VIRGINIA'S MATHEMATICS SPECIALIST INSTITUTE PROJECT: A SUMMARY OF EVALUATION FINDINGS

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Introduction

Horizon Research, Inc. (HRI) serves as the external evaluator for the NSF Institute's "Preparing Virginia's Mathematics Specialists" project, described in a previous article. Participants in this project do coursework at each of three Summer Institutes. These five-week residential experiences have been held on the campuses of Norfolk State, Virginia Commonwealth University, and George Mason University. During each Institute, participants complete two of the five required mathematics courses and the first half of an Educational Leadership course. Participants complete the second half of each Leadership course by February of the following year. At the third Institute, participants complete the final mathematics course, as well as a course entitled, *Mathematics for Diverse Populations*. These nine courses—six mathematics and three leadership courses—are the major components of the Mathematics Specialist preparation program.

In our capacity as external evaluator, we have observed several days of each Summer Institute. In addition, we have surveyed Institute participants and interviewed them on several occasions. Data from these activities point to specific impacts resulting from the Institutes. In this article, we discuss three kinds of outcomes:

1) Impacts on Mathematics Content Knowledge;
2) Impacts on Participants' Perception of their Pedagogical Content Knowledge; and,
3) Impacts on Participants' Perceptions of their Leadership Skills.

We devote one section of the article to each impact, ending with a discussion of participants' thoughts about the residential aspect of the Institute.

Impacts on Participants' Mathematics Content Knowledge

Each summer, HRI conducts several different evaluation activities to assess the impact of Institute courses on participants' mathematics content knowledge. Data from pre- and post-course content assessments, a post-Institute questionnaire, on-site observations, and post-Institute interviews indicate that the courses have affected the participants' mathematics content knowledge substantially.

Over three Summer Institutes, participants complete five mathematics courses. During the first Institute, participants take the *Numbers and Operations* and *Geometry and Measurement* courses. *Rational Numbers and Proportional Reasoning* and *Probability and Statistics* are offered at the second Institute, and participants complete *Algebra and Functions* at the third Institute.

The evaluation primarily uses project-developed assessments to gauge impacts on content knowledge. While some rigorous, externally developed content assessments for teachers exist, only a geometry instrument was aligned well enough with the Institute courses to be considered a fair measure. This assessment was developed by the Learning Mathematics for Teaching project at the University of Michigan, as described by Hill, Schilling, and Ball [1]. Horizon Research scored the *Geometry and Measurement* assessment with a key provided by the instrument developers. In addition, Horizon Research developed scoring guides for all the project-developed assessments. Two staff members, trained to 90% inter-rater agreement, scored the papers.

The data in Table 1 show the pre- and post-course means of participant content knowledge across all five courses. The increase in mean scores is significant, and all the courses appear to have had a large positive effect on participants' mathematics content knowledge. Each effect size is based on a different measure. Therefore, it is inappropriate to make comparisons among courses. For instance, these data cannot be used to argue that one course is more effective than another. This caveat applies to each data table in this article; i.e., effect sizes should not be used to compare courses.

Table 1
Mean Scores for Content Assessments Administered in Institute Courses

Courses (in the order participants completed them)	N	Pre-Course		Post-Course		Effect Size
		Mean	S.D.	Mean	S.D.	
Numbers and Operations	27	71.08	13.69	85.01*	10.03	0.83
Geometry and Measurement	27	55.25	21.58	73.77*	16.29	1.11
Rational Numbers and Proportional Reasoning	26	76.20	14.66	96.03*	6.10	1.44
Probability and Statistics	26	68.73	15.99	88.13*	9.65	1.44
Algebra and Functions	26	46.26	22.64	75.91*	23.66	0.90

*Post-Institute score is significantly different from pre-Institute score (two-tailed paired samples *t*-test, $p < 0.05$.

In addition to the content knowledge assessments, items on the post-Institute questionnaire asked participants to report their perceived preparedness in content knowledge before and following each course. A "retrospective baseline" (asking about prior preparedness *after* the Institute) was gathered because participants often do not recognize gaps in their understanding before taking a course. It is only after they engage with the content that they realize how much they initially did and did not know.

