Math that Matters

Math for the Modern World

Virginia Military Institute
Quality Enhancement Plan
Submitted 12 September 2016

VIRGINIA MILITARY INSTITUTE
NO ORDINARY COLLEGE. NO ORDINARY LIFE

12 September, 2016

Belle Wheelan, Ph.D., President
The Southern Association of Colleges and Schools
Commission on Colleges
1866 Southern Lane
Decatur, Georgia 30033

Dear Dr. Wheelan:

The efforts of the SACSCOC staff, as well as the peer reviewers who have participated in this year's reaffirmation efforts, are greatly appreciated. At the Virginia Military Institute, we are committed to uncompromising quality and excellence in all of our programs and services. The work required for reaffirmation of accreditation, though extensive at times, helps proud, distinguished institutions like ours uphold this commitment.

VMI's mission has remained to prepare young men and women "for the varied work of civil life." The nature of that "varied work" has evolved, and we believe that our Quality Enhancement Plan (QEP) modernizes the skills and attributes all VMI graduates will require to succeed in a rapidly evolving, data-rich, computationally-driven world. *Math that Matters: Math for the Modern World* addresses the nation's need for problem-solvers capable of collaborating across disciplines, solving complex problems, while simultaneously leveraging the advantages that computers provide.

Our QEP was the product of an Institute-wide topic search, and has the broad support of our faculty, cadets, staff, and Board of Visitors. We've committed nearly $700k of funds over a five-year period to support its implementation. We believe that this QEP, in particular, will enhance VMI's capability to provide this nation with Citizen Soldiers for generations to come.

Thank you again, Dr. Wheelan, for the extensive time, effort, and energy that you, your staff, and the peer reviewers have put forth on our behalf. We look forward to receiving the on-site committee and to the work that their feedback will inspire.

Sincerely,

J. H. Binford Peay, III
General, U.S. Army (Ret)
Superintendent

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Belle Wheelan, Ph.D., President
The Southern Association of Colleges and Schools
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Decatur, Georgia 30033

Dear Dr. Wheelan:

On behalf of Virginia Military Institute, I want to thank you and your staff for your exceptional support on behalf of our reaffirmation efforts. The work required for reaffirmation of accreditation has helped VMI ensure that it maintains its pursuit towards uncompromising excellence. To that end, we have conceived a Quality Enhancement Plan that prepares our young men and women to carry on that same pursuit after graduating from VMI. As an outcome of our QEP, students will, as articulated in the VMI mission, be better prepared for the "varied work of civil life" in a modern world.

Our QEP, *Math that Matters: Math for the Modern World,* seeks to modernize both our pedagogical methods, as well as the skills and attributes required of our graduates. Today's world is characterized by global connectivity, data-rich problems sets, and ubiquitous computational technologies. Our QEP will introduce contextualized, authentic approaches to teaching and learning that are designed to enhance the educational experience of students, while assembling a set of complementary math and computational skills that are relevant to the modern world, regardless of discipline or profession.

The Institute's interest in the implementation and success of this QEP is broad. The topic selection process included ten white papers from across the staff and faculty. The Leadership Team has kept faculty, staff, and VMI's Board of Visitors informed of the Plan's evolution. The Applied Math Department has collaborated across the Institute to design courses that combine the best pedagogical practices, the students' perspective, and the contextualizing context from a collaborating faculty member. To that end, VMI has committed $687K over five years to implement the QEP that is closely aligned with VMI's strategic plan to produce exceptional problem-solving leaders for generations to come.

Sincerely,

Jeffrey G. Smith, Jr.
Brigadier General USA (Ret)
Deputy Superintendent and Dean of the Faculty

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Executive Summary

The Virginia Military Institute's (VMI) QEP, ***Math That Matters: Math for the Modern World***, ties directly to the VMI mission statement and the goals set forth in its strategic plan, *Vision 2039*. Furthermore, it represents a data-driven extension of the transformation of both student learning and the student learning environment initiated with VMI's first QEP, which focused on a re-envisioning of the core curriculum. By leveraging research from the learning sciences broadly and mathematics education specifically, as well as instructional innovations like the high-impact practices, VMI's QEP aims to enhance non-STEM students' cognitive outcomes for and affective orientations toward "***math that matters***" for all walks of life.

VMI's ultimate selection of ***Math that Matters*** as its QEP:

- Is the result of a highly inclusive, broad-based topic development process;
- Is situated in the broader, national conversation about math educational reform;
- Capitalizes upon best practices for curricular and instructional design from the learning sciences;
- Leverages existing campus expertise in applied mathematics, general education, and assessment and evaluation; and
- Addresses key gaps in student learning and the student learning experience revealed by rich institutional assessment data.

Mathematics is deeply embedded in everyday life; it is also the language of science and forms a crucial part of the body of knowledge necessary for a scientifically literate society. VMI regards the mathematical sciences, like scientific inquiry, as a cornerstone for the intellectual development of critical thinking and analytical skills. However, through a robust assessment of our institutional data, we realize that the lived experiences and learning outcomes of our non-STEM students within existing math courses in the VMI core curriculum do not rise to the level of our current expectations or future aspirations.

VMI's concerns over students' mathematical/computational knowledge, skills, and abilities mirror those captured by national calls for STEM undergraduate education reform broadly, and math education reform specifically. A synthesis of national reports, studies commissioned by professional societies, and peer-reviewed research reveals an apparent consensus both within and beyond the academy that:

- Every undergraduate should have the opportunity to encounter math coursework that goes beyond calculation and rote problem solving.
- However, current undergraduate math structures, curricula, and pedagogies are insufficient for achieving the 21st century mathematical/computational skills that today's business, industry, public service, education, the professions, and the military require.
- Students will learn complex mathematical/computational concepts and skills best when they have opportunities to (a) encounter these concepts and skills in varied, complex contexts; (b) practice using this new knowledge repeatedly by translating it from one format to another; and (c) receive regular and consistent feedback.

- Additionally, the traditional "one-size-fits-all" lecture-based instructional approach coupled with the standard "two tests and a final" approach to assessment is arguably the least effective strategy for achieving long-term retention and transfer, particularly for the attainment of higher order mathematical/computational thinking skills beyond initial memorization and comprehension.
- This type of approach places students in a more passive, receiving role versus that of active constructor of his or her own learning. These principles transcend disciplinary boundaries, but are especially critical to consider as part of transforming undergraduate math courses for non-STEM majors.

The conclusions drawn by these national and professional society reports, as well as math educators and scholars studying the nexus of higher-order mathematical/computational skills and general education collectively, represent a challenge that VMI can begin to address on its own campus through the ***Math that Matters*** QEP. It also provides an opportunity for VMI faculty and students to contribute possible solutions to the math preparation problem.

Math That Matters: Mission Statement

To improve student learning in non-STEM core curriculum math courses by (a) collaborating with faculty in non-STEM departments to develop discipline-specific, contextualized math problems, (b) helping non-STEM students to be computationally confident problem-solvers, and (c) designing and implementing instruction that is contemporary and evidence-based (e.g., authentic/inquiry learning) and incorporates academic motivation strategies designed to enhance perceptions of interest and usefulness.

Math that Matters will implement a series of interventions for students and/or faculty (both applied math and non-math faculty) in order to improve non-STEM students' learning in VMI's core curriculum math sequence to achieve the following goals:

Goal 1	To ensure non-STEM students are better able to use mathematical/computational skills to solve a wide variety of disciplinary and interdisciplinary problems.
Goal 2	To promote non-STEM students' affective development and attitudinal shifts toward math coursework to improve learning.
Goal 3	To foster an exciting and supportive collaborative environment for the learning of mathematical/computational skills for non-STEM students.
Goal 4	To promote a broader awareness of the applicability of mathematical/computational skills in all disciplines and professions.

The interventions encapsulated by ***Math that Matters*** drill down first to address a large, structural issue, then proceed to make course-based curricular changes, and finally hone in on fine-grained instructional enhancements at the faculty level. This approach is driven in large part by lessons learned, again, from VMI's first QEP, which focused on structural and some curricular level changes for general education, which may best be described *as necessary, but insufficient* for the kind of student learning outcomes desired of the program. The tripartite approach taken by ***Math that Matters*** is designed to address this shortcoming of the previous QEP's implementation.

- **Structural Change.** VMI will combine the two existing core math sequences for non-STEM majors into a single two course sequence (MA 101/102) containing the most relevant skills from both, while adding a set of modern computational skills, a comprehensive assessment structure, and a reduced classroom size.

- **Curricular Change**. The new course will consist of modules that are informed by cadet perspectives, best pedagogical practices, and interdisciplinary problems shaped by faculty from other departments. The modular design is intended to increase cadet interest, ownership, and mastery of skills by learning a framework for solving problems in the context of their own academic and professional interests.

- **Pedagogical Change**. Course Faculty will establish a cadet-centered educational environment that enhances learning outcomes and knowledge retention, while preserving classroom faculty's sense of authorship and ownership for their classes.

Success of this QEP is measured through success on the MAI Student Learning Outcomes (cognitive learning outcomes), through improved interest and perception of usefulness (affective learning outcomes), and through effective faculty training. This training is both for the applied mathematics instructors and for the broader faculty members across Post who are involved in all aspects from authorship to revision of the modules, management of the summer institute, and grading of the final poster session.

In summary, our QEP was the product of an Institute-wide topic search, is designed to solve math-related student learning outcomes, and enjoys the broad backing of our faculty, cadets, staff, and Board of Visitors. We've committed almost $700K of funds over a five-year period to support its implementation. We believe that this QEP, in particular, will produce better learners, better problem-solvers, and better teachers, capable of shaping positive outcomes in a modern world.

Background

Overview of the Virginia Military Institute

Established by the Virginia General Assembly in 1839, the Virginia Military Institute (VMI) is the oldest state-supported military college in the United States, and the second institution of higher education founded by the Commonwealth of Virginia, after the University of Virginia. A four-year institution focused exclusively on undergraduate education, VMI's student body is organized as a military corps under the command of the Superintendent and is constituted as the guard of the Institute. As a military institution, VMI makes a unique contribution to the diversity of the Commonwealth's system of state-supported (15 senior institutions and 24 two-year colleges) and independent institutions of higher education as it contributes to meeting society's need for educated citizens and leaders.

VMI is a selective institution, offering admission to approximately 44-52% of the applicants each year. The admissions process for VMI involves a thorough evaluation of the applicant's academic and personal record. The decision to admit an applicant is based on a variety of elements, including a student's: (a) strength of courses, (b) overall GPA, (c) standardized test scores, (d) level of physical fitness and activity, (e) involvement in extracurricular activities and leadership programs, (f) written recommendations, and (g) interest in pursuing a commission in the military. As of fall 2015, the Institute enrolled 1717 students from 43 states and 10 countries. The population included 11% women, 6% African-American, 5% Hispanic, and 5% Asian or Pacific Islander. The ratio of students to faculty was 11.1 to 1.

VMI believes the measure of a college lies in the quality and performance of its graduates and their contributions to society. Successful completion of VMI's unique educational system enables cadets to enter many civilian professions, the armed forces, or to continue at graduate and professional schools. Approximately 98 percent of each class has full-time employment or has entered graduate school within five months of graduation, with 50 percent of graduates taking a military commission, and about 18 percent of VMI graduates make the armed forces a career.

The Institute's mission statement amplifies VMI's special statutory role. It is the mission of VMI to *produce educated, honorable men and women, prepared for the varied work of civil life, imbued with love of learning, confident in the functions and attitudes of leadership, possessing a high sense of public service, advocates of the American Democracy and free enterprise system, and ready as citizen-soldiers to defend their country in time of national peril*.

VMI's strategic plan is driven by *Vision 2039,* named after the upcoming 200th anniversary of its founding. This master plan aims at improving the academic, military, and athletic programs and the infrastructure of the Institute to enhance cadet leadership development and the environment in which it takes place. From *Vision 2039* springs many initiatives, including refinements to the academic curriculum, which will help position VMI today to continue to fulfill its mission well into the future.

The VMI Undergraduate Experience

VMI's academic offerings are designed to advance both the Institute's mission as well as *Vision 2039*. VMI offers 14 degrees at the baccalaureate level, with a healthy balance between STEM and non-STEM majors. VMI does not offer certificate programs or graduate degrees, and does not offer online or distance education. VMI's 14 degree programs as well as the degrees awarded within each for the previous academic year are listed below:

Table 1. Degrees Conferred 2014-15

Major Discipline	**Degree**	**Degrees Conferred June 2014-May 2015**
Engineering		
Civil & Environmental	B.S.	56
Electrical & Computer	B.S.	13
Mechanical Engineering	B.S.	19
Natural Science and		
Applied Mathematics	B.S.	9
Biology	B.A.	16
Biology	B.S.	24
Chemistry	B.A.	0
Chemistry	B.S.	9
Computer Science	B.S.	11
Physics	B.A.	0
Physics	B.S.	9
Arts & Humanities		
English, Rhetoric, & Humanistic	B.A.	12
History	B.A.	41
Modern Languages & Cultures	B.A.	12
Social Sciences		
Economics & Business	B.A.	54
International Studies & Political	B.A.	46
Psychology	B.A.	36
Psychology	B.S.	8
Total		375

In addition to its rigorous academic majors, VMI's core curriculum (general education) is designed to achieve the Academic Program's mission to "educate cadets in a rigorous academic environment that encourages life-long learning and develops citizens of character who anticipate, respond, and lead in a complex and changing world." Implemented in 2007, the core curriculum was the focus of VMI's first QEP. Thematically organized as "The Nucleus of Effective

Citizenship and Leadership," the core curriculum covers a wide breadth of domains, including:

- Mathematical Inquiry,
- Citizenship,
- Leadership and Human Relations,
- Communication,
- Scientific Inquiry,
- History and Culture,
- Critical and Creative Thinking, and
- Health and wellness.

The core curriculum comprises a substantial component of each undergraduate degree program, specifying 52+ credit hours of requirements, which represents a minimum of 38% of the total credit hours required for graduation, depending on the total number of hours required for a particular degree (ranging from 136 to 140). Whether they are pursuing the B.S. or the B.A. degree, all cadets must satisfy the same core curriculum requirements.

Finally, whether embedded within the majors, threaded throughout the core curriculum, or part of co-curricular and military experience, the Institute already affords students the opportunity to engage in multiple empirically validated "high-impact practices" (Kuh, 2008), including, but not limited to: a common first-year experience, study abroad, internships, capstone courses, service learning, and undergraduate research.

VMI's QEP, ***Math That Matters: Math for the Modern World***, ties directly to the goals set forth in the VMI mission and *Vision 2039.* Furthermore, it represents a data-driven extension of the transformation of both student learning and the student learning environment initiated with VMI's first QEP, which focused on a re-envisioning of the core curriculum. By leveraging research from the learning sciences broadly and mathematics education specifically, as well as instructional innovations like the high-impact practices, VMI's QEP aims to enhance non-STEM students' cognitive outcomes for, and affective orientations toward, "math that matters" for all walks of life: business, industry, public service, education, the professions, and the military.

Topic Selection, Phase I: Initial Topic Development

Selecting ***Math that Matters*** as the topic of the VMI Quality Enhancement Plan (QEP) began with an off-site academic retreat in August 2014. The retreat was attended by academic program departments heads, academic administrators, and other Institute faculty. The upcoming decennial reaffirmation of accreditation was a topic of discussion, as was the need to develop a QEP. Shortly thereafter, a Topic Development Committee was formed. The committee was charged with the following:

To identify, research, and deliberate the merits of suitable topics for the next VMI Quality Enhancement Plan, using existing assessment results, literature reviews, and a needs assessment, if necessary. This committee must demonstrate broad-based involvement of institutional constituencies in the development of the QEP. To inform the Leadership Team's selection of the QEP topic, each potential topic should be presented with an outline, including an estimation of how the project will enhance student learning and an analysis of opportunities, obstacles, and associated costs.

The committee consisted of faculty and administrators and was chaired by COL Chuck Newhouse, Professor of Civil and Environmental Engineering. A more detailed description of the committee's membership is provided in Table 2 below.

Table 2. QEP Topic Development Committee

COL Chuck Newhouse, Professor, Civil & Environmental Engineering, *Chair*
CAPT Mike Sebastino, Associate Dean for Administration & Planning
COL Jay Johnson, Associate Professor of Physical Education
COL Christina McDonald, Institute Director of Writing
LTC Lee Rakes, Director of Institute Assessment & Evaluation
MAJ Jenny deHart, Staff Engineer and Sustainability Coordinator
MAJ Meagan Herald, Assistant Professor of Applied Mathematics
MAJ Chris Perry, Assistant Commandant of Cadets

As part of its preliminary work, the committee reviewed SACSCOC criteria for an acceptable QEP, reviewed survey data from the Office of Assessment and Institutional Research, and generally discussed ideas for topics that might be interesting to pursue. Through its deliberations, the committee articulated five guiding principles for VMI's QEP development process:

1. Based on the data derived from VMI's continuous improvement processes, it became clear that VMI's first QEP, The Core Curriculum: The Nucleus of Effective Citizenship and Leadership (2006), was exceedingly expansive in scope and had proven difficult to assess. As such, the new QEP needed to be more focused with a more manageable number of learning outcomes.

2. The new QEP needed to be explicitly aligned with the Institute's mission and *Vision 2039* (the strategic plan).

3. Since all cadets are required to complete core curriculum requirements which include ROTC and Physical Education courses, some majors currently have very few or no free elective courses. All proposed QEP topics would be required to address the fact that additional courses could not be added in some majors.

4. The evaluation of proposed QEP topics should consider pedagogical strategies such as the High-Impact Practices (HIPs) promoted by the Association of American Colleges & Universities (AAC&U).

5. As budgetary support from the Commonwealth of Virginia is not expected to increase significantly in the foreseeable future, all proposed QEP Topics need to be mindful of the financial realities inherent to the current budgetary climate and address resources for the QEP appropriately to ensure the greatest impact on student learning and the student learning environment.

Ultimately, the committee wanted to be mindful of the need for broad-based involvement from institutional constituencies, which led to the decision to invite the faculty to submit white papers and then attend an Open Forum to discuss the topics (see Appendix A). The invitation for white papers was sent via email to the faculty on November 5, 2014. The email stated that any white papers received by November 14, 2014 would be reviewed and considered for discussion during the Forum. On November 24, 2014 the committee hosted the Forum. With over fifty members of the faculty and staff in attendance, committee members explained the purpose of a QEP, and discussed possible impacts of the topics with participants.
Interestingly, although the five guiding principles were not explicitly introduced at the Forum, faculty and staff comments echoed these principles, which served as affirmation of the committee's development and planned use of these principles in the QEP topic evaluation process.

By the Forum, the committee had received six topic proposals, including:

1. FYI@VMI (First Year Initiative at VMI)
2. Preparing Leaders of Integrity for the 21st Century
3. Alternative to the MA 105/106 (Intro to Prob & Stats) & MA 125/126 (Quant. Methods) Core Curriculum Sequence
4. The VMI Experience: Leading with Courage, Competence, Caring, and Integrity
5. Collaboration: A Pathway to Broad-Minded Leaders
6. Every Cadet a Citizen Leader

The discussion about the six submitted topics was thoughtful, and ultimately led to an extension of the deadline for the submission of proposals to January 5, 2015.

The committee then received six additional topic proposals by the new deadline, two of which were withdrawn. The remaining four topics included:

1. Rowan Electronic Interactive Textbooks
2. QEP Civic Engagement – CORE
3. Civic Engagement/Investment
4. A Proposal for Core Curriculum Leadership

In early January 2015, the committee evaluated all proposed QEP topics and determined that all ten topics were indeed feasible. Since many of the topics shared common goals, the committee grouped them into four distinct QEP Categories:

1. ***FYI@VMI:*** A first year initiative that would build on successes of our existing Miller Academic Center and provide our freshman, or *Rats*, with support through the Rat Year;
2. ***Leadership at VMI***: A broad set of proposals that focused on the topic of formalizing leadership education and/or infusing it across the curriculum;
3. ***Civic Engagement: Creating Responsive Citizens***, which would formalize civic engagement for our cadets by creating and promoting common objectives that could be achieved across a variety of service experiences; and
4. ***Computational Reboot of Core Math. Coding Across the Curriculum***, which aimed to improve the common core math requirement by replacing two of the three sequences with a new course sequence that focused on technology-driven mathematical topics and basic programming skills in a language, such as Python, all embedded in problems drawn from cadets' majors.

