) to 12 (1 participant). Thirty-two teachers (86%) had overall gains, with 20 (54%) having gains of 4 or more points (at or above the mean).

Course 2, algebraic relationships/number operations. The possible range of scores was 0-24. Pre-test scores ranged from a low of 5 (2 participants) and a high of 24 (1 participant), with a mean score of 15.86 (*SD* = 5.73). Post-test scores ranged from 7.5 (1 participant) to 24 (4 participants), with a mean of 19.18 (*SD* = 5.30). Average gain for the whole group was 3.32. Individual participants showed gains ranging from -3.5 (1 participant) to 11.5 (1 participant). Twenty-two teachers (88%) had overall gains, with 13 (52%) having gains of 3 or more points.

Course 3, geometry. The possible range of scores was 0-21. Pre-test scores ranged from a low of 4.5 (1 participant) and a high of 21 (1 participant), with a mean score of 11.53 (*SD* = 4.709). Post-test scores ranged from 6 (1 participant) to 21 (1 participant), with a mean of 15.00 (*SD* = 4.933). Average gain for the whole group was 3.47. Individual participants had gains ranging from -2.0 (1 participant) to 9.5 (1 participant). Twelve teachers (75%) had overall gains, with 8 (50%) having gains of 3.5 or more points.

Course 4, measurement. The possible range of scores was 0-22. Pre-test scores ranged from a low of 2.0 (1 participant) and a high of 15.0 (1 participant), with a mean score of 10.36 (*SD* = 4.495). Post-test scores ranged from 1.5 (1 participant) to 19.0 (2 participants), with a mean of 14.18 (*SD* = 5.224). Average gain for the whole group was 3.82. Individual participants showed gains ranging from -2.5 (1 participant) to 9.0 (1 participant). Thirteen teachers (93%) had overall gains, with 9 (64%) having gains of 4.0 or more points.

For the first three courses, participants with lower pre-test scores tended to show more gain than those with higher pre-test scores. For example, in the algebraic relationships/number operations course, average gain for those with pre-test scores below the mean (12 teachers) was 4.63, for those above the mean (13 teachers), 2.00. However, for course 4, participants with lower pre-test scores did not show more gain than those with higher pre-test scores. The average gain for those with pre-test scores below the mean (5 teachers) was 3.5, for those above the mean (9 teachers), 4.0.

For all three courses that we had teacher background data (course 2, 3, and 4), teachers with bachelor's degree and teachers with graduate degrees showed no differences in gains in content knowledge. Similarly, years of experience teaching math and teaching *Connected Mathematics* were not associated with differences in gains.

Using the pre and post test data, we also calculated effect sizes of each course, which are presented in Figure 2. These findings show that each course had a positive effect on teachers' learning. Effect sizes range from .58 to .91 which can be considered medium to large effects.

Figure 2. Effect sizes of Math Masters content courses

Course	Effect size*
Statistics and probability	0.914705
Algebraic relationships/ number operations	0.581185
Geometry	0.685403
Measurement	0.732555
*using composite standard deviations	

Although results were not compared to a control group of teachers, or to another intervention, the overall findings on average gains and effect size support the conclusion that teachers benefited directly in increased content knowledge from each of the four Math Masters courses. Teachers' individual reflections, written at the end of each course, offered supporting qualitative evidence that teachers found the courses to be valuable, that they increased their content knowledge, and that the courses were successful (these reflections are summarized in the reports for each course).

Three Pedagogy Courses

Follow-up professional development on pedagogy was provided after three of the content courses. Each course addressed one of these three Principles of Learning (see https://workspace.wcer.wisc.edu/PRINCIPLES_OF_LEARNING/ri/ri_index.html): Accountable Talk, Organizing for Effort, and Self-Management of Learning. Ten teachers participated in Accountable Talk, seven in Organizing for Effort, and four in Self-Management of Learning. Eleven different teachers participated in the three courses, with three taking all three courses, four taking two, and four taking one.

The pedagogy courses comprised 20 hours of work that included participating in facilitated online discussions with their classmates and the district math Instructional Resource Teacher; visiting another teacher's classroom to observe their colleague's use of the content and content-specific pedagogy; viewing videotaped lessons and discussing them online with their classmates as part of "lesson studies;" creating and sharing lesson plans, differentiation plans, and evaluation plans; conducting in-class evaluations; and working with the Instructional Resource Teacher in their own classroom via coaching and modeling.