Items on the post-Institute questionnaire addressed specific content presented in each course. Horizon Research combined these items to create course-specific content knowledge composites. For example, on the *Numbers and Operations* questionnaire, participants rated their content preparedness on the following items:

- Mathematics of counting and the natural numbers;
- Place value system; and,
- Structures and concepts underlying the arithmetical operations.

For *Geometry and Measurement*, the following items were included:

- Understanding basic shapes, their properties, and the relationships between them;
- Measuring and understanding of angles; and,
- Solving problems involving right triangles and the Pythagorean Theorem.

Table 2 shows the composite mean scores for impacts on participant perceptions of their content preparedness. To capture the most recent versions of the course, it should be noted that the data for *Numbers and Operations* and *Geometry and Measurement* are from Cohort II participants.

Data for the remaining three courses are from Cohort I, the only group to have completed those courses at the time data were collected for this article. Large effect sizes are evident in all five courses, indicating that participants thought that their content knowledge increased substantially in each course.

Table 2
Composite Mean Scores for Impacts on Participant Perceptions of Their Content Preparedness

Courses (in order participants completed them)	N	Pre-Course		Post-Course		Effect Size
		Mean	S.D.	Mean	S.D.	
Numbers and Operations	27	53.27	21.68	78.58*	15.22	1.52
Geometry and Measurement	27	37.48	19.33	69.07*	18.39	1.90
Rational Numbers and Proportional Reasoning	24	31.79	25.35	74.62*	16.81	1.92
Probability and Statistics	26	38.68	21.81	69.17*	12.71	1.91
Algebra and Functions	26	41.52	24.74	83.04*	16.89	1.94

*Post-Institute score is significantly different from pre-Institute score (two-tailed paired samples *t*-test, $p < 0.05$).

When asked on the post-Institute questionnaire what they gained from the courses, participants often commented on content knowledge impacts. For instance, in *Rational Numbers and Proportional Reasoning*, twenty-one of the twenty-six responses pointed to impacts on understanding of rational numbers and participants' ability to solve problems in multiple ways. Some of those comments are included here:

- "I gained more knowledge about how the basic aspects of rational numbers may be seen through illustrations as compared to how I was taught with formulas and/or computation."
- "I feel I have a better understanding of rational numbers and have gained more background knowledge of the content. In *Proportional Reasoning*, I would have solved most situations with a proportion—and solved for the missing value. Now, I can find other ways to do it. It's a much clearer understanding."
- "I gained a flexible way to look at percents and at fractions. I feel more comfortable using fractions in a variety of ways now."

Impacts were similarly evident in responses to both closed- and open-ended questions about the *Algebra and Functions* course. An item on the post-Institute questionnaire asked

participants to rate the extent to which they had increased their knowledge of the course content. Two-thirds of participants gave a rating of 6 or 7 on a 7-point scale with 1 being "Not at all" to 7 being "To a great extent." Similarly, in response to a question about effective aspects of the course, eighteen of the twenty-six responses described having a better understanding of algebra concepts. The following comments are two examples:

- "From this experience, I was able to relearn algebraic concepts with a contextual and conceptual understanding instead of only procedural understanding."
- "I developed my own understanding of algebra by seeing and identifying patterns in ways I had not understood before. I developed various representations for algebra as well."

The content courses are the central part of the Virginia Mathematics Specialist program. Offering these courses in an institute setting provides for a focused and intensive experience with mathematics content, and the data point to substantial positive impacts on participants' knowledge of content.

Impacts on Participants' Perceptions of Their Pedagogical Content Knowledge

The post-Institute questionnaire also asked participants about impacts on their pedagogical content knowledge. Shulman originally described pedagogical content knowledge as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" [2]. Participants rated their preparedness to *teach* the mathematics content presented in each course, before and after taking the course. Participants responded to items targeted at pedagogical practices specific to each content course. For example, on the *Rational Numbers and Proportional Reasoning* questionnaire, participants rated their preparedness before and after taking the course on the following items:

- Use examples to show and illustrate the relationship between rates and ratios;
- Show how ratios can be used to represent a variety of relationships within a set and between two sets; and,
- Model and illustrate situations or problems where proportions are used to show patterns of change.