The committee then deliberated about the four proposals, sought clarifications as necessary, and discussed the role of assessment data for each, as appropriate. The committee then evaluated the topics and ranked them from most to least feasible. The proposals were evaluated using criteria from rubrics developed by SACSCOC to evaluate standards CR 2.12 and CS 3.3.2. Specifically, they were assessed using a scale of (Y) for *Yes - Likely Present*, (N) *for No - Likely Not Present*, and (U) for *Uncertain*. Each committee member rated each proposal using this scale for each dimension described in Table 3 below.

Table 3. Proposal Evaluation Criteria

1B	Identifies key issues that emerge from assessment
2A	Focus on learning outcomes that align with mission of the institution
2B	Focus on the environment supporting student learning
3A	Capability to initiate the plan
3B	Capability to implement the plan
4A+4B	Broad-based buy-in and involvement
5A	Identifies goals for the QEP
5B	A plan that assesses the achievement of the goals

Each topic was also rated overall. The overall ratings were used in conjunction with the Y-N-U ratings as well as readily available institutional assessment data to rank the topics from most to least feasible. As a result of this deliberative process, two topics emerged for further development: (a) a "computational reboot" of the core curriculum mathematics sequences for non-STEM majors and (b) civic engagement.

Once the proposals were narrowed to two topics, the committee split into two groups, each charged with more fully developing one of the topics into a form that the Leadership Team could evaluate. Final proposals for the two topics were then submitted to the Leadership Team for review in early March 2015. At the conclusion of this phase of the process, the Leadership Team felt that the mathematics proposal was the strongest, but wanted to further deliberate, at an institutional-level, the proposal's feasibility and sustainability. A meeting to achieve this end took place on June 18, 2015. The minutes from this meeting were posted on the OAIR's website, along with the two topic proposals. Additionally, the Leadership Team, led by the Dean, BG Jeffrey Smith, Jr., held a small forum to discuss the two topics on June 25, 2015. Attendees included approximately 20 academic program department heads and other faculty and staff members. The Power Point presentation used for this small forum was also posted on the OAIR's website.

After careful consideration of the final input from the VMI community, the Dean of the Faculty drafted an internal memorandum to the Superintendent recommending the selection of the "Math QEP," ***Computational Reboot of Core Math. Coding Across the Curriculum.*** In July of 2015, the Leadership Team and the Superintendent enthusiastically selected the core curriculum mathematics proposal as VMI's next QEP. Both the Leadership Team and the Superintendent felt that the proposal was innovative, evidence-based, and timely, given the ever changing, intensifying demands for computational and mathematical skills necessary for today's graduates. The approval memorandum is Appendix B.

Topic Selection, Phase II: Refinement of the Topic From Coding to "Math that Matters"

Mathematical Inquiry and VMI's Core Curriculum: A Brief Overview

Mathematics is deeply embedded in everyday life; it is also the language of science and forms a crucial part of the body of knowledge necessary for a scientifically literate society. VMI embraces the Mathematics Association of America's belief that students must learn "to confront, explore, and communicate important ideas of modern mathematics and the uses of mathematics in society" (MAA, 2004, p. 5). Inquiry learning, an approach to learning that incorporates problem-based methods of instruction (Ronis, 2007), was the framework through which the core curriculum mathematics student learning outcomes were articulated and implemented via VMI's first QEP in 2007. The intention of VMI's core curriculum (CC) requirements for mathematical inquiry is to provide high-quality, introductory mathematics courses, with quantitative, problem-rich experiences. Consistent with the principles of the National Council of Teachers of Mathematics, these courses were designed to provide meaningful and appropriate foundations for problem-solving in advanced courses in other disciplines.

VMI regards the mathematical sciences, like scientific inquiry, as a cornerstone for the intellectual development of critical thinking and analytical skills. As such, VMI requires that all entering freshmen take two semesters of mathematics (six credit hours of two CC-designated sequential courses). There are three two-course sequences students can choose from: (a) MA 105 - Introduction to Probability and Statistics I & MA 106 - Introduction to Probability and Statistics II; (b) MA 125 - Quantitative Methods I & MA 126 - Quantitative Methods II; and (c) MA 123 - Calculus & Analytic Geometry I & MA 124 - Calculus & Analytic Geometry II. A student's academic major determines which course sequence is necessary to meet the CC requirements. Students majoring in non-STEM fields typically take the MA 105/106 or MA

125/126 sequences, whereas STEM majors typically take the MA 123/124 sequence. Notably, the interpretation we use for STEM majors is not strict.

In a typical semester, five sections of one sequence would be offered, along with one course for the opposing sequence. For example, in fall 2015, five sections of MA 105 and MA 125 were offered, but only one section of MA 106 and MA 126 were offered. The table below shows the course sequences required for STEM and non-STEM majors.

Table 4. Core Curriculum Math Sequences by Discipline

Major	Course Sequence
STEM: Calculus Track	
Applied Mathematics	123/124 Calculus & Analytic Geometry
Chemistry	123/124 Calculus & Analytic Geometry
Civil & Environmental Engineering	123/124 Calculus & Analytic Geometry
Electrical & Computer Engineering	123/124 Calculus & Analytic Geometry
Mechanical Engineering	123/124 Calculus & Analytic Geometry
Physics	123/124 Calculus & Analytic Geometry
Non-STEM: Statistics Track	
Computer & Information Sciences	105/106 Probability & Statistics
English, Rhetoric, & Humanistic Studies	105/106 Probability & Statistics
History	105/106 Probability & Statistics
International Studies	105/106 Probability & Statistics
Modern Languages & Cultures	105/106 Probability & Statistics
Psychology	105/106 Probability & Statistics
Non-STEM Methods Track	
Economics & Business	125/126 Quantitative Methods
Biology	125/126 Quantitative Methods

Within VMI's core curriculum, mathematical inquiry is operationalized through five learning outcomes, regardless of course sequence. Referred to as the Mathematical Inquiry (MAI) outcomes, as a result of the mathematical inquiry courses students at VMI will be able to:

1. Connect ideas of modern mathematics to applications in real-world settings.
2. Understand the relationship between variables and parameters of mathematical models and the patterns or phenomena they represent.

3. Formulate a problem using appropriate mathematical techniques and expressions.
4. Apply mathematical techniques to solve quantitative problems.
5. Communicate a solution in a manner that clearly indicates the line of reasoning.

The language captured by the original Mathematical Inquiry learning outcomes highlight the value and importance Institute faculty attached to higher-order quantitative thinking and reasoning skills that students could, in turn, apply nimbly and effectively to solve complex, authentic problems in highly dynamic and varied contexts. As such, the refinement of the "Math QEP" topic focused less upon a revision of extant learning outcomes, but instead provided the opportunity for much deeper consideration of whether current structural, curricular, and/or pedagogical approaches were most effectively promoting these learning outcomes for non-STEM students. In short, the focus of the Math QEP **was not intended to be a revision of the core curriculum**. Rather, it is the vehicle through which VMI will seek to improve **structural, curricular, and pedagogical** approaches to ensure that non-STEM students' educational experiences at VMI promotes the attainment of the desired cognitive student learning outcomes and affective dispositions vis-à-vis mathematical inquiry.

Balancing Broad Participation & Disciplinary Expertise in the Development of "Math That Matters"

After the selection of the topic, the QEP Topic Development Committee handed over the development process to a working group charged with investigating the selected topic more thoroughly, as well as refining it into a manageable plan designed to maximize its benefits for our cadets. The membership roster of the working group is provided in Table 5 below.

Table 5. QEP Working Group

Name	Title and Department
COL Greg Hartman (chair)	Professor of Applied Mathematics
COL Atin Basuchoudhary	Professor of Economics & Business
COL Merce Brooke	Professor of Physics & Astronomy
LTC Pieter deHart	Associate Professor of Biology
COL Mary Ann Dellinger	Professor of Modern Languages
MAJ Dan Harrison	Assistant Professor of Chemistry
LTC Meagan Herald	Associate Professor of Applied Mathematics
LTC Wakeel Idewu	Associate Professor of Civil Engineering
MAJ Matt Jarman	Assistant Professor of Psychology
LTC Mike Krakow	Associate Professor of Physical Education
Dr. Ramoni Lasisi	Assistant Professor of Computer and Information Sciences
COL David Livingston	Professor of Electrical and Computer Engineering
COL Turk McCleskey	Professor of History
COL Bob McMaster	Professor of Mechanical Engineering
LTC Howard Sanborn	Associate Professor of International Studies
LTC Pennie Ticen	Associate Professor of English, Rhetoric & Humanistic Studies
MAJ Sara Whipple	Assistant Professor of Psychology

Initial conceptions of the "Math QEP" focused almost exclusively on computational thinking and coding, with a particular emphasis on providing non-STEM majors training in Python, a coding language. Though heralded over the past few years as a highly marketable skill for college graduates, the emphasis on coding as a standalone skill is increasingly seen as misplaced (see, for example, NPR, 2016). In its review of extant literature and campus models (e.g., Baylor University; Brown University), the working group found that simply adding coding into a mathematics course was more problematic than anticipated, and became concerned about the perceived need to sacrifice important mathematical and computational **reasoning/thinking** topics to make space for the new subject of coding. Returning to consideration of the MAI learning outcomes, the QEP Working Group placed renewed emphasis on the development of a math curriculum for non-STEM majors that emphasized contextualized content delivery through empirically validated active learning teaching strategies.

As a result, the Working Group engaged a smaller group of Applied Mathematics faculty to develop and recommend specific structural, curricular and pedagogical/instructional approaches for the Math QEP. This smaller Working Group included junior faculty, mid-level faculty, and senior faculty, as well as an adjunct who had significant experience teaching the original courses. A detailed description of the membership is provided in Table 6 below.

Table 6: Applied Mathematics Curriculum Working Group

Name	Title and Department
COL Greg Hartman (chair)	Professor of Applied Mathematics
MAJ Karen Bliss	Assistant Professor of Applied Mathematics
MAJ John David	Assistant Professor of Applied Mathematics
LTC Meagan Herald	Associate Professor of Applied Mathematics
MAJ Jessica Libertini	Assistant Professor of Applied Mathematics
COL Troy Siemers	Professor of Applied Mathematics
LTC Meagan Herald	Associate Professor of Applied Mathematics
Mr. John Vosburgh	Adjunct Professor of Applied Mathematics

With engagement and representation from across the Institute's relevant constituencies, to include support from staff in the Office of Assessment and Institutional Research, the process of further developing and refining the topic through careful consideration of the literature and an in-depth examination of institutional data in relation to the desired learning outcomes for Mathematical Inquiry at VMI was initiated.

Math that Matters: Support from the Literature

Current Calls for Reform from Within the STEM/Mathematics Community

The reform of mathematics teaching and learning for non-STEM majors at VMI is situated in a decades-long, larger, national conversation about STEM education broadly and math preparation in particular. Within just the past four years, there have been multiple clarion calls for the academy to address the math preparation problem (e.g., Saxe & Brady, 2015). In 2012, the President's Council of Advisors on Science and Technology released their report on the state of STEM undergraduate education, *Engage to Excel: Producing One Million Additional College*

Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Although the report focused on STEM majors in particular, two of its five recommendations are relevant to ***Math that Matters****,* namely that colleges and universities should (1) catalyze widespread adoption of empirically validated teaching practices, and (2) launch a national experiment in postsecondary mathematics education to address the math preparation gap. Both recommendations have applicability for STEM and non-STEM majors, and for courses in a major, as well as courses within the general education curriculum.

One year after the PKAST report, the National Research Council released its report *The Mathematical Sciences in 2025,* giving the following finding:

> Mathematical sciences work is becoming an increasingly integral and essential component of a growing array of areas of investigation in biology, medicine, social sciences, business, advanced design, climate, finance, advanced materials, and many more. This work involves the integration of mathematics, statistics, and computation in the broadest sense and the interplay of these areas with areas of potential application. All of these activities are crucial to economic growth, national competitiveness, and national security. **Education in the mathematical sciences should also reflect this new stature of the field**. (2013, p.2, emphasis added)

Finally, in 2012, the Conference Board of the Mathematical Sciences (CBMS) called a national Forum, at which VMI had representation. CBMS articulated several reasons for convening the Forum, including:

- The way mathematics is being used in many fields is evolving;
- The need for mathematical competence in many areas of work is increasing;
- The first two years of college math are key to student success in many areas;
- A primary mission of college mathematics departments is to give our students the mathematical competence they will need to succeed in their careers and in life;
- Mathematics departments should be leading the effort to determine and satisfy student needs in mathematics and to increase student success in collegiate mathematics.

At the Forum, Deborah Hughes-Hallett and Peter Turner, both national leaders in undergraduate mathematics curricular design, presented on "Modeling Across the Curriculum," an approach involving mathematical modeling that is designed to answer the charge of connecting mathematics to the real world by teaching a problem-solving framework that is supported by mathematical skills and embedded in a contextualized problem from the real world. These national-level conversations motivated two organizations, the Society for Industrial and Applied Mathematics (SIAM) and the Consortium for Mathematics and Its Applications (COMAP), to jointly commission a report entitled "Guidelines for Assessment and Instruction in Mathematical Modeling Education," or GAIMME, to help address the question of what colleges and universities should be teaching students about mathematics. Notably, two VMI Applied Mathematics faculty members contributed to the GAIMME report (Bliss & Libertini, 2016).

Mathematics Education & General Education: The "Home" for Contextualization and Transfer

Within the realm of general education reform, mathematics education and its related learning outcomes have received increased attention as an essential 21st century life skill (AAC&U, 2007 Elrod, 2014). While proponents argue that not all students necessarily need to learn "sophisticated mathematics," every undergraduate "should be able to apply simply mathematics to understand, interpret, assess, challenge, and draw conclusions. College graduates should be equipped to handle quantitative data in order to evaluate, construct and communicate arguments in their professional, as well as personal lives" (Agustin, Agustin, Brunkow, & Thomas, 2012, p. 311).

Much attention has been paid in the literature to exploring the common ground among and points of departure between such concepts as numeracy, quantitative literacy, quantitative reasoning, and – more recently – computational thinking (e.g., Karaali, Hernandez, & Taylor, 2016; Vacher, 2014; Wing, 2006 & 2010). Although the nuances inherent to definitional clarity are important, in the context of ***Math that Matters*,** two key attributes transcend the various articulations of math-related learning outcomes: (1) the importance of moving "beyond calculation" (Madison & Deville, 2014) to higher-order outcomes (such as quantitative reasoning, quantitative literacy, or computational thinking) as the primary outcomes for and focus of undergraduate math courses, and (2) the need to create structures, curricula, and/or approaches to instruction that privilege contextualization and application to enhance student learning (Elrod, 2014).

The underlying assumption is that "regardless of the structure of a general education program… students will transfer what they learn in these general education courses to their discipline-based courses, and, eventually, to their careers" (Benander & Lightner, 2005, p. 199). Unfortunately, the evidence on general education outcomes does not bear this out, regardless of discipline. Benander and Lightner (2005) articulate four reasons for this: (1) students never actually learned the material; (2) students learned the material, but do not see connections; (3) students are unable to use the material in meaningful ways later in other contexts; and/or (4) students are prevented from transferring learning from one situation or condition to another by the very way faculty are communicating the original or the later material. They argue "any of these situations may be happening, and it is important for the success of any series of courses, especially those involved in a general education program, to actively promote transfer" (ibid.)

This issue of contextualization and transfer appears to be particularly acute for mathematics education for non-STEM majors. Proponents of change in undergraduate mathematics education increasingly argue for a focus on higher-order quantitative and/or computational thinking skills, particularly for this faction of students. The best approach to reframing courses to promote non-STEM students' attainment of quantitative thinking and problem solving skills focuses on:

> …the practical application of mathematics and statistics as well as the use of computational skills in addressing real-life problems. Tackling mathematical ideas in various contexts will enable students to realize the relevance and value of statistics in everyday life… The corner-stone of quantitative literacy is the ability to apply quantitative ideas in new or unfamiliar contexts. This is very different from most students' experience of mathematics courses, in which the vast majority of problems are types that they have seen before. Mathematics courses that concentrate on teaching algorithms, but not on varied application in context, are unlikely to develop quantitative literacy" (Agustin, Agustin, Brunkow, & Thomas, 2012, p. 311).

Such transformation need not require a dilution or "dumbing down" of mathematical content. Instead, a more multidimensional model of academic rigor (Draeger et al 2013; Brogt & Draeger, 2015) for college-level courses comprised of multiple, overlapping dimensions provides a useful framework for thinking through math education reform for non-STEM majors. According to this multifaceted model, an academically rigorous course (Brogt & Draeger, 2015, p. 17-18):

1. Moves learners beyond rote memorization toward conceptual understanding,
2. Prepares for the transfer of learning from one context to another,
3. Sets high standards,
4. Encourages learners to critically examine assumptions, evidence, concepts, and implications,
5. Develop higher-order thinking skills, and
6. Engages students in active learning.

This model for academic rigor reflects many of the underlying tenets of the higher-order mathematical thinking skills – from numeracy, quantitative literacy, and quantitative reasoning to computational thinking and mathematical modeling – and related recommended instructional strategies that inform VMI's ***Math that Matters*** QEP. Furthermore, the conclusions drawn by these national and professional society reports, as well as math educators and scholars studying the nexus of higher-order mathematical/computational skills and general education collectively, represent a challenge that VMI can begin to address on its own campus through the ***Math that Matters*** QEP. It also provides an opportunity for VMI faculty and students to contribute possible solutions to the math preparation problem.

In short, the status quo is unacceptable. To address this issue, math preparation in the 21st century should draw upon the rich, extant body of empirical research produced by the disciplines collectively known as the learning sciences in the development of structural, curricular, and instructional/pedagogical models for undergraduate math education for non-STEM majors.

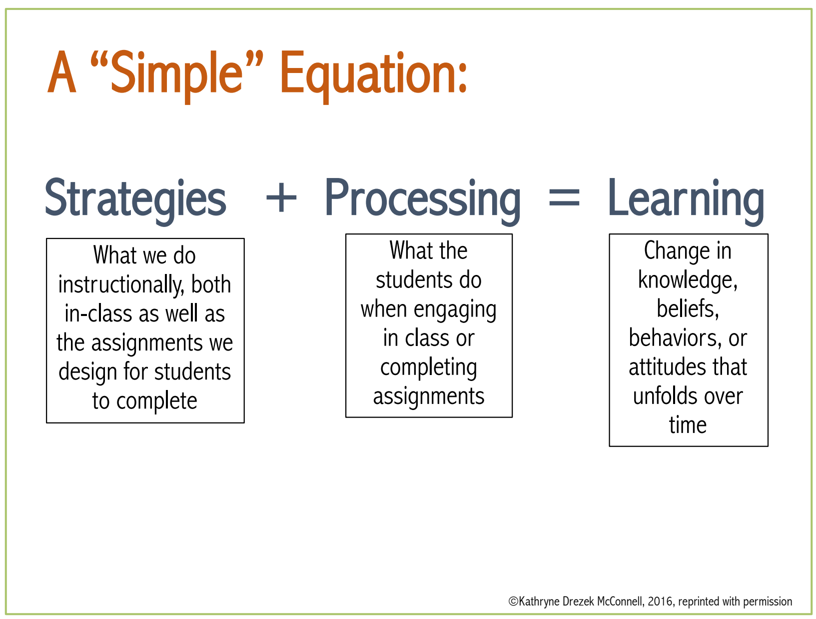
The Learning Sciences' Lessons for Undergraduate Math Educational Reform at VMI

What we process, we learn. This seemingly simple proposition can be best represented by the following equation:

Strategies + Processing = Learning

Strategies fall squarely within the purview of faculty designing and delivering coursework, while *processing* the material encompassed by a course or program – be it cognitively, affectively, or behaviorally, or socially– is the ultimately the responsibility of the students. Students, like all human beings, constantly engage in meaning making. That stated, the purposeful, directed *learning* that most faculty intend with their courses does not happen automatically, as if by magic. Instead, it is the direct result of a structural and curricular design that works to align appropriate instructional strategies – from a faculty member's approach to content delivery and assignment design – with the specific type of processing most likely to facilitate the requisite change in students' knowledge base, beliefs, or behavior that constitutes learning.

