Vermont Mathematics Initiative

Program Evaluation

May, 2005

Prepared by
H. (Bud) Meyers
The University of Vermont

And

Douglas Harris
The Evaluation Center
The Vermont Institutes, Montpelier, VT

Dedication

This report is dedicated to the memory of Dr. Marc E. Hull, the Vermont Commissioner of Education at the founding of the Vermont Mathematics Initiative (VMI). The VMI owes its existence to his dedication to the children of Vermont.

Acknowledgement

This evaluation was made possible through the generous support of the grant *Improving Teacher Content Knowledge in Mathematics* funded by the U.S. Department of Education. Special thanks are extended to the Principal Investigators Dr. Douglas Carnine and Dr. James Milgram for their ongoing support of this work and mathematics education in general.

Vermont Mathematics Initiative Program Evaluation

Table of Contents

A detailed description of the VMI program titled *Overview of the VMI*, requested by the Validation Panel (see page 11), is available as a supplement to this Evaluation Report.

Vermont Mathematics Initiative Program Evaluation

Executive Summary

Brief Summary of the Program

The Vermont Mathematics Initiative (VMI) is a comprehensive, statewide, three-year, master's degree granting mathematics professional development program for elementary teachers at the heart of which is mathematics content knowledge. Begun in 1999, the VMI is designed to train a cadre of mathematics teacher leaders across the elementary schools of Vermont. To date the VMI has trained 184 teachers (136 graduates, 48 currently enrolled) representing over 40% of the elementary schools and 85% of all school districts in Vermont. The target over the lifetime of the program is to place at least one mathematics teacher leader in every Vermont school district and in at least 75% of the elementary schools.

VMI is guided by four goals. Through coursework, classroom applications, mentoring by VMI staff, and leadership training, teachers in the VMI:

- Build a strong and deep knowledge and understanding of mathematics content
- Demonstrate effective mathematics instruction
- Conduct action research that informs instructional decisions at the classroom level and beyond
- Provide leadership that supports school-wide improvement of mathematics teaching and learning.

The VMI is a partnership of the University of Vermont, the Vermont Department of Education, and school districts throughout Vermont.

In 2004 the VMI commissioned this external evaluation of the program. Dr. H. (Bud) Meyers, former Vermont Deputy Commissioner for Assessment and Accountability, and Dr. Douglas Harris, Executive Director of The Vermont Institutes, have served as lead evaluators.

Evaluation Methodology

This evaluation employed a mixed methods approach, combining quantitative and qualitative data collection and analysis.

Quantitative Methodology

Unit of Sampling: The VMI is a professional development program targeted at teacher leaders. The impact of the teacher leaders occurs at the school level. Therefore, the unit of analysis is the school. Student outcomes on statewide standardized testing are the variables being measured, and these are aggregated to the school level.

Measures of Student Performance: During the years the VMI has been in existence, the state of Vermont has tested students in grades 4, 8, and 10 using the New Standards Reference Examination (NSRE). The New Standards Reference Exam includes embedded items from the Stanford Achievement Test, Ninth Edition (SAT-9). These items yield a scale score predictive of student results were the student to have taken the entire SAT-9. Because the SAT-9 yields scaled scores that are linked and vertically equated, and because the NSRE is not vertically equated, the embedded SAT-9 items provide a stronger data set over time than would the NSRE. At this writing comparison data is currently available for grades 4 and 8.[1]

Cross-sectional study: Cross-sectional comparisons were made at grade 4 for two groups of VMI schools – one of which had multiple VMI teachers in a school and the other of which had only one VMI teacher in each school – and one group of control schools. These comparisons consider changes in performance at grade four, and were made annually from 1999 (baseline year) through 2004. In each year, the currently enrolled group of students was tested.

Longitudinal study: Since results of cross-sectional analysis may be masked by 'cohort effects,' a longitudinal analysis was also conducted. The fourth grade cohort of students tested in the spring of 2000 in grade 4 was tested again as eighth graders in the spring of 2004, and this cohort formed the basis for the longitudinal comparison. The longitudinal studies comprised matched sets of scores representing performance of the same student in fourth and eighth grade. This controlled for the potential of migration as a threat to validity. A similar longitudinal comparison was made for the baseline student sample tested in grade 4 in 1999 and again in grade 8 in 2003, which is reported as baseline data.

Annual gains in mean percentile rank between grade 4 and grade 8 were calculated for students in the two groups of VMI schools and the group of control schools. Percentile rank gains were compared across the groups of schools in 2000-2004 (the intervention data). Comparison was also made with the 1999-2003 baseline data.

Overall Findings: Quantitative Results

Overall findings of the quantitative study of student performance are presented according to differences in mean scaled scores in the cross-sectional analysis and mean percentile gain in the longitudinal analysis.

Finding 1: Cross-sectional

Comparisons of VMI grouped schools with control schools yielded an overall consistent pattern of the VMI schools exceeding the performance of Control schools in the cross-sectional analysis.

[1] Data for grade 10 is expected to be available for subsequent analysis in 2005-2006.

Finding 2: Longitudinal

A pattern of gain favoring the group of VMI schools having more concentrated numbers of VMI teachers emerged from the comparison of percentile rank gains over time. Students in these VMI schools progressed at a rate more than three times that of their peers in either the group of schools having a single VMI teacher or the group of Control schools having no VMI teacher. The results for the intervention year cohort are contrasted with those for the baseline year cohort, with the results substantially favoring the intervention year cohort of VMI schools having concentrated numbers of VMI teachers. The educationally meaningful statement is that Vermont students who are taught by teachers who have studied mathematics in the VMI program can expect to increase their percentile gains in an average range of from 14 to 23 percentile points over a period of 4 years.

Qualitative Methodology

The qualitative data sources utilized in this evaluation included the following:

- Interviews of twenty current VMI participants and graduates.
- Interviews with twelve administrators
- Categorizations of themes emerging from interview debriefing by the interview team
- Observations of VMI sessions
- Interviews and informal discussion with VMI staff and leaders
- Review and analysis of course evaluations
- Review and analysis of participant portfolios

Overall Findings: Qualitative Results

Impact on Participants and Their Teaching

Finding 1: Mathematics Content

Virtually all participants described themselves as unprepared in mathematics prior to VMI. An overarching theme is the impact of the VMI experience on the teacher's own understanding of mathematics content.

Finding 2: Increased Confidence Related to Mathematics

Increased understanding of mathematics content impacts the confidence of participants as related to mathematics, as well as their enthusiasm and enjoyment of mathematics.

Finding 3: Impact on Instructional and Assessment Practice

Participants and principals report that the instruction in VMI, increased content knowledge, and increased confidence have had major impact on instructional and assessment practice in the classroom.

Finding 4: The Impact of Action Research on Classroom Practice

The impact of action research is mixed, with some participants and principals reporting considerable impact, others less so.

Finding 5: Principal Support

The active support of principals makes a profound difference in the VMI participant's work in the classroom and in leadership positions.

Finding 6: Personal Impact on Participants

Beyond the impact of VMI on teachers in relation to math content, instruction, and leadership, the program also has profound personal impact on many participants.

Impact on Students

Finding 7: Transfer of VMI Content to the Classroom

Teachers report direct transfer of mathematics content used in VMI to the math experiences of their students.

Finding 8: Impact on Student Problem Solving

Teachers report that the problem solving emphasis in VMI has significant impact on their understanding of how to engage students in problem solving in the classroom.

Finding 9: Impact of Action Research on Students

Some teachers believe that the interventions begun in their action research projects will continue to impact their students over time.

Impact on Teacher Leadership in Schools and Districts

Finding 10: Impact of Teacher Leaders

Teachers who are currently working as teacher leaders credit VMI for providing the knowledge, confidence, and support for them to take on leadership roles. This is true of teachers working in leadership at the school, district, and state levels.

Finding 11: Need for Ongoing Support

There is a common desire among VMI graduates to maintain the type of professional learning community afforded them through VMI.

Recommendations

Based on the above findings, the evaluators make these recommendations for the Vermont Mathematics Initiative and its leadership.