For *Probability and Statistics*, preparedness items included the following:

- Help students recognize the differences in representing categorical and numerical data;
- Have students formulate and solve problems that involve collecting, organizing, and analyzing data; and,
- Provide examples to help students explore concepts of fairness, uncertainty, and change.

At the third Institute, participants completed the *Mathematics for Diverse Populations* course, designed to develop participants' ability to recognize and respond to the needs of learners with a variety of backgrounds and abilities. Items on the post-course questionnaire assessing the increases in preparedness in this area include the following examples:

- Recognize and respond to students' cultural diversity;
- Recognize and respond to students' diverse learning needs; and,
- Encourage the participation of minorities in mathematics.

The items were combined to create "preparedness to teach" composites for each course. The data in Table 3 show pre- and post-Institute composite mean scores for each course. The effect sizes are large across all six courses, suggesting large impacts.

Table 3
Composite Mean Scores for Impacts on Participants' Perceived Preparedness to Teach Mathematics

Courses (in order participants completed them)	N	Pre-Course		Post-Course		Effect Size
		Mean	S.D.	Mean	S.D.	
Numbers and Operations	27	55.31	20.36	88.64*	13.01	1.82
Geometry and Measurement	27	47.22	19.33	59.40*	18.11	0.96
Rational Numbers and Proportional Reasoning	24	54.21	21.97	73.26*	19.33	1.67
Probability and Statistics	26	46.89	23.78	73.08*	20.20	1.47
Algebra and Functions	26	41.96	20.60	78.90*	17.58	1.89
Mathematics for Diverse Populations	26	66.15	18.66	81.54*	13.51	1.67

*Post-Institute score is significantly different from pre-Institute score (two-tailed paired samples *t*-test, $p < 0.05$).

In responses to open-ended items on the post-Institute questionnaire, participants described both impacts on their ability to teach mathematics content and expected changes in their classroom practice. After completing the *Numbers and Operations* course, nineteen of the twenty-six participants mentioned their intent to provide extra time for students to explore their own ideas and develop algorithms rather than simply providing algorithms and asking students to apply them. Two participants commented:

- "I foresee myself giving my students more time to develop algorithms on their own. I also foresee allowing my students to share their way more and giving them time to explore and develop their own efficiency."
- "I really want to focus more on developing number strategies with my students instead of the one old traditional method. This course helped me to understand how students can invent strategies. This was a huge breakthrough for me!"

In addition, ten of the participants mentioned their plan to incorporate the use of manipulatives in classroom instruction around number concepts more frequently. One offered this comment:

> I will use many manipulatives. I am leaving this course with multiple strategies to offer my students instead of one method. I will provide more open-ended problem solving, rather than fact worksheets. I also want to provide more opportunities for students to use many different strategies and manipulatives to solve a problem.

Similar comments were made by interviewees:

- "Honestly, that class changed the way I do my job. I have so much more knowledge about the way students learn math."
- "In that class, we always had manipulatives available to use. We worked in groups, sometimes in pairs, and we always took time to talk as a whole class about what we were learning. This is what I want my classroom to be like."

Many of the participants indicated that the importance of "hands-on" activities and manipulatives was reinforced for them by taking the *Geometry and Measurement* course. Participants also noted the Van Hiele levels of geometric understanding were useful. One participant had this to say:

> [The Van Hiele levels] helped me to understand why some kids get it and some don't. As a teacher, I knew some didn't seem to understand some geometry ideas, but I was never aware why, and these Van Hiele levels helped to explain why.