Critical Components for Effective Cognitive Processing. Disciplines such as cognitive psychology, educational psychology, computer-human interaction, and instructional design and technology, each with its own literature base, methodological approaches, and areas of emphasis, collectively contribute to the broader conception of the learning sciences. The empirical research from these complementary fields, along with applied research from scholarship of teaching and learning endeavors, is captured both in peer-reviewed, disciplinary-based journals, along with the rich body of literature that presents these findings for a "lay" higher education academic audience. Such articles and books (e.g., *Make it Stick: The Science of Successful Learning* (2014) by Brown, Roegiger, & McDaniel, *The New Science of Learning: How to Learn in Concert with Your Brain* (2013) by Doyle and Zakrajsek, and *How Learning Works: 7 Research-Based Principles for Smart Teaching* (2010) by Ambrose, Bridges, DiPietro, Lovet, & Norman) are explicitly designed to provide faculty, regardless of their discipline, with the knowledge, skills, and abilities necessary to design and deliver a course that employs strategies intended to capitalize upon how humans process cognitively, affectively, behaviorally, and socially.



In one such powerful, practical resource, Halpern and Hakel (2003) assert that there is but one true purpose of college teaching: *long-term retention and transfer*. In other words, college teaching should facilitate students' ability to organize knowledge, retain it, and appropriately retrieve it to use it in a completely new or novel situation. The article delineates ten principles of college teaching that synthesize empirical research into learning and cognition that should inform course design and delivery:

10 Laboratory Tested Principles to Promote Long-Term Retention & Transfer

1. The single most important variable in promoting long-term retention and transfer is practice at retrieval.
2. Varying the conditions under which learning takes place makes learning harder for learners but results in better learning.
3. Learning is generally enhanced when learners are required to take information that is presented in one format and "re-present" it in an alternate format.
4. What and how much is learned in any situation depends heavily on prior knowledge and experience.
5. Learning is influenced by both our students' and our own epistemologies.
6. Experience alone is a poor teacher. Too few examples can situation learning. Many learners don't know the quality of their own comprehension and need systematic and corrective feedback.
7. Lectures work well for learning assessed with recognition tests, but work badly for understanding.
8. The act of remembering itself influences what learners will and will not remember in the future. Asking learners to recall particular pieces of information (as on a test) that has been taught often leads to "selective forgetting" of related information that they were not asked to recall.
9. Less is more, especially when we think about long-term retention and transfer. Restricted content is better.
10. What learners do determines what and how much is learned, how well it will be remembered, and the conditions under which it will be recalled.

(Halpern & Hakel, 2003; reprinted in Madison, 2014)

Threaded throughout each of these principles is support for the rationale behind ***Math that Matters*** – students will learn complex mathematical/computational concepts and skills best when they have opportunities to (a) encounter these concepts and skills in varied, complex contexts; (b) practice using this new knowledge repeatedly by translating it from one format to another; and (c) receive regular and consistent feedback. Additionally, the traditional "one-size-fits-all" lecture-based instructional approach coupled with the standard "two tests and a final" approach to assessment is arguably the least effective strategy for achieving long-term retention and transfer, particularly for the attainment of higher order mathematical/computational thinking skills beyond initial memorization and comprehension. This type of approach places students in a more passive, receiving role versus that of active constructor of his or her own learning. These principles transcend disciplinary boundaries, but are especially critical to consider as part of transforming undergraduate math courses for non-STEM majors.

Addressing Motivational & Affective Barriers. Cognitive processing does not happen in a vacuum. The motivational and affective orientations of both students and faculty powerfully influence what is – or is not – learned in any one course. As such, motivation is a vital part of the learning process. Researchers have found that when students are motivated, they engage in learning activities willingly and persist at activities when faced with challenges (Schunk, Meece, & Pintrich, 2014). Given the importance of students' motivation, it is critical to understand why and how students are motivated so that instructors can intentionally design instruction to motivate students. Students' internal characteristics—thoughts and beliefs (e.g., affect, needs/desires, goals)—affect their motivation and engagement in learning activities (Jones, 2015). In fact, some instructors may believe that the reason for students' lack of motivation is due to these types of internal factors. Although these factors can play a part in students' motivation, researchers have discovered that students' motivation and engagement is also **critically dependent upon the environmental context in which they are learning** (Christenson, Reschly, & Wylie, 2012). These findings suggest that instructors can have a significant impact on students' motivation and engagement in their classes because they can influence the learning environment. However, in order to design effective instruction, professors need to understand how to apply motivation research and theories to practice.

The MUSIC Model of Motivation. Researchers in the field of motivation science and educational psychology use many different theories and approaches to understand the factors that motivate students (Reeve, 2015). These different theories and approaches have led to a plethora of teaching strategies from which instructors can choose to motivate their students (Wentzel & Wigfield, 2009). Given the large number of theories and strategies available, it can be difficult for instructors unfamiliar with motivation science to decide which ones are most appropriate for their teaching. To address this problem, Jones (2009) developed the MUSIC® Model of Motivation. The MUSIC model is based on current research and theories in the field of motivation science, including (but not limited to) attribution theory (Weiner, 1986), belonging theories (Baumeister & Leary, 1995), competence theories (Elliot & Dweck, 2005), expectancy-value theory (Eccles et al., 1983), interest theories (Hidi & Renninger, 2006), self-determination theory (Deci & Ryan, 2000), and self-theories of intelligence (Dweck, 1999) (Jones, 2015). The MUSIC model provides an organization for the motivational teaching strategies that are based on these theories and research. The MUSIC model framework divides teaching strategies into one of five categories: empowerment, usefulness, success, interest, and caring. In doing so, it simplifies the broad array of strategies into five groups that can be readily understood by instructors.

To assess the validity of the MUSIC model, researchers have examined the five-component structure of the model in a variety of classes and settings. Findings from several studies indicate that students' perceptions of the five components of the model are distinct within a class setting (Jones & Skaggs, 2016; Jones & Wilkins, 2013). In other words, students can hold different perceptions about these five components in a particular class. Because all five of these components have been associated with students' motivation and engagement, designing instruction to support one or more of the MUSIC components can foster students' motivation and engagement in a class.

Researchers have used the MUSIC model in undergraduate courses to examine students' motivation and to identify barriers to students' motivation, which could then be used to identify strategies to support students' motivation and engagement. For example, in one study, researchers used the MUSIC model to examine how problem-based learning in engineering courses affected undergraduate students' motivation to engage in the courses (Jones, Epler, Mokri, Bryant, & Paretti, 2013). The researchers documented that some aspects of the courses provided motivating opportunities for students which could either motivate them or cause them to become frustrated and lose motivation in the class. These findings were then used to develop instructional implications to improve the teaching methods in the future. Researchers in non-STEM courses have also used the MUSIC model to examine and design instruction to motivate students, including in undergraduate education and psychology courses (e.g., Jones, Ruff, Snyder, Petrich, & Koonce, 2012; McGinley & Jones, 2014).

By incorporating motivational constructs along with the cognitive principles delineated above into its curriculum and instruction, ***Math that Matters*** will provide a non-STEM general education math experience well-positioned to facilitate the development of the higher-order thinking captured by the MAI learning outcomes, and at the same time enhance the likelihood of students' long-term retention and ability to transfer those skills into new, unanticipated contexts. The holistic consideration of the national dialog on math education, as well as the rich contemporary corpus of research from the learning sciences, signals that math education, if not teaching and learning at the collegiate-level writ large, is primed for change. ***Math that Matters*** is situated within this broader context. A thorough consideration of VMI's institutional assessment data provides the compelling, institution-specific rationale for focusing on its core curriculum math courses for non-STEM majors.

Math that Matters: Data-Driven Change to Enhance Learning and the Learning Environment

In tandem with a review of extant literature on undergraduate math education reform, VMI engaged in an in-depth examination of pertinent institutional data. This investigative process started by posing and empirically answering the following five Research Questions (RQs) related to the non-STEM general education math courses (MA 105/106 Probability and Statistics and MA 125/126 Quantitative Methods):

1. How well are students' performing in the current non-STEM general education math courses: MA 105/106 and MA 125/126? (Examined by analyzing existing student learning outcomes data, to include assessment methods, and analyzing pass/fail/withdrawal rates.)

2. To what extent are students motivated to engage in these courses? (Examined through the MUSIC Model of Academic Motivation Inventory.)

3. How do students perceive technology and its use (or potential use) to solve mathematics problems in these courses? (Examined through students' perceptions of their confidence in their ability to use Excel to solve problems, comfort with using technology to solve math problems.)

4. How do students in these courses perceive the use of group work during class? (Examined through students' course perceptions).

5. Do the courses provide meaningful and appropriate foundations for problem-solving in advanced courses in other disciplines? (Examined through a survey of faculty in disciplines serviced by the non-STEM general educational math courses).

An analysis of these RQs follows, along with a summary and recommendations for an intervention.

RQ 1: Examination of Incomplete/Fail/Withdrawal Rates & Mathematical Inquiry (MAI) Learning Outcomes Data

MAI outcome data. A brief examination of the core curriculum student learning outcomes discussed previously - locally known as the Mathematical Inquiry, or MAI, outcomes – data for the non-STEM math sequences, MA 105/106 and 125/126, was included in the selected topic proposal; however, an in-depth exploration of the data was not undertaken. An examination of the success rates of students who enrolled in these courses (i.e., pass, fail, and withdrawal rates) was not conducted. By subsequently analyzing these data, we were able to gain a more complete understanding of students' performance and the pedagogy that accompanied that performance.

For the academic year 2014-15, the targets for success (~70%) in the MA 105/106 sequence were met for two of the five learning outcomes (MAI 3 and 5). The two outcomes with the lowest proficiency were MAI 1 (59%) and MAI 2 (53%). Only one outcome had a proficiency level above 75%: MAI 3. For the MA 125/126 sequence, the targets for success (~70%) were also met for two out of the five outcomes (MAIs 1 and 3). The two outcomes with the lowest proficiency were MAI 4 (60%) and MAI 5 (68%). See Table 9 below for more detail.

In addition to examining students' performance on MAI outcomes, we also examined the adequacy of the assessment methods selected for this measurement. As demonstrated in Table 9, for both sequences and for all outcomes, only one final exam question was utilized to assess student learning. This finding was disconcerting for two reasons: (a) learning is complex and is best measured by triangulating the results of multiple measures (Allen, 2006), and (b) this approach to assessment is not appropriate for the pedagogical framework (active, inquiry- and/or problem-based learning) intended to execute the core curriculum MAI student learning outcomes.

Table 9. 2014-15 Non-STEM CC MAI Student Learning Outcomes Data

MAI Outcomes	Method & Target	Section Results
1. Connect ideas of modern mathematics to applications in real-world settings.	One embedded final exam question. Target: ~70%	105/106: 59% 125/126: 81%
2. Understand the relationship	One embedded final	105/106: 53%

between variables and parameters of mathematical models and the patterns or phenomena they represent.	exam question. Target: ~70%	 125/126: 69%
3. Formulate a problem using appropriate mathematical techniques and expressions.	One embedded final exam question. Target: ~70%	105/106: 97% 125/126: 91%
4. Apply mathematical techniques to solve quantitative problems.	One embedded final exam question. Target: ~70%	105/106: 66% 125/126: 60%
5. Communicate a solution in a manner that clearly indicates the line of reasoning.	One embedded final exam question. Target: ~70%	105/106: 75% 125/126: 68%

Note: In 2013-14, the MAIs for core curriculum course sequences underwent minor revisions. The revised outcomes were implemented in 2014-15.

The pedagogical approaches of inquiry and problem-based learning are intended to be executed through authentic, real-world activities, as research has demonstrated that such approaches can "increase the probability that students will transfer knowledge, skills, and problem-solving strategies to real-world contexts" (Ormrod, 2008, pg. 425), which is the aforementioned intention of the core curriculum math courses. Significantly, the MAI outcome assessment results helped to reveal this significant misalignment between the intended learning outcomes and the instructional strategies employed as part of the existing math courses, thereby providing local confirmation of the literature on the appropriate use of authentic assignments and assessment strategies (Hmelo-Silver, 2004; Rogoff, 2003). Discussions with the Applied Mathematics Department Head confirmed this disconnect and revealed that the outcomes were developed with the inquiry and problem-based learning frameworks in-mind, but that the classroom pedagogy was mostly lecture-based and devoid of multiple measures and authentic assessment activities to determine how well students were performing on the outcomes.

Enrollment volume and rates of failure. In addition to direct assessment of learning data, we also examined course completion and success data for the two course sequences. From 2013-14 to 2015-16, the MA 105/106 and MA 125/126 course sequences serviced 1929 students. Of these students, 6.9% received a failing grade and 7.6% withdrew from the course. The highest rates of failure were in the 2015-16 academic year. See Table 7 below for more detail.

Table 7. Enrollment Volume & Rates of Failure: MA 105/106 & MA 125/126

Year		Grade				Incomplete; Withdrew-Fail; Withdrew-w/out Fail			
	F	D	C	B	A	I	W-w/F	W-w/out F	Total
2015-16	43 7.2%	60 10.1%	180 30.2%	161 27.0%	100 16.8%	0 0.0%	0 0.0%	52 8.7%	596 100%
2014-15	46 6.8%	64 9.5%	161 23.9%	193 28.6%	158 23.4%	1 0.2%	1 0.2%	50 7.4%	674 100%
2013-14	44 6.7%	71 10.8%	185 28.1%	180 27.3%	132 20.0%	1 0.2%	1 0.2%	45 6.8%	659 100%
3-yr Avg.	**133** **6.9%**	**195** **10.1%**	**526** **27.3%**	**534** **27.7%**	**390** **20.2%**	**2** **0.1%**	**2** **0.1%**	**147** **7.6%**	**1929** **100%**

When disaggregating the data by course section, results indicated that failure rates among the four sections was lowest for MA 105 (4.4%) and highest for MA 125 (8.4%). Interestingly, the withdrawal rates were higher in the subsequent course sections for each sequence: 6.2% vs. 12.1% for the 105/106 sequence; 5.4% vs. 7.3% for the 125/126 sequence. This finding suggests that foundational skills necessary for success in subsequent sections may not have been attained at an appropriate level in the first course or that the subsequent courses are more difficult in some way. See Table 8 below for more detail.

Table 8. Enrollment Volume & Rates of Failure or Withdrawal

Section	2013-14 *n*		2014-15 *n*		2015-16 *n*		3-Yr Avg. *n*	
	F%	W%	F%	W%	F%	W%	F%	W%
MA 105	202		218		196		616	
	6.4%	6.9%	8.7%	5.0%	6.1%	6.6%	7.1%	6.2%
MA 106	160		176		167		503	
	8.1%	7.5%	5.1%	15.3%	9.0%	13.2%	7.4%	12.1%
MA 125	167		171		129		467	
	7.8%	6.6%	8.8%	2.9%	8.5%	7.0%	8.4%	5.4%
MA 126	130		109		104		343	
	4.6%	6.9%	3.7%	7.3%	4.8%	7.7%	4.4%	7.3%

Note: "F%" represents the percentage of students enrolled in a course sequence who failed the course. "W%" represents the percentage of students enrolled in a course a course sequence who withdrew from the course, but did not fail.

Research Question 2: Academic Motivation & Engagement

As discussed in the literature review, motivation and engagement affect what students learn and the extent to which they learn it, as well as aid in students' decisions to continue to engage in activities that implicate and require the application and use of previous learning (Jones, 2015). The relationship between students' motivation and learning is significant (Schunk, Meece, & Pintrich, 2014); as such, instructors need to seriously consider the factors that contribute to academic motivation and engagement, as well as understand and be able to assess their students' motivation and engagement. To date, this type of assessment had not been conducted in core curriculum math courses. The pedagogical focus has been exclusively on cognitive outcomes, rather than a more comprehensive consideration of the learning environment and intentional instructional design to addresses non-cognitive (i.e., motivational and affective) outcomes that impact student learning.

To answer Research Question 2, the Office of Assessment and Institutional Research surveyed all VMI students enrolled in all fall 2015 math courses (44 course sections; $n = 925$). We selected the MUSIC Model of Academic Motivation Inventory (MUSIC Inventory) as the diagnostic tool for this assessment for three reasons: (a) it is a validated instrument with acceptable statistical properties (Jones, 2016; Jones & Skaggs, 2016), (b) it has been used to analyze the motivational effects of instruction in STEM and non-STEM courses at the university-level (Jones, Epler et al., 2013; Jones, Watson, Rakes, & Akalin, 2012; McGinley & Jones, 2014), and (c) it, unlike other validated instruments, parsimoniously combines five key motivational components into one multidimensional model, which makes measuring several motivational factors at once easier to achieve (e.g., there is no need for multiple scales with different anchors). As noted in a book commissioned by the American Association of State Colleges and Universities, "[the MUSIC model] is not only inclusive, evidence-based, and research-validated, it is also versatile, and applied—which makes it relatively straightforward, and therefore easier to implement" (Aldridge & Harvatt, 2014, p. 54).

MUSIC Inventory

The five MUSIC model variables were measured using the MUSIC Inventory (Jones, 2016, available at www.theMUSICmodel.com). Table 10 shows the constructs, a description of the instrument used to measure the construct, the number of items in the instruments, and an example item from each instrument.

Table 10. MUSIC Model of Academic Motivation Inventory

Construct	Instrument description *The degree to which students:*	No. items	Example item
Empowerment	perceive they have control of their learning environment in their math course.	5	I have the opportunity to decide for myself how to meet course goals.
Usefulness	perceive their math course are useful to their future.	5	In general, the coursework is useful to me.
Success	perceive they can succeed in their math course.	4	I am confident that I can succeed in my coursework.
Interest	perceive the instructional methods and assignments in their math course to be interesting or enjoyable.	6	The coursework is interesting to me.

Caring	perceive the instructors in their engineering courses to care about their success in the course.	6	The instructors care about how well I do in their courses.

MUSIC Inventory Method

The MUSIC Inventory was administered at the same time as the end-of-course faculty evaluations. Each instructor distributed paper-based surveys along with corresponding Scantron forms. The demographic section of the survey was provided after the items were rated in order to reduce the effects of stereotypes that might affect students' responses to the inventory. The forms were returned to VMI's Office of Assessment and Institutional Research for scoring and analysis.

Of the 925 eligible students, 796 of them completed the questionnaire, a response rate of 86%. Nine response forms were not included in analyses due to illegible or nonsensical response patterns. They were not calculated as part of the overall response rate. Of the 796 students included, most students 89.5% (n = 679) were male, which is very close to the Institute's overall population demographics. Regarding class standing, 19.3% (n = 146) were seniors, 25.1% (n = 190) were juniors, 23.5% (n = 178) were sophomores, and 31.3% (n = 237) were freshmen.

Regarding the MA 105/106 and 125/126 course sequences, six of the MA 105 course sections were offered; one MA 106 course; six MA 125 courses; and one MA 126 course. Five out of the six courses of both MA 105 and MA 125 reported and both the MA 106 and MA 126 courses reported. The total number of students enrolled in the MA 105, MA 125, MA MA 106 and MA126 courses was 269, of which 215 responded (80%).

MUSIC Inventory Results

Department-wide, students were, on average, motivated at least "somewhat," with mean scores on each of the five MUSIC Model scales ranging from 4.4 to 5.1 (using a six-point agreement scale, where 6 = *Strongly agree*). Among the MA 105/106 courses, there were significant differences between these sections and the department mean on the usefulness scale ($p <.001$), but not the other scales. Among the MA 125/126 courses, there were significant differences between these sections and the department mean on three scales: usefulness ($p < .001$); interest ($p < .05$); and caring ($p < .05$). Table 11 below presents the mean scores across the sections and the department.