Data on the pedagogy courses included a self-assessment inventory of instructional practice, participants' written reflections on what worked well and what could be improved, and a focus group interview with four teachers who participated in multiple content and pedagogy courses. We summarize below what we learned from these data. Resources did not allow for more

systematic investigation of the influence of the pedagogy courses, but the findings are suggestive.

The self-assessment inventory (Appendix B) was used by participating teachers to reflect on changes in their classrooms practice. They completed the inventory at the beginning and end of each course. Overall, 68% of teachers believed they enhanced their instruction as reflected across the 11 characteristics. Increases ranged from 5 points (about a .5 increase on all 11 characteristics) to almost 30 points. Teachers in Accountable Talk reported the most increase, averaging just over a 13 point gain. Organizing for Effort showed a 5.5 point average gain, and Self-Management of Learning a -.55 average gain. We were unable to question teachers about their specific responses to the self-assessment inventory, but we speculate that some of the decreases in ratings were due to teachers' being more critical of their practice. This critical stance was likely supported by their enhanced understandings of the relevant Principle of Learning and by the spirit and practice of reflective dialogue that was encouraged in the online and face-to-face discussion of the courses.

Participants' written reflections at the end of each course asked them to comment on what worked well and what could be improved for the course. Across all three courses, teachers' responses were overwhelmingly positive. They emphasized the importance of the dialogue focused on classroom observations conducted by the math Instructional Resource Teacher and on the videotapes of lessons. One teacher put it this way, "The follow-up that we did after every observations was very effective—going through the transcript of the class and identifying the teacher moves that I made and then figuring out what category of *accountable talk* moves they fit into." A teacher in Accountable Talk also commented on reviewing a colleague's videotaped lesson, "Watching the videos, especially (A's) was effective. I enjoyed watching her teach. I always wonder how I'm doing and if I' m doing it 'right.' I know that she is an experienced teacher and so I felt that I gained some new insights by observing her. As well, looking for moves that she did and commenting on them helped me clarify just what these moves are--not reading about them, but how do they look, how do they sound, what effect do they have on the teaching."

Teachers made reference to the "learning community" or "collaborative community of teachers" they felt emerged in the courses. They noted favorably the emphasis on constructive feedback on teaching and on being reflective, as one teacher in Organizing for Effort put it, "Making me more aware of what I'm doing and not doing." Teachers' self-critical stance was evident in one participant's end-of-course reflections from Accountable Talk. They stated, "If I would have been able to participate in online discussions, I could have benefited more. I became overly self-conscious. I was worried about saying too much, too wordy, coming across bossy or 'know-it-all' attitude. I was worried that my horrible spelling would show how stupid I am. I was not trusting enough to have other teachers that I know and admire see the real me. Also I couldn't admit that I could not figure out the technology."

Some participants liked the readings that were assigned and the online discussions of them, while others, like the teacher quoted above, noted some difficulties and challenges of the online discussion format. For example, "Discussions about the readings were more disconnected. Part

of that is the online nature of the course. Since people were reading and responding at different times it was hard to have a fluid conversation. When quotes were referenced etc., it was harder to follow if it had been a few weeks since I'd read the article." Some participants in the Self-Management of Learning course struggled with the timing of the course (toward the end of the school year) and wanted more face-to-face discussion sessions. Also of note, however, was how one teacher saw what she was learning in a math pedagogy course transfer to her teaching in science. "I have found the work that I have been doing in this class carrying over into my science classes--the *accountable talk* and improving class discussions and small group work. As well, the unit that we are doing right now, Foss Forces and Motion, has lots of math in it that is actually very challenging. It has been fun watching students grapple with math in a science setting where the math is truly in context."

Focus Group on Content and Pedagogy Courses

Finally, we conducted a focus group interview with four MMSD teachers who participated in multiple content and pedagogy courses. Two had taken all four content courses and all three pedagogy courses. The four teachers taught at four different middle schools with two of them teaching sixth grade and two teaching seventh grade (see Appendix C for the focus group interview protocol).

The focus group participants concurred that the courses were extremely valuable. Regarding the content courses, they noted that while the four different instructors varied in teaching styles and approaches, all four established at positive learning environment in which participants were comfortable interacting with their colleagues. Across all four content courses, activities were well-thought out, engaging, and hands-on and open-ended. The focus group participants continually referred to "having to grapple" with the content. As one noted, "All the professors, I think, made me feel comfortable in asking questions and not doing what we do to our students, not giving us the answers, but guiding us in some way or another."