When making open-ended comments on the questionnaire, participants pointed to several examples of expected impacts on their teaching of geometry and measurement concepts:

- "I will give more time for my students to explore and work with shapes, not just waiting for the two weeks allotted in the spring for geometry."
- "I plan to pay closer attention to how I design assessments. I want to spend more time discussing work, with less focus on covering material. This will help students with building connections and making meaning."

Similar impacts were evident among participants in the course, *Mathematics for Diverse Populations*. Thirteen of the twenty-four respondents to the post-course questionnaire focused on planning lessons to meet the needs of individual students. The following are two sample comments:

- "I will be better prepared to make necessary modifications based on student needs. I will also be better equipped when planning lessons."
- "I am going to be more aware of the learning preferences of my students as I plan classroom activities. I'd like to be more reflective in my practice to see if I'm addressing the needs of all learners."

These comments, as well as the large composite score effect sizes across the six courses, suggest large impacts on the participants' perceptions of their preparedness to teach mathematics. Such growth, coupled with their deepened content knowledge, will be a valuable asset as the participants assume leadership roles in their schools.

Impacts on Participants' Perceptions of Their Leadership Skills

Strong mathematics content knowledge and pedagogical content knowledge are important aspects of the project's vision for what makes an effective Mathematics Specialist. A third part of the vision is leadership skills that enable Specialists to work collaboratively with teachers. During each Summer Institute, participants take the first half of a leadership course. The balance of the course is completed in the fall as participants meet once a month for full-day sessions. Each of the three leadership courses focuses on different aspects of the knowledge and skills Specialists need. *Leadership I* provides participants with opportunities to develop their familiarity with the K–5 *Standards of Learning for Virginia Public Schools*, as well as the NCTM *Principles and Standards for School Mathematics* [3, 4]. *Leadership II* focuses on developing participants' coaching skills. *Leadership III* continues a focus on coaching skills, includes work on formative assessment and the facilitation of Lesson Study.

At the end of each course, HRI administered a questionnaire to all participants and interviewed a sample of participants for more in-depth information about their experience. As with the other questionnaires, individual items were combined into composite variables reflecting the central themes of each course. For *Leadership I*, course participants indicated their familiarity (both before and at the end of the course) with the Virginia *Standards of Learning* (*SOL*) and the NCTM *Principles and Standards for School Mathematics* [3, 4]. For *Leadership II*, examples of items used to form a coaching composite included asking participants to rate their familiarity with the following:

- Coaching as a model for teacher professional development;
- The skills required to be an effective coach for mathematics professional development; and,
- The challenges of coaching experienced teachers.

For *Leadership III*, three composites were formed focusing on participants' familiarity with the following items:

- Formative Assessment
- Strategies for Coaching
- Lesson Study

Table 4 shows the pre- and post-course means for the composites in each of the three leadership courses. The data suggest that *Leadership I* participants' familiarity with standards documents increased substantially. Participants also showed large increases in their familiarity with coaching as a result of *Leadership II*; effect sizes associated with *Leadership III* are similarly large.

Table 4
Composite Mean Scores for Participants' Familiarity with Leadership Course Topics

Courses (in order they were offered)	N	Pre-Course		Post-Course		Effect Size
		Mean	S.D.	Mean	S.D.	
***Leadership I* Composites**						
Virginia's *Standards of Learning*	27	46.30	24.28	67.49*	26.14	1.55
NCTM *Standards for School Mathematics*	26	20.51	22.81	68.80*	25.73	2.40
NCTM *Principles for School Mathematics*	26	13.08	23.13	73.85*	25.15	2.31
***Leadership II* Composites**						
Peer Coaching	27	49.58	24.67	88.18*	13.47	1.86
***Leadership III* Composites**						
Formative Assessment	25	55.67	25.43	91.33*	14.53	1.63
Strategies for Coaching	25	53.56	19.70	91.11*	12.21	1.88
Lesson Study	23	18.36	28.55	95.17*	10.50	2.52

*Post-Institute score is significantly different than pre-Institute score (two-tailed paired samples t-test, $p < 0.05$).

