THE VERMONT MATHEMATICS INITIATIVE

2019

Building Partnerships for Change

Today's school districts are seeking to improve teachers' mathematics understanding and instruction in ways that improve mathematics performance for all students. The Vermont Mathematics Initiative's (VMI's) expertise in mathematics, instruction and professional development offers support for long term system change to succeed in these efforts.

The Vermont Mathematics Initiative, in partnership with district leaders, institutions of higher education and state departments of education, provides schools with in-depth professional learning and success that ensures continuous growth.

This report for potential partners illustrates how a VMI collaboration benefits all students.

Prepared by Lighthouse Evaluation, LLC
5431 Martin Cove,
Bokeelia, FL 33922
www.LighthouseEvaluation.com

www.LighthouseEvaluation.com

Report developed by: *Ruth Farrell, MBA*
Douglas Harris, PhD
Herman Meyers, PhD
Stephanie Ratmeyer, MA

The team would like to thank VMI's program management, staff, faculty, partners and participants for the time and care they took responding thoughtfully to surveys, making documents available, administering pre and post assessments, cooperating with VMI course and classroom observations, and, in general, answering our questions and engaging in discussions about every aspect of the program.

All photos used by permission Depositphotos, Inc., US

Table of Contents

Purpose 1

What is VMI 2

Implementing VMI in Schools and Districts 3

Goal 1: Empowered teachers and teacher leaders 3

Goal 2: Deep content knowledge and understanding 10

Goal 3: Effective mathematics instructional practice 13

Goal 4: Action research to inform instructional decisions 18

Student Outcomes 21

Results from the first evaluation study (2004) 21

Results from the follow-up longitudinal analysis in 2005-2006 . . . 22

Results from the follow-up longitudinal analysis in 2006-2007 . . . 22

Results from the district case study in 2016 23

Results from a state-wide study in 2017 24

Conclusions and Recommendations to Districts 25

Lesson 1: Leadership development and implementation 25

Lesson 2: Deep content knowledge and understanding 25

Lesson 3: Effective mathematics instruction 26

Lesson 4: Action research to inform instructional decisions 26

References 27

". . . We chose to establish a partnership with VMI to improve our mathematics teaching and student performance because we knew that the program would provide us with strong content knowledge and a pedagogical learning system grounded in personalized inquiry learning for both teachers and students . . . VMI was not a hard sell. It has a good reputation among teachers. In our district it was a systems oriented project designed for the long haul . . . and, it worked!"

Comment from a district superintendent
– Spring 2019

Purpose

The following report provides the rationale, evidence and opportunities for school district leadership, institutions of higher education and state departments of education to consider in planning for continuous district and school improvement in mathematics education. Collaboration among these important partners will lead to higher levels of performance and the equity of student outcomes that is the birthright of every student. The Vermont Mathematics Initiative (VMI) and its partners have demonstrated that investment now in the knowledge of mathematics that teachers must have in order to successfully teach all students, coupled with enhanced teaching strategies and leadership support, will pay dividends in a few short years.

What follows summarizes both descriptive and evaluative reporting over the past several years of the implementation and outcomes of this unique professional learning program. VMI began in 1999 and has undergone formal evaluation annually since 2004.

What is VMI?

The Vermont Mathematics Initiative (VMI), is a collaborative, comprehensive, master's degree granting mathematics professional development program for elementary and secondary teachers.

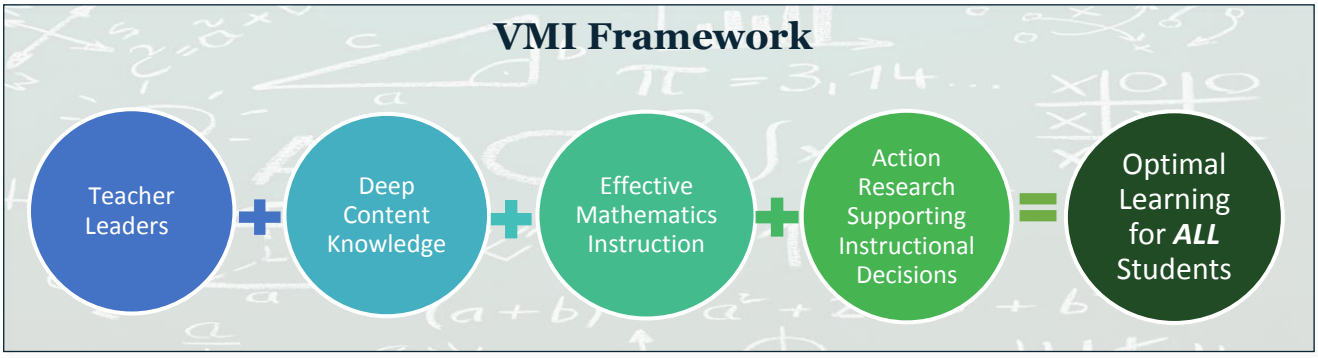
Mission of VMI

VMI's mission is to improve the teaching and learning of mathematics in all grades through collaboration with higher education, district personnel and state leadership. VMI was developed to train a cadre of elementary, middle level and secondary teachers who are deeply knowledgeable in mathematics content and can apply their knowledge to improve mathematics instruction. In turn, the teachers trained in VMI serve as mathematics resources to all teachers in their school and/or district, or work statewide in delivering professional development to their peers. The role of school and district administrators in the VMI collaboration is to create a climate conducive to improving mathematics instruction and to support ongoing professional development in the school and/or district. The outcome of investment of time and effort in a shared mission embodied in VMI's comprehensive mathematics teaching framework is optimal learning of mathematics for all students.

VMI goals

VMI is supported by four goals. Through collaborative planning, leadership training, developing required course work, supporting classroom application, and on-site mentoring by VMI staff, a shared commitment to embedded professional learning emerges that:

1. Collaborates with school and district leadership to ***empower teachers to become teacher leaders*** so that school-wide school and district implementation is sustainable,
2. Provides teachers with a ***deep content knowledge and understanding*** of mathematics,
3. Demonstrates ***effective mathematics instructional practice*** and works directly with teachers to enhance classroom teaching, and
4. Empowers teachers to ***conduct action research that informs instructional decisions*** at the classroom level and beyond.



The following narrative illustrates how, by accomplishing these four goals, the partnership between VMI and its partners succeeds in implementing a new approach to teaching mathematics and obtains higher levels of performance among teachers and students.

Implementing VMI in Schools and Districts

Long term, systemic change in the depth of content and method of learning mathematics is a process and not an event. Much has been written on the complexity of the change process. Systemic change involves many individuals, groups and stakeholders in the organizations that we call schools and school districts. Whether change occurs across organizations, integrated among students, teachers, parents, administrators and specialists, or is initiated with one group and remains confined to that group, depends upon how the change is supported. Most schools and districts have experienced the initiation of an innovation that has slowed and disappeared after a short period of time. VMI not only works closely with school and district leadership during implementation, but also enables the teachers it works with to become leaders within their own districts so that changes in mathematical instruction will be broad and sustainable.

Goal 1: Empowered teachers and teacher leaders

The school implementation component of VMI was developed to assist teachers in transferring their deepened understanding of mathematics to the work they do in their classrooms and the work they do as leaders within their school or district. This aspect of VMI is comprehensive, is based in the teacher's content knowledge, and ties together the four VMI goal areas of leadership, mathematics content, results of classroom practice, and action research.

Overview

Recently, efforts to initiate and sustain change in school policy and practice are expressed through research associated with "Implementation Science." The VMI model for school and district implementation is consistent with emerging Implementation Science research as described by Duda and Wilson (2015) and Penuel et al (2011). The process of implementing a systemic professional learning program that can achieve sustainability:

- Provides a "usable intervention" (the VMI curriculum),
- Identifies "implementation teams" of teachers, teacher leaders, principals, curriculum coordinators and superintendents,
- Structures the professional learning systematically with the process of delivering the courses according to the principles of process identified above,
- Occurs during a time-frame that ensures the development of teacher competence and fidelity to the curriculum on a three-year cycle,
- Creates a culture of trial and learning (including coaching) that enables teachers to adopt and adapt mathematics content and teaching methods from theory into practice. (Duda & Wilson, (1) p. 16)

VMI's implementation process allows for and supports four stages of implementation identified by Duda and Wilson (2018, p. 15):

(1) Exploration of the range of mathematics knowledge and pedagogy needed for successful teaching,
(2) Installation of the lead personnel, resources and action planning for school-wide implementation,

(3) Initial implementation of the first cohort of lead teachers' instruction and coaching for the first year of courses, developing support systems and culture, and
(4) Full implementation of new mathematics content and pedagogy, inquiry methods of teaching and assessment of fidelity.