Recommendations Related to the Funding of VMI

The State of Vermont, local schools and districts, and the Vermont business community should develop a diverse, sustainable revenue stream for VMI to ensure its continuation, its availability to participants from poor and rural schools and districts, and continuous research and evaluation of its success. To this end, VMI leadership should work with state government, businesses, foundations, higher education institutions, and non-profit organizations to support the following investments in VMI:

- Title 2 funds that are received by districts
- MSP funds received by the state
- Local district funds that are set aside for professional development from the general fund (local) budget
- Private business and foundation support of mathematics professional development
- Partnership funding of professional development that includes Higher Education and non-profit contributions

Recommendations Related to the VMI Program

- Mentoring
    - Continue to strongly support and enhance the mentoring and coaching components of the program
    - Evaluate the mentoring and coaching components with a 'theory into practice' based research design
- Statistics
    - Continue to integrate the action research content with statistics content while also exploring ways to emphasize the interrelationships among statistics and the mathematics portion of the courses
    - Track the statistics content learned through action research to content taught in classrooms as well as to action research
- Leadership
    - Reexamine current leadership strategies and engage principals and teacher leaders in determining ways to increase the consistency of principal awareness of the VMI program and its impact on mathematics in the classroom

    - Determine ways to support teacher leaders as they transition from the classroom into leadership positions and as they continue in these critical positions over time
- Learning Community
    - Determine ways to continue support of VMI graduates as a professional learning community

Recommendations Related to Continued Study of the Vermont Mathematics Initiative

- Continue to gather longitudinal data from the State of Vermont's Assessment System. In particular, the spring 2005, 10^{th} grade results should be added to a longitudinal analysis of grade 8 results for 2003. This will provide a first data point on students who may be matched across time and schools.
- As Vermont transitions to statewide assessment utilizing the New England Common Assessment, carefully analyze the logic and structure of the NECA and review VMI course content in relation to the Grade Level Expectations upon which this assessment is built.
- Continue qualitative analysis utilizing existing data sources and consider adding series of observations within VMI participants' classrooms to better understand what exactly is happening in those classrooms.
- Select and implement a "theory into practice" change model considering, for example, the IBM/Harvard School of Business Change Toolkit and the McREL Balanced Leadership Model.

Validation Panel

The Validation Panel met on December 8, 2004 in Burlington, VT. The Panel consisted of the following individuals.

- Peter Lax, Distinguished Mathematician
- Cynthia Char, Program Evaluation Specialist
- Bruce R. Joyce, Author and Curriculum/Instruction Specialist

Vermont Mathematics Initiative Director Kenneth Gross and Evaluators Bud Meyers and Doug Harris joined the panel, providing information and support as requested.
Two weeks prior to the meeting the Validation Panel received a draft copy of the evaluation. At the meeting they also received a copy of *The Program Evaluation Standards*[2] and a sample Validation Panel Report written by Robert L. Linn for a national evaluation conducted in 2002.

Having reviewed the evaluation in advance, the panelists requested that the meeting begin with a more detailed program overview. As a result, much of the morning was spent in discussion of the history of the Vermont Mathematics Initiative, its operating procedures, and its curriculum. The Panel also posed clarifying questions regarding the evaluation design and results.

At the conclusion of this discussion, the Panel requested time to work on its own and to frame its recommendations. Following these deliberations, the Panel and the Evaluators and Dr. Gross reconvened, with the Panel sharing the following major recommendations:

- Develop a detailed description of the VMI program that summarizes its history operating procedures, and offerings. The Panel recommended that this material be developed by VMI staff, then be reviewed and edited by the evaluators.
- Include a detailed description of the curriculum, including syllabi, content focus, expectations, and course assessments.
- Frame the findings and recommendations of the evaluation within the context of this rich descriptive information.

As a result of the Validation Panel's recommendations, Dr. Gross and colleagues at VMI did develop a detailed description of the program titled *Overview of the Vermont Mathematics Initiative*, which is available as a supplement to this Evaluation Report. The evaluators rewrote the evaluation findings to connect to the content of this description. This work occurred in early 2005.

The panelists received the revised evaluation in March 2005. Each panelist has submitted a letter certifying the validation of the evaluation report. Vitae of the panelists and the certifying letters appear in an Appendix to this report.

[2] The Joint Committee on Standards for Educational Evaluation (1994). The Program Evaluation Standards. Thousand Oaks, CA: Sage Publications, Inc. All rights reserved. Approved by the American National Standards Institute as an American national standard. Approval date: March 15, 1994.

Purpose of This Evaluation

In 2004, the VMI commissioned an external evaluation under the direction of H. (Bud) Meyers, former Vermont Deputy Commissioner for Assessment and Accountability. Under Dr. Meyers' overall leadership, The Vermont Institutes was contracted to complete qualitative aspects of the evaluation, under the direction of Dr. Douglas Harris.

Audiences:

This report may be of interest to anyone interested in improving mathematics instruction and performance in elementary schools including:

- Mathematics teachers
- School and district administrators
- Professional development and technical assistance providers
- Providers of initial teacher preparation
- Researchers and policymakers in mathematics education
- Those within Vermont and in increasing numbers of states and international venues interested in replicating VMI

This report is based on work funded in part by the Vermont Department of Education, the University of Vermont, and participating schools and districts. Any opinions, findings, conclusions, or recommendations are those of the authors and do not necessarily reflect the views of these organizations.

Organization of This Evaluation

Findings from this evaluation are organized in terms of impact and include two major sections.

The first section deals with Student Performance on Standardized Tests.

The second section includes discussion of these areas of impact.

- Impact on Participants and Their Teaching
- Impact on Students of VMI Participants
- Impact on Teacher Leadership in Schools and Districts

While the VMI experience and its impact is unique for each participant and his/her students, school, and district, common themes and perceptions emerged and are discussed in each section of the report.

For more information, contact:

H. (Bud) Meyers, Ph.D.
University of Vermont
Associate Professor
Education Department
477 Waterman Bldg
Burlington, VT 05405:
(802) 656-3356
bmeyers@uvm.edu

or

Douglas Harris, Ph.D.
The Vermont Institutes
Alumni Hall, 45 College Street
Montpelier, VT 05602
(802) 828-0061
dharris@vermontinstitutes.org

or

Kenneth I. Gross, Ph.D.
Department of Mathematics and Statistics
University of Vermont
16 Colchester Avenue
Burlington, VT 05405
(802) 656-8186
gross@cem.uvm.edu

Program Evaluation: Design Dimensions

Background

As part of the external evaluation of the Vermont Mathematics Initiative, The Vermont Institutes convened a Quantitative and Qualitative Evaluation Team in the spring and summer of 2004. Team members included the following personnel:

- Bud Meyers, The University of Vermont, Lead Evaluator (Quantitative Analysis)
- Douglas Harris, The Vermont Institutes, Team Leader (Qualitative Focus)
- Penny Nolte, The Vermont Institutes, Evaluation Specialist
- Robin Gorges, The Vermont Institutes, Data Specialist
- Phyllis Brown, Lesley University, Lead Interviewer
- Alyssa Mayer, Lesley University, Interviewer
- Akiba Smith, Harvard School of Government, Interviewer

Methodology

Team Leader Douglas Harris and Lead Evaluator Bud Meyers have communicated with one another throughout the evaluation, to ensure coherence and continuity across qualitative and quantitative aspects of the evaluation. They have also communicated with VMI Director Kenneth Gross to receive formative feedback on issues of design and implementation.

Quantitative Methodology

The design of the quantitative evaluation is both cross-sectional and longitudinal. Since the VMI is a professional development program targeted at teacher leaders, the impact of the teacher leaders occurs at the school level. Therefore, the unit of analysis is the school. Student outcomes on statewide standardized testing are the results being measured, and these are aggregated to the school level.

Following a procedure suggested by the evaluation of Everyday Math [as reported in the NRC publication "On Evaluating Curricular Effectiveness: Judging the Quality of K-12 Mathematics Evaluations" (2004), p. 114.[3]], the target schools were divided into two groups, according to characteristics of the VMI teachers within the school. The schools selected from these two groups are referred to in this evaluation as the Group 1 and Group 2 treatment (or intervention) schools, respectively. Year by year performance of cohorts of students in Group 1 and Group 2 schools were compared with student performance in matched control schools.

---

[3] NRC publication "On Evaluating Curricular Effectiveness: Judging the Quality of K-12 Mathematics Evaluations", http://www.nap.cdu/openbook/030902426/html/114.html, copyright 2004, 2002, The National Academy of Sciences (2004).

These comparisons constitute a record of measures in multiple years among two groups of treatment schools and one control group of schools whose tested student populations number approximately 1000 students across twenty-four schools each year. Longitudinal comparisons of students within the Group 1 schools were also made from the year 2000 to 2004 for one cohort of students (same student, grade 4 and grade 8). Similar longitudinal comparison occurred for the baseline student sample in grade 4 in 1999 and grade 8 in 2003 and is reported as baseline data. The longitudinal comparisons were made across the years with schools as units of analyses, both intervention and control, and with matched pairs of student scores.

Assuming that data points become available for the cohort tracked from 1999 to 2003 when these students are tested in grade 10 (2005), a slope and intercept calculation of the growth of one cohort of students from 1999 through 2005 (grades four, eight, and ten) will be possible (See Figure 1).