Another teacher's comments about the instructional activities of the content courses suggested she was seeing some new light about the way math is or should be taught. She said, "Instructors used a lot of open-ended questions and left us wondering and didn't always jump right in and give us the answer. (For example) I remember, does it matter what side you call the base on a three-dimensional figure? So we all played with that for a while. And it seemed to me it took a couple days before we got the answer. That was kind of frustrating for me, but we got the answer." This kind of pedagogy brought a mixed response. She continued, "It was like, ok, so why can't you tell me? Isn't this just a simple question? I guess it wasn't because they wanted us to grapple with it. And then there was a lot of grappling going on which frustrated me a lot because I'm used to getting things pretty quickly and I didn't like the uncertainty of it all. I felt very uncomfortable." She then tied this experience in to her own teaching. "The good thing was there was time to grapple and there was time to stop and think about it. And I think that the thinking was good. And it was good in another way in that I think I learned how frustrating it can be for kids and them not understanding and then leading them to answers as opposed to just telling the answers. And I think that I learned that that's a better way to do it because I think that

there's more learning going on in the frustrated person's mind than in the non-frustrated person's mind."

Focus group participants agreed they increased their math content knowledge, citing specific terms in the measurement course, or understanding the Pythagorean Theorem in the geometry course and polynomials in the algebraic relationships course (as opposed to simply applying a formula or procedure to solve). One teacher criticized the Statistics and Probability course for covering content that she could have learned herself from the CMP materials. Another teacher who took all four courses and who had taken a number of math courses in college was skeptical that she would learn much, but she felt she did indeed, and "that's what was reassuring to me and kept making me come back. I was learning something and learning a lot of *why* things were the way they were, which I didn't learn in school because it wasn't taught. We just did it (the math)." The courses seemed to prompt critical reflection, for these four teachers at least, about curriculum issues (such as breadth and depth of content coverage) and instructional strategies.

They were similarly positive about the three pedagogy courses. Each of them gave examples of using strategies for Accountable Talk, Organizing for Effort, and Self-Management of Learning in their classrooms, although it was noted that the Self-Management of Learning course came too late in the year to allow for careful or extensive implementation. One teacher explained why she felt Accountable Talk was the best course of the three, "I think because you're promoting conversation in your teaching all day long and that is the most specific thing that you're doing and you're just using it throughout the day…I mean some of the other courses were more abstract to me and this one was very concrete and you could use it instantly." As with the written reflections following each course, there were very positive responses from the focus group participants to the classroom observations and lesson video components but mixed responses to the online discussion groups. These teachers also cited time with students and the press for curriculum coverage as hurdles to further implementation to what they had learned in the Math Masters courses.

Conclusion

In summary, both quantitative and qualitative results suggest that the courses met their goals and that teachers learned both important math content and related instructional strategies. The evaluation suggests a number of important implications both for future Math Masters courses and mathematics professional development in general and for district policy:

For Math Masters and math professional development:

- Embed pedagogy into the mathematics content class by expanding the course hours.
    - To improve participation in the pedagogy learning and discussions.
    - To enhance modeling specific Principles of Learning in the class.
- Continue to provide middle school teachers with opportunities to learn mathematics content in a context that models the pedagogy they need to use.

- Continue to attend to the importance of building a professional learning community among participating teachers.

For District Policy:

- The district should consider staff's mathematics knowledge as well as certification when assigning mathematics teaching responsibilities.

- The district should consider requiring technology proficiency for all staff.

Recent research on professional development has identified a number of criteria for effective learning opportunities for teachers. Among these are: professional development enhances teachers' knowledge of, skills for, and dispositions about both content and pedagogy; the content and pedagogy of professional development experiences relate directly to teachers' classroom contexts; and professional learning experiences involve teachers in collaborative work with colleagues through inquiry and reflective dialogue. Our evaluation shows that the Math Masters courses of 2004-05 were very successful in meeting these criteria.