Table 11. MUSIC Inventory Mean Scores

MUSIC Inventory Scale	**MA 105 & MA 106 Mean**	**MA 125 & MA 126 Mean**	**Department Mean**
eMpowerment	4.6	4.5	4.6
Usefulness	4.2*	4.3*	4.5

Success	4.7	4.6	4.7
Interest	4.2	4.1*	4.4
Caring	5.1	4.9*	5.1

*Significant difference with department mean.

Overall, students in both non-STEM course sequence reported being motivated. However, the lowest ratings on the MUSIC Inventory scales were on Interest and Usefulness, with average scores ranging between 4.1 and 4.2 for Interest and 4.2 and 4.3 for Usefulness. It seems reasonable to conclude that these lower scores might be attributable to the incongruence between the intended pedagogical approach (i.e., student-centered, problem-based learning) and the actual approach (i.e., teacher-centered, devoid of authentic activities and feedback). These findings provide further, local substantiation of the need to focus on cognitive and affective dimensions of learning in higher education STEM courses. After all, if students are not interested in or fail to see the utility of math, the likelihood of learning it in deep and highly transferrable ways is an unlikely outcome.

RQs 3 & 4: Course, Technology & Group Work Perceptions

At the same time that we administered the MUSIC Inventory, we also queried students' course- and technology-related perceptions. We were interested in these perceptions because the "Math QEP" proposal as originally conceived placed a high degree of emphasis on the need to facilitate learning through contemporary technological means (e.g., using a computer program or software to solve problems). Additionally, because research has demonstrated the importance of being able to work in groups to solve problems once employed (AAC&U, 2013; 2015), we wanted to examine the extent to which students were developing this skill set. Gathering these data helped us locate potential deficiencies in these areas, as well as establish baseline data should an intervention be deemed necessary.

Course perceptions were assessed with seven quantitative items (created in-house) that queried students' perceptions of instruction (e.g., use of analogies or real-world examples, frequency of group work), as well as the frequency with which they used certain tools to solve math problems (e.g., handheld calculators or computers). These items used a four-point frequency scale (1 = *Never*; 4 = *Very often*). Results for these items are reported by the percent of participants responding to the top two response options (% O*ften* and *Very often*).

An additional five quantitative items were used to assess students' perceptions of technology and its (potential) usefulness to solve math problems (e.g., confidence in ability to use Excel to solve problems, comfort with using technology to solve math problems). An additional four items were adapted from the Student Attitude Survey (SAS), which measures students' beliefs about mathematics and learning of mathematics (Brookstein, Hegedus, Dalton, & Moniz, 2011), including perceptions related to group work. These items used a six-point agreement scale (1 = Strongly disagree; 6 = Strongly agree). Results for these items are reported by the percent of participants responding to the top three response options (% *Somewhat agree*, *Agree,* and *Strongly agree*).

Course, Tech, & Group Work Results

Course perceptions. In the MA 105 and MA 106 courses, students indicated that handheld calculators (97%) were used more frequently than computers (75%). The frequency of group work (70%), clarity of how math could be used outside of math class (74%), and the use of analogies and examples to facilitate understanding (80%) were rated lower than the remaining items in this section.

In MA 125 and MA 126 courses, students indicated that handheld calculators (96%) were used much more frequently than computers (25%). The frequency of group work (30%), the use of analogies and examples to facilitate understanding (75%), and clarity of how math could be used outside of math class (79%) were rated lower than the other items in this section. In Table 12 below, the combined percentage of the top two response categories is provided for each course sequence and the department. The presence of asterisk is used to indicate significant differences between course sequence ratings and department ratings (six total, four in MA 105/106; two in MA 125/126).

Table 12. Course-Related Perceptions

Course Perceptions	**MA 105 & MA 106 (%Often, Very often)**	**MA 125 & MA 126 (%Often, Very often)**	**Department (%Often, Very often)**
This course includes real-world examples.	87%*	86%*	71%
This course includes analogies and examples to help me understand difficult concepts.	80%	75%	71%
In this course, it is clear how the course material can be used to solve problems outside of math class.	74%	79%	70%
This course involves group work.	70%*	30%*	46%
This course involves individual work.	94%	97%	94%
This course requires the use of a computer to solve problems.	75%*	25%	38%
This course requires the use of a handheld calculator to solve problems.	97%*	96%*	76%

*Significant difference with department mean.

Technology and group work perceptions. In MA 105 and MA 106, a majority of students indicated that they would be comfortable using technology to solve math problems (82%) and that technology can make math easier to understand (80%). Students were least confident in their ability to use Excel to solve math problems (54%) and seemed to have little interest in learning programming languages such as Java, Python, or perl (58%). Only 69% were confident in their ability to solve math problems with a computer. About 75% indicated that they enjoyed working in groups to solve math problems, 58% preferred to work alone.

In the MA 125 and MA 126 courses, students were not as enthusiastic about the use of technology. A little over two-thirds indicated that they would be comfortable using technology to solve math problems; the same percentage indicated that technology could make math easier to understand (69%). Students were least confident in their ability to use Excel to solve math problems (30%) and seemed to have little interest in learning languages Java, Python, or perl (42%). Only 46% were confident in their ability to solve math problems with a computer. About 40% indicated that they enjoyed using a computer when solving math problems.

About 60% indicated that they enjoyed working in groups to solve math problems, 52% preferred to work alone. In Table 13 below, the combined percentage of the top three response categories is provided for each course sequence and the department. The presence of asterisk is used to indicate significant differences between sequence ratings and department ratings (6 total, all in the MA 125/126 sequence).

Table 13. Technology & Group Work Perceptions

Technology & Group Work Perceptions	MA 105 & MA 106 (SA, A, & SwA%)	MA 125 & AM 126 (SA, A, & SwA%)	Department (SA, A, & SwA%)
I feel confident that I can use Excel to solve math problems.	54%	30%*	57%
I feel confident that I can use computers to solve math problems.	69%	46%*	70%
I enjoy using a computer when learning mathematics.	65%	38%*	63%
Technology can make mathematics easier to understand.	80%	69%	79%
I am comfortable using technology in math class.	81%	69%*	81%
I am interested in learning to use a computer language, such as Java, Python, or perl, to solve math problems.	61%	42%*	61%

I enjoy working in groups better than alone in math class.	74%	58%	66%
I prefer working alone rather than in groups when doing mathematics.	58%	52%*	61%
I learn more about mathematics working on my own.	64%	55%*	65%

*Significant difference with department mean.

Summary of technology and course perceptions. For both non-STEM math course sequences, clarity of how the math they learned would transfer was below 80%, even though real-world examples were used frequently (>85%). The courses involved individual work more often than group work, with ratings over 90% (*Often* & *Very often*) for individual work and ratings between 30% and 70% for group work. About half indicated that they preferred to work in groups rather than individually, with about as many rating their own ability to learn math when working alone. Their confidence to use technology to solve math problems was low, as were their ratings for experiencing joy when using a computer to learn math, with no ratings above 70%. Their comfort using technology was rated higher, especially for the MA 105/106 participants (81% vs. 69%), but was less than desired, nonetheless.

These findings suggest that there is a disconnect with the aims of the core curriculum math courses for non-STEM students and the students' perceptions of those aims. Four key findings include: (a) courses were providing real-world examples, but these examples have failed to help students see the how the math would transfer to the real-world; (b) students mostly utilized outdated technology to solve math problems (i.e., handheld calculators); (c) students did not have the confidence to use computational technology to solve math problems, which is very much how it works in the real-world, and (d) there was significantly more individual learning taking place than group learning, which is contrary to the tenets of problem-based learning.

Student Focus Group Results

In addition to the extensive survey work, we conducted three student focus groups to provide a more complete understanding of students' perceptions of the MA 105/106 and 125/126 sequences. The list questions for the focus groups is found in Appendix D. The focus groups consisted of students who had successfully completed one of these sequences. The three focus groups included a total of 17 students and lasted between 30 and 40 minutes each. The students' participation was voluntary and they were given the opportunity to leave at any time during the focus group. The students were advised that the focus groups were confidential and that they may have any comments redacted at any time. The focus groups were recorded with permission from the participants.

When asked about their feelings towards the overall usefulness of the math sequence courses they had during the course sequence compared to those at the present time, the most common response was that the information that they learned in the sequence was never used (n =7). Five cadets commented that the information from the sequence was valuable, but only in real-world uses. An equal amount of cadets (*n* = 5) stated that the information was useful in other courses such as astronomy, economics, and biology.

When asked how often the skills learned in those classes were used currently in their major, most cadets said that the skills were never used (*n* = 7), while five commented that the information was only used in a limited amount in select courses. Four cadets further commented that statistics were most useful in real-world applications as opposed to academic uses.

The focus group participants did not provide much feedback when asked to identify specific "rewarding aspects" of the core math sequence. The ability to use statistics to solve real-world problems was the most common answer (*n* = 3).

Contrary to the minimum responses regarding rewarding aspects, comments towards negative aspects were much more numerous. Two primary themes with significance for the QEP development process emerged from the three focus groups: (1) Cadets felt they didn't learn much and/or were not challenged (*n* = 14); and (2) Five cadets added that they felt there was no real-world integration of the information learned in the sequence.

When asked what the cadets would have liked to see in the sequence, 12 said they would have liked to have seen a sequence that was appropriate and applied to their major. Eight cadets alluded to removing the use of calculators since they were not used afterwards. A few cadets indicated that they would like to have learned basic programming in languages such as Java or Python (*n* = 8) and/or Excel (*n* = 7).

The final question asked the cadets to list three things that they would make sure are included in the new math sequence. The top three responses were (a) how to conduct data analyses using statistics, algebra, and/or calculus depending relevant to their major, (b) move the math sequence to the third year, and (c) learn how to use a database.

After taking the initial math sequence, cadets recalled using confidence intervals, knowledge of outliers, the understanding of sample sizes and bias, and significance testing to better understand journals and other types of reported research.

In summary, the overarching themes derived from the three focus groups – course material not being readily associated to real-world practices, the lack of applicable computational skills, and an overall lack of usefulness of the math sequences for non-majors – offered further confirmatory evidence for the conclusions reached from analyses of the previously discussed survey data.

RQ 5: Faculty Perceptions of Meaningful & Appropriate Foundational Skills

To better understand faculty perceptions of the current core math sequence and its ability to provide meaningful and appropriate foundational mathematical/computational problem-solving skills for use in advanced courses in other disciplines, a survey of non-STEM faculty members was conducted. The list questions for the Faculty Survey is found in Appendix C. The QEP

Faculty Survey was administered online using Survey Monkey online survey software, between November 19 and December 2, 2015. The survey was confidential to ensure candid responses. The survey was sent to 80 faculty members from eight majors that did not qualify as math-intensive. A total of 29 (36%) faculty members responded to the survey as "teaching one or more courses that require students to be familiar with basic mathematical concepts."

Respondents to the survey were from the following departments:

- Economics & Business (*n* = 6)
- International Studies (*n* = 6)
- Biology (*n* = 5)
- Psychology (*n* = 4)
- History (*n* = 3)

Results from the survey revealed that faculty, regardless of sequence required, perceived student understanding of math concepts and skills to be lower than the necessary levels of understanding required to perform discipline-specific tasks (see Figures 1 & 2). Faculty rated students' knowledge as below the necessary levels for all but three concepts (matrices, integration, and int. meaning). The largest levels of discrepancies within the statistics track occurred in the topics of correlation (mean difference of 2.7), hypothesis testing (mean difference of 2.6), and standard deviations (mean difference of 2.6). The largest levels of discrepancies within the methods track occurred in the topics of graphs (mean difference of 2.6), algebra (mean difference of 2.5), and single variable max/min (mean difference. of 1.5).

Figure 1. Faculty Satisfaction with Students' Math Efficacy: MA 105/106

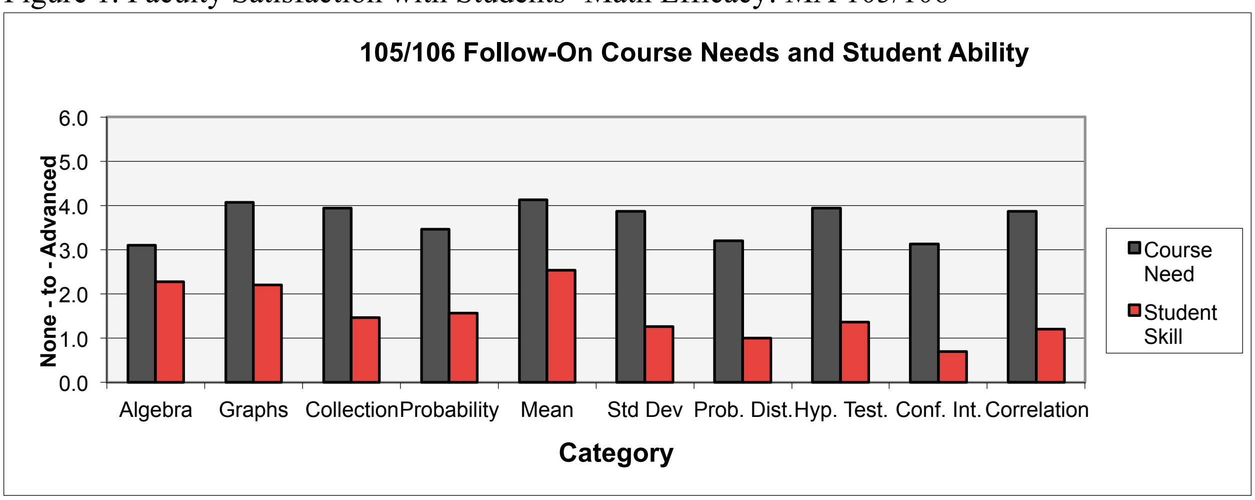
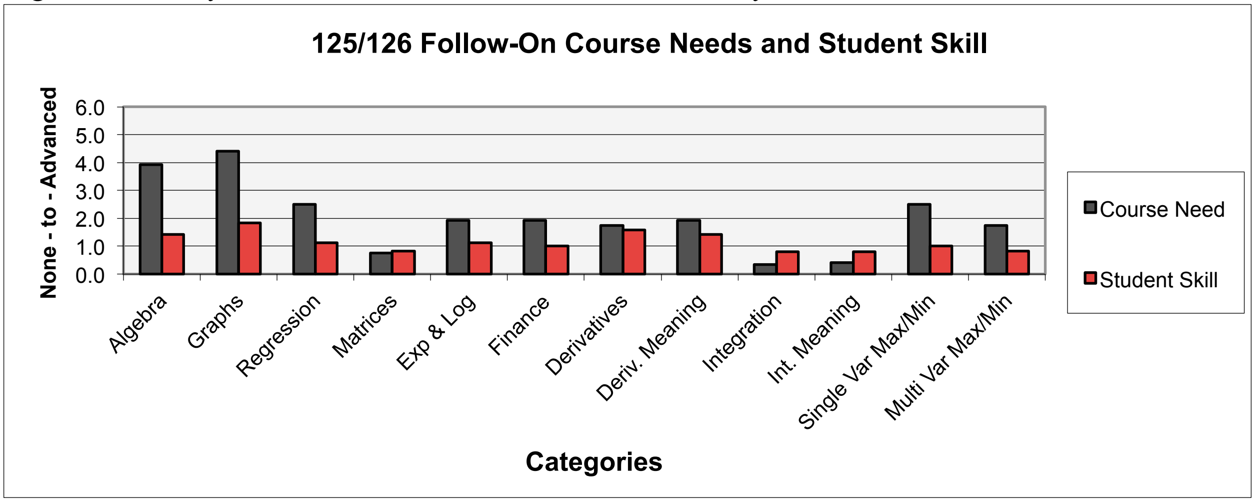


Figure 2. Faculty Satisfaction with Students' Math Efficacy: MA 125/126



Although the overall amount of perceived deficiencies was greatest among those faculty members whose students took the statistics track, faculty of students who took the quantitative methods track had similar overall perceptions. The levels of student skills for statistics track majors was below the level of course need for all ten categories (100%) surveyed. The levels of student skills for the methods track majors was below the level of course need for nine of the 12 categories (75%) surveyed. According the results of the Faculty Perception Survey, faculty members do not believe their students are well-prepared for problem-solving in advanced courses within their disciplines.

Summary of Findings

The rates of student failure were not terribly disconcerting, with a three-year average for both MA 105/106 and MA 125/126 sequences at less than 7%. However, the withdrawal rates for the MA 106 and 126 sections of the sequences were significantly higher than the MA 105/125 sections. Although it is unclear what might be causing these higher rates, it is reasonable to assume that a lack of foundational skills could be a primary reason. The MAI outcomes data provide some substantiation of this assertion, with only two of five outcomes for each sequence achieving the proficiency target of ~70%.

Further exploration of the MAI outcomes data revealed a potential significant disconnect – or misalignment - between how the outcomes and courses were intended to be implemented pedagogically and their actual implementation. Specifically, the outcomes and courses were intended to be executed through authentic, real-world activities, orchestrated through an inquiry-rich, problem-based learning approach. They were designed in this manner in order to achieve the intention of the core curriculum math courses: "to provide meaningful and appropriate foundations for problem-solving in advanced courses in other disciplines." However, we discovered that the classroom pedagogy was mostly lecture-based and did not incorporate multiple measures or authentic assessment in order to determine how well students were performing on the learning outcomes.

Other key findings included:

- Only cognitive outcomes were deliberately addressed in the design and implementation of the courses, not affective (i.e., motivational) outcomes,
- Students were not as interested in the content as desired and did not perceive it to be very useful,
- Courses were providing real-world examples, but these examples alone failed to help students see the how the math would transfer to the real-world,
- Students mostly used traditional handheld graphing calculators to solve problems, which most perceived to be outdated technology,
- Students do not have the confidence to use computational technology to solve math problems, which is very much how it works in the real-world,
- There is significantly more individual learning taking place than group learning, which is contrary to the tenets of inquiry/problem-based learning and,
- Faculty in the departments serviced by the non-STEM core curriculum math courses were mostly dissatisfied with students' foundational math skills.

Recommendations

Although the topic proposal selected for VMI's QEP was specific to teaching mathematics through computer coding and programming, an analysis of VMI's institutional assessment data revealed that a more comprehensive reconsideration of core curricular math education for non-STEM majors was needed. Specifically, the data strongly suggested that VMI's non-STEM students would be best served by addressing student learning in these two sequences by taking the following actions:

- Redesign the core curriculum non-STEM majors' math sequences and refocus the pedagogy used in these courses on the frameworks under which they were originally designed. Specifically, transition from the current teacher-centered approach to an inquiry-rich, problem-based approach. In accordance with best practices, the redesigned courses should focus learning on creative exploration, projects, problem solving, and innovation rather than rote memorization of facts (Marshall, 2010).
- Authentic activities and multiple measures of assessment should be driving forces in the courses' (re)design, implementation, and evaluation, as both help to make knowledge more relevant, which increases the likelihood of learning transfer (Bransford, Brown, & Cockling, 2000). Opportunities for teamwork and team projects should be included in instructional planning.
- Engage with faculty in other disciplines that are serviced by these core curriculum math sequences to develop discipline-specific problem-sets, the goal of which is make learning

interesting, useful, and transferrable. Intentional, evidence-based instructional design that addresses both cognitive and affective outcomes in the sequences' redesign will help achieve the goal.

- Engage in a "computational reboot" regarding the technology utilized to teach math. Namely, transition from outdated handheld graphing calculators to technology more likely to be utilized in the real-world (i.e., computers).

Considered in conjunction with the literature, ***Math that Matters*** will improve non-STEM students' attainment of the higher-order quantitative skills delineated in the Mathematical Inquiry outcomes and enhance their motivation through the development and implementation of research-based structural, curricular, and pedagogical/instructional enhancements.

Implementation of *Math that Matters*: Structural, Curricular, & Instructional Enhancements for Non-STEM Students

To review, VMI's ultimate selection of ***Math that Matters*** as its QEP:

- Is the result of a highly inclusive, broad-based topic development process;
- Is situated in the broader, national conversation about math educational reform;
- Capitalizes upon best practices for curricular and instructional design from the learning sciences;
- Leverages existing campus expertise in applied mathematics, general education, and assessment and evaluation; and
- Addresses key gaps in student learning and the student learning experience revealed by rich institutional assessment data.