Figure 1

Current and Potential Trend Studies with 3 data points for VT Data							
Others are cross-sectional, independent group comparisons							
Year	**Gr 4**	**Gr 5**	**Gr 6**	**Gr 7**	**Gr 8**	**Gr 9**	**Gr10**
1999	**x**						
2000	**x**						
2001	**x**						
2002	**x**						
2003	**x**				**x**		
2004	**x**				**x**		
2005							**X**

x = Years in which data is available
X = Year in which date may become available

- The Team collected and analyzed student performance data from twenty-four Vermont schools during the five-year period 1999 to 2004.
    - From the total list of all schools having a VMI trained teacher in the school, eight schools were chosen. These were selected without regard to the year in which the teacher enrolled in VMI, grade level taught, or number of VMI teachers in the school. These schools will be referred to as Group 1 schools. There was a total 20 VMI trained teachers in these eight Group 1 schools.
    - These Group 1 schools had a range of student poverty as measured by eligibility for free or reduced priced lunch from 13 to 62 percent, with a median of 28 percent eligible. Tested class size for each of the schools was

recorded and became a matching criterion for the selection of eight control schools (Table 7).

  - A second group of eight VMI schools, termed Group 2 schools, were chosen from a smaller population of VMI schools determined by the following criteria: There was one and only one VMI teacher in the school, and the VMI staff judged that teacher to have made substantial gains in mathematics content knowledge and to have had implementation support from the school administration. Thus, there was a total of 8 VMI trained teachers in these eight schools, distributed one VMI teacher per school. These eight schools were chosen without regard to the grade level of the teacher.
  - The Group 2 schools were matched, to the extent possible, to satisfy the demographic criteria for Group 1 schools. The distribution of poverty and class size for each of the groups is presented in Table 7.

- The SAT-9 (Stanford Achievement Test, Version 9) mathematics items embedded in the New Standards Reference Examination were chosen as the measure of mathematics performance. During the years the VMI has been in existence, the state of Vermont has tested students in grades 4, 8, and 10 using the New Standards Reference Examination (NSRE). The New Standards Reference Exam included embedded items from the Stanford Achievement Test, Ninth Edition (SAT-9). These items yield a scale score predictive of student results were they to have taken the SAT-9. Because the SAT-9 yields scale scores that are linked and vertically equated, and because the NSRE is not vertically equated, the embedded SAT-9 items provide a stronger data set over time than the NSRE as a whole. Comparisons of students within and between schools can thus be done with less concern for scoring and content changes in the instrument and with some confidence that the Vermont standards provided a common framework for measurement and opportunity to learn.
- Mean scaled scores of the Group 1 and 2 and Control schools were calculated and tested for significance with either independent t-tests (for cross-sectional comparisons) or paired samples t –tests (for longitudinal comparisons)

Qualitative Methodology

The Team collected qualitative data from multiple sources including the following:

- Interviews of twenty current VMI participants and VMI graduates. Of the twenty, twelve were selected at random and eight were selected by the VMI staff. The teachers included both teachers still in the classroom and teachers who have assumed leadership roles in the schools, in their districts, or statewide.
- Interviews with twelve administrators whose schools or districts have been impacted by VMI. Administrators included nine principals, two curriculum directors, and one superintendent. Eight were selected at random and four by VMI staff.

- Categorization of themes emerging from debriefing by the interview team using NVivo, by a Project Evaluator not associated with the interviews (Nolte).
- Observation at VMI sessions in the spring and the summer, including the culminating oral examinations and presentations in 2004.
- Interviews and informal discussions with VMI staff and leaders.
- Review and analysis of course evaluations from three VMI representative courses: *Mathematics as a Second Language* (Course 1); *Functions and Algebra for Elementary Teachers* (Course 2); and *Calculus for Elementary Teachers I* (Course 10).
- Review and analysis of representative portfolios and power point presentations of VMI graduates.

Major Findings

Section I: Student Performance on Standardized Tests

Quantitative Analysis

The analysis of test data began with Group 1, Group 2, and Control schools during the year 2000, using 1999 as a baseline year for test data. Mean differences between schools were calculated and a significance test calculated on the difference scores. As described in the previous section on methodology, scores represented the SAT-9, multiple choice items embedded in the New Standards Reference Examination forms C through F. SAT-9 items were common across all forms of the test for all years, yielding scaled scores, linked and equated across all grades tested. Following a procedure used by Robert Meyer, (2004) p. 16,[4] differences between groups are expressed as "effects" and were considered significant if p values were less than or equal to .05 on a t-test of independent means.

Data analysis was performed on both unmatched and matched student groups in order to assess program effects on a school-wide basis. The data is collected in seven tables that appear at the end of this Section.

Cross-sectional analysis

Cross-sectional comparisons were performed on a yearly basis with cohorts of fourth graders who were attending a treatment or control school each year (Tables 1 and 2). A summary of the grade 4 cross-sectional findings for Group 1 and Group 2 schools is indicated below under the heading "Summary of the Quantitative Evaluation."

[4] The concept of "effect" is discussed in: Participation in the Student Achievement Guarantee in Education (SAGE) Program and Performance on State Assessments at Grade 3 and Grade 4 for Three Cohorts of Students - Grade 1 Students in 1996-97, 1997-98 and 1998-99. by Norman L. Webb and Robert Meyer with Adam Gamoran and Jianbin Fu. Wisconsin Center for Educational Research. Madison, WI: University of Wisconsin. February 9, 2004, p. 16.

The Group 1 schools outperformed the Control schools in 2000 and 2004, and there was no statistically significant difference in performance between the Group 1 schools and the Control schools in 1999 (the baseline year of the program), 2001, 2002, and 2003 (Table 1). It is possible that the performance difference in 2000 results from a 'cohort effect' rather than being a result of instruction. Group 2 schools outperformed the control schools in every year of the program including the baseline year (Table 2). Given the pattern of performance in 1999 it is possible that baseline differences for the Group 2 treatment schools as represented in Table 2 were also the result of 'cohort effects.'

Longitudinal analysis

Longitudinal comparisons were also made to assess effects over time that might appear from matching students who remained within the school system served by the program. Such comparisons were possible from 1999 to 2003 and from 2000 to 2004, when each fourth grade cohort was tested as eighth graders. The 1999-2003 comparison is baseline and the 2000-2004 comparison represents the initial intervention year.[5] The results appear in Tables 3 through 5. All three groups significantly increased their scores. Since these are scale scores, the increase is both statistically significant and educationally important. For example, the increases may indicate steady growth on the SAT-9 across the state. Also, since only students who could be matched from grade 4 to grade 8 were included, the data may reflect consistent opportunity to learn, as well as normal growth.[6]

In any case, given the size of the groups, mean scale score differences – although statistically different between VMI and Control schools – do not of themselves establish a pattern of consistent growth. It is only when one adds a comparison of mean percentile rank gains over the four year period that a pattern of important differences favoring the VMI schools emerges.

The magnitude of the effects can be shown by comparing the percentile gains of each of the groups over the years, as represented in Table 6. Table 6 tracks percentile gains per year of students in Group 1, Group2, and Control schools for the comparison years 1999-2003 (baseline) and 2000-2004 (intervention). The annual gain of 3.5 percentile units per year (14 percentile units over four years) for Group 1 schools may reflect the presence of multiple VMI teacher leaders in the Group 1 schools.[7]

[5] The 1999 student testing took place prior to the start of VMI. Also, in 1999, the first year of the VMI, all teachers who applied were admitted to the program, whereas in 2000 the admission process was selective in favor of prospective teacher leaders. As well, during the first year in 1999 the VMI curriculum was still being invented and undergoing extensive change, whereas from 2000 onward the VMI program had benefited from the experience of the previous year.

[6] For this reason, the data also raises questions for further research concerning the effects of student mobility on the opportunity of students to learn mathematics, especially as related to presence of VMI teacher leaders in the schools.

[7] Five of the eight Group 1 schools had multiple VMI teachers in the same school, and a total of 20 VMI teachers were in the eight Group 1 schools. Contrastingly, the eight Group 2 schools were chosen on the basis of having only one VMI teacher in each school.

Summary of the Quantitative Evaluation

Summary of cross-sectional analysis

The pattern of difference between the Group 1 and Group 2 VMI schools and the Control schools is an overall consistent pattern of the VMI schools exceeding the performance of Control schools in the cross-sectional analysis.[8]

Summary of longitudinal comparison

A pattern of gain favoring the Group 1 schools, which is the group having more concentrated numbers of VMI teachers, emerged from the comparison of percentile rank gains over time. Students in Group 1 schools progressed at a rate more than 3 times that of their peers in either the Group 2 or Control schools. The educationally meaningful statement is that Vermont students who are taught by teachers who have studied mathematics in the VMI program can expect to increase their percentile gains in an average range of from 14 to 23 percentile points over a period of 4 years.