Data from open-ended questionnaire items about effective aspects of the courses provide evidence of the participants' positive views. For instance, one *Leadership I* participant wrote:

> The course was helpful in understanding the NCTM *Standards* for each area—*Numbers and Operations*, *Geometry and Measurement*. I also think looking at the *Standards* and correlating them with activities and the tasks we give to students [was helpful]. As a Math Specialist, the coursework prepared me by giving me knowledge and skills to manage the standards and consider ways to effectively apply them in the classroom.

Participants highlighted coaching-related aspects of *Leadership II*. Of the twenty-seven participants responding to an open-ended item about effective aspects of the course, twenty-one commented on the coaching part. Participants were enthusiastic about the project, in which they videotaped themselves coaching another teacher in their school. Two examples of open-ended responses around coaching and the usefulness of the coaching project were:

- "The videotaping experience was extremely meaningful in reflecting on my own videotape and through watching the videos of my cohort members."

- "I found the readings very helpful, as well as the class discussions. The process of the videotape assignment also furthered my understanding."

There were large increases in participants' ratings of their familiarity with Lesson Study, and positive comments about Lesson Study featured prominently in open-ended questionnaire responses (eleven out of twenty-five responses). Some examples included the following:

- "The focus on Lesson Study taught me how to successfully plan with teachers to develop meaningful lessons."
- "The opportunity to participate in a Lesson Study group was hugely rewarding."

Data from the post-course questionnaires, and interviews, show the extent to which participants' perceptions of their leadership skills have grown. With a deepened understanding of mathematics and strong pedagogical content knowledge, these leadership skills position the Specialists to work successfully with teachers.

The Residential Aspect

The Summer Institutes are unique learning experiences that impact participants in substantial and meaningful ways. The Institute's residential setting likely heightens the learning experience beyond other professional development settings, such as workday, evening, or on-line classes, which fit more conveniently into the schedule of practicing teachers. Participants' comments show the value placed on living and working together. Included among them are the following examples:

- "I guess I'd say again everyone being together on campus gave us lots of opportunities to work together on the projects and share ideas and help out one another."
- "The most helpful aspect was being able to talk, share, and ask questions in the evenings in the dorms. If I left class confused and frustrated, I was able to get help in the evenings from classmates."
- "I think it was a great opportunity. I never imagined that I would grow so much in twenty days. The dinner panels and excursions made it a great experience. They provided a needed break and gave us the opportunity to leave the academics and build more relationships with one another."
- "I think it was very good, very professional and respectful. I am very pleased. You work really hard, but you are learning a lot. The dinner panels and excursions were very

helpful. We learned more about the program and what was going on with Math Specialists."

Obviously, the teachers who come to the Institutes are those whose schedules can accommodate a five-week residential experience. Still, all made sacrifices to attend, and they seem to feel that they received much more in return.

Summary

In the most general terms, the project's theory of action is to work on three fronts simultaneously—developing participants' mathematics knowledge, pedagogical content knowledge, and leadership skills—in a residential institute setting. The evaluation has produced a large body of evidence strongly suggesting that this model impacts the participants positively and substantially. Whether the outcome is content knowledge, pedagogical content knowledge, or leadership skills, participants report large positive changes. With regard to knowledge of mathematics, end-of-course content assessments provide more objective and similarly compelling evidence of impact. Comments from teachers suggest the residential aspect led to deeper impacts than they might have experienced in more traditional professional development settings.

At the end of July 2008, the project had completed its fifth Institute, each one an immense investment of time for the project and the participants. Impact data indicate that the return is well worth the investment.

References

[1] H.C. Hill, S.G. Schilling, and D.L. Ball, "Developing Measures of Teachers' Mathematics Knowledge for Teaching," *The Elementary School Journal*, **105**(1) (2004) 11-30.

[2] L.S. Shulman, "Knowledge and Teaching: Foundations of the New Reform," *Harvard Educational Review*, **57**(1) (1987) 1–22.

[3] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[4] *Principles and Standards for School Mathematics,* National Council of Teachers of Mathematics, Reston, VA, 2000.