Evidence indicating that VMI can be successfully implemented through the development of teacher leadership on a school and district-wide basis has been gathered through interviews, surveys and focus groups with teachers and administrators since VMI began as part of VMI's annual evaluations.

A Closer Look

One collaborating district recently became the focus of a more intensive evaluation case study. The case study, conducted by Lighthouse Evaluation, LLC, covering the years 2010 through 2016 provided a systemic view from participants of the benefits of VMI implementation and lessons learned.

The following closer look at VMI's attention to district and teacher leadership, drawn from the case study, shows how one district engaged in a district-wide process to change the ways that teachers and students learn mathematics.

In 2010 a new curriculum director, who went on to lead the district as superintendent in 2013, arrived (referred to as district leader throughout the study). In July, 2010 she made two key observations: 1) the district educators - principals and teachers - worked in isolated schools and classrooms rather than as a collaborative learning community, and 2) the main academic focus was literacy – such that only limited resources were invested in mathematics. A principal who came to the district shortly after the district leader was also stuck by the emphasis on literacy. Right from the start the district leader began to lay the foundation for giving mathematics equal status with literacy.

> *"I was amazed at how uncomfortable we were with math, and how comfortable everybody was with literacy, to the point of saying, like literacy is more important than math."*
>
> Principal interview

Many students were not proficient in mathematics. Time for math instruction was generally limited to only 30-45 minutes per day. Professional development for mathematics consisted primarily of Vermont Portfolio Network trainings and/or coaching on use of published mathematics materials such as *Investigations* or *Everyday Math*. Each school, and sometimes teachers within each school, had different access to mathematics specialists or consultants. A few isolated teachers had graduated from VMI, but were not serving in leadership roles. To effect system-wide change, the district leader leveraged available resources, including the VMI graduates, other non-VMI trained mathematics teachers with potential capacity for teacher leadership, teacher interest in mathematics professional development, Consolidated Federal Funds, and a strong relationship with the VMI Director to target professional learning at four levels:

- Principals (Administrative Team)
- Math Leadership Team
- All Mathematics Teachers
- Math Coaches/Interventionists

What follows is a description of actions taken in the district at each of the four levels. The work at each level was distinct, yet closely coordinated and aligned to work in the other levels. Interwoven at each level was support from VMI in the form of direct leadership consulting, direct work with classroom teachers and professional learning groups, courses offered in the district, and the district teachers as enrollees in the VMI master's degree program.

The Administrative Team (principals)

During the 2010-2011 academic year, principals met regularly with the district leader for collaborative professional development and strategic planning. The district leader facilitated sessions on comprehensive assessment and the team read *Unmistakable Impact* by Jim Knight (Corwin, 2011). Bringing these two strands of their collective learning together, the Administrative Team decided to use Knight's "one-page plan" strategy to craft a district-wide professional development plan for the following year focused on formative assessment based on data collected at the August in-service. The plan was implemented beginning at the August 2011 district in-service and continued throughout the year in school-based Professional Learning Communities (PLCs).

The following year, in 2011 – 2012, the Administrative Team's focus shifted to instructional leadership to support not only the PLCs, but also math teacher leaders who were just beginning to assume new roles in each of the district schools. During this year the principals participated with teacher teams from their schools in workshops on the new Common Core State Standards (CCSS) for Mathematics and English Language Arts at Lyndon State College. The mathematics sessions were led by VMI staff members who worked with the district school teams to plan for CCSS implementation at their sites.

> *". . . the theory of action is really the nucleus of it. There is nothing that has been dictated . . . she [district leader] has made us think. She has made us talk. She has made us have hard conversations and made us celebrate and brainstorm. She continually . . . facilitates that.*
>
> Principal interview

The Administrative Team's focus on instructional leadership continued in the following years, and included ongoing CCSS implementation. Central to the Administrative Team's work in this period was creating and using a theory of action for improving teaching and learning in the district. This was an important step in the process of learning how to work together across schools – to develop a common language and shared values. As they were developing their theory of action, discussion centered on collaboration and its importance. Ultimately, the team agreed that learning is social, and if every member of the community takes responsibility for their own learning and the growth of others, then students will be engaged and perform successfully.

This theory of action helped to guide development of a new teacher growth model, and was foundational to later work on a new comprehensive assessment system and a new K-6 standard's based report card.

Math Leadership Team

Parallel to the Administrative Team, in 2010 the district leader convened a Math Leadership Team to, in her words, "cultivate teacher leadership, to develop a learning community, to create a common vision for math, and to shine a spotlight on mathematics in the supervisory union." One result of the relative isolation of teachers and schools was a limited sense of shared responsibility for student learning, and a tendency to attribute low student achievement to the failures of teachers in previous grade levels or other schools to cover material or get students to learn. For the district leader, a primary goal for the Math Leadership Team in the first year was to "break down the silos between schools and stop the blame game."

The Math Leadership Team consisted of VMI graduates and those who were enrolled in the VMI graduate program (6 elementary and middle level teachers), high school and career center math teachers (3 teachers), other teachers interested in math (4 teachers), and the district leader. Every school in the district was represented. The team met monthly after school, and for four half-day sessions facilitated by the VMI Director. Costs for substitute teachers and professional development were covered with Consolidated Federal Programs funds. These sessions served to help team members develop a shared vision for mathematics teaching and learning across the district.

Establishing this team was another step in creating a culture of systemic collaboration for continual improvement of mathematics teaching and learning. Team meetings were designed as professional learning sessions, which included reading sections of *Adding it Up: Helping Children Learn Mathematics* (National Academies Press, 2001). Based on their collective learning, the team developed a district math mission statement, defined math proficiencies, and agreed to work toward implementation of shared strategies for mathematics instruction.

The first ever district-wide in-service in August 2010, focused on the Formative Assessment Process (FAP), was also intentionally designed as a foundation for professional collaboration among all educators in the supervisory union. Teachers got to know each other while engaging in discussion designed to identify assessment practices used across the curriculum. The main outcome of those discussions – consensus that there was little common language around assessment – informed the Administrative Team's decision to focus the 2011-2012 district professional development on comprehensive assessment. All teachers participated in the August 2011 in-service FAP training and follow-up school-based FAP PLCs. Consolidated Federal Program funds were available to cover the cost of substitute teachers on the district's PLC days. They were also used to support high school teachers' time to develop new instructional units using *Universal Backward Design* (Wiggins and McTigue, 2011).

All mathematics teachers

With the Administrative Team and Math Leadership Teams in place, and PLCs established at each school, efforts to "break down silos" and bring mathematics back into the conversation were extended to include all mathematics teachers in the district. After the initial two years of more general learning about assessment, the district in-services included opportunities for math teachers to explore instructional strategies specific to mathematics, the CCSS mathematics practice standards, and math intervention for struggling students. Beginning in 2013 – 2014, grade level teachers K-6th met in the district-wide PLCs monthly for half-days to work on understanding and implementing the CCSS for mathematics (and also for English language arts). In 2015 – 2016, the PLC meeting schedule switched to four full days each year, and included work with the Next Generation Science Standards. Sessions were facilitated either by the district leader or by members of the Math Leadership Team. Each grade level team included a teacher either enrolled in or who had graduated from VMI, and when not leading the sessions, these individuals were often looked to as local "experts" for their deeper understanding of math content and exposure to research on how students learn that content. The opportunity for regularly scheduled professional dialogue and availability of trusted teacher leaders encouraged even reluctant teachers to try new teaching approaches and these PLC's were often a space for feedback and reflection.

> *. . . these meetings are planned. They have a focus. They have a purpose. I think that productivity in these collaborative meetings, the way they are set up now with a strong focus are a lot more . . .definitely the productivity is much higher.*
>
> Teacher focus group

During focus groups for this case study, the vast majority of teachers talked about the importance of collaboration across the district. In-services, school-based PLCs, and the district-wide PLCs represented more than just an increased number of opportunities for teachers to collaborate. They were qualitatively different from the district gatherings prior to 2010, which had been primarily "…just more of a get the teachers together to discuss what's happening in everybody's schools but … not looking forward as to what the group can do together to improve instruction" (teacher focus group). In describing the district-wide PLCs, teachers said the meetings were useful because they were part of a long-term coordinated effort to help teachers deepen their knowledge of the standards and change their classroom practice. Some teachers described the great care given to planning and facilitation of the PLC meetings, which were much more productive than any previous district professional development.