Additional analyses of covariance were performed on both cohorts of matched pairs in order to control among the three groups for prior differences among the groups in the baseline years. In the 2000-2004 comparisons, Groups 1 and 2 outperformed the Control schools, even after adjustments in baseline.

Finally, since many of the annual comparisons of cross-sectional groups favored the VMI schools, the data indicates that each year a new group of students is well served in schools whose teachers are VMI trained.

Data Tables

Scaled Scores

The mean scores reported in Tables 1 through 5 are *scaled scores* on the ninth edition of the Stanford Achievement Test (SAT-9) multiple choice items embedded in the New Standards Reference Examination (NSRE). According to Harcourt Educational Measurement, Inc., the company that authors the NSRE, Stanford scaled scores express performance on all forms of a given subtest along a single scale. That is: "The scaled score system for the Stanford series also links together the levels at which content domains are tested, yielding a scale across levels on each subtest and total that is common to those levels. For example, the Mathematics total is linked across the thirteen levels from SESAT through TASK,[9] forming one continuous scale that makes it possible to compare scaled scores in Mathematics from form to form and from level to level." (See the reference noted in Table 6 below.)

The choice of scaled scores for analysis was an obvious one because of the need to compare student scores across years of testing in Vermont. The State of Vermont chose to

[8] Note, however, in the case of the Group 2 comparison, that the intervention schools outperformed the Control schools in the baseline year.

[9] SESAT refers to the Stanford Early School Achievement Test and TASK refers to the three levels of the Stanford Test of Academic Skills.

administer the Stanford 9 portions of its state test, the New Standards Reference Examination, by selecting forms B, C, D, E and F in subsequent years. The use of scaled scores made longitudinal comparisons possible. The disadvantage of using scaled scores is that it is not obvious with scale comparisons in Tables 1 through 5 how to interpret the scales as the magnitude of relative performance of the student cohort groups. To enable comparisons that communicate the magnitude of differences, the scaled scores were converted to percentile ranks (Table 6) that express change in performance of groups across years.

Table 1: Cross-sectional Comparison
Group 1 Treatment vs. Control Schools
Tested at Grade 4 Level (New Students in Grade 4 Each Year)

Grade 4	Group 1 Participant Schools Mean	SD	Control Schools Mean	SD	t value	df	Significance
1999	659	42.73	655	46.76	1.55	1128	ns
2000	658	42.03	648	44.02	3.83	1213	p<.001
2001	661	42.69	659	44.60	.78	1005	ns
2002	663	42.98	659	44.08	.98	952	ns
2003	664	41.67	664	43.99	.22	931	ns
2004	673	39.88	667	43.38	2.01	888	p<.05

Table 2: Cross-sectional Comparison
Group 2 Treatment vs. Control Schools
Tested at Grade 4 Level (New Students in Grade 4 Each Year)

Grade 4	Group 2 Participant Schools Mean	SD	Control Schools Mean	SD	T value	df	Significance
1999	681	47.44	655	44.51	8.99	1030	p<.001
2000	677	48.30	648	46.47	9.49	948	p<.001
2001	689	47.67	659	44.60	10.21	954	p<.001
2002	691	46.98	660	44.08	10.40	941	p<.001
2003	691	44.20	664	43.98	9.25	900	p<.001
2004	690	48.97	667	43.38	7.25	864	p<.001

Table 3

Matched Pair Comparisons from Grade 4 to Grade 8
Group 1

Year	Participant Matched Pairs Mean	SD	t value	Df	Significance
1999 (Gr4)	662	44.55	-30.80	449	p<.001
2003 (Gr8)	716	43.77			
2000 (Gr4)	658	41.12	-39.60	571	p<.001
2004 (Gr8)	718	45.05			

Table 4
Matched Pair Comparisons from Grade 4 to Grade 8
Group 2

Year	Participant Matched Pairs Mean	SD	t value	Df	Significance
1999 (Gr4)	654	38.04	-30.37	359	p<.001
2003 (Gr8)	711	38.86			
2000 (Gr4)	652	41.90	-32.69	395	p<.001
2004 (Gr8)	714	42.18			

Table 5
Matched Pair Comparisons from Grade 4 to Grade 8
Group 3 (Control)

Year	Participant Matched Pairs Mean	SD	t value	Df	Significance
1999 (Gr4)	658	40.53	-30.37	252	p<.001
2003 (Gr8)	707	45.22			
2000 (Gr4)	651	43.07	-44.05	792	p<.001
2004 (Gr8)	710	41.92			

Table 6

Comparison of Percentile Changes*
Percentile Gains per year for Group 1, Group 2 and Control schools
On the Difference between Grade 4 and Grade 8 Matched Pairs

Comparison Years	Group 1	Group 2	Control
1999-2003	-.5	.25	1.25
2000-2004	3.5	1.0	1.29

*Author. (1997). Stanford Achievement Test Series, Ninth Edition, Spring Norms Book. San Antonio, TX: Harcourt Educational Measurement. Gains of 3 percentile points per year are generally statistically significant.

Table 7
Characteristics of VMI Group 1, Group 2 and Control Schools

Enrollment*				Percent Poverty		
School	Group 1	Group 2	Control	Group 1	Group2	Control
1	156	53	208	15	25	17
2	97	43	63	27	7	50
3	83	28	60	13	38	7
4	67	22	40	32	32	38
5	55	11	44	21	64	39
6	41	9	44	58	11	37
7	19	9	20	62	11	72
8	17	4	15	29	24	38

* The numbers represent the total number of students tested in Grade 4 in the school during the 1999-2000 school year.

Section II: Qualitative Analysis

The findings below emerged from analysis of multiple data sources described in the "Methodology" section of this report. These sources include participant interviews, administrator interviews, participant portfolios, final project presentations, and course evaluations.

The qualitative analysis yielded eleven findings, organized in three categories of impacts: (*i*) Impact on Participants and Their Teaching, (*ii*) Impact on Students, and (*iii*) Impact on Teacher Leadership in School and Districts.

Findings of the Qualitative Analysis

Impact on Participants and Their Teaching

<u>Finding 1: Mathematics Content</u>

Virtually all participants described themselves as unprepared in mathematics prior to VMI. An overarching theme is the impact of the VMI experience on the teacher's own understanding of mathematics content.

Finding 2: Increased Confidence Related to Mathematics
Increased understanding of mathematics content impacts the confidence of participants as related to mathematics, as well as their enthusiasm and enjoyment of mathematics.

Finding 3: Impact on Instructional and Assessment Practice
Participants and principals report that the instruction in VMI, increased content knowledge, and increased confidence have had major impact on instructional and assessment practice in the classroom.

Finding 4: The Impact of Action Research on Classroom Practice
The impact of action research is mixed, with some participants and principals reporting considerable impact, others less so.

Finding 5: Principal Support
The active support of principals makes a profound difference in the VMI participant's work in the classroom and in leadership positions.

Finding 6: Personal Impact on Participants
Beyond the impact of VMI on teachers in relation to math content, instruction, and leadership, the program also has profound personal impact on many participants.

Impact on Students

Finding 7: Transfer of VMI Content to the Classroom
Teachers report direct transfer of mathematics content used in VMI to the math experiences of their students.

Finding 8: Impact on Student Problem Solving
Teachers report that the problem solving emphasis in VMI has significant impact on their understanding of how to engage students in problem solving in the classroom.

Finding 9: Impact of Action Research on Students
Some teachers believe that the interventions begun in their action research projects will continue to impact their students over time.

Impact on Teacher Leadership in Schools and Districts

Finding 10: Impact of Teacher Leaders
Teachers who are currently working as teacher leaders credit VMI for providing the knowledge, confidence, and support for them to take on leadership roles. This is true of teachers working in leadership at the school, district, and state levels.

Finding 11: Need for Ongoing Support
There is a common desire among VMI graduates to maintain the type of professional learning community afforded them through VMI.

Discussion of Findings

Impact on Participants and Their Teaching

Finding 1: Mathematics Content

Virtually all participants described themselves as unprepared in mathematics prior to VMI. An overarching theme is the impact of the VMI experience on the teacher's own understanding of mathematics content.

Discussion

Participating teachers consistently cite the focus on mathematics content in VMI as having profound impact on them as teachers and as learners.

Four courses are cited most often as changing teachers understanding of mathematics content:

- "Mathematics as a Second Language," the first course in the sequence;
- "Functions and Algebra for Elementary Teacher," the second course in the sequence, and ;
- Calculus for Elementary Teachers I and II," the final two courses before the Capstone VMI experience.

While these courses may be cited most frequently due to their positions at the beginning and ends of the VMI sequence, each has unique attributes that contribute to their impact on participants.

"Mathematics as a Second Language" utilizes a powerful metaphor that compares mathematics relationships to the relationships among words in the grammar of the English language. This metaphor provides a means for students to rethink their understanding of the operations of arithmetic. Students learn that numbers serve as adjectives modifying nouns. (For example, in addition, one adds the adjectives and keeps the common noun, while in multiplication one multiplies both the adjectives and the nouns.)