QEP Mission

The mission of VMI's QEP is to improve student learning in non-STEM core curriculum math courses by (a) collaborating with faculty in non-STEM departments to develop discipline-specific, contextualized math problems, (b) helping non-STEM students to be computationally confident problem-solvers, and (c) designing and implementing instruction that is contemporary, evidence-based (e.g., authentic/inquiry learning), and incorporates academic motivation strategies designed to enhance perceptions of interest and usefulness.

Math that Matters will implement a series of interventions for students and/or faculty (both applied math and non-math faculty) in order to improve non-STEM students' learning in VMI's core curriculum math sequence to achieve the following goals:

Goal 1	To ensure non-STEM students are better able to use mathematical/computational skills to solve a wide variety of disciplinary and interdisciplinary problems.
Goal 2	To promote non-STEM students' affective development and attitudinal shifts toward math coursework to improve learning.
Goal 3	To foster an exciting and supportive collaborative environment for the learning of mathematical/computational skills for non-STEM students.
Goal 4	To promote a broader awareness of the applicability of mathematical/computational skills in all disciplines and professions.

The interventions encapsulated by ***Math that Matters*** drill down first to address a large, structural issue, then proceed to make course-based curricular changes, and finally hone in on fine-grained instructional enhancements at the faculty level. This approach is driven in large part by lessons learned, again, from VMI's first QEP, which focused on structural and some curricular level changes for general education, which may best be described *as necessary, but insufficient* for the kind of student learning outcomes desired of the program. The tripartite approach taken by ***Math that Matters*** is designed to address this shortcoming of the previous QEP's implementation. Desired changes, accompanied by rationales and indicators of success, follows.

Change #1: Math that Matters Structural Enhancement

Re-conceptualize MA 105/106 and MA 125/126 as a combined 2-semester course sequence.

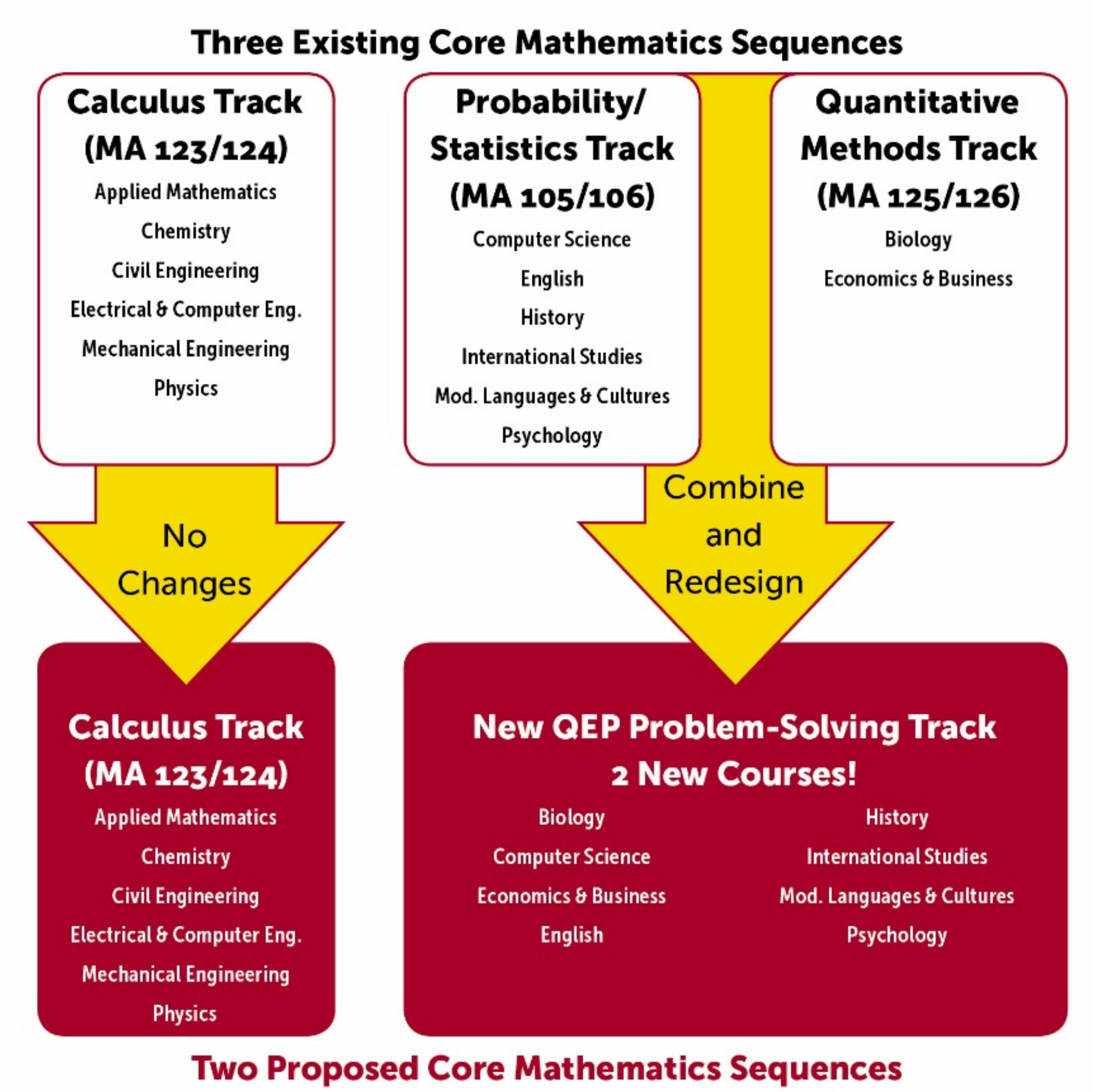
Designed to Address:

Goal 1: To ensure non-STEM students are better able to use mathematical/computational skills to solve a wide variety of disciplinary and interdisciplinary problems.

Goal 2: To promote a broader awareness of the applicability of mathematical/computational skills in all disciplines and professions.

Rationale for the Change:

Currently, both the Probability/Statistics Track (MA 105/106) and the Quantitative Methods Track (MA 125/126) suffer from the presentation of seemingly disparate skills through an information dissemination approach of lecture, versus an information creation approach through inquiry and discovery. This approach, coupled with assessment techniques that focus on short-term mastery of those isolated skills versus long-term conceptual understanding, diminishes the likelihood of cadets internalizing the material they learn in the existing courses, as evidenced by the lack of retention when cadets see these topics in their majors.



It is our belief that every non-STEM graduate needs not only exposure to statistics, the key concepts from calculus, and computational skills, but facility with each as a complement to their other academic pursuits and in preparation for entry into the competitive post-baccalaureate world. Segregating students into one or the other of these courses, therefore, is not acceptable. We are also mindful of balancing the VMI's Core Curriculum's goal of a common experience with the specific needs of each department. By including cadets from VMI's eight different non-STEM disciplines, we provide a setting for cadets from a broad range of interests and skills to work together. A figure of the proposed structural change is provided below, along with a sample of the concepts and skills to be covered in the new sequence.

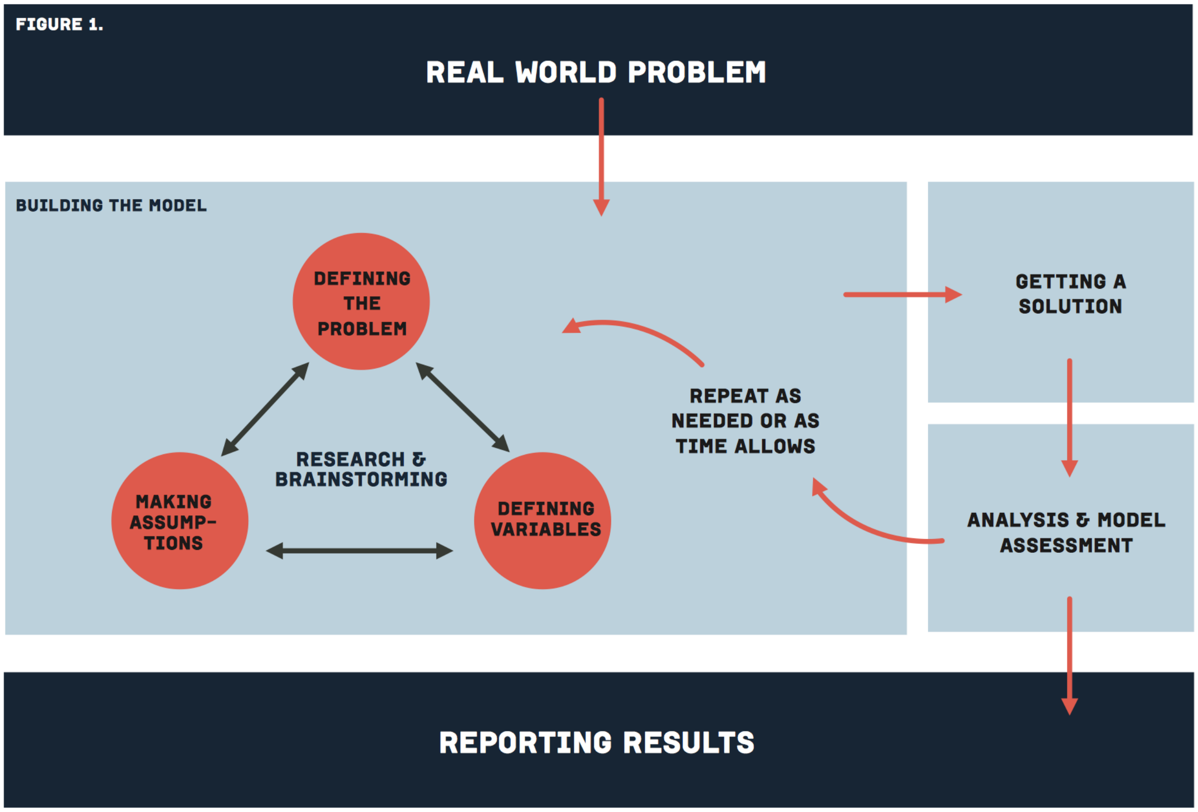
Sample Concepts/Skills for Inclusion in New Non-STEM Math Sequence "MA101/102"		
Calculus Skills	**Statistics Skills**	**Computational Skills**
Curve-fitting	Descriptive Statistics	Internet Searches
Differentiation	Hypothesis Testing	Data Importing/Cleaning
Integration	Types of Distributions	Data Analysis
Optimization	Correlations	Data Visualization

With the collapse of four courses to two, tentatively titled MA101 and MA102 and with a draft syllabus in Appendix G, we are being mindful of Halpern & Hakel's principle #9 that "Less is more" in terms of long term retention. By removing and/or combining much of the material from the existing core sequences, we will have the opportunity to include (a) essential skills (e.g., computational skills), (b) teach under a providing a time-intensive problem solving framework, and (c) focus on the skills that we would like to see transferred to courses in the cadet's field of study. In essence, the structural change facilitates the "flipping" of the current approach of content coverage (breadth) to one that is focused on contextualized, transferable skills (depth).

The course structure will leverage a problem-solving framework based on principles derived from the aforementioned GAIMME report that:

- Directly relates to problem solving supported by mathematical and computational skills;
- Addresses another key component of the QEP topic selected through our institutional process - contextualization - as the problem-solving is always launched, or motivated, by a real world problem;
- Aligned with VMI's core curriculum's five Mathematical Inquiry outcomes;
- Explicitly addresses issues of transfer through its emphasis on reporting, which implicates cadets' need to communicate (in writing or orally) individual or team results.

The figure below demonstrates this problem-solving framework.



An additional benefit derived by employing the problem-solving framework suggested by the GAIMME report is that it allows VMI to leverage existing "in-house" expertise in designing the structure of the new two-course sequence, as members of the applied mathematics department were co-authors of the report.

Because of its immersive pedagogical approach (student-centered, guided inquiry, problem-based learning), the course will transition from its current 21/22 cadet ceiling to a new cap of 15 cadets. We account for the additional sections by allocating funds for the hiring of teaching post-doctoral faculty members who have research and teaching backgrounds and interests compatible with the QEP.

<u>Action(s) to be Implemented:</u>

- A template (syllabus) for the merged 2-course sequence "MA101/102" will be developed by the end of Spring 2017.
- Simultaneously, the revised 2-course sequence will be put through the appropriate governance approval processes of discussion, review, and eventual approval by the Core Curriculum Oversight Committee, the Curriculum and Instruction (sub)Committee of the Academic Board and the full Academic Board during the 2017-2018 academic year.
- The 2-course sequence will be implemented in full for all non-STEM students for the 2018-2019 academic year.
- Search for post-doctoral positions

Indicator(s) of Success:

- Baseline assessment data captured for the general education Mathematical Inquiry (MAI) student learning outcomes in the first year of implementation.
- Successful approval of the 2-course sequence "MA101/102" for non-STEM math courses in the core curriculum.
- Hiring of post-doctoral positions, one for Academic Years 2018/2019 & 2019-2020 and one for Academic Years 2020/2021 & 20221/2022.

Change #2: Math that Matters **Curricular Enhancement**

Design and implement a modular-based curricular approach for the new math course sequence for non-STEM majors.

Designed to Address:

Goal 1: To ensure non-STEM students are better able to use mathematical/computational skills to solve a wide variety of disciplinary and interdisciplinary problems.

Goal 2: To promote non-STEM students' affective development and attitudinal shifts toward math coursework to improve learning.

Goal 3: To create an exciting and supportive collaborative environment for the learning of mathematical/computational skills for non-STEM students**.**

Goal 4: To promote a broader awareness of the applicability of mathematical/computational skills in all disciplines.

Rationale for the Change:

This curricular change is designed to provide the broader problem-solving framework for teaching VMI's non-STEM students critical computational and mathematical skills. For applied mathematicians, computation is inherently included in the set of tools we use to solve data-rich problems. Mathematical skills and computational skills simply go hand in hand. Our QEP is choosing the most relevant math skills from existing courses, and incorporating new computational skills to handle problems of the modern world. Changes to the curriculum will be accomplished through the design and implementation of a modular-based approach to content delivery and skill development. Complete modules, acting in effect as "chapters in the QEP textbook," brings together components of the cadet-centered and teacher-centered pedagogies. The modules are heavily contextualized in a variety of disciples and are designed to promote teamwork, student reflection, and perceptions of usefulness, interest, and success.

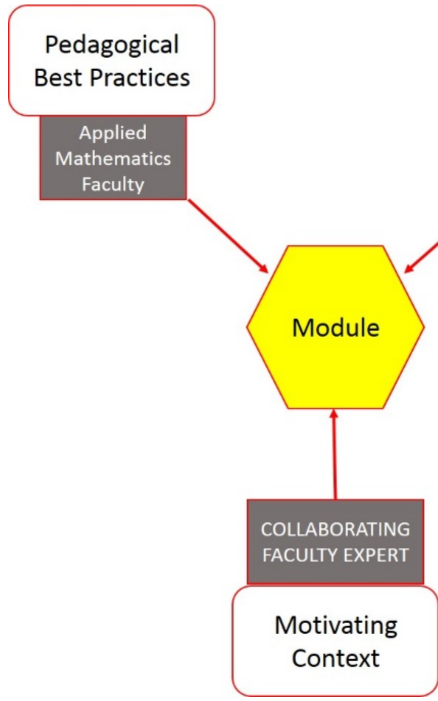
The QEP learning modules will be designed to address the shortcomings in non-STEM math education highlighted by the literature review and supported by VMI's review of its institutional data by leveraging the suite of best practices for teaching and learning implicated by research in the learning sciences and math education. Specifically, modules will:

- Be launched and driven by a contextualized question;
- Contain a set of questions, leveraging guided inquiry, such that cadets discover and develop the skills they need to address the motivating question;
- Have cadets take on clearly defined roles within their groups, so that they are able to work effectively together;
- Leverage the collective intelligence of the room through share-outs and class discussions; and
- Require cadets to report their findings to a clearly defined audience of stakeholders by translating their mathematical results back into the context of the original problem.

Modules are developed collaboratively by teams that include: (a) members of the Applied Mathematics Faculty; (b) a Collaborating Faculty Expert, defined broadly as faculty or staff from across Post; and (b) cadets themselves. Leveraging in-house expertise in mathematics education, the applied mathematics faculty member helps take initial ideas and translates them into the course's framework. For example, the applied mathematics faculty member aids in the identification of in-class versus out-of-class activities, the flow of instruction within days and across days of a multi-day module, the overall length of the module, necessary scaffolding, and ways to connect ideas across modules. Collaborating non-math faculty can be members of the faculty and staff from across Post, who are encouraged to contribute motivating questions and module ideas from their field.

Finally, since these modules will be used by cadets, we believe it is important to involve them in the design process. Cadets provide the best perspective about what they find motivating and they also help us develop meaningful out-of-class assignments that make the best use of the limited time they have in their schedules. They will have opportunities to work closely with both the collaborating non-math faculty expert and the applied mathematics faculty member, so they not only contribute to the process, but also get an opportunity to learn about educational best practices.

The figure below depicts the development of these modules that the new courses utilize.



The cadet-centered portion of the modules are launched and driven by an overarching contextualized question. Each modules contains a set of specific questions, leveraging guided inquiry, such that cadets discover and develop the mathematical and computational skills they need to address the question. The modules have cadets take on clearly defined roles so they can effectively work in groups and bring to bear the collective intelligence of the room through share-outs and class discussion. The module incorporates multiple pedagogical approaches, to include targeted lectures, quizzes/tests, and problem-solving sessions. It serves as the problem-solving framework that will be used to facilitate the learning of mathematical and computational skills.

As of summer 2016, four modules have been developed, drawing on examples from VM's departments of Modern Languages & Cultures and Biology. Four more are in various stages of completion, with modules under development from the Economics & Business and International Studies departments. One such example, called "Dream Trip!" is provided as proof of concept in Appendix H.

Modules have been developed, and will continue to be developed, through a series of VMI Summer Institutes involving Applied Mathematics faculty members, cadets, and faculty in non-STEM departments and from across the VMI community. The Summer Institutes bring together the best practices from the Applied Mathematics faculty, the student perspective from cadets, and the motivating, discipline-specific context from the collaborating faculty experts.

The VMI QEP Summer Institute is two 5-week sessions (aligned with the VMI summer school calendar) designed to bring together Applied Mathematics faculty, faculty from other disciplines across Post, and cadets in order to develop modules. The non-math faculty provide an idea for a module based on an idea or problem relevant to their discipline. These faculty members serve as consultants during the development of the modules. Participating cadets will develop the modules under the guidance of Applied Mathematics faculty, who will coach on matters of pedagogy, mathematics, and intentionality of design. During each 5-week session, multiple modules will be developed in parallel.

The first VMI QEP Summer Institute was held in 2016, providing several modules for future use and experience that will ensure the success of future Summer Institutes. The significant components of module development, along with the cadet and faculty roles, are provided in the Appendix E.

Finally, the two-course sequence will culminate in a "capstone" experience designed to help cadets integrate all components of the course through a final poster session. Groups of two or three cadets will formulate a question that is of interest to them and work collaboratively to answer it, by leveraging the skills they developed in the course and perhaps learning new skills in the process. Each team will then showcase their mathematical and communication skills by creating a visual presentation of their work through text, graphs, and graphics on a poster. Each subsequent course in the new sequence will have a common Poster Session, hosted at VMI's Center for Leadership and Ethics, which serves as an on-Post conference center. The entire VMI faculty will be invited and encouraged to attend, and presenting cadets will be provided with invitations to give to upper-class mentors, coaches, and other guests.

To help the VMI faculty see the value in and potential opportunities that we hope will arise from this new approach to teaching general education math, all faculty will be invited and encouraged to attend the annual poster session and to listen to cadets describe their diverse project topics and how they were able to use the skills they acquired in the course to solve problems of interest. Faculty attendance at the poster session is designed to inspire our faculty to develop ideas for modules during the VMI Summer Institute and potentially even modify elements of their own courses to take advantage of the cadet skills on display at the poster session. Similarly, we will invite members of the ROTC faculty and the coaching staffs to attend the poster session, in the hopes that they also may be inspired to submit ideas and participate in VMI Summer Institute.

To ensure the success of the curricular enhancements, we will pilot various aspects of the new course, to include test-runs of the modules during the 2016-2017 and 2017-2018 academic years. These tests-runs will occur in one to two sections of each of the existing four sections of MA105 & MA125 and MA106 & MA126 in the fall of 2017. In each case of piloting, we will explicitly test the modules for length and appropriateness of questions, as well as collect baseline data through student feedback.

<u>Action(s) to be Implemented:</u>

- Identify partner faculty experts in non-STEM fields and Post-wide professionals.
- Develop contextualized, interdisciplinary "wicked" problems for development as modules.
- Align and intentionally design each module and its constituent parts (e.g., student assignments, tests, other assessments, etc.) to target the appropriate (1) MAI outcome(s) and (2) MUSIC model for motivation construct(s) within a two-semester framework.
- Pilot module(s) in existing non-STEM math course sequences (MA 105/106 and MA 125/126) in 2016-2017 and 2017-2018 academic years.

- Design and implement a course-sequence capstone project culminating in an end-of-year research poster session.
- Continued implementation of the VMI Summer Institute and module refinement processes (see Appendix E)

Indicator(s) of Success:

- Assessment of student learning artifacts generated by each module for evidence of achievement of targeted MAI outcomes.
- Assessment of student motivation using the MUSIC model inventory (baseline collected 2015-16).
- Assessment of the culminating poster session using an adapted rubric adapted from the Joint Mathematics Meeting poster session.
- Initially, at least 14 modules developed in conjunction with the non-applied math faculty members for implementation of the course, expanded through the subsequent Summer Institutes to a bank of modules sufficiently large enough for both applied mathematics faculty and cadets to choose from.
- Expansion of module development to include examples from groups such as the VMI ROTC departments, Commandant's office, and coaching staff.

Change #3: Math that Matters **Instructional Enhancement**

Identify and utilize a range of research-based, active learning pedagogical approaches while preserving classroom faculty's sense of authorship and ownership for their classes.

Designed to Address:
Goal 1: To ensure non-STEM students are better able to use mathematical/computational skills to solve a wide variety of disciplinary and interdisciplinary problems.

Goal 2: To promote non-STEM students' affective development and attitudinal shifts toward math coursework to improve learning.

Goal 3: To create an exciting and supportive collaborative environment for the learning of mathematical/computational skills for non-STEM students.

Goal 4: To promote a broader awareness of the applicability of mathematical/quantitative skills in all disciplines.

Rationale for the Change:

The emphasis of the Mathematical Inquiry (MAI) learning outcomes, namely on student inquiry, has not truly been realized through our current approach to instruction (i.e., teacher-centered). To address this issue, we will realign the MAIs with more appropriate active-learning approaches.

By blending new cadet-centered approaches with more traditional formats (e.g., lectures, quizzes, tests, etc.), we are able to provide flexibility for faculty to take different paths to ownership of their classroom.

We are being intentionally "big tent" in our conceptions of appropriate active learning instructional strategies. First, different modules may implicate the use of multiple, different approaches to teaching and learning from both the applied math perspective, as well as the collaborating discipline/contributing problem context. Second, we also acknowledge – as supported by research by such experts in transfer as Schwartz and Bransford – that there is an appropriate role for effective lecture or "a time for telling," in college instruction (1998). Third, we want to simultaneously leverage existing faculty expertise in specific instructional strategies such as problem-based learning (e.g., Hmelo-Silver, 2004) and process oriented guided inquiry learning (POGIL) (e.g., Daubenmire, 2015), both of which have long traditions in STEM education, without being overly proscriptive. Finally, the faculty responsible for teaching the new course sequence is reflective of the diversity of faculty teaching nationally, from short-term adjunct, to long-term instructor, to tenure/tenure-track faculty, with varying levels of teaching experience. This all implicates the need for an investment in faculty development.

Faculty development within ***Math that Matters*** will be designed according to the following guiding principles (Franke, Carpenter, Levi, & Fennema, 2001; Martensson, Roxa, & Olsson, 2011):

- To sustain change, it must be from the ground-up, with ownership situated among the faculty involved;
- Discussions and dialogue that incorporate evidence and first-hand instructor experiences can help achieve a mature culture of teaching and learning;
- Peer review is a powerful force for change among educators;
- In order to fully implement a new practice or idea, opportunities to collaborate with peers and to engage in experimentation is necessary;
- When opportunity and preparedness meet, great things can happen. A clear mission and thoughtful timing are crucial to facilitating such conditions.

As a result of ***Math that Matters*** faculty development, participants will be able to:

- Develop and use active learning instructional strategies and attend to issues of academic motivation when creating student assignments, classroom activities and discussions, and student assessments;
- Align the knowledge, skills, and attitudes necessary to achieve the MAIs in ways that are appropriate to the domain and to the specific characteristics (i.e., prior knowledge) of freshmen;
- Reflect on the results of teaching math through the new framework in a process of continual improvement; and
- Share best practices in teaching core curriculum mathematics as part of an effort to demonstrate the efficacy of their approach to teaching and learning.

We do not intend to engage in randomized controlled trials in order to statistically prove that faculty development was efficacious. Rather, efficacy will be determined thorough holistic means. As stated in the Assessment and Evaluation section of this Plan, we will use a variety of assessment measures to determine achievement of MAIs. Having collected baseline data for MAI proficiency, Pass, Fail, and Withdrawal rates, motivation perceptions, and course and technology perceptions, we are well positioned to make inferences about the efficacy of faculty development, as well as the QEP as a whole.

Assessment activities related to faculty development will include a self-assessment of teaching, observation of classroom instruction, faculty portfolios of student activities, and focus groups in which faculty discuss (a) the effectiveness of various instructional and assessment strategies and (b) the contribution of faculty development activities in achieving faculty and student outcomes.

Additionally, an organizational guide to class instruction will be created to accompany the modules will be provided for all faculty teaching new core curriculum math courses. Faculty will be asked to share their guides on a shared VMI network drive. They will be de-identified.

The QEP Curriculum and Assessment Committees will assess these de-identified guides with a rubric and provide a summary report to the QEP Steering Committee annually. They will examine the extent to which course planning incorporated the new pedagogical approaches and corroborate this data with the data collected from the self-assessments of teaching, observations of classroom instruction, faculty portfolios of student activities, and focus groups. Faculty and members of the QEP committees will not report publicly on individual classes or faculty performance, and students' performance on outcomes will not influence decisions about reappointment, promotion, or tenure.

The Boot Camp will be an intensive one-week faculty development workshop designed to introduce the entire Applied Mathematics faculty, including the adjunct faculty, to the new courses, to ensure all of our faculty are informed and prepared to teach a section of the course. It will leverage faculty development workshop ideas from nationally recognized programs, including two National Science Foundation (NSF) funded workshop programs: the Faculty Development Workshop (FDW) at The United States Military Academy at West Point, and the Professional Enhancement Program (PREP) of the Mathematical Association of America. VMI is fortunate to have two experts in the area of faculty development for teaching mathematics through active learning and contextualization. MAJs Bliss and Libertini are both graduates of West Point's FDW, they ran a 2015 MAA PREP workshop on teaching mathematical modeling, and they have been invited to run faculty development workshops at several institutions, including Virginia Wesleyan University, Carroll College in Montana, and Singapore University of Technology and Design. A layout for the five-day Boot Camp is provided in Appendix F.

In addition, outside experts will be invited to Post in order to provide workshops and seminars on active learning pedagogies. Two such speakers are presently scheduled for visits in spring 2017.

Action(s) to be Implemented:

- Provide faculty development on active learning pedagogies/instructional strategies that align with the intended learning outcomes.
    - External facilitators/experts
    - Internal facilitators/experts
- Create an organizational guide to accompany the "QEP textbook." The *5e Learning Cycle* (Engagement, Exploration, Elaboration, Explanation, and Evaluation) (Goldston, Day, Sundberg, & Dantzler, 2010) will serve as a framework for the guides.
- Create of a faculty self-assessment instrument designed measure the extent to which the training has been efficacious, which aspects of the training have or have not been incorporated into their instruction, and the extent to which students have responded positively towards the new approach.
- Create of faculty portfolio template for self-reflection and showcasing of pedagogical lessons learned and successes.
- Create of a peer observation protocol.
- Create of interdisciplinary community of practice around active learning pedagogies engaging both applied math as well as collaborating expert faculty peers.
- Conduct the summer seminar (boot camp) for applied mathematics faculty – program outlined in Appendix F.
- Promote of faculty development opportunities including call for summer institute, invitation to speaker series, and call for travel grant proposals.

Indicator(s) of Success:

- Student course-level feedback, including traditional end-of-course evaluations and the MUSIC inventory.
- Syllabus and organizational guide inventory for evidence of active-learning pedagogical strategies.
- Showcase event for faculty teaching with more active learning pedagogies.
- Correlations to improvements on MAI outcomes.

Implementation Timeline for the QEP

The official start for the QEP is June 2017. Assuming the plan is accepted, the QEP Program Committee will continue to proceed under the following phases. The full table of QEP milestones concludes this chapter.

Phase 1. Ongoing work and Academic Year 2016/2017

- Initial course development (collapsed sequence into MA 101/102).
- Initial module development and broad faculty discussion of pedagogical approach.
- Conduct Summer Institutes for module development.
- Continuing faculty development seminars, module development committee work, and limited piloting of modules within existing math sequences in Spring 2017.
- Development of additional assessment materials.

Phase 2. Academic Year 2017/2018.

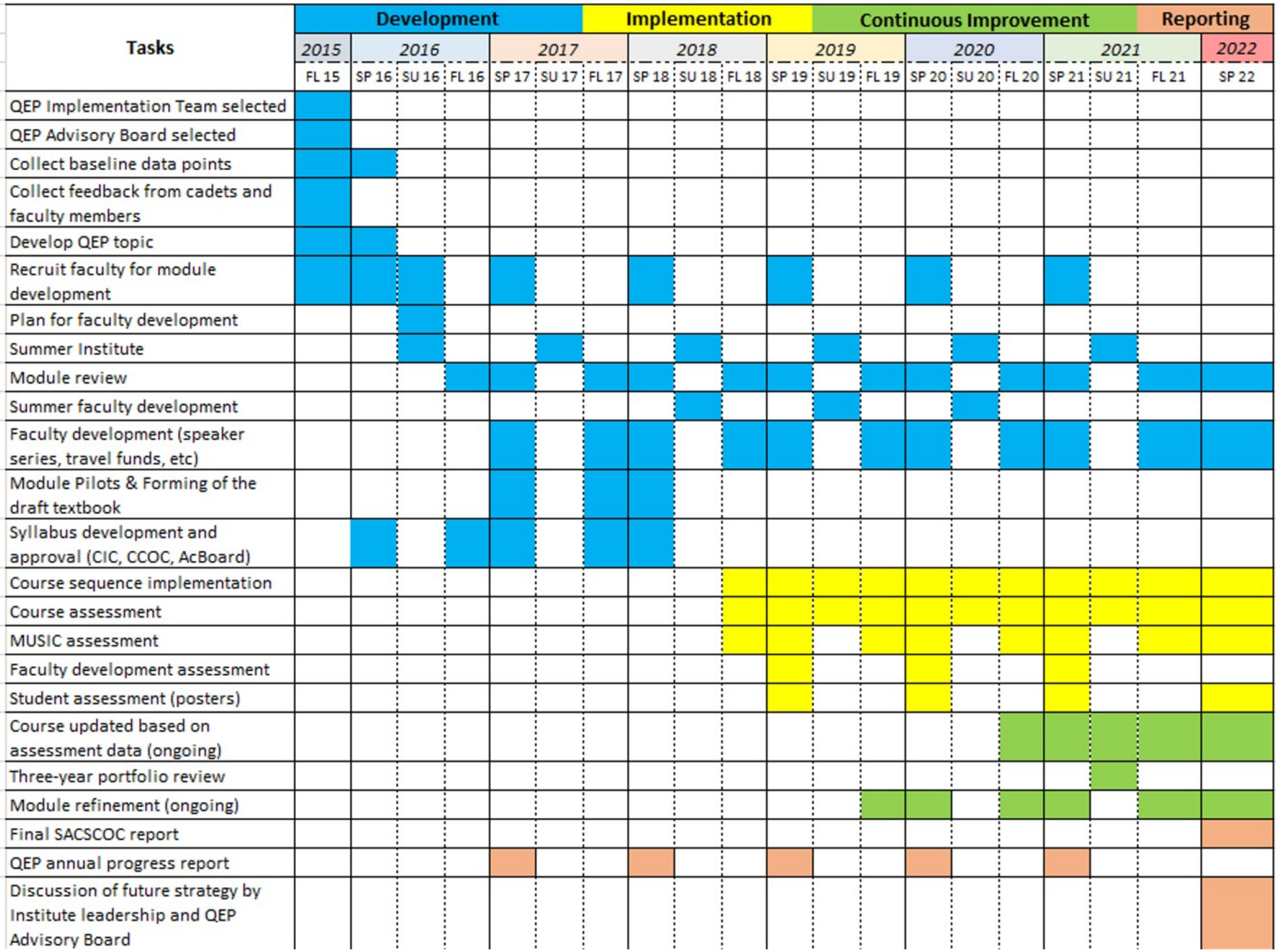
- Complete the draft textbook in the form of 14 modules for the two course sequence.
- Complete the development of faculty assigned to the core courses (boot camp).
- Introduce broader implementation of pilot modules in the Fall and Spring.
- Add teaching post-doctoral positions to faculty.

Phase 3. Academic Year 2018/2019.

- Full implementation of MA101 in fall 2018
- Full implementation of MA102 in spring 2019.
- Weekly teacher seminars to keep outcomes, approaches aligned.
- Initial collection of assessment data from new courses

Through the structural, curricular, and instructional enhancements detailed above, ***Math that Matters*** encapsulates VMI's creative approach to solving the "math problem" for non-STEM majors. The specific changes and sequencing of implementation are designed to both maximize in-house expertise and resources as well as provide the Institute the appropriate time and space necessary for testing out new ideas and bringing on new collaborators to the process. Furthermore, the pacing of the changes implicated by ***Math that Matters*** ensures that the QEP works in concert with important campus constituencies and governance structures to ensure that it does not devolve from an interdisciplinary, institutional strategy for fulfilling VMI's mission and *Vision 2039* into a project relegated to the purview of a single department or discipline. Finally, the complex, multifaceted, ongoing approach to assessment – through a robust mix of direct assessment of student learning with other key indices of performance like student perceptions of motivation, faculty pedagogical innovations, and key institutional markers of success – will ensure that ***Math that Matters*** attends to a process of continuous improvement that leverages formative and summative evaluation opportunities.

An implementation timeline is provided on the following page.


Tasks
Development
Implementation
Continuous Improvement
Reporting
2015
2016
2017
2018
2019
2020
2021
2022
FL 15
SP 16
SU 16
FL 16
SP 17
SU 17
FL 17
SP 18
SU 18
FL 18
SP 19
SU 19
FL 19
SP 20
SU 20
FL 20
SP 21
SU 21
FL 21
SP 22
QEP Implementation Team selected
QEP Advisory Board selected
Collect baseline data points
Collect feedback from cadets and faculty members
Develop QEP topic
Recruit faculty for module development
Plan for faculty development
Summer Institute
Module review
Summer faculty development
Faculty development (speaker series, travel funds, etc)
Module Pilots & Forming of the draft textbook
Syllabus development and approval (CIC, CCOC, AcBoard)
Course sequence implementation
Course assessment
MUSIC assessment
Faculty development assessment
Student assessment (posters)
Course updated based on assessment data (ongoing)
Three-year portfolio review
Module refinement (ongoing)
Final SACSCOC report
QEP annual progress report
Discussion of future strategy by Institute leadership and QEP Advisory Board

Assessment & Evaluation Plan

In this section we discuss the assessment and evaluation plan that will be used to determine the extent to which the QEP was successful. First, we again state the mission of the QEP and then we outline the five outcomes that will help us achieve that mission. Those outcomes are then "unpacked" by describing the specific assessment and evaluation methods and measures.

QEP Mission

The mission of VMI's QEP is to improve student learning in non-STEM core curriculum math courses by (a) collaborating with faculty in non-STEM departments to develop discipline-specific, contextualized math problems, (b) helping non-STEM students to be computationally confident problem-solvers, and (c) designing and implementing instruction that is contemporary, evidence-based (e.g., authentic/inquiry learning), and incorporates academic motivation strategies designed to enhance perceptions of interest and usefulness.

The success of the QEP will be determined by the extent to which the following outcomes are achieved:

1. Students' performance on the core curriculum learning outcomes, the Mathematical Inquiry (MAI) outcomes.
2. The extent to which evidence-based strategies for enhancing academic motivation are incorporated in the design of instruction and impact students' perceptions.
3. The extent to which students feel that they can confidently solve problems with computational technology.
4. The extent to which evidence-based practices for teaching and assessing authentic/inquiry-rich learning are used in the design and implementation of instruction.
5. Faculty and student satisfaction with (a) the redesigned courses and (b) the degree of learning transfer to disciplines serviced by these courses.

Outcome 1. Student Learning Outcomes

As discussed previously in this document, the core curriculum math outcomes – referred to as the Mathematical Inquiry (MAI) outcomes are:

Students will be able to:

1. Connect ideas of modern mathematics to applications in real-world settings.
2. Understand the relationship between variables and parameters of mathematical models and the patterns or phenomena they represent.
3. Formulate a problem using appropriate mathematical techniques and expressions.
4. Apply mathematical techniques to solve quantitative problems.
5. Communicate a solution in a manner that clearly indicates the line of reasoning.

Previously, all the MAIs were assessed in a rather unidimensional manner. Assessment for each outcome was completed using a single, albeit complex, final exam question. Through the QEP development process – with reference to research from the learning sciences and VMI's own institutional data –such an approach does not in fact align appropriately from either a pedagogical or an evaluative perspective. In short, the assessment tool does not fit the learning task. As such, the redesigned courses will include multiple, authentic measures, in addition to traditional assessments. The outcomes will not change, only the methods by which they are taught and assessed. This overall approach will help VMI engage not only in learner-centered teaching and learning, but learner-centered assessment (Huba and Freed, 2000). Often referred to as the missing part of pedagogy (Brookhart, 1999), course-embedded assessment that is truly integrated with the pedagogical process should not simply capture evidence of the end-product of learning; instead, completion of the assessment tool should itself promote intentional, appropriate processing designed to foster students' learning (McConnell & Doolittle, 2012). At its core, course-embedded, learner-centered assessment is implemented through the judicious use of course assignments (ibid.) created and/or selected by faculty experts and designed to facilitate the very specific processing requisite for each learning outcome (e.g., *Strategies + Processing = Learning*).

To that end, ***Math that Matters*** will utilize the full spectrum of potential assessment tools available through the new two-course sequence, from smaller, low-stakes module-based assignments that can be used for just-in-time, formative assessment, to larger, end-of-sequence projects like the poster session that provide summative assessment data reflective of the culmination of students' learning across multiple MAIs. Multiple choice quizzes and tests may be leveraged, as appropriate, to ascertain students' knowledge and comprehension of key concepts and skills, whereas open-ended problem sets, reflection prompts, and classroom presentations will provide students the opportunity to demonstrate higher-order thinking. Rubrics – either existing rubrics like AAC&U VALUE rubrics or locally created/customized – will be used to mine such assignments for evidence of student learning, serving as translational tools that generate data points appropriate for analysis. In short, anything students encounter through the syllabi for MA 101/102 has the potential to serve as an assessment tool, ensuring that ***Math that Matters*** engages in not only assessment of student learning, but assessment **for** student learning.

Baseline data for each individual MAI will be collected during Year 1, at which point appropriate targets/thresholds will be established for each MAI. Subsequent assessments will address annual results in light of the targets/thresholds. As the courses are an important constituent part of VMI's core curriculum, the assessment of MAIs within ***Math that Matters*** will directly feed into the Institution's efforts to address SACSCOC Comprehensive Standard 3.5.1 and any State Council of Higher Education for Virginia (SCHEV) assessment requirements, and comply and coordinate with all appropriate VMI governance structures.

In addition to the direct, authentic, course-embedded assessment of the MAIs within the courses, we will also monitor pass, fail, and withdrawal rates. Baseline data indicated that the average fail rate for the non-STEM course sequences was about 7%; grades of C, B, or A were 75.2% of the total. Withdrawal rates were higher in the subsequent sections of the sequences (between 2.1 and 6.1%). Failure rates at or less than 6% and withdrawal rates at or less than 5% would be indicative of success. The Office of Assessment and Institutional Research will provide pertinent data to the QEP Assessment Committee, which has responsibility for the analysis and reporting of assessment data.

Outcome 2. Incorporation of Academic Motivational Pedagogy

As discussed previously, ***Math that Matters*** is concerned with students' affective processing as well as their cognitive processing. Therefore, instructors will assess students near the mid-point and end of the course using the MUSIC Inventory and associated open-ended items (e.g., "What could be changed about this course to make it more interesting?"). The mid-point assessment will be used as a formative assessment and instructors will make modifications as needed to address students' concerns. On the MUSIC Inventory, the targets for success range between a mean score of 4.5 and 4.8 for interest, usefulness, and success by year three of implementation.

VMI's uses Campus Labs' Course Evaluation module to evaluate end-of-course evaluations, which allows for the inclusion of additional items for assessment and evaluation purposes. Allotting time for end-of-course evaluations is mandatory, which typically results in a high rates of responding. The MUSIC Inventory will be included as an addendum to the end of course evaluations for all math courses each semester from fall 2017 through the spring of 2021. The table below shows the assessment schedule and targets for success for each MUSIC model dimension.

MUSIC Model Summative Assessment Targets and Schedule

Dimension	Baseline Means (105/106; 125/126)	Post-Intervention Targets (3-yr)	Schedule of Assessment Fall 2017-Spring 2021
eMpowerment	4.6; 4.5	Monitor	End of course evals
Usefulness	4.2; 4.3	4.5	End of course evals
Success	4.7; 4.6	4.8	End of course evals
Interest	4.2; 4.1	4.5	End of course evals
Caring	5.1; 4.9	Monitor	End of course evals

Note: The MUSIC Inventory uses a six-point Likert-style scale (Strongly agree = 6).

Examples of open-ended items for formative assessment (assessed at the mid-point of the course):

- What could be changed about this course to make it more interesting?
- What could be changed about this course to make it more useful?
- So far, do you feel like you can successfully meet the learning objectives of this course?
    - If not, how could the course be changed to help you to be more successful?

Instructors will be asked to keep a record of the feedback solicited from the formative assessments, as well as the changes that were made as result of that feedback. These de-identified data will be provided to the Assessment Committee each semester.

Outcome 3. Computationally Confident Problem-Solvers

To determine the extent to which students feel confident in their ability to use computational technology to solve problems, we will survey students using the same pre-intervention items used to assess technology perceptions. Three-year targets for each item range between 75% and 85% *Strongly agree, Agree, and Somewhat agree*. As with the assessment of students' motivation perceptions, the OAIR will include these survey items as an addendum to the end-of course evaluations and the QEP Assessment Committee will analyze and report on the data. The table below shows the assessment schedule and the targets for success for each survey item.

Technology Perceptions Assessment Schedule & Targets for Success

Technology Perceptions	Baseline 105/106;125/126 %SA, A, & SwA	Post-Intervention Targets (3-yr)	Schedule of Assessment Fall 2107-Spring 2021
I feel confident that I can use Excel to solve math problems.	54%; 30%	75%	End of course evals
I feel confident that I can use computers to solve math problems.	69%; 46%	80%	End of course evals
I enjoy using a computer when learning mathematics.	65%; 38%	75%	End of course evals
Technology can make mathematics easier to understand.	80%; 69%	85%	End of course evals
I am comfortable using technology in math class.	81%; 69%	85%	End of course evals

Note: A six-point Likert-style scale is used for these items (*Strongly agree* = 6). The data will be reported by aggregating the top three response categories: *Strongly agree, Agree, Somewhat agree*.

Outcome 4. Use of Evidence-Based Instructional Design and Implementation

Math that Matters also explicitly requires the development, implementation, and assessment of evidence-based practices for teaching and learning within non-STEM math courses. This aspect of the QEP will involve the following five assessments:

1. **Faculty self-assessment.** A faculty self-assessment survey will be created by the QEP Assessment Committee by spring 2017. The survey will query the following and be administered every other spring semester beginning in 2017:
    a. Proficiency in the knowledge of teaching and/or assessment strategies appropriate for authentic/inquiry learning (before and after professional development training).
    b. Frequency of teaching and assessment strategies utilized in classes taught (before and after professional development training).

c. Effectiveness of teaching and assessment strategies used (before and after professional development training).
d. Alignment of teaching and assessment strategies with SLOs (before and after professional development training).

2. **Evaluative teaching observations.** Professional development over time is more likely to be effective when instructors are provided feedback through classroom observations that track the targeted instructional behaviors (VanTassel-Baska, Feng, Brown, Stambaugh, French, & Bai, 2008). An observation rubric will be adapted from the one created by Stearns, Morgan, Capraro, and Capraro, (2012) by the QEP Assessment Committee by spring 2017. Observations will occur twice a semester for each new course section starting in fall 2018. Each faculty member will receive the scores from their visitation along with an after action debrief from the observer. The QEP Assessment Committee will receive the de-identified rubric scores from observers and aggregate the scores for reporting purposes.

3. **Faculty-developed portfolios of students' work.** Professional socialization and supporting organizational structures are important to faculty vitality; workshops and opportunities to share expertise keep faculty engaged in developing their professional skills. As part of this professional socialization, math faculty will present portfolios of students' work- to include good and bad exemplars. This collaborative exercise will help to demonstrate what is working well and what is not.

4. **Review of syllabi and corresponding organizational guides.** Syllabi and organizational guides will be reviewed by the QEP Assessment Committee each year in order to ensure alignment of outcomes with appropriate teaching and assessment strategies.

5. **Course perceptions.** Because the items we used pre-intervention to assess math students' course perceptions measure important aspects of authentic/inquiry learning (e.g., group work, use of real-world examples, use of real-world technology), we will use the same items post-intervention. Three-year targets for each item range between 50% and 90% *Often* and *Very Often.* As with the assessment of students' motivation perceptions, the OAIR will include these survey items as an addendum to the end-of course evaluations and the QEP Assessment Committee will analyze and report on the data. The table below shows the assessment schedule and the targets for success for each survey item.

Course-Related Perceptions

Course Perceptions	Baseline 105/106;125/126 (% Often, Very often)	Post-Intervention Targets (3-yr)	Schedule of Assessment Fall 2017-Spring 2021
This course includes real-world examples.	87%;86%	90%	End of course evals
This course includes analogies and examples to help me understand difficult concepts.	80%;75%	85%	End of course evals
In this course, it is clear how the course material can be used to solve problems outside of math class.	74%;79%	85%	End of course evals
This course involves group work.	70%;30%	80%	End of course evals
This course involves individual work.	94%;97%	80%	End of course evals
This course requires the use of a computer to solve problems.	75%;25%	85%	End of course evals
This course requires the use of a handheld calculator to solve problems.	97%;96%	50%	End of course evals

Outcome 5. Faculty & Student Satisfaction

Finally, ***Math that Matters*** is also concerned with the relative faculty and student satisfaction. Specifically, we will be interested in ascertaining: (1) faculty's level of satisfaction with the observed/perceived degree of the transfer of MAI skills and abilities on the part of non-STEM students to subsequent classes as a result of ***Math that Matters***; and (2) students' satisfaction with the redesigned courses.

Surveys will be created and administered by the QEP Assessment Committee in order to gauge the extent to which faculty and students are satisfied with the redesigned courses and the extent to which faculty serviced by the new courses are satisfied with students' transfer of math skills. The same survey that was used to assess faculty perceptions of students' math efficacy in their courses will be used again post-intervention in order to detect any improvements in course needs and students' skill level (with any necessary modifications/revisions).

In order to determine the degree of math faculty and staff satisfaction with the new courses, the QEP Assessment committee will create a new survey that will be administered every other spring beginning in 2018 that measures satisfaction perceptions related to the following three areas:

- Pedagogy (teaching and assessment strategies),
- Effort exerted (perceived burden), and
- Resource needs being met (classroom space, adequacy of technology, support from academic services such as tutoring).

Assessment Reporting & Dissemination

The QEP Assessment Committee reports to the QEP Steering Committee and has the following charge:

To have oversight of the ongoing assessment of both student learning outcomes and program outcomes. This includes development, maintenance, and implementation of the assessment materials. The subcommittee will make recommendations for improvements based on assessment data and track the "closing-the-loop" process.

Members of the committee are as follows:

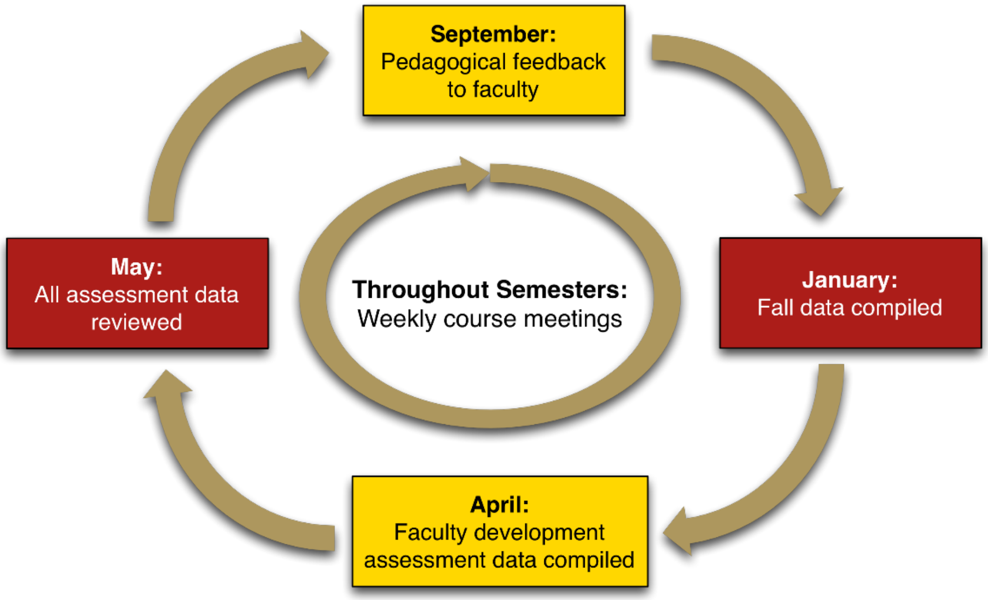
- MAJ Matt Jarman, Assistant Professor of Psychology, Chair
- COL John Cerkey, Professor, Modern Languages and Cultures
- LTC Mike Krackow, Assistant Professor, Health and Physical Education
- MAJ Jessica Libertini, Assistant Professor, Applied Mathematics

The QEP Assessment Subcommittee will receive SLOs and portfolio data from relevant math faculty at the end of each semester throughout the QEP's implementation. Additional data will be provided to the Committee by the Office of Assessment and Institutional Research, to include pass, fail, and withdrawal rates for the new core curriculum math courses and survey data from collected alongside the end-of-course evaluations: MUSIC Inventory, Course Perceptions, and Technology Perceptions. These data will be analyzed by the QEP Assessment Committee. All other assessment data, to include the faculty and student satisfaction surveys, faculty self-assessments, and evaluative observations, will be collected and analyzed by the QEP Assessment Committee.

Annual feedback cycle:

- September: Pedagogical feedback to faculty
- January: Fall data compiled
- April: Faculty development assessment data compiled
- May: All assessment data reviewed
- July: Summary report sent to QEP Steering Committee
- July: Summary report from the QEP Steering Committee to the Leadership Team.

See the figure below for more detail.

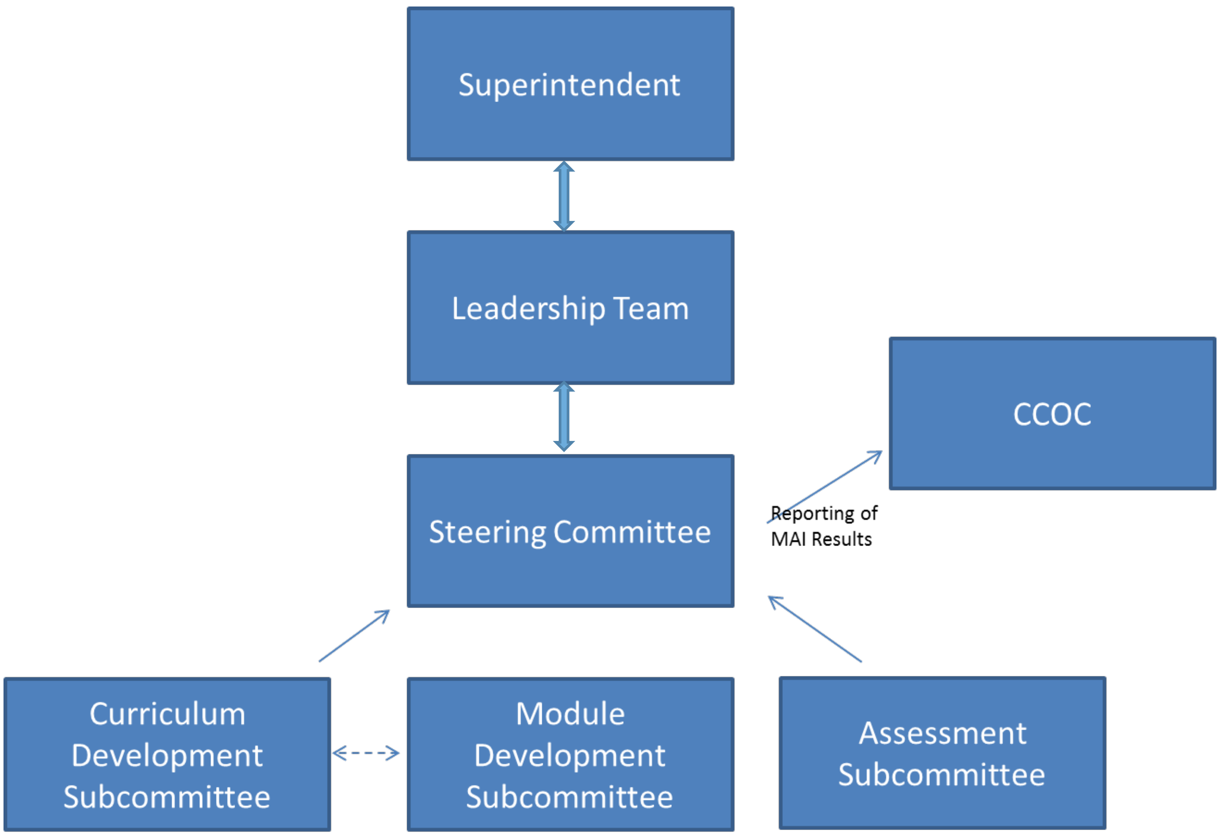


Human & Financial Resources

Human Resources

In this section, we discuss the organizational structure and associated financial plan needed to adequately initiate, implement, and complete the QEP. An organizational chart is provided below, along with the charge of the committees and associated membership.

QEP Organizational Chart



A description of the QEP committees, to include committee charges and membership follows:

Leadership Team. The charge of the Leadership Team is:

To provide oversight for the Compliance Certification Committee, the QEP Topic Development Committee, the QEP Steering Committee, the QEP Assessment Working Group, the QEP Resources Working Group, and the Faculty Qualifications Committee in support of VMI's application for reaffirmation by the Southern Association of Colleges and Schools Commission on Colleges in 2017.

Members of the leadership team are:

- BG Jeffrey Smith, Deputy Superintendent for Academics & Dean of the Faculty, Chair
- COL Jamie Inman, Chief of Staff, Deputy Chair
- Dr. Dave Diles, Director of Athletics
- BG Robert Green, Deputy Superintendent for Finance, Administration, and Support
- COL William Wanovich, Commandant of Cadets
- COL Tom Hopkins, Director of Information Technology
- LTC Lee Rakes, Director of Assessment & Evaluation

QEP Steering Committee. The charge of the steering committee is:
To manage the development, implementation, and evaluation of a Quality Enhancement Plan (QEP) in support of the Institute's bid for reaffirmation by the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC). In accordance with Core Requirement 2.12 and Comprehensive Standard 3.3.2, the committee will ensure the broad-based involvement of the VMI community in presenting and implementing a viable plan, in coordination with the Leadership Team, the Core Curriculum Oversight Committee, the Academic Board, and the Institute Planning Committee.
Key responsibilities include:

(a) oversight of related curriculum and faculty development programming,
(b) oversight of the ongoing assessment of both student learning outcomes and program outcomes,
(c) recommendations for improvements or changes in relation to assessment results,
(d) recommendations for the allocation of fiscal and human resources, and
(e) oversight and maintenance of a communication plan with stakeholders and the appropriate constituencies."

Members of the Steering Committee are:

- COL Troy Siemers, Applied Mathematics Department Head, Chair
- LTC Lee Rakes, Director of Assessment & Evaluation, ex officio
- COL Rob McDonald, Associate Dean of Academic Affairs
- COL Stewart MacInnis, Director of Communications & Marketing
- Cadet Easton Haslam, '17
- Chairs of the QEP Module Development, QEP Curriculum Development, and QEP Assessment Subcommittees

QEP Curriculum Development Subcommittee. The charge of the Curriculum Development Committee is:

To develop and manage the curriculum for the two-course sequence of the QEP that brings together aspects of calculus, statistics, computation, and the modules developed by the Module Development Subcommittee.

Members of the Curriculum Committee are:

- MAJ Jessica Libertini, Assistant Professor of Applied Mathematics, Chair
- COL Gregory Hartman, Professor of Applied Mathematics
- LTC Meagan C. Herald, Associate Professor of Applied Mathematics
- Mr. John R. Vosburgh, Applied Mathematics Adjunct Professor

QEP Module Development Subcommittee. The charge of the Module Development Committee is:

To manage the module development process for use in the two-course QEP sequence, to solicit and review applications for the summer institute, and to direct the judging of the end-of-year poster session.

Members of the Module Development Committee are:

- MAJ Karen Bliss, Assistant Professor of Applied Mathematics, Chair
- COL Atin Basuchoudhary, Professor of Economics & Business
- COL Turk McCleskey, Professor of History
- COL John Cerkey, Professor of Modern Languages and Cultures
- LTC Pennie Ticen, Associate Professor of English, Rhetoric, & Humanistic Studies
- LTC Howard Sanborn, Associate Professor of International Studies
- MAJ Ashleigh Smythe, Assistant Professor of Biology
- MAJ Matt Jarman, Assistant Professor of Psychology
- MAJ Ramoni Lasisi, Assistant Professor of Computer & Information Sciences
- Cadet Ross Schmeisser, '18

Assessment Subcommittee. The charge of the Assessment Committee is:

To have oversight of the ongoing assessment of both student learning outcomes and program outcomes. This includes development, maintenance, and implementation of the assessment materials. The subcommittee will make recommendations for improvements based on assessment data and track the "closing-the-loop" process.

Members of the Assessment Committee are:

- MAJ Matt Jarman, Chair
- COL John Cerkey
- LTC Mike Krackow
- MAJ Jessica Libertini

Core Curriculum Oversight Committee. The core curriculum oversight committee (CCOC) is not a QEP committee per se. It is the governing body of the Institute's core curriculum. The committee is chaired by the Associate Dean for Academic Affairs and is charged with reviewing proposals for new core curriculum courses or requirements; monitoring the assessment of the core curriculum offerings as conducted by the sponsoring academic departments; and advising the Academic Board on any proposed changes to the core curriculum, including general education competencies. Designated CCOC Liaison Teams work with departmental course coordinators to ensure assessment compliance, including the use of assessment results for improvement. Because VMI's QEP is focused on math education courses within its core curriculum, the new courses must be approved by the committee; the review includes an examination of course syllabi, pedagogy, and methods of assessment. Course development will involve the appropriate CCOC subcommittee. The committee must also approve any changes to the core curriculum learning outcomes. Membership of the committee includes representation from each of the Institute's academic departments, with 16 members total.

Financial Resources

The Institute's commitment of financial resources in support of this QEP, as outlined in the table provided below, is $686,903 over a six-year period. Of this amount, $171,148 represents "in-kind" funding from existing Institute funding sources, which is also described below. The total amount of new funding committed in support of the QEP is $515,755.

QEP Itemized Budget

Category	Year 0 2016-17	Year 1 2017-18	Year 2 2018-19	Year 3 2019-20	Year 4 2020-21	Year 5 2021-22	5-Year Total
Module Development							
Summer Institute	$16,995	$16,995	$7,959	$7,959	$7,959	$0	$57,866
Academic Year Initial Module Development	$6,000	$6,000	$0	$0	$0	$0	$12,000
Module Revision	$0	$0	$6,000	$6,000	$6,000	$6,000	$24,000
Module Total	**$22,995**	**$22,995**	**$13,959**	**$13,959**	**$13,959**	**$6,000**	**$93,866**
Training & Development							
Summer Boot Camp	$0	$60,675	$0	$0	$0	$0	$60,675
Support Staff Training	$0	$0	$3,000	$3,000	$3,000	$3,000	$12,000
Conference Travel	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$90,000
Speaker Series	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$5,000
Ambassador Lunches	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$6,000
Training & Dev. Total	**$16,000**	**$77,675**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$173,675**
QEP Leadership							
Steering Chair & Course Directors	$5,702	$5,702	$17,106	$17,448	$17,797	$18,153	$81,906
Teaching Post-doc	$0	$0	$70,967	$72,026	$73,107	$74,209	$290,308
QEP Leadership Total	**$5,702**	**$5,702**	**$88,072**	**$89,474**	**$90,903**	**$92,361**	**$372,215**

Assessment							
Assessment Chair	$2,691	$2,691	$2,691	$2,691	$2,691	$2,691	$16,148
Poster Judging	$0	$0	$1,000	$1,000	$1,000	$1,000	$4,000
Assessment Total	**$2,691**	**$2,691**	**$3,691**	**$3,691**	**$3,691**	**$3,691**	**$20,148**
Equipment & Supplies							
Computers	$0	$10,000	$0	$10,000	$0	$0	$20,000
Poster\Module Supplies	$0	$1,000	$1,500	$1,500	$1,500	$1,500	$7,000
Equip. & Supplies Total	$0	$11,000	$1,500	$11,500	$1,500	$1,500	$27,000
Overall Total	**$47,388**	**$120,062**	**$127,223**	**$138,624**	**$130,054**	**$123,553**	**$686,903**

Budget Items Rationale

Module Development. Module development is the key interdisciplinary component of the QEP, and it involves faculty from the Applied Mathematics department, faculty from across Post including the eight departments served by the two-course core sequence, and groups of cadets. Modules are scheduled for development both during the summer in the VMI Quality Enhancement Plan Summer Institute and throughout the academic year. In an iterative process driven by assessment data, the modules will be refined over time. The total budget for the module development and refinement is $93,866.

VMI Summer Institute. We held the first VMI Summer Institute devoted to module creation in summer 2016 with two Applied Mathematics faculty, consulting faculty from the Biology, International Studies, Modern Languages and Cultures, Economics & Business departments, and two cadets: one from Applied Mathematics and one from Mechanical Engineering. The Applied Mathematics faculty, the consulting agents, and the cadets were all compensated for their efforts. We will hold similar efforts in summer 2017 and 2018, with smaller iterations in the subsequent summers. The QEP Module Development Committee will solicit applications for both the summer institute and the AY module development and award mini-grants. Through this program, we aim to include a wide variety of consulting agents - not just faculty from other departments, but also coaching staff and ROTC leadership, as many of our cadets also have strong athletic and military interests. The budget costs include funding to provide stipends for Applied Mathematics faculty and the cadets throughout the five-week Summer Institute. Consulting agents, who are each asked to contribute a week of effort, will also be compensated for their efforts through stipends.

Academic year module development. Although we aim to eventually have all of our modules jointly created through the Summer Institute, initially the Applied Mathematics department will need to generate some modules in-house to make sure that cadets are exposed to an adequate breadth of mathematical material; we also need modules that act like on-ramps and off-ramps between the modules generated through Summer Institute. The budget includes funding for the first two academic years, when the course directors of MA101 and MA102, both of whom are Applied Mathematics faculty, will work to generate modules designed to round out these courses in time for the official launch in the Fall of 2018.

Module revision. In the words of German war strategist, Helmuth von Moltke, *"No battle plan survives contact with the enemy."* In practice, even the most carefully designed modules will require modifications. The budget includes funding to support the Applied Mathematics faculty, in concert with the QEP Module Development Committee and the co-authors of the modules, in revision processes based on new developments in the fields and in reaction to assessment data.

Funding for both academic year module development, as well as subsequent module revisions, will be provided in the form of mini-grants through the Faculty Grants-in-Aid (GIA) of Research Program. Funding support for three to five grants for module development/revision (estimated cost of $1,000 to $2,000 each) will be allocated within the GIA program annually. GIA grant proposals for module development/revision will be reviewed annually through the established process by the Faculty Development Committee.

Training & Faculty Development

The teaching styles used in the modules is inherently different than traditional lecturing, and as such, training for our instructors, both full-time and part-time Applied Mathematics faculty, is paramount to the success of these courses. We will implement training through a "boot camp" in summer 2018, in-year seminars and meetings, and invited speaker sessions. The total budget for training and faculty development is $173,675.

Summer Boot Camp 2018. All members of the Applied Mathematics faculty will attend an intensive, one-week faculty development workshop. The camp will focus on the shift in pedagogy, including helpful hints about how to facilitate guided inquiry and group work. Participants will hold practice class periods and get feed-back from their peers and the camp leaders. Within the department, we have two experienced faculty members who have run similar sessions at other schools and professional societies, and they will be joined by one or two visiting facilitators from within the applied mathematics education community. The budget includes compensation, meals, and any necessary travel for the workshop facilitators as well as stipends for faculty providing and participating in the training. Additional information about the Summer Boot Camp is provided in the Implementation section of the Plan.

Support staff training. The two-course sequence will be actively supported by two of VMI's successful student support centers: the Open Math Lab, which is a drop-in mathematics help-center, and the Writing Center, which is a drop-in or appointment-based writing clinic. These centers are staffed by faculty, part-time support staff (many of whom are long-term employees), and a new set of cadets each year. We will encourage all staffers to attend training opportunities, such as workshops, weekly course meetings, and class visitations, by paying them their hourly rates to attend these events.

Conference travel. Dissemination of information about our efforts is very important, and therefore the budget is designed to support and encourage conference engagement. We hope to support travel for up to six faculty members a year to attend and participate in conferences related to STEM education, disciplinary education in their field, and/or general education, including first-year experiences. As examples: we anticipate Applied Mathematics faculty presenting at the Society of Applied Mathematics Educational Conference; we hope that Economics faculty will present their co-developed module at the annual meeting of the America

Economic Association; and we will encourage our QEP leadership (Program Director, Course Directors, Assessment Director) to attend more general higher educational conferences such as the Gardner Institute's Gateways Conference and the AAC&U's PKAL Conference. Given an emphasis on outside validation for scholarly engagement in the tenure and promotion process, our ability to support faculty to present at conferences sends a clear message that this work is important, it matters, and it counts towards tenure and promotion.

Funding for conference travel will be provided through the Dean's Office Faculty Development Budget. The Faculty Development Budget is currently funded at $127,000 annually, and it is anticipated that this budget will increase by $20,000 annually when the privately funded grant that has funded 75 percent of this budget since 2001 is renewed in spring 2017. The Dean's Office, which will be responsible for managing the solicitation and awarding of these funds, will allocate $15,000 annually for QEP-related travel for a total budget of $90,000.

Speaker series. Although we are explicitly making pedagogical changes within these Applied Mathematics courses, many of the skills we are promoting through these pedagogical practices are transferable across department lines. Therefore, all members of the VMI faculty will be invited to attend a pedagogical speaker series each year. Experts will present information from the fields of inquiry-based, project-based learning, and academic motivation. The budget includes $1,000 annually in funding for regional travel and a small honorarium, which will be allocated from the Dean's Speaker Series.

Ambassador Lunches: We will hold information session working lunches during the year. We plan to have 10 faculty members join us per semester for informal discussions so that over time most, if not all, of the faculty at VMI have an opportunity attend.

QEP Leadership

To ensure adequate leadership of the QEP, as well as administrative oversight and support, the budget includes several positions – both part-time and full-time. The QEP Steering Committee Chair position is a part-time, collateral duty assigned to the Applied Mathematics Department Head. The two course directors will also be assigned as part-time, collateral duties for Applied Mathematics faculty. Each of these positions will receive a one-course release to support their efforts. Following are descriptions of the roles and responsibilities of these positions:

QEP Steering Committee Chair: The QEP Steering Committee Chair will oversee the work of the QEP and oversee the three QEP Subcommittees. The committee's charge and membership is provided in the Human Resources section above.

Course Directors. Two members of the Applied Mathematics department will work as Course Directors, one for each of the two courses being developed through the QEP. In order to provide sufficient support for the transition in pedagogy, all QEP course instructors will meet weekly to discuss observations, successes, and potential improvements in the course, and to prepare for upcoming classes. The Course Directors will be responsible for coordinating the weekly meetings, conducting class visitations and assessment, and preparing reporting materials. After visiting classes, the Course Directors will provide actionable, constructive feedback for instructors. Additionally, other instructors will be invited to observe the Course Director teach his or her class, providing yet another training opportunity.

Furthermore, in order to help cover these course releases during our ramp-up of the program, to aid with harnessing the incredible educational research potential of this project, and to promote VMI's commitment to serving as a national leader and trainer in the field of applied mathematics education, we are committing to supporting a post-doctoral teaching fellow spanning Years 2-5 of the program. The intent is to cover this position in two, two-year appointments – one in Years 2 and 3, and one in Years 4 and 5. This position will carry the requirement of teaching four sections of QEP courses per semester. This position also requires a combination of course management, reporting, authorship of QEP findings, and\or other duties as appropriate to the skill level of the person and specifically described at the time of hiring. The post doc will receive a salary equivalent to the adjunct salary for this teaching load along with full-time benefits. After year five, the funds committed for the post doc salary will be transferred to the part-time faculty budget to provide continued adjunct support for the new mathematics course sequence.

Equipment & Supplies

The budget includes costs for three categories of equipment purchases: computers; poster session supplies; and module materials. Given that the costs of these last two budget items is highly variable, rather than including individual line items in the budget, we have consolidated the costs into a single line item; however, the rationale for each type of purchase is broken out below. The total allocation for equipment and supplies is $27,000.

Computers. Although the vast majority of our cadets arrive at VMI with their own laptops, VMI does not require students to purchase one. Therefore, the department will need to have a small number of computers that the cadets can borrow for in-class use. We anticipate an initial outlay of 6-8 laptops in the first year, followed by supplementary, upgraded computers as needed, and these costs are included in our equipment budget. Funding support for these equipment purchases will be allocated from the Institute's allocation from the Higher Education Equipment Trust Fund (HEETF). The HEETF was established in 1986 by the Virginia General Assembly and provides Virginia institutes of higher education with funding for the purchase of equipment for instruction and research. The Institute receives approximately $750K in HEETF funding annually.

Poster Session Supplies. The culminating assignment of the course sequence requires cadets to create a poster for display at a broadly attended VMI poster session. We anticipate at least 100 posters per year. In anticipation of this event, the Applied Mathematics Department has already procured the large-scale printer, but we will need to supply it with paper and toner. These costs, as well as the costs of poster stands, such as tri-folds, are included in the equipment budget.

Module Materials. While none of the modules require any expensive or specialized equipment, some of the modules require simple materials. The costs of these materials are included in the equipment budget.

Assessment

As described in the Assessment & Evaluation Plan, the assessment of both the cognitive and affective learning outcomes will be imbedded into the new course sequence through projects, writing assignments, quiz/exam questions, and surveys. Some of these assessments will serve two purposes: assessment for grades within the course and assessment with respect to the QEP. Therefore, this data collection does not require any additional stipends, as faculty will only have the minor additional responsibility of reporting their findings. For further broad-based involvement, we will have members of the Module Development Committee be responsible to recruit an interdisciplinary panel of judges for the end-of-year poster session. The administration of some surveys, such as the MUSIC survey, will be overseen by the Assessment Subcommittee, with support from the Office of Assessment & Institutional Research. Regardless of the collection method, the QEP Assessment Committee will be responsible for analyzing the data and providing formative feedback to the QEP Steering Committee. The head of the QEP Assessment Committee will write annual reports summarizing the findings. The assessment budget of $20,148 includes annual stipends for the head of the QEP Assessment Committee, as well as small stipends for the poster session judges. Funding support for assessment efforts will be provided from the Institute Assessment budget.

In-Kind Funding

The new funding outlined in the budget amounts to $515,755 over the six-year period. In addition, in-kind funding will be available through several existing Institute funding sources. The table below provides a summary of in-kind funding that has been committed for the implementation of the QEP.

In-Kind Funding	Year 0 2016-17	Year 1 2017-18	Year 2 2018-19	Year 3 2019-20	Year 4 2020-21	Year 5 2021-22	5-Year Total
Institute Assessment Budget	$2,691	$2,691	$3,691	$3,691	$3,691	$3,691	$20,148
Grants-in-Aid Program	$6,000	$6,000	$0	$0	$0	$0	$12,000
Grants-in-Aid Program	$0	$0	$6,000	$6,000	$6,000	$6,000	$24,000
Faculty Development Funds	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$90,000
Dean's Speaker Funds	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$5,000
Equipment Trust Funds	$0	$10,000	$0	$10,000	$0	$0	$20,000
TOTALS	**$23,691**	**$34,691**	**$25,691**	**$35,691**	**$25,691**	**$25,691**	**$171,148**

Facilities & Physical Services

The QEP does not require significant resources in terms of space. The new course sequence will replace current mathematics courses in the core curriculum; therefore, we will use existing classroom space to teach the new courses. Training and module development activities will also use existing facilities. QEP leadership and assessment staff are all full-time employees who will be able to perform their QEP related duties using their current office spaces. Teaching post-docs will be assigned to available adjunct office space.

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Appendix A: Communicating the QEP

From: Newhouse, Charles D, "Chuck"
Sent: Wednesday, November 05, 2014 3:08 PM
To: Faculty
Cc: AdminHeads
Subject: Quality Enhancement Plan Open Forum and Call for Papers

The Quality Enhancement Plan Topic Development Committee invites all faculty members to:

(1) attend an open forum to discuss VMI's next QEP and
(2) submit white papers to the committee with ideas.

The meeting will be **November 24, from 1100-1200, in the NEB Auditorium**. Any white papers submitted by Friday, November 14, will be reviewed and considered for the discussion. Please send white papers and any questions to the chair of the committee at: NewhouseCD@VMI.edu

The QEP is an important part of the SACS accreditation process. We hope to hear from you and/or see you on Monday before Thanksgiving Furlough. Additional information about the QEP is included at the bottom of this message.

Sincerely,
Col. Charles D. "Chuck" Newhouse, Ph.D., P.E.
Civil & Environmental Engineering

Approved by the Dean's office for distribution

The QEP is part of the SACS accreditation process. According to the SACS website at:
http://www.sacscoc.org/genaccproc.asp
"The concept of quality enhancement is at the heart of the Commission's philosophy of accreditation. Each institution seeking reaffirmation of Accreditation is required to develop a Quality Enhancement Plan (QEP). Engaging the wider academic community and addressing one or more issues that contribute to institutional improvement, the plan should be focused, succinct, and limited in length. The QEP describes a carefully designed and focused course of action that addresses a well-defined topic or issue(s) related to enhancing student learning."

Sample QEP summaries, which are good examples for a white paper, can be found at:
http://www.sacscoc.org/2010TrackAQEPSummaries.asp
http://www.sacscoc.org/2010TrackbQEPSummaries.asp

Appendix B: Superintendent QEP Approval

VIRGINIA MILITARY INSTITUTE
LEXINGTON, VIRGINIA 24450-0304

OFFICE OF THE DEAN OF THE FACULTY
Phone 540-464-7212
Fax 540-464-7719

Memorandum

JHB Peay III 5/9/15

Date: 21 July 2015

To: General Peay, Superintendent

From: BG Jeffery G. Smith, Dean of the Faculty

Subject: Leadership Team Feedback and Recommendation for QEP

Dear General Peay. Sir. LTC Lee Rakes has gathered all comments from each member of the SACS COC Leadership Team. The Team has unanimously recommended the Math Proposal. If the math proposal is selected, LTC Greg Hartman has agreed to assume the role and responsibilities as Director for the QEP. Once you have made your decision, sir, we will inform Greg and have the team get going on the significant work ahead of us all.

Many thanks for your significant interest and personal oversight into ensuring that this process included broad proposals from across the Institute, reflected the passions and interests of our faculty, cadets, and staff, represented transformation opportunities, and was derived from VMI's mission and its fundamental learning objectives.

Very Respectfully,

JG Smith Jr

5 Sept 2015

THRU: Chief of Staff

TO: Dep Supt and Dean of the Faculty

Approved

File

JHB Peay
Superintendent

Appendix C: Faculty Survey

On Questions #3 - 17, a comment box was provided for additional comments apart from the indicated response type.

1. What department do you teach in? (BI, ECBU, CIS, PS, HI, IS, ML, ERHS)

2. Do you teach one or more courses that require students to be familiar with basic mathematical concepts? (Yes, No)

If No, "Thank you" message is displayed and survey ends.
If "Yes" and answer to #1 is CIS, PS, HI, IS, ML, or ERHS, move to #3.
If "Yes" and answer to #1 is BI or ECBU, move to #5.

3. The following mathematical concepts are covered in the 105/106 math sequence. Using this list of concepts, we want to first get a sense of the math needs of your typical courses. (Later, we'll ask about how well students actually do understand these concepts upon entering your courses.) Below, please indicate **what level of understanding is required** for each of these concepts upon entering your courses.

(*The following items were rated on a 7-point Likert scale, with indications of 1=None, 3=Basic, 5=Intermediate, 7=Advanced)*

Basic algebraic manipulation of equations and expressions; Understanding graphs and charts; Principles of collecting good sample data; Basic probability; Mean; Standard Deviation; Probability distributions; Hypothesis testing; Confidence Intervals; Correlation.

4. Below you will find the same list of mathematical concepts covered in the 105/106 math sequence. Now please rate your average student's understanding of these mathematical concepts upon entering your courses.

(*The same items as in #3 were rated on a 7-point Likert scale, with indications of 1=None, 3=Basic, 5=Intermediate, 7=Advanced, along with the option of 'N/A or Unknown'.)*

The participant is now moved to #7.

5. The following mathematical concepts are covered in the 125/126 math sequence. Using this list of concepts, we want to first get a sense of the math needs of your typical courses. (Later, we'll ask about how well students actually do understand these concepts upon entering your courses.) Below, please indicate **what level of understanding is required** for each of these concepts upon entering your courses.

(*The following items were rated on a 7-point Likert scale, with indications of 1=None, 3=Basic, 5=Intermediate, 7=Advanced)*

Basic algebraic manipulation of equations and expressions; Understanding graphs and charts; Regression; Matrix operations; Exponential and Logarithmic functions; Basic mathematics of finance: simple/compound interest, present/future value, etc.; Computing
derivatives of single variable functions; Understanding the meaning of the derivative; Computing integrals of single variable functions; Understanding the meaning of the
integral; Finding maximum/minimum of single variable functions; Finding maximum/minimum of multi-variable functions.

6. Below you will find the same list of mathematical concepts covered in the 125/126 math sequence. Now please rate your average student's understanding of these