> *The value I found here was talking to other colleagues. And I do like the fact that we went through the Common Core together because I think many times my interpretation is very different than others, so if you hear it from 2-3 others the same way, you sort of think in your head, OK, maybe I better think that way too.*
>
> Teacher focus group

Implicitly referring back to the district's Theory of Action – that learning is social – some teachers emphasized the value of talking through the CCSS for mathematics as a way to deepen their understanding for instruction and assessment.

Collaboration for mathematics teaching and learning was a powerful force in the district. It was a vehicle for leveraging the expertise of VMI graduates to help all mathematics teachers discover why change was important and understand how to adjust their classroom practice. And it was a safe place for teachers to ask questions, share concerns, grapple with uncertainly, and be affirmed in their efforts to grow professionally. Sustainability of district wide effort and processes of integration of curriculum across the grades were supported by the development of a cadre of teacher leaders with a common language with which to communicate about mathematics and its teaching.

Math coaches/interventionists

To ensure that all classroom teachers had access to school-based embedded mathematics professional development with trained math teacher leaders, the district leader actively recruited math teachers in district schools to participate in VMI, and committed to the supervisory union covering the cost of all but one course in the three-year master's degree program. Despite some staff turnover, by 2014-2015, each school had at least one VMI graduate or participant serving in a teacher leadership capacity. There was some overlap between these leaders and the Math Leadership Team described earlier. Some of these teacher leaders were classroom teachers and some were released from the classroom to serve as math coaches or interventionists. In 2011, the elementary level math teacher leaders began to meet monthly, and several began training with the district leader in the *Math Recovery Intervention Program*. In 2013, two elementary level math teacher leaders began implementing the *Primary Number and Operations Assessment* (PNOA) as part of their action research for the VMI master's degree program, and in subsequent years trained other teachers to administer and use data from this assessment.

VMI's role in developing the district's mathematics teacher leadership

As part of the process of empowering teachers to lead their peers, VMI graduates in the district talked about how the VMI program first helped them to be more effective leaders in their own classrooms. Theses graduates developed a deep understanding of learning progressions and connections within and across mathematical areas, along with ways to translate that knowledge to student learning.

> *It has really opened up my eyes to more efficient and successful ways of teaching kids to help them feel…to help them succeed.*
>
> VMI graduate and math teacher leader

Over the three-year program, VMI enrollees were required to take increasingly complex teacher leadership roles in their schools. For example, in order to better understand mathematics teaching and learning across their schools, they asked questions of existing

local data and presented their findings and conclusions to local stakeholders – peer teachers, school administrators, and sometimes even a school board. The required action research project also typically involved engaging peer teachers in closely studying some aspect of mathematics instruction. Through such projects, VMI supported its enrollees to understand the importance of a coherent system to support student learning of mathematics, to envision improvements in their own school system, and understand how to participate in leadership for change.

> *And one of the changes I have seen through this collaboration is I have other colleagues in other schools that I know. So, we work together to teach courses. We can communicate with other teachers at different grade levels. Like, if I know somebody from 1st grade in my building, we can communicate with a 1st grade teacher in another building. I'm not working with just one grade level. I'm seeing the continuum and know people in every building from my years of experience in the SU, working through VMI and other courses that have been offered here. I have built a network that has helped me to help this group.*
>
> VMI graduate and math teacher leader

Math teacher leaders also talked about the importance of meeting regularly and working with other math leaders in the district. They supported each other with resources and worked together to meet different local challenges.

Math teacher leaders played a key role in the district's efforts to increase student opportunity to learn mathematics. With the foundation of knowledge and skill gained through participation in VMI, this group directly supported other math teachers in their own schools and also served on the district Math Leadership Team, working with the district leader to build and facilitate the district-wide professional collaboration.

By leveraging its partnership with VMI to help teachers understand why change was desirable, envision new instructional approaches, develop confidence in its ability to enact change, and experience deep conceptual learning, the district has been able to elevate the status of mathematics to one approaching that of English language arts in the curriculum and has been able to systematically build a culture for professional collaboration aimed at improving classroom practice.

> *Everything working together has made the difference. So there is the VMI, lots of different things, the different math coaches who come into my classroom a couple of times a week now, and the collaboration, which is most important . . .*
>
> Teacher during focus group

Goal 2: Deep content knowledge and understanding

The emphasis on mathematics content infuses all aspects of VMI and enables VMI to bring high-level mathematics and the classroom application of that mathematics together in way that is empowering and transformative.

Overview

Strong mathematics content knowledge is the foundation of VMI. VMI has four foundational underpinnings:

1. Treat teachers well and with great respect.
2. Engage teachers as adults with their own intellectual needs.
3. Teach 'serious mathematics.'
4. Embed problem solving and inquiry as a primary method of learning

The term 'serious mathematics' implies that the extent of mathematical content and the depth and level of its presentation are not limited by immediate classroom needs. For if a teacher at any level, in any setting, and in any discipline is to be effective in transmitting knowledge, the teacher must know far more of the disciplinary content than is taught to students. In brief, mathematics content knowledge is at the heart of VMI, mathematics content pervades all aspect of VMI, and the program's overarching philosophy can be summarized by the adage "competence leads to confidence."

In the VMI approach to mathematics professional development, VMI participants begin to view themselves as mathematicians, to view mathematics as part of their lives, and to see the world around them in a mathematical light. These transformations take place through a curriculum that is rich in mathematics content, and the impact in the VMI teachers' classrooms and schools is far-reaching. As teachers feel more comfortable with mathematics, they are more able to effectively communicate their knowledge and convey their enthusiasm to their students and other teachers.

A Closer Look

Curriculum

Few professional learning programs provide the scope and sequence needed to provide a teaching workforce with the necessary depth and repertoire to support the levels of instruction needed by today's science, technology, engineering and mathematics programs. The following description of the VMI curriculum appeared in a 2006 VMI Evaluation report. Although courses since the 2006 evaluation have undergone revision and updating, including adapting content to the needs of middle and high school teachers, the scope and sequence of the program remains essentially as it was designed in that year. Of VMI's twelve-course sequence, eight courses are content mathematics courses and three courses (entitled *Statistics, Action Research, and Inquiry into Effective Practice I*, *II*, and *III*) develop statistics in relation to the teacher as researcher in her/his classroom and school. The twelfth and final course in the curriculum,

The *VMI Capstone Experience*, is designed to help teachers synthesize their work in all four areas of VMI – course work, classroom practice, leadership, and research. Each course adds value to the teacher's repertoire. By completing the entire sequence of courses teachers build the depth of knowledge needed to provide the foundation for supporting a district's mathematics education program across all grade levels and topics.

The VMI mathematics courses

Eight courses provide the basis for learning mathematics:

1. *Mathematics as a Second Language* (summer Year 1)
2. *Functions and Algebra for Elementary Teachers* (summer Year 1)
3. *Trigonometry for Elementary Teachers, and Algebra and Geometry II* (fall Year 1)
4. *Measurement, Geometry, and Probability for Elementary Teachers* (spring Year 1)
5. *Number Theory for Elementary Teachers* (summer Year 2)
6. *Algebra and Geometry for Elementary Teachers III: Exponential Growth and Decay* (spring Year 2)
7. *Calculus for Elementary Teachers I* (summer Year 3)
8. *Calculus for Elementary Teachers II* (fall Year 3)

These courses form a sequential mathematics curriculum that takes teachers from a deep understanding of arithmetic to the ideas of calculus. Each course leads seamlessly into the next, each course clearly conveys the connectedness of mathematics. Much of each course day is devoted to problem solving, and each course reinforces the learning that has taken place in preceding courses. Described below in more detail are the signature courses *Mathematics as a Second Language*, *Calculus for Elementary Teachers* and *Statistics, Action Research, and Inquiry into Effective Practice*.

Mathematics as a Second Language

The purpose of this course is to transform the teacher into a mathematical thinker who sees mathematics in the world around her/him, is excited to be a mathematical learner, and has a love of mathematics. As the first course in VMI, it is foundational for all that follows, and it can be regarded as VMI's 'signature' course. The course is taught in an intensive mode, teachers are immersed in mathematics, and teachers and instructors bond together as a community of learners.

Calculus for Elementary Teachers

Calculus is directly linked to arithmetic and it is, therefore, critical for elementary teachers to know the fundamental concepts of calculus and vividly conveys why their students should have a solid understanding of and fluent procedural capability in arithmetic. The course emphasizes connections with the K-6 curriculum, and to arithmetic in particular.

Statistics, Action Research, and Inquiry into Effective Practice

Statistics Action Research and Inquiry into Effective Practice is a sequence of three related courses that integrate the basic concepts of descriptive and inferential statistics with school-based research projects

initiated and completed by VMI participants. Although this sequence of courses also develops material that is part of the K-6 mathematics curriculum and fosters deeper understanding of mathematics, these courses differ from the other mathematics courses in that they also provide a unique opportunity for participants to apply quantitative critical analysis to real situations in their schools.

There are three strands that run through this sequence of courses:

- A deeper understanding of the basic concepts of statistics as they appear in the K-6 mathematics curriculum,
- An ability to read critically and respond to research articles both in the education literature and in the popular press, and
- An ability to interpret statistics that are used in school assessment, so that teachers can see both the value in such assessments and their potential misuse.

At several points in their VMI experience, teachers are asked to identify problematic areas in their classes or schools that they would like to investigate. The task of describing such a problem and deciding how one might measure the success or failure of an attempt to improve the situation draws naturally and directly on the tools acquired in their statistics courses. This is a fundamentally distinct kind of problem solving, one in which the participant herself/himself defines the problem, attempts an intervention and then has to deal with the messiness of real data. This is in sharp contrast to a typical mathematics problem in which the parameters are explicit and there are no issues of the inherent variability of human response.

Pre and post assessment of teacher learning of mathematics content

Since VMI began, a series of pre and post assessments developed by project instructors was used routinely to determine the effect of the courses on teacher content knowledge. Assessments were administered on the first class meeting and at the final class meeting. All pre and post tests were assessed for reliability with Cronbach's alpha coefficient and statistical analyses were used to examine the difference/gain from pre-test to post-tests. Results showed that VMI courses significantly increased the mathematics content knowledge of nearly all participant teachers in each area of concentration.

What teachers say about learning mathematics content

In a January 2018 online survey of teachers at the mid-point of the program, conducted by Lighthouse Evaluation, all respondents reported that participation in VMI deepened their understanding of mathematics, with over 80% reporting that it "very much" deepened their understanding. Most respondents also reported believing "very much" that changes in their understanding of mathematics have influenced their ability to help students meet or exceed mathematics learning standards.

Each year, as part of VMI's annual evaluations, teachers were asked about the extent to which they felt that they had actually learned the mathematics they were taught. Participants used 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.

Each VMI teacher is required to create a portfolio that chronicles his/her learning across all three years of the program. In a telling example from one portfolio, a teacher described the moment when she "gained understanding of where I stopped understanding math." She described herself as "unstuck" and related her plans to continue her study of mathematics.

Teachers and administrators identified this renewed enthusiasm and increased confidence with having profound impact in the classroom. Teachers discussed confidence in two different ways. First, they stated that their increased knowledge and understanding of mathematics content increased their confidence as a teacher, both of mathematics and in general. Secondly, they reported that their increased confidence had 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.

Examples of deeper content knowledge can be observed across VMI activities. For example, in a sample observation of a graduating cohort of teachers in 2015, oral presentations included:

- An elementary teacher showing high school teachers in her district how to model arithmetic through the lens of geometry, and how to derive algorithms from models
- Another teacher constructing box plots to make senses of student achievement results on the New England Common Assessment Program and sharing the information with school colleagues.

Goal 3: Effective mathematics instructional practice

The teaching process model for teachers to learn the VMI curriculum is the same inquiry based model of teaching that teachers are expected to emphasize in their own teaching. Ideally, the application of content and principles of instruction should be seamlessly consistent from professional learning to the application of content and methods in teachers' classrooms.

Overview

Achieving high levels of mathematical knowledge and a repertoire of teaching pedagogy depends upon a professional development program design that is both flexible and effective. All VMI courses contain a support system that enables professionals who may be encountering this content for the first time to be successful adult learners of advanced mathematics. Few professional learning programs provide the care of process and depth of content that VMI has demonstrated.

The constructivist approach used in VMI courses is designed not only to support participant learning of mathematics content, but also to model research-based instructional practices. Throughout the courses, instructors and facilitators explicitly point out the instructional strategies they are using, or ask participants to reflect on how the instructional activities in the courses affected what they ultimately learned. Teaching and Learning Sessions, interspersed throughout the three years of the VMI program, are explicitly designed to introduce participants to research on pedagogy and include the following big ideas: content-based formative assessment; unifying mathematical themes – progressions central to particular grade spans; and mathematics learning through problem solving.

To help enrollees believe in their ability to change how they teach mathematics – implement a constructivist approach that engages students in rigorous problem solving and deep conceptual understanding – and to provide individualized support, the VMI master's degree program also provides each teacher with two years of classroom mentoring.

A Closer Look

Lighthouse Evaluation has observed VMI courses annually for several years and these observations have consistently shown attention to modeling new instructional strategies. To cite one example, an observation session from 2016 of *Math as a Second Language,* the first course in the Master's degree, showed the following: The class went on a "gallery walk" in which small groups of participants presented posters with their own proofs of the Pythagorean Theorem. Enrollees were surprised by the variety of approaches taken to address this challenge. During the debrief of this learning process, they talked about the power of working in groups to discuss the problem, the value of having a challenge with time limits, the importance of clues – but not solutions – from instructors or facilitators, and the conceptual understanding some gained from using manipulatives.

The critical support provided by VMI's classroom mentoring was presented in the 2016 Lighthouse Evaluation case study discussed earlier. The district leader requested that all the district teachers enrolled in VMI have the support of the same VMI mentor for consistency across schools. This mentor's skill at building strong working relationships with teachers and her knowledge of mathematics teaching and learning convinced the district leader to contract with her to work several additional days each month supporting other math teachers in their classrooms. As a consultant, this VMI mentor also worked with school and the district PLCs on mathematics curriculum and assessment.

> *She has a good working relationship with my teachers. She's been working with them for a while, and the way she gets them to think without telling them what to do is exactly what a coach is supposed to do. So, she is able to go into a lesson study model with them and never be prescriptive or put them on the defensive, but still get them thinking. I can see changes in the weeks after [VMI consultant] works with a team. Those conversations persist long after [she] has gone . . .*
>
> A district school principal

> *I mean, we had a math consultant before, and we felt like we had a lot pushed on us…. [This VMI consultant] just comes in and sits down and will start questioning the kids and it is just a nice addition when she comes in. And you can just hear, listening to the questions she is asking that student - just totally you hear and it's like "I never thought of that!"*
>
> VMI graduate interview

Most of the teachers who worked with the VMI mentor appreciated that she is not prescriptive, and commented on how much they learned by simply watching her work with their students.

Annual surveys of teachers in the VMI program highlighted the effectiveness of the VMI approach that combines modeling new instructional strategies with mentoring teachers in their classrooms as they begin to implement these strategies. For example, in response to a question on the January 2018 online survey all respondents reported increased awareness of a range of strategies for mathematics instruction, and all indicated that participation in VMI changed the strategies they use in their own instruction. Respondents reported implementing use of models, asking students to share problem-solving strategies, using formative and

summative assessments and allowing students at least "somewhat" to investigate concepts prior to any direct instruction. Other reported changes include shifts away from focus on procedures toward conceptual understanding, more open-ended questioning, less teacher talk and more student talk, more time for student inquiry and questions, and more use of manipulatives for modeling.

Mathematics education researchers point to two critical instructional shifts to improve student mathematics learning; both are integral to VMI and were evident in the interviews for the Lighthouse Evaluation 2016 case study: *active learning* and opportunities for *creative engagement with relevant problems* (Boaler, 2015; Leinwand, 2012). Most who participated in interviews and focus groups reported changes in classroom practice that represent shifting to these two instructional dimensions.

Active learning

During the 2016 Lighthouse Evaluation case study, teachers reported that they and their students were much more actively engaged with important math concepts and far less reliant on scripts from teacher manuals or student workbooks. As a result of professional development through VMI courses and coaching, the grade level PLCs, and support from their school-based teacher leaders, mathematics teachers expressed increased confidence in their understanding of mathematics content, the Common Core standards for mathematics, and their ability to facilitate student learning.

> *Definitely less scripted. I have the confidence to say, OK, we are going to just have that concept, and even if we didn't have the teacher manual, be able to think about it and present it in a meaningful way*.
>
> Teacher focus group

Teachers reported being more likely to gauge student understanding before, during, and after a lesson, and adjusting plans accordingly. Such "testing" took many forms, including informal questioning, student reflection on their own confidence of their understanding, formal pre-post lesson unit testing, and lesson "exit tickets."

> *. . . I find I just do more testing of kids to see where they are starting from and where I need to guide them. So, you may not have two or three weeks of lessons planned out. You're kind of going every few days and adjusting to meet the needs of the child.*
>
> Teacher Focus Group

Teachers also described how their roles have shifted in relation to students. One teacher talked about "guiding" her students. This is fundamentally different from "telling" her students what they need to know. Most teachers described ways in which they were creating more opportunities for their students to engage with mathematical problems and build conceptual understanding. Many of the elementary level teachers report using a workshop model rather than relying on a textbook.

Increased student collaboration and sharing out of student work, either in pairs, small groups, or presenting to the full class was another change teachers reported. As teachers experienced the power of collaboration themselves, they were more able to operationalize the district's Theory of Action – that learning is social – in their own classrooms. There was growing recognition that students need to talk about the mathematics – the problems they are trying to solve, the strategies they are applying, connections they see between the current problem and other problems on which they have worked.

> *Lots of questioning students, and I don't ask for the answer right away. I'm like, "don't tell me the answer! How did you start to solve the problem? What were you doing in your head to figure this out?" Those kinds of questions to get at their process, so peers can teach peers strategies, things like that. Lots of student work being shared.*
>
> Teacher focus group

Creative engagement with relevant problems

As teachers began to move away from traditional direct instruction, some were also changing their approach to problem-solving. Prior to the partnership, problem-solving was frequently understood as specific procedures – often associated with Vermont Portfolio problems. Problems students were asked to solve were described by teachers as disconnected from students' real life experiences. As one teacher put it, "We were doing a lot of problem-solving and I felt it was very cookie cutter language for them to learn vs. real learning."

The new instructional approach to problem solving often still involved the teacher posing a problem for students. However, instead of walking students through a step-by-step procedure, teachers offered them a variety of resources for developing solution strategies.

> *We are still solving problems within our little station times. But before, it was you did the whole lesson. You guided them with your white board and sent them back to their seats to solve that problem only with paper and pencil, or for those who drew pictures. But now they have their tubs with all their different manipulatives and they are doing it differently. They are still problem solving.*
>
> Teacher focus group

Over the past several years Lighthouse Evaluation engaged in classroom observations each year to explore the degree to which the program impacted instruction and assessment practices in classrooms of participating teachers. The observations used 14 indicators of effective teaching practice from the Math/Science version of the Diagnostic Classroom Observation Tool (DCO) developed by Nicole Saginor (Corwin Press, 2008). DCO was initially developed at The Vermont Institutes and subsequently validated by that organization, Mathematica, Inc. and the Northwest Regional Labs in 2006-2007. In 2014 it was slightly modified by Core Research and Evaluation to align with the Common Core State Standards for Mathematics. Each indicator is rated on a scale of 1 to 5 (no evidence to extensive evidence).

The charts below illustrate the changes in teaching practice observed over four time points for a sample of VMI enrollees. As illustrated in Chart 1 (Implementation Indicators) and Chart 2 (Content Indicators), the observed teachers shifted from below consistent evidence toward consistent evidence on all DCO indicators of effective teaching practices.

Figure 1: Teachers shift to consistently using best implementation practices in their classrooms.

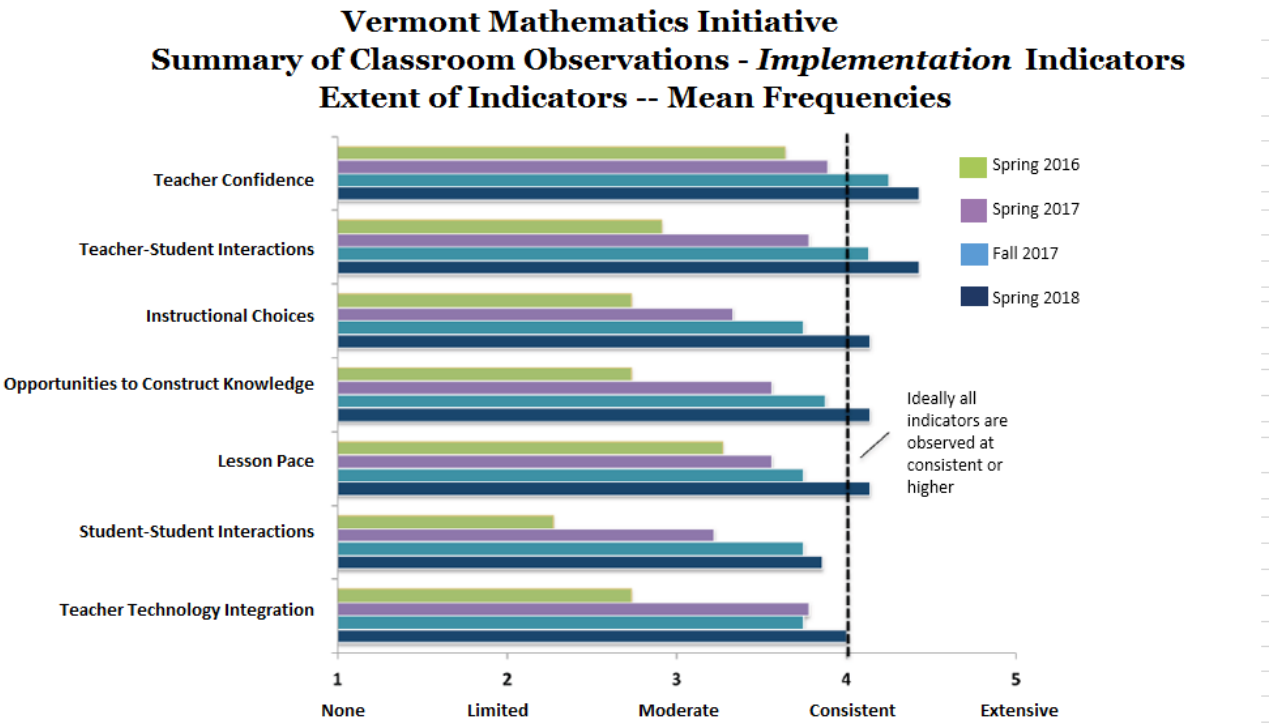
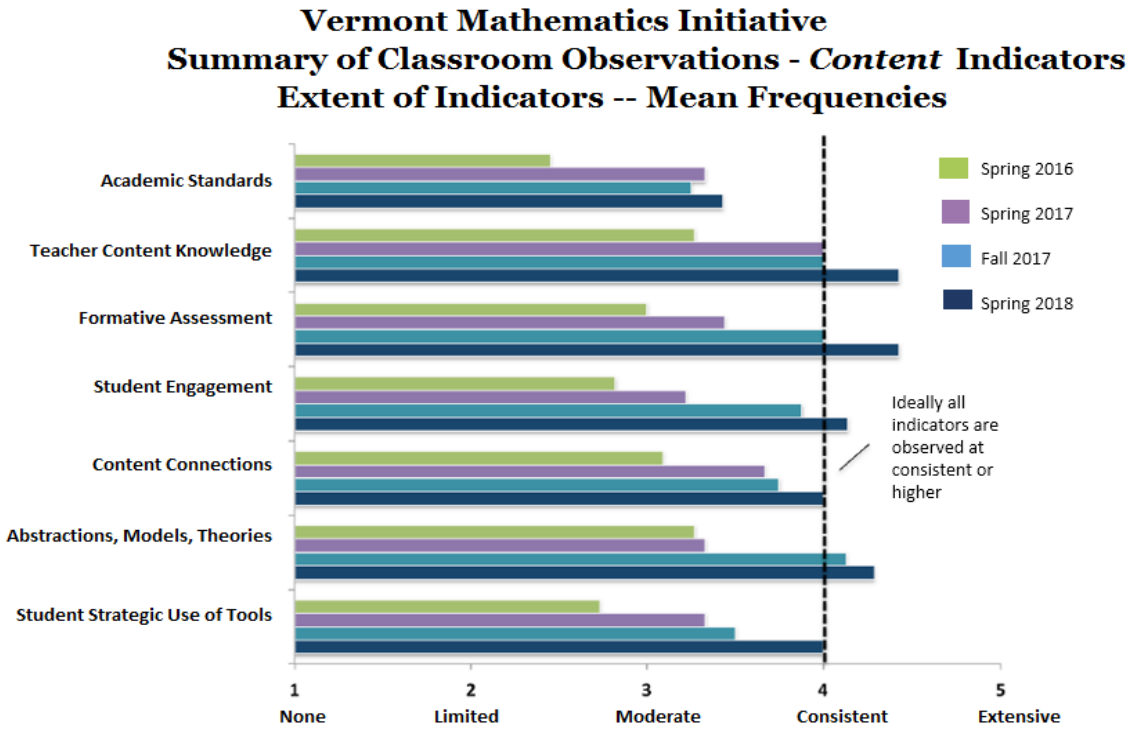


Figure 2: Teachers shift to consistently using best practices related to content.



Goal 4: Action research to inform instructional decisions

Action research designed to investigate the impact of the VMI model of teaching mathematics has been a constant companion to the program from its beginning.

Overview

Action research is the methodology by which teachers can evaluate, adjust and validate the results of instruction for *ALL* students. All VMI participants create and carry out an action research project, developing the skills to identify questions about their professional practice and then designing and conducting quantitative and qualitative action research studies in their own schools. For most participants, action research in VMI is their first research project at this scale. VMI courses, projects, and mentoring are all focused on helping teachers to better support *ALL* students to succeed in mathematics. In the process of conducting action research, participants begin to explicitly explore equity and excellence in their own teaching contexts.

The final semester *Capstone* course concludes this school-based-research component and it is in this course that VMI enrollees focus on the completion of their action research projects. It is the culmination of work begun in *Statistics, Action Research, and Effective Inquiry I*, and continued in the second and third courses in this strand. Teachers synthesize their coursework and field experiences and revisit key mathematical concepts from arithmetic through calculus. They focus on a specific action research topic, usually one that lends itself to statistical analysis. Key topics include research design, hypothesis development and testing, identification of control group(s), threats to internal and external validity, drawing conclusions, and identifying alternative explanations. In addition to providing a comprehensive written treatment of their action research project, each participant is responsible for an oral presentation to the VMI academic community. Fellow participants, VMI instructors, program evaluators, and UVM faculty, students, and staff are welcome to attend. Action research is also shared at the annual VMI Symposium.

A Closer Look

Results from a typical action research case study

The following study was drawn from a compendium of action research studies compiled by VMI over the past ten years. It was chosen from over 100 studies to illustrate both the quality of VMI's action research projects and the typical outcomes obtained by VMI enrolled teachers from their students.

Action Research Project: *Direct Instruction of Mathematical Discourse*

Evaluation Question:

Does direct instruction of mathematical discourse have an effect on students' mathematical achievement?

Study Design:

To answer the research question, (the author) used a quantitative comparative pre-post control group study to measure types of student discourse and student achievement in mathematics. This design created experimental treatment and control groups. The author included qualitative data using video of classroom discourse to enhance and support the quantitative data gathered from the measures of the study.

N of Students:

39

Literature Basis:

During this study (the author) explicitly modeled research-based classroom strategies for promoting and developing high quality, productive talk during math class. This was achieved using two ideas: (First,) Edwards and Mercer (1987), who described two kinds of instructional scaffolding: analytic and social. Analytic scaffolding is "the scaffolding of mathematical ideas which is intended to support students' learning of mathematical content during classroom interactions" (Williams & Baxter, 1996, p.24). Social scaffolding is the scaffolding of norms for social behavior and expectations regarding discourse. This facilitates the students' participation in discourse. (Second,) the scaffolding was paired with direct teaching of "talk moves," (Chapin, O'Connor, Anderson, 2013) which are research based ways to lead classroom discussions that support students' mathematics learning and promote their ability to think, reason, and solve problems. There are five important talk moves

Outcome Measures:

OGAP Pre-Post Multiplicative reasoning assessment (Multiplication Progression Score). (The author) compared analytic and social discourse within his 4th grade classroom the Treatment Group, and the analytic and social discourse in a control classroom of 4th grade math students within my school to see what effect discourse had on mathematical achievement. Between the OGAP pre and post assessments, three, ten minute video samples of math classroom discussions were gathered from each group to code and analyze the types of discourse that occurred in the two classrooms. The coding was done using the Video Coding Scale. Discourse was coded by gathering occurrences of social and analytic talk, looking closely at the direction of discourse, between teacher-to-student, teacher-to-class, student-to-teacher, and student-to-student. Discourse instances were tallied for both treatment and control classrooms.

Action Research Project: *Direct Instruction of Mathematical Discourse (Cont'd.)*

Intervention:

The treatment classroom received direct instruction around the usage of talk moves (Re-voicing, Repeating, Reasoning, Adding on, and Wait time) and the control group did not. Math class for the treatment group featured daily review problems followed by a whole class mini-lesson. Students then worked on their own for a few minutes before engaging partners and triads of peers. A whole class debrief closed the math session. An underlying component to the class time was student discourse where all students were encouraged to engage in discourse with peers and with the class as a whole. The class attempted to model the "You-We-I-You" style of instruction modeled throughout the Vermont Mathematics Initiative (VMI) curriculum. The control classroom experienced the typical Investigations approach to teaching: the teacher led the lesson, students listened, and then practiced the lesson using pages from the math text. Typical math lessons in the control classroom began with a single math computation review problem. This was solved and followed by a teacher lead lesson. Using the IRE model, lessons and discourse were channeled through the classroom teacher. Students attended to the teacher lesson and followed the instruction and teacher demonstration. Students then worked on examples at their seats. A whole class check-in of the work culminated each lesson. One day a week the classroom practice was altered by the infusion of guided math groups. The classroom teacher was joined by the Math Coordinator, a parent volunteer, an Academic Support tutor. Each adult lead small group, guided math station work. Groups were created by the teacher based on student responses from exit questions used throughout the week. During this day, students often visited at least two stations during the math period.

Findings:

Given (that) the two classrooms began this study with statistically similar OGAP Multiplicative Pre-assessment scores, the data suggests differences in achievement were a result of the instructional differences each group received during the study. (The author) believe(s) that the focus on student discourse in the treatment group was one of the major reasons for this difference in achievement.

What teachers say about action research

Action research becomes a vehicle to improve instruction and student learning outcomes on a daily, weekly, yearly and career basis. It is essentially the same process by which physicians adjust dosage, track wellness of patients and help improve health outcomes. Recognizing this important role of teachers as clinicians serving all students with systematic evaluation of learning changes the role of a teacher from consumer of test data to keen observer of student performance.

Teachers believe that action research not only impacts their own understanding of research but also directly impacts 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 teachers report that they and their colleagues continue or modify the interventions. Over time action research becomes an integrated part of the teaching/learning process.

Student Outcomes

Changing the process of demonstrating effective mathematics instruction would be of little interest to parents, students and teachers without clear documentation of positive change in student performance.

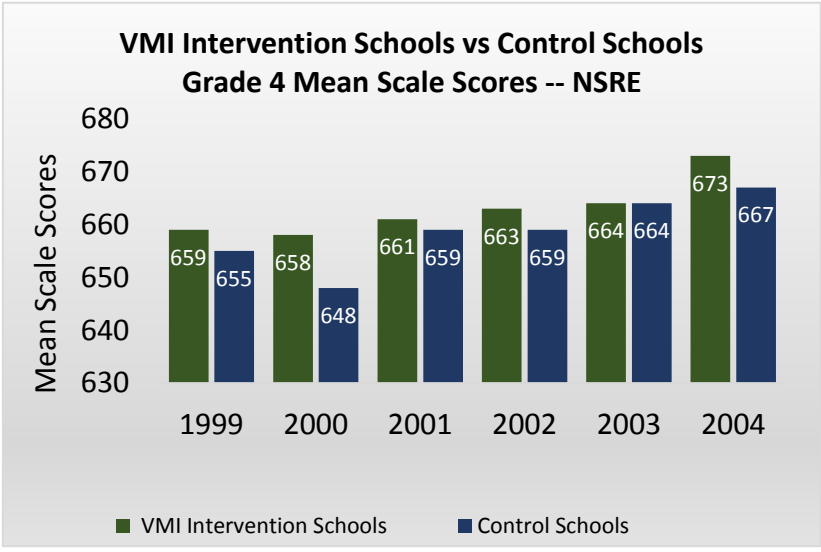
Positive changes in student mathematical performance have been documented in several ways over the history of VMI. In addition to the teacher-made performance measures described in the section of this report about action research, (goal 4, above), independent evaluation studies that utilized valid and reliable measures such as the New Standards Reference Examination (NSRE) in 1999-2005, the New England Common Assessment (NECAP) (2006-2013) and the Smarter Balanced Assessment Consortium (SBAC) were published by University of Vermont Researchers, Core Research and Evaluation, and Lighthouse Evaluation. These studies demonstrate a pattern of VMI teachers' students outperforming their peers and of VMI partner schools' students outperforming students in other schools.

Comparisons made between groups of VMI intervention and control schools as well as cohorts of VMI enrollee or teacher-taught and control students were made on the basis of groups that were similar in proportions of low income students. Groups were adjusted for student mobility, proportions of special education students and school size. Results of four such comparisons are described below.

Results from the first evaluation study (2004)

The first evaluation study was carried out by University of Vermont researchers in 2000-2004. The analysis of test data began with VMI Intervention and Control schools during the year 2000, using 1999 as a baseline year for test data. Schools in the intervention and control groups were matched on the characteristics of poverty levels and grade levels. There were no significant differences between VMI intervention and control schools in student performance at the baseline year in 1999 in Grade 4. Results of the first evaluation study indicated that VMI Intervention schools significantly outperformed the Control schools on the NSRE in 2000, 2001, 2002 and 2004. (See figure below.)

Figure 3. VMI intervention schools significantly outscored peer schools.



Longitudinal comparisons following cohort student groups were also made to assess effects over time that might surface from matching students who remained within the school systems served by the program and the control schools. A pattern of gain favoring the VMI Intervention schools emerged from the comparison of NSRE percentile rank gains over time. Students in the VMI intervention schools who were followed as a cohort from the intervention year to 2004 progressed at a rate more than 3 times that of their peers. In this study it became evident that Vermont students who were taught by teachers who had studied mathematics in the VMI program could expect to increase their scale score gains by 3 percent per year over at least a period of 4 years.

Results from the follow-up longitudinal analysis in 2005-2006

The follow-up study in 2005-2006 used a value added model that followed a panel of about 1000 students who began with VMI teachers in 2000 at grade 4 and were tracked forward to grade 10 in 2006. The VMI panel was then compared with a similar number of students who likewise formed a panel of control students in schools matched with the intervention schools according to school size and concentrations of low income students.

Finding 1. Students from the aggregate group of VMI schools showed a statistically significant advantage over the matched comparison group of schools when students were matched from grade 4 through grade 8 to grade 10.
Finding 2. A subset of the VMI schools had four or more VMI trained teachers enrolled in the program during the evaluation. Students from these VMI high concentration schools significantly out-performed the matched schools and appeared to carry most of the difference between the VMI and matched schools in the previous comparison.
Finding 3. Not surprisingly, whether in intervention schools or matched schools, students eligible for free or reduced lunch scored significantly lower than their non-eligible for free or reduced lunch peers. This pattern continued through the grade 8 testing. Rather surprising is that given the lack of cohort differences at grades 4 and 8, at grade 10 the free or reduced lunch eligible students in the VMI schools significantly out-scored their free or reduced lunch eligible peers, and they gained on students who are not eligible for free or reduced lunch in the matched schools.

Results from the follow-up longitudinal analysis in 2006-2007

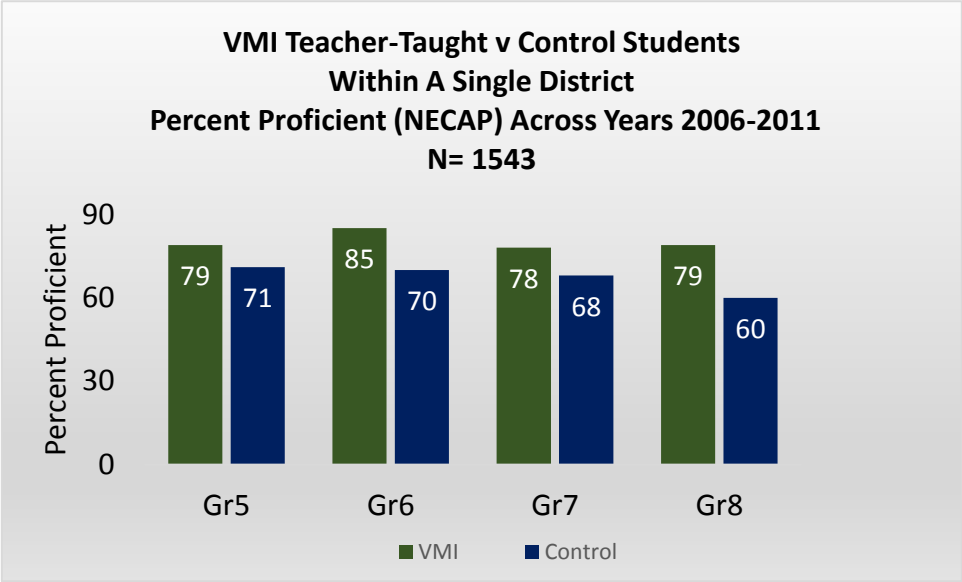
This analysis followed a second panel of students of teachers who entered VMI in 2001. As in the previous study, students in two groups of VMI intervention schools, one with a higher concentration of VMI teachers, were compared with a control panel of students from a matched control group of 18 schools. The findings were similar to those of the previous cohort study.
Finding 1. Intervention schools consistently outperformed control schools.
Finding 2. VMI high concentration schools significantly out-performed the matched schools and appear to carry most of the difference between the VMI and matched schools.

Finding 3. Free or reduced lunch eligible students in the VMI schools significantly out-scored their free or reduced lunch eligible peers, and they gained on students who are not eligible for free or reduced lunch in the matched schools.

Results from the district case study in 2016

In 2016, Lighthouse Evaluation compared students taught by VMI teachers with their peers from a single district that had begun a district-wide intervention in 2006 by enrolling six teachers in the VMI master's program. This study found that when the cohort of students who were taught by VMI teachers were followed over a period of four years (Grades 5-8) students taught by VMI teachers out-performed their peers on the NECAP by an average of 12 percentile points each year, over four years.

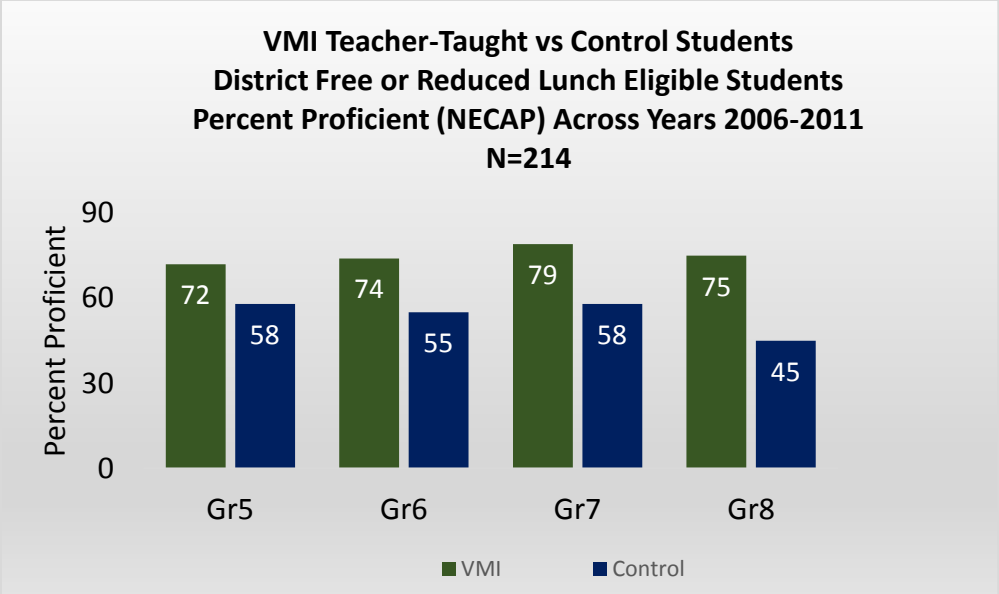
Figure 4. VMI Teacher-taught students outperformed peers.



The chart above provides an estimate of the value added by the VMI intervention to each grade level performance of a single cohort of students from a system-wide perspective. Proportions from the matched groups in the charts are accounted for by following one cohort of students who were matched to controls at Grade 5. The difference in proficiency rate ranges from 8 percentage points in Grade 5 to 19 percentage points in Grade 8. All differences in Chi-square proportions of percent proficient which favor the VMI group are statistically significant at $p<.05$.

Historically, free or reduced lunch eligible students typically perform at levels nearly 30 percent lower than other students. However, in this case, students eligible for free or reduced lunch taught by VMI trained teachers outperformed other students in the district who were eligible for free or reduced lunch by as much as twenty-one percent proficiency.

Figure 5. VMI Teacher-taught free or reduced eligible students outperformed peers.



Results from a state-wide study in 2017

The most recent evaluation of student performance on the Vermont State assessment for mathematics (Smarter Balance Assessment Consortium) for 2017 demonstrated a pattern of performance of VMI partner schools outperforming other schools. In evaluating student performance of all partner schools in Vermont during 2017 VMI partner schools' students exceeded the performance levels of other schools in grades three and five through eight. Notably, students with IEP's and those eligible for free or reduced lunch outperformed their peers across grade levels on the SBAC total scaled scores and problem solving scores. See table below:

2017 Results of SBAC Performance in Mathematics

All Cohorts Combined

Students with IEPs and Eligible for Free or Reduced Lunch

		N	Mean	Std. Deviation
Total Scale Score *	Control	2979	2393.61	88.937
	VMI	737	2404	82.844
	Total	3716	2395.67	87.849
PROB *	Control	2963	2388.12	103.911
	VMI	736	2399.93	100.147
	Total	3699	2390.47	103.267

- Statistically significant difference P<.05

Conclusions and Recommendations to Districts

The following conclusions are summary findings from each section (goal) of the report and related to recommendations for potential adopters of the VMI approach to improving mathematics instruction on a district wide basis. Lessons learned by the staff and partners of VMI over the past twenty years can inform each new adaptation of the basic design of the program.

Lesson 1: Leadership development and implementation

The implementation of a district-wide mathematics professional learning initiative rests on the development of leadership to support the initiative from awareness of the need to change to the evaluation of each phase of its progress. VMI has learned that each district has a unique character and history. A unified "school district" will find curricular change complex but easier to manage than a district of schools separated by differing values and cultures. A common language describing curricular goals and objectives must be developed across the district in order to support planning and development. Gradual, systematic and detailed introduction to the four goals of implementation which are the foundation of the VMI approach should occur for all members of the community beginning with the superintendent, district staff, board members, and school staff. Students and their parents should be included in the discussion of the need for change in mathematics instruction and the relationship of this initiative to other on-going initiatives to improve learning. The discussion and subsequent decision to begin a comprehensive program to improve mathematics instruction and learning should emphasize that the initiative is a long term process and not a single event.

Recommendation: The long-term, sustainable process of improvement should begin with a formal commitment to accomplishing the four VMI goals. This expression can be a memorandum of understanding (MOU) or similar document between VMI and a district. It should include a clear expression of commitment to the minimum number of teacher participants in the full VMI program in order to establish a cohort sufficient to realize the change in instruction within at least one school.

Lesson 2: Deep content knowledge and understanding

In VMI evaluation studies, the defining VMI characteristic cited by superintendents, principals, teachers, higher education faculty and state education officials was the sharp focus given to mathematics content. Many teachers are keenly aware of the gaps in their mathematics preparation for teaching. A master's degree that concentrated on building the level of mathematics knowledge and reasoning ability for all teachers was an ambitious goal in 1999 and remains so twenty years later. Partnerships among mathematicians, school of education faculty and teachers remain relatively unusual. However, VMI history reveals that it is both possible and productive to provide teachers with the depth of preparation needed for today's demanding career requirements in science, technology, engineering and mathematics (STEM). Beginning with a strong foundation in arithmetic the integration of the language of mathematics with foundational concepts of geometry, algebra, statistics and calculus as applied to the world of instruction requires about three years of applied study. Providing the kind of coaching that enables teachers to reach and demonstrate proficiency in this demanding curriculum is essential to build teacher leaders to sustain a high level of transfer to all students.

Undergraduate curriculum related to mathematics content has generally not advanced beyond the level observed twenty years ago. Recently prepared elementary and middle level teachers rarely demonstrate the integration of mathematics content across the discipline described in the VMI curriculum. So, it is essential for districts and schools to provide professional development in mathematics at the level and proficiency needed in order to provide all students with learning opportunities that they need and deserve.

Lesson 3: Effective mathematics instruction

With the level of content expertise needed to achieve the foundation for the integration of all areas of mathematics comes the need to support the individualized instruction that enables all teachers and students to really learn mathematics. The adage "don't do as I say, do as I do" or more recently, "just do it" becomes the modality for inquiry learning that enables students to generalize complex concepts to new applications. With proficiency in basic arithmetic both teachers and students have the ability to generalize their learning to new processes. By designing the teacher's curriculum for learning mathematics as a student centered, inquiry based method and by demonstrating how students learn mathematics in this way, teachers are provided with the tools and procedures to become successful with a wider range of students. Maintaining the balance between the introduction of new ideas and practice, feedback and coaching in order to arrive at an internalized understating of complex mathematical ideas is itself a complex process.

Recommendation: Few professional learning programs require the depth and sustainability of VMI. The investment needed to support and sustain a full master's program that includes coaching and mentoring of teachers is significant but necessary to obtain results that VMI has demonstrated.

Lesson 4: Action research to inform instructional decisions

The link between instruction and student outcomes requires direct and accurate feedback from students to teachers. Recent emphasis on large scale, standardized testing has generally not supported individual and personal student learning. Thought to be the province of accountability rather than supportive of individual student growth, the provision for integrating student assessment with instruction was generally directed to special educators. Without the tools for constructing valid and reliable assessments and analyzing their results most teachers were unable to link student responses to instruction in ways that enabled change and improvement.

Action research that depends upon well-developed procedures for assessment and feedback to students is a very important part of the VMI curriculum. The integration of student assessment with the model of inquiry learning described and implemented in the VMI courses and fieldwork provides the basis for teachers to assume the role of coach for their own students. Action research enables teachers to bring this process of learning full circle to their own students. By evaluating the action research as a product of their professional learning program teachers gain understanding of the coaching process that supports the fundamental shift in role from didactic lecturer to learning guide.

Recommendation: Sharing action research products among teachers supports the evolution of professional learning communities from the consumption of externally manufactured topical presentations to the production of knowledge owned by teachers. The fundamental shift from teachers as an audience to a community of research scholars can also become a basis for transforming a school and district culture from 20th to 21st century learning paradigms.

References

Boaler, J. (2015). *Mathematical Mindsets: Unleashing Students' Potential through Creative Math, Inspiring Messages and Innovative Teaching*. San Francisco, Calif: Jossey-Bass

Duda, M.A. & Wilson, B.A. (2018). *Implementation Science 101. Perspectives on Language and Literacy. International Dyslexia Association*. Retrieved from: https://mydigitalpublication.com/publication/?i=529782#{"issue_id":529782,"page":10} www.DyslexiaIDA.org

Duda, M.A. & Wilson, B.A. (2015). *Using implementation science to close the policy to practice gap* (White Paper). San Francisco, CA: Literate Nation. Retrieved from https://tinyurl.com/WilsonIS

Knight, J. (2011). *Unmistakable impact: A partnership approach for dramatically improving instruction*. Thousand Oaks, Calif: Corwin Press.

Leinwand, S. (2012). *Sensible Mathematics Second Edition: A Guide for School Leaders in the Era of Common Core State Standards*. Portsmouth, N.H.: Heinemann Publishing.

National Research Council. 2001. *Adding It Up: Helping Children Learn Mathematics*. Washington, DC: The National Academies Press. Retrieved from https: //doi.org/10.17226/9822

Penuel,W., Fishman, B., Cheng, B, & Sabelli, N. (2011). *Organizing research and development at the intersection of learning, implementation, and design.* Educational Researcher, Vol. 40, No. 7, pp. 331–337.

Primary Number and Operations Assessment (PNOA). Vermont-based Assessment. Retrieved from http://www.pdfsdocuments2.com/p/49/pnoa-kindergarten-assessment-test.pdf

Saginor, N. (2008). Diagnostic Classroom Observation: Moving Beyond Best Practice. Thousand Oaks, Calif: Corwin Press.

University of Chicago School Mathematics Project. (2016) *Everyday Mathematics.* New York, NY: McGraw Hill.

US Math Recovery Council. *Math Recovery Intervention Program.* See https://www.mathrecovery.org/

Wiggins, G., & McTighe, J. (2011). The *Understanding by Design Guide to Creating High-quality Units*. Alexandria, VA: ASCD.