Participants report that the power and simplicity of the language metaphor provides a unique way to approach arithmetic and to organize their thinking about mathematical relationships. They find it especially helpful to ground this metaphor in specific aspects of arithmetic, such as understanding fractions with like and unlike denominators. Because many elementary teachers have greater expertise in language than in mathematics, they report that this metaphor helps them to clarify their own thinking about mathematics. They also report that the use of the metaphor is directly applicable in the classroom and that they embed its use in instruction.

“Mathematics as a Second Language” also begins to build conceptual understanding of the interrelationships among arithmetic, algebra, and geometry. Participants report that while they may have utilized isolated strategies combining these aspects of mathematics (such as the area model for multiplication); the course provides a framework to begin to build a holistic understanding of mathematics. An example is the introduction of the geometry of the number line, combined with uses of the number line to understand division of fractions and the application of the number line to irrational numbers.

“Mathematics as a Second Language” also provides students an introduction to the intensive coaching model that VMI utilized in its approach to problem solving. This coaching model, which requires multiple instructors and assistants in each course, includes multiple opportunities for participants to interact with mathematicians and math educators within the VMI classroom. These opportunities include early morning one-on-one consultation, continuous dialogues and critiques during sharing of problems solved, reinforcement of multiple approaches and techniques, and explicit attention to building the interrelationships among algebra, arithmetic, and geometry in problem-solving settings (this focus on interrelationships continues during the course sequence and expands to include trigonometry, number theory, and ultimately calculus).

This coaching model is at the very heart of the Vermont Mathematics Initiative; without it, while a content-rich sequence would still have significance in terms of the participants’ understanding of mathematics, it is unclear that the transfer to problem solving would occur. Participants consistently report that it is this ability to problem solve that has the most lasting and profound impact on them as students and as teachers.

While “Mathematics as a Second Language” intentionally focuses on interrelationships among branches of mathematics, “Functions and Algebra for Elementary Teachers” provides a focused, in-depth analysis of functions. Although functions are central to the K-6 mathematics curriculum, many teachers report a partial understanding of functions, as well as misconceptions related to functions prior to this course. They report that the opportunity to explore functions in depth, to graph functions, and to relate functions to the solving of linear equations significantly impact their understanding of algebra. By connecting tables, graphs, and formulas through their problem-solving experiences in the course, they are able to extend their understanding of connections among arithmetic, algebra, and geometry, building on the knowledge gained in “Mathematics as a Second Language.”

Students experience the above two courses in the first summer of VMI. By the time they reach the two calculus courses in the third summer and fall, they have widened their study of mathematics in VMI to include trigonometry, measurement, number theory, and probability and statistics. They also have completed two additional courses focusing on algebra and geometry, and have transferred their learning to action research based in their classroom or school.

"Calculus for Elementary Teachers I and II" is designed to reinforce and extend arithmetic, geometry, and algebra knowledge and skills through problem solving using calculus. Participants report that these courses serve to pull the math strands together and to reinforce prior learning, especially in algebra.

Most the participants either have not taken a calculus course prior to VMI, or have not done so in many years, Not surprisingly, many approach calculus with trepidation. Participants report that the review of algebra at the outset of the first calculus course is very valuable in preparing for the study of calculus and in helping to boost their confidence as students of calculus.

Many participants speak of the structure of mathematics becoming clear during the calculus course sequence. Participants report that the sequencing of the calculus course, combined with the coaching model and problem-solving processes described above, along with frequent opportunities for reflection, bring unity and coherence to the study of mathematics in a way that they have not previously experienced.

Interestingly, while participants report increased understanding of the interconnections among algebra, geometry, and arithmetic, they tend to think of the statistics work in VMI as most explicitly connected to action research rather than these branches of mathematics. At the same time they report much better understanding of statistical methods, especially as related to their action research and to analysis of student results.

Finding 2: Increased Confidence Related to Mathematics

Increased understanding of mathematics content impacts the confidence of participants as related to mathematics, as well as their enthusiasm and enjoyment of mathematics.

Discussion

Participants use terms such as "empowerment," "big leap," "solidified confidence," and "comfortable taking risks" to describe the impact of VMI on their confidence related to mathematics. With this increased confidence comes a consequential impact on their enthusiasm and enjoyment of mathematics.

As an example, one participant described in her VMI portfolio the moment when she "gained understanding of where I stopped understanding math." She describes herself as "unstuck" and relates her plans to continue her study of mathematics.

Teachers and administrators both identify this renewed enthusiasm and increased confidence with having profound impact in the classroom. Teachers discuss confidence in two different ways. First, they state that their increased knowledge and understanding of mathematics content increases their confidence as a teacher, both of mathematics and in general. Secondly, they report that their increased confidence gained from VMI has increased their willingness to take on mathematics-related leadership roles, to present action research and data to colleagues, and generally to emerge as a teacher leader in the building. This is especially true of teachers in the lower grades who state that, prior to VMI, their limited understanding of mathematics taught in the upper grades would have precluded their considering mathematics-related teacher leadership roles.

Principals and teachers also report that changes in confidence have, in many cases, led to increases in opportunities for teachers to interact with educators throughout the school system. Many have taken leadership roles in K-12 curriculum and assessment initiatives and formed new relationships with teachers in other buildings, including middle and high schools, as well as with principals, curriculum directors and other central office personnel.

Most importantly, increased confidence has led to increased enthusiasm for mathematics in the classroom. These comments were typical: "Math is now my favorite subject." I'm passionate about math." "I love math." "My students have to stop me because I'll go over into other subjects' time."

On the subject of time, most teachers report that their school's policy calls for approximately one hour of mathematics per day. VMI participants find that they are maintaining and in many cases increasing this dedicated mathematics instruction time. In addition, they are finding more opportunities to incorporate mathematics in other content areas. Participants report that while interdisciplinary curriculum experiences have been common in their classroom they typically involved integrating content, such as science, health, and social studies with mathematics applications often limited to representation of data. Participants report that they now "see" many more opportunities to integrate mathematics in other content areas. However, they emphasize that this integration is in addition to, not instead of, dedicated mathematics instructional time.

Finding 3: Impact on Instructional and Assessment Practice

Participants and principals report that the instruction in VMI, increased content knowledge, and increased confidence have had major impact on instructional and assessment practice in the classroom.

Discussion

Most participants strongly support the focus on mathematics content in VMI. Many contrast this to their past experiences in mathematics methods classes, indicating that the have learned more methodology from the mathematicians and educators in VMI than in all of their methods classes.

The major changes in instructional practice, and therefore possibly a major impact on student achievement, emerges from the coaching model at the heart of VMI pedagogy. Though teachers acknowledge that they cannot replicate the VMI experience of having multiple mathematicians and educators in the classroom, they can apply aspects of the program's instruction, especially as related to problem solving.

Participants cite several aspects of VMI instruction as especially useful in their classrooms. The first is the balance of direct instruction, problem-solving, and student-led discussion of problems. They cite the typical sequence in VMI (one-on-one review of homework, new material, guided practice and coaching during problem solving, and student sharing of problems), as applicable, with modifications, in their classroom.
Participants also consistently cite the variety and quality of the problems presented, as well as the time devoted to problem solving and discussion of problems with peers and instructors. They leave VMI with an increased awareness of the importance of selecting problems that illuminate the underlying mathematics content and concepts. Some report a new understanding of why certain problems were selected for their published curriculum while at the same time worrying that these problems will not be sufficient for their students.

Participants are universally appreciative of the quality, the availability, and the caring of the instructors, as well as their patience and encouragement. When asked what about VMI needs to remain the same, the number and quality of instructors and the combination of mathematicians and classroom teachers are consistently included.

Participants likewise cite the importance of opportunities to learn from peers and the value of the relationships that they build with peers over time. While recognizing the differences in peer learning at the adult and student levels, they report increased incidence and success of peer learning in their mathematics classrooms.

Participants also identify specific aspects of VMI that they find particularly useful in the classroom. These include, but are not limited to, the following:

- Mathematics/language connections and particularly the mathematics/English grammar metaphor
- Multiple uses and applications of the number line
- Expanded use of the area model to teach multiplication and multiplicative reasoning
- Classroom application of limits and derivatives
- New understanding of ways to use formulas, charts, and graphs

Participants were of mixed opinion regarding the “classroom connections” components of the VMI. Most valued these sessions and appreciated the insights gained from presenting classroom teachers. Others felt that these sessions took away time from mathematical content study. Sessions that received positive feedback from virtually all participants were those related to the application of calculus to the elementary classroom. These sessions were valued because they not only provided strategies not incorporated in elementary curriculum, but also spurred participants to plan ways to apply these strategies in their own classrooms.

Several teachers also cited ways in which the instruction in VMI increased empathy for their students. One participant describes himself as often feeling like “remedial students must feel in his classroom.” He discussed ways in which he gained empathy even as he gained confidence in himself as a student of mathematics.

Many participants discussed their surprise at what their students can actually do with mathematics. For example, a kindergarten teacher reports introducing functions to her students, something she would never have done prior to VMI.

Although the VMI curriculum does not address classroom assessment directly, participants report that assessment in the classroom is different largely because teachers have a new understanding of the structure of mathematics as well as the structure of the mathematics curriculum. Therefore, they report, they have newfound skills in scaffolding mathematics assessment and differentiating instruction based on student understanding.

In several cases, groups of VMI participants have formed ad hoc grade level groups to discuss mathematics assessment and to develop assessments for their grade levels. Likewise, VMI participants are serving as school-based leaders in the On-Going Assessment Project (OGAP), a major initiative of The Vermont Mathematics Partnership.

Finding 4: The Impact of Action Research on Classroom Practice

The impact of action research is mixed, with some participants and principals reporting considerable impact, others less so.

Discussion

The VMI curriculum includes three courses entitled "Statistics, Action Research, and Inquiry into Effective Practice." The initial course incorporates critical analysis of research articles, an introduction to quantitative, qualitative, and library research techniques, and a foundation in basic statistics and data display. In the two subsequent courses participants build their knowledge of statistics, conduct "mini-studies," and design an action research project. The research focus culminates in the student's VMI "Capstone Project," the final course of the sequence, and in their presentation of their research to peers and VMI leadership and staff.

While participants highly praise the instruction in statistics, both they and their principals are mixed in their appraisal of the impact of action research. On the one hand, some participants report that they really enjoyed conducting the action research and that they now think about action research and data collection in the classroom. Others report that, although themselves not continuing as researchers, they have increased their reading of research and their application of the research of others in the classroom.

Many participants discuss the amount of work that went into their action research and their sense of accomplishment in its completion. This theme is evident in VMI portfolios and in final oral presentations as well as in interviews and evaluations.

While participants clearly tie the work in statistics to their action research, they perceive less explicit ties between statistics and the other mathematics content areas in VMI (arithmetic, algebra, geometry, trigonometry, and calculus). This is perhaps intentional in that grounding statistics in practical applications is consistent with statistics as applied mathematics.

Finding 5: Principal Support

The active support of principals makes a profound difference in the VMI participant's work in the classroom and in leadership positions.

Discussion

VMI includes leadership as a priority area. Although there are multiple opportunities for principals to participate in VMI activities and learn about the program the degree to which principals take advantage of these opportunities varies significantly from no involvement to direct participation as VMI participants.

On the one hand, some principals have taken advantage of multiple opportunities to learn about VMI. These include VMI events, such as the summer leadership sessions at the Grafton Institute, invitations to visit the VMI courses, and invitations to attend their teachers' Capstone Presentations. In addition, many of these principals and their VMI teachers have incorporated VMI in the teachers' individual professional development plan (IPDP) required for Vermont educators. Other principals likewise are articulate about the VMI program and especially about the impact of the program transforming mathematics education in the teacher's classroom.

Likewise, many of these principals have intentionally built the work of VMI participants into teacher leadership positions within their schools and have worked with these teacher leaders to impact mathematics across the school. For example, one principal in a small school has supported four teachers attending VMI and is developing a shared leadership model incorporating all four into the leadership of mathematics in the school.
At the other extreme, other principals have devoted little or no time to VMI events, nor formally included VMI in professional development.

Other principals have limited knowledge of VMI, its impact on teachers and students, and its potential for building mathematics leadership. These principals frequently refer to the multiple demands on their time and their inability to devote the time they would wish to instructional leadership.

Principals also reflect differing understanding and support of action research. Some principals are very clear on the nature of the research in their schools and the impact of this research on students. At least one is using the action research in mathematics as a model for promoting action research throughout his building. Others were aware that action research had taken place or was continuing in their schools but were unclear as to the nature of the research.

VMI teachers are very aware of the level of support they are receiving from their principals and make it very clear that any opportunity for impact beyond the classroom must involve the support of their principals. Those who have such support tend to seek opportunities for leadership within their school settings while those lacking administrative support frequently leave for other opportunities.

Unfortunately, this trend for teachers lacking support to leave their schools can lead to even less support for future teachers to embark on the program. One principal who had experienced this refers to VMI as a "hard sell," stating that the school board and community perceive that the program cost them one of their best teachers.

Overall, the understanding and support of principals is crucial to the success of VMI and its participants. This is discussed further in the recommendations.

Finding 6: Personal Impact on Participants

Beyond the impact of VMI on teachers in relation to math content, instruction, and leadership, the program also has profound personal impact on many participants.

Discussion

Students, VMI faculty, and program leaders all speak of the closeness within the VMI "family" and the value of experiencing this type of sustained learning community. Graduates, and especially those in leadership roles, report missing these relationships and hoping for ways to continue to be part of the VMI community.

Participants also describe strong impacts on themselves as learners. Many first year VMI students report initial discomfort with ambiguity as they have to go back and relearn arithmetic—a topic that they had felt that they had mastered—from a deeper perspective. Students report an initial discomfort but at the same time excitement and pride in their newfound learning.

In many cases teachers report changes in their level of understanding immediately from time of exposure to the mathematics, which is typically well before the knowledge of the mathematics has been understood and internalized. Again, that may manifest itself in feelings of confidence or disequilibrium.

Many teachers reflect on their prior experiences as math students in school and report a new understanding of when and why they got "off the track" as math students. This has profound impact on them as learners as well as on their work as teachers.

By Year 3, although many students have a preconceived dread of calculus, no experience with calculus, or a limited bad experience coming into the course "Calculus for Elementary Teachers," many report that the explicit connections made in the calculus courses among algebra, geometry and calculus lead to things "falling into place," often for the first time.

For many teachers, the experience of being students dealing with challenging content in a formal learning environment is one they have not experienced in many years. As discussed in the instructional section above, many of these teachers gain increased empathy for their students as they struggle with difficult concepts.

Impact on Students

Teachers report that increases in their own enthusiasm and confidence have diminished math phobia among their students. Teachers also report changes in student engagement and motivation, reporting renewed excitement "spilling over" into the classroom.

Finding 7: Transfer of VMI Content to the Classroom

Teachers report direct transfer of mathematics content used in VMI to the math experiences of their students.

Discussion

Although the content focus on VMI emphasizes learning advanced mathematics at an adult level, participants readily transfer their new knowledge to their work with children.

An immediate application for virtually all participants is use of the adjective/noun relationship that is part of the language metaphor in "Math as a Second Language." Teachers and principals also report that as teachers and students utilize this metaphor, and teachers focus more on mathematical language, students also use more complex mathematical language.

Teachers also report that as they better understand interrelationships among arithmetic, algebra, and geometry they are better able to engage students in multiple approaches to problems. In this way, students begin to internalize the underlying structure of mathematics early in the elementary years.

Finding 8: Impact on Student Problem Solving

Teachers report that the problem solving emphasis in VMI has significant impact on their understanding of how to engage students in problem solving in the classroom.

Discussion

The VMI coaching model engages participants in problem solving in multiple contexts, including one-on-one coaching with mathematicians and math educators, joint problem solving with peers, and opportunities to share and critique multiple approaches to problems. Teachers report that as they increase the time devoted to problem solving and engage students in similar problem-solving contexts, they see significant changes in problem solving in the classroom.

Because students historically have not done well on problem-solving subtests on state-wide and norm-referenced tests, administrators are very interested in the potential impact on problem-solving scores. One principal reports that 100% of his students improved in problem-solving as measured by standardized tests. Administrators tend to pay close attention to these test results and to look at test results both in terms of overall increase and in closing achievement gaps across subgroups. The quantitative findings of this evaluation will provide important information to these administrators, especially in terms of the overall increase in student performance over time.

Teachers acknowledge the importance of test results but worry that some of the high level concepts and problem solving techniques that their students learn are not reflected on statewide or standardized assessments. Many of these teachers are involved in statewide efforts to develop valid, reliable classroom assessments to augment external testing. At the same time, at this writing, the State of Vermont is in transition to new tests in grades three to eight to meet the requirements of No Child Left Behind. These new tests will provide important information at each of these grade levels as well as enabling schools to more accurately track progress over time.

Finding 9: Impact of Action Research on Students

Some teachers believe that the interventions begun in their action research projects will continue to impact their students over time.

Discussion

Teachers believe that their experiences with action research, as related to classroom interventions, not only impact their own understanding of research but also directly impact student performance. This is especially true of teachers whose action research projects have been incorporated into school wide intervention strategies. The support of the principal is a key in these cases.

Many report that they and their colleagues will continue or modify the interventions though fewer plan to continue action research at the level of rigor demanded for their VMI action research projects.

Impact on Teacher Leadership in Schools and Districts

Teachers and principals report that increases in mathematics enthusiasm and confidence increase the comfort level in providing leadership to colleagues. This is true in individual mentoring situations as well as in taking school wide or district leadership in activities such as curriculum development, data analysis, action planning, and developing school level assessments.

Finding 10: Impact of Teacher Leaders

Teachers who are currently working as teacher leaders credit VMI for providing the knowledge, confidence, and support for them to take on leadership roles. This is true of teachers working in leadership at the school, district, and state levels.

Discussion

Teachers report that VMI opened new possibilities for them. Many had never before considered leaving the classroom, partly because of their desire to work with children and partly because they tend to be successful teachers. VMI forced teachers into leadership roles, such as sharing assessment results with colleagues and school board members and participating in developing curriculum and Grade Level Expectations.

When VMI teachers assume formal teacher leader positions much of their success is dependent upon their principals. Teacher leaders tend to succeed when the principal is publicly supportive; when there is clarity of role; and when they have express authority and responsibility to facilitate change. When these conditions are in place, the likelihood of success of the teacher leader dramatically increases.

While these conditions relate more to the school setting than to VMI, they reflect a common theme among teacher leaders.

Finding 11: Need for Ongoing Support

There is a common desire among VMI graduates to maintain the type of professional learning community afforded them through VMI.

Discussion

Many VMI participants working as teacher leaders expressed the wish that VMI would continue to provide a formal support group for graduates working as teacher leaders. A common theme was the loneliness of a teacher leader isolated in a school or district and the need for ongoing support.

VMI graduates remaining in the classroom likewise expressed interest in VMI-based support opportunities. Some suggested that these be organized regionally, others by grade levels, still others by topic.

Several VMI graduates now working in leadership positions expressed the wish that VMI would continue to provide a formal support program for graduates working as mathematics leaders. Some teacher leaders express frustration at lack of clarity in their roles and/or lack of expressed authority to facilitate change. While these comments related to the school setting, not to VMI, they reflect a common theme in teacher leadership.
Teachers and administrators indicated the importance of administrator awareness of the VMI experience. This was true both in terms of validation of the importance of this awareness where it exists and frustration where it does not.

In all cases, VMI clearly filled, or created, a need for professional support that continues beyond the program.

Section III: Recommendations and Implications

Based on the preceding findings, the overarching recommendation of the evaluators is that the Vermont Mathematics Initiative should be continued as a major strategy for building the capacity for teacher leadership in mathematics in Vermont schools. Moreover, the VMI should be considered as a model for developing teacher leaders and considered for replication both within mathematics in other settings and in other content areas. Indeed, replication is already occurring in mathematics at several sites nationwide and within Vermont in science.

The recommendations below are intended for the consideration of VMP leadership in the continuous improvement of VMI, as well as for those considering replication.

Recommendations Related to the Funding of VMI

The State of Vermont, local schools and districts, and the Vermont business community should develop a diverse, sustainable revenue stream for VMI to ensure its continuation, its availability to participants from poor and rural schools and districts, and continuous research and evaluation of its success. To this end, VMI leadership should work with state government, businesses, foundations, higher education institutions, and non-profit organizations to support the following investments in VMI:

- Title 2 funds that are received by districts
- MSP funds received by the state
- Local district funds that are set aside for professional development from the general fund (local) budget
- Private business and foundation support of mathematics professional development
- Partnership funding of professional development that includes Higher Education and non-profit contributions

Recommendations Related to the VMI Program

- Mentoring
    - Continue to strongly support and enhance the mentoring and coaching components of the program
    - Evaluate the mentoring and coaching components with a ‘theory into practice’ based research design
- Statistics
    - Continue to integrate the action research content with statistics content while also exploring ways to emphasize the interrelationships among statistics and the mathematics portion of the courses
    - Track the statistics content learned through action research to content taught in classrooms as well as to action research
- Leadership
    - Reexamine current leadership strategies and engage principals and teacher leaders in determining ways to increase the consistency of principal

awareness of the VMI program and its impact on mathematics in the classroom
    - Determine ways to support teacher leaders as they transition from the classroom into leadership positions and as they continue in these critical positions over time
- Learning Community
    - Determine ways to continue support of VMI graduates as a professional learning community

Recommendations Related to Continued Study of the Vermont Mathematics Initiative

- Continue to gather longitudinal data from the State of Vermont's Assessment System. In particular, the spring 2005, 10th grade results should be added to a longitudinal analysis of grade 8 results for 2003. This will provide a first data point on students who may be matched across time and schools.
- As Vermont transitions to statewide assessment utilizing the New England Common Assessment, carefully analyze the logic and structure of the NECA and review VMI course content in relation to the Grade Level Expectations upon which this assessment is built.
- Continue qualitative analysis utilizing existing data sources and consider adding series of observations within VMI participants' classrooms to better understand what exactly is happening in those classrooms.
- Select and implement a "theory into practice" change model considering, for example, the IBM/Harvard School of Business Change Toolkit and the McREL Balanced Leadership Model.

Appendix — Validation Panel Letters and CV's

New York University
A private university in the public service

Peter D. Lax
Professor Emeritus

Courant Institute of Mathematical Sciences
251 Mercer Street
New York, NY 10012–1185

Tel. (212) 998–3232
Fax (212) 995–4121
Internet: lax@cims.nyu.edu

May 4, 2005

Professor Bud Meyers
Department of Education
University of Vermont
533 Waterman Building
Burlington, VT 05405

Dear Bud and Doug,

I read, with pleasure and interest, the revised Evaluation Report of the Vermont Mathematics Initiative, an in-service Masters Degree program directed, very broadly, at elementary school teachers in Vermont. You describe very well the situation on the ground, and how the VMI, initiated in 1999, has already made better and more effective teachers out of a substantial portion of teachers.

Your report would be of interest not only to the Vermont Department of Education, but to Departments in other states, who may wish to emulate this program.

With best regards,

Peter D Lax

Peter Lax, Professor Emeritus
Department of Mathematics
Courant Institute
New York University

117 Seminole Drive
ST SIMONS ISLAND GEORGIA
31522
TEL 912 634 4759 FAX 912 634
4759

VERMONT MATHEMATICS INITIATIVE:Validation

DATE: 20 June, 2005

TO: Bud Meyers

FROM: Bruce Joyce

Subject: The initiative and its evaluation

The Vermont Mathematics Initiative has two features that are long overdue in American Education. The focus is to prepare elementary school mathematics teacher leaders who have studied mathematics seriously over a long period of time (three years) and conducted action research on instruction. The goal – to develop such a well-prepared group for all, or nearly all, Vermont schools and have them help their colleagues who, traditionally, have very thin backgrounds in mathematics, is ambitious and appropriate. Essentially, mathematics instruction will not improve in America until its schools contain faculty members who have much greater backgrounds than has been the case for elementary school staffs in the past.

The organizers have been able to recruit teachers who contribute to the costs of their graduate education and retention in the program is very high.
Judged by the mathematics tests used by the state of Vermont, student achievement in the schools where the teacher leaders have been concentrated appears to have improved, which has particular importance given the relatively short time since the first graduates have been in service.

This is an important initiative in a vital area and is succeeding.

Cynthia A. Char, Ed.D.
147 Connor Road
Montpelier, VT 05602
(802) 224-9955

Dr, H. 'Bud' Meyers
Department of Education
University of Vermont
Burlington, VT 05405

April 5, 2005

Dear Bud,

It was a pleasure to serve as a member of your external validation panel for the Vermont Mathematics Initiative (VMI), along with Bruce Joyce and Peter Lax. I felt our panel meeting in Burlington on December 8, 2005 afforded us a good opportunity to offer our feedback on the earlier draft of your VMI Evaluation report, and that we engaged in a productive, lively exchange of ideas at that time.

Upon review of your current evaluation report, I am pleased to see that you have incorporated many of the suggestions and recommendations offered by the panel. Your report offers the reader a comprehensive description of the VMI and a thorough and interesting discussion of results yielded from your quantitative and qualitative analyses.

Best wishes on your continuing work on this important initiative in mathematics education.

Sincerely,

Cynthia A. Char, Ed.D.
Char Associates

CURRICULUM VITAE

Peter D. Lax
New York University
Courant Institute of Mathematical Sciences
251 Mercer Street
New York, N.Y.   10012

BORN: May 1, 1926
Budapest, Hungary

EDUCATION: New York University, AB 1947
New York University, Ph.D. 1949

POSITIONS

Los Alamos Scientific Laboratory 1945--46
Manhattan Project

Staff Member 1950
Los Alamos Scientific Laboratory

Assistant Professor 1951
New York University

Fulbright Lecturer in Germany 1958

Professor 1958--Present
New York University

Director 1972--80
Courant Institute of Mathematical Sciences
New York University

HONORS AND AWARDS

Lester R. Ford 1966, '73

von Neumann Lecturer, S.I.A.M. 1969

Hermann Weyl Lecturer 1972

Hedrick Lecturer 1973

Chauvenet Prize, Mathematical Association of America 1974

Norbert Wiener Prize, American Mathematical Society and Society of Industrial and Applied Mathematics 1975

Member, National Academy of Sciences of the U.S.A.

Member, American Academy of Arts and Sciences

Honorary Life Member, New York Academy of Sciences 1982

Foreign Associate, French Academy of Sciences

National Academy of Sciences

HONORS AND AWARDS (continued)

Award in Applied Mathematics and Numerical Sciences1983
National Medal of Science 1986
Wolf Prize 1987
Member, Soviet Academy of Sciences 1989
Steele Prize 1992
Member, Hungarian Academy of Sciences 1993
Member, Academia Sinica, Beijing 1993
Distinguished Teaching Award, New York University 1995
Member, Moscow Mathematical Society 1995
Abel Prize, Norwegian Academy of Science and Letters 2005

HONORARY DOCTORAL DEGREES

Kent State University 1975
University of Paris 1979
Technical University of Aachen 1988
Heriot-Watt University 1990
Tel Aviv University, 1992
University of Maryland, Baltimore 1993
Brown University 1993
Beijing University 1993
Texas A & M University 2000

PROFESSIONAL SOCIETIES

Board of Governors
Mathematical Association of America 1966--67
New York Academy of Sciences 1986--87
Member, Society of Industrial and Applied Mathematics
Vice President, American Mathematical Society 1969--71
President, American Mathematical Society 1977--80

GOVERNMENT SERVICE:

President's Committee on the National Medal of Science 1977
National Science Board 1980--86
DOE Related:
Theory Division, Advisory Committee, LANL
Senior Fellow, Los Alamos Scientific Laboratory
Review Committee, Oak Ridge National Laboratory

Cynthia A. Char, Ed.D.
147 Connor Road
Montpelier, VT 05602
(802) 224-9955
cynthiachar@earthlink.net

Education

Harvard Graduate School of Education, Ed.D., 1985, Human Development
Harvard Graduate School of Education, Ed.M. 1979, Human Development
Swarthmore College, B.A., 1977, Psychology and Linguistics

Professional Work Experience

1996-present Educational Design and Evaluation Specialist, Char Associates, Montpelier, VT
1987-1996 Senior Associate, Center for Learning, Teaching, and Technology, Education Development Center, Newton, MA.
1981- 1987 Research Scientist/Media Designer, Center for Children and Technology, Bank Street College of Education, New York, NY.
1979-1981 Researcher, Harvard Project Zero, Cambridge, MA.
Summer 1979 Research Intern, Abt Associates, Cambridge, MA.
1977-1978 Research Assistant, Center for Research on Children & Television, Harvard Graduate School of Education, Cambridge, MA.
Summer 1978 Researcher, Children's Television Workshop, New York, NY.

Selected Clients

Apple, IBM, RCA David Sarnoff Research Lab, Harvard Graduate School of Education, Dartmouth College, Boston Public Schools, Phillips Academy, Society for Automotive Engineers, COMAP (Consortium for Mathematics and Its Applications), Montshire Museum of Science, Indianapolis Children's Museum, Living on Earth, Compass Learning.

Selected Papers and Publications

Science and Mathematics Education

Char, C. (2004) *Engaging Schools in Standards-Based Mathematics: Evaluation of the Building Capacity for Change Program.* A report prepared for COMAP (Consortium for Mathematics and Its Applications), Lexington, MA.

Char, C. (2004, 2003) *Environmental Detectives: An Environmental Science Curriculum for Middle Schools, Years Two and Three Evaluations.* Two reports prepared for the Montshire Museum of Science, Norwich, VT.

Char, C. (2002) *Evaluation of "Science in the Stacks": A Museum-Library Collaboration to Create Traveling Science Exhibits for Libraries.* A report prepared for the Montshire Museum of Science, Norwich, VT.

Char, C. (1999) *Looking Back: A Retrospective Study of Dartmouth Science Alumnae (1973-1996).* A report prepared for the Women in Science Project at Dartmouth College.

Char, C. (1996) *Animal Inquiries: An Inter-disciplinary Unit for Elementary and Middle School Students: Teacher Case Studies of Student Learning.* A report prepared for the Montshire Museum of Science, Norwich, VT.

Char, C. (1991). *Computer graphic feltboards: New software approaches to children's mathematical exploration.* Technical Report 91-1, Center for Learning, Teaching and Technology, Education Development Center, Newton, MA.

Brush, L., with C. Char and G. Takata. (1980) *Encouraging Girls in Mathematics: The Problem and the Solution.* Cambridge, MA: Abt Books.

Educational Technology and Media

Char, C. & Rockman, S. (2002) *Living on Earth Ecological Literacy Project: Year Two Evaluation.* A report prepared for Living on Earth, Cambridge, MA.

Char, C., Miller, C. and Rockman, S. (2001) *Solidifying the Gains: MetroLINC Year 4 Evaluation.* A U.S. Department of Education Technology Innovation Challenge Grant.

Char, C. (1997; 1996) *Evaluation of the Electronic Mentoring Program: A Telecommunications-based Program for Women in Science, Mathematics and Engineering (Year Two; Pilot Year).* Two reports prepared for Dartmouth College.

Char, C. and Forman, G. (1994) Interactive technology and the young child: A look to the future. In Wright, Shade, and Hohman (Eds.), *Young Children: Active Learners in a Technological Age.* Washington, DC.: National Association for the Education of Young Children.

Char, C. & Hawkins, J. (1987). Helping Chart the Course: Involving Teachers in Formative Research and Design of the "Voyage of the Mimi." In R.D. Pea & K. Sheingold, *Mirrors of Minds: Patterns of Experience in Educational Computing.* Norwood, NJ: Ablex.

Char, C., Newman, D., & Tally, W. (1987). Interactive Videodiscs for Children's Learning. In R.D. Pea & K. Sheingold, *Mirrors of Minds: Patterns of Experience in Educational Computing..* Norwood, NJ: Ablex.

Sheingold, K., Hawkins, J. and Char, C. (1984) I'm the thinkist, you're the typist": The interaction of technology and the social life of classrooms. *Journal of Social Issues,* Vol. 40, No. 3, pp. 49-61.

Meringoff, L., Vibbert, M., Char, C., Fernie, D., Banker, G., & Gardner, H. (1983) How is children's learning from television distinctive? Exploiting the medium methodologically. In J. Bryant and D.R. Anderson (Eds.), *Children's understanding of television: Research on attention and comprehension.* New York: Academic Press.

Professional Development

Char, C. & Rockman, S. (2002, 2001, 2000) *Boston-Harvard Leadership Development Initiative (LDI): Evaluation (Years 2, 3 and 4)* Three reports prepared for the Office of School Partnerships, Harvard Graduate School of Education.

Char, C. (2002) *African Studies Institute Evaluation: The Educational Value and Impact of the ASI on Program Participants and Institutions.* A report prepared for the International Academic Partnership, Phillips Academy, Andover, MA.

Char, C. (2000) *A Study of the International Academic Partnership: Impact on the Faculty, Classroom Practices and Institutional Climate of Phillips Academy.* A report prepared for the International Academic Partnership, Phillips Academy, Andover, MA.

Char, C., Ellis, J., & Nelson, M. (1996) *Learning to See: Children's Inquiry in Science: Video Case Studies for Teachers' Professional Development.* Newton: Education Development Center.

Selected Software and Media Products

Gulliver's Worlds (1998, Creative Publications) Mathematics curriculum unit focusing on measurement and scale designed for middle school children. Part of the Seeing and Thinking Mathematically series.

A World In Motion (1996, Society for Automotive Engineers) Design engineering curriculum for middle school students.

Learning to See: Children's Inquiry in *Science* (1996, Heinemann Publications) Video case studies for teachers' professional development in science.

Exploring Mathematics with Manipulatives (1992, IBM) Software modules featuring pattern blocks, base ten blocks, and other mathematics manipulative environments, designed for children in kindergarten through sixth grade.

Exploring Measurement, Time and Money **-** Level I (1989, IBM) Three software modules in early mathematics designed for children in kindergarten through second grade.

Pirate's Gold, Lost at Sea, Hurricane, Rescue Mission (1983, "The Voyage of the Mimi," Sunburst). A series of simulation games featuring navigational and mathematical concepts for elementary school children.

Island Survivors (1983, "The Voyage of the Mimi," Sunburst). An ecosystems model for elementary school children.