APPENDIX A: Four content courses of Math Masters, 2004-05

Course 1: Statistics and Probability	August 2004 Instructor: David Griffeath, Professor & Chair, Dept. of Mathematics
Topics to be covered: ❖ Formulating questions, displaying results ❖ Selecting, using, interpreting statistical methods for analyzing data ❖ Making conjectures and predictions, developing and evaluating inferences based on data ❖ Understanding and applying basic concepts of probability ❖ How students learn statistics and probability content ❖ Teaching statistics and probability for student understanding ❖ Teaching statistics and probability within the CMP curriculum	
Course 2: Algebraic Relationships/Number Operations	**October/November 2004** **Instructor: Terry Millar, Professor, Dept. of Mathematics; Associate Dean of the Graduate School (Physical Sciences)**
Topics to be covered: ❖ Understanding patterns, relations, functions ❖ Representing and analyzing math using algebraic symbols ❖ Using mathematical models to understand quantitative relationships ❖ Solving linear equations ❖ Using verbal descriptions, geometric models, and mathematical notation ❖ Understanding meaning and relationships of operations ❖ Computing fluently and making reasonable estimates ❖ How students learn algebraic/number operations content ❖ Teaching algebraic/number operations for student understanding ❖ Teaching algebraic/number operations within the CMP curriculum	
Course 3: Geometry	**February/March 2005** **Instructor: Robert Wilson, Professor, Dept. of Mathematics**
Topics to be covered: ❖ Analyzing characteristics of 2- and 3-D geometric shapes ❖ Specifying locations, describing spatial relationships linking coordinate geometry with algebraic representations, including slope ❖ Applying transformations and using symmetry to analyze mathematical situations ❖ Applying visualization, spatial reasoning, and geometric modeling ❖ How students learn geometry content ❖ Teaching geometry for student understanding ❖ Teaching geometry within the CMP curriculum	
Course 4: Measurement	**April 2005** **Instructor: Nicola Ferrier, Assistant Professor, Dept. of Mechanical Engineering**
Topics to be covered: ❖ Understanding measurable attributes and units, systems and processes of measurement ❖ Applying appropriate techniques, tools and formulae to direct measurements ❖ Applying appropriate techniques, tools and strategies to indirect measurements ❖ How students learn measurement content ❖ Teaching measurement for student understanding ❖ Teaching measurement within the CMP curriculum	

APPENDIX B: Teacher self-assessment inventory for the three pedagogy courses

Characteristics of a Standards-Based Mathematics Classroom

1. Students are **doing** mathematics, not simply watching the teacher "do" mathematics.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

2. There is a classroom climate of intellectual inquiry and respectful pursuit of mathematical knowledge.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

3. Students are making and checking hypotheses/conjectures.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

4. Students are searching for and finding patterns, identifying relationships and applying them to real and hypothetical situations.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

5. Students have daily access to calculators, and/or graphing calculators, and are learning when calculator us is appropriate.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

6. Appropriate support is given to students as they struggle with challenging problems.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

7. When listening to other classmates or the teacher, students are actively listening and mentally engaged.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

8. Student thinking is valued; students share their ideas with other students during the lesson.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

9. Students, as well as the teacher, ask questions of other students that require mathematical thinking to respond.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

10. Students are pushed by other students, as well as the teacher, to make their thinking explicit, and, where appropriate, to think deeper.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

11. Each student is experiencing a variety of learning opportunities designed to engage his or her participation.

Is not evident Is evident Is highly evident
1_____2_____3_____4_____5_____6_____7_____8_____9_____10

Adapted from The Principles of Educational Reform*: Supporting Mathematics and Science Teachers in Your School*. Inverness Research Associates: www.inverness-research.org

APPENDIX C: Focus group interview protocol

Math Masters Participant Interview ***8-29-05***

Focus Group Questions:

1. Participant(s) info. Include name, position, school, district. Which content courses and which pedagogy course did you take?

2. First, we are interested in your perspective on the overall learning environment of the course(s). To what extent were you comfortable engaging in activities, asking questions, taking risks, critiquing or challenging ideas, requesting help for your learning? How well did course facilitators lead activities and create a positive learning environment?

3. How have the courses helped you improve your level of understanding of *specific mathematical content*? Please explain.

4. How have the courses helped you improve *specific instructional approaches in math*? Please explain.

5. Because of your participation in the Math Masters, what changes have you made or are you likely to make to *what you teach and how you teach (and assess)* in your math classes?

6. What challenges or hurdles to implementing what you learned in Math Masters have you encountered or do you anticipate?

7. How well was the focus of the course(s) aligned with what your school, the district, or the state requires or promotes for math?

8. For the coming school year, what further professional development or other forms of support would help you to implement what you learned in Math Masters?

Thanks for your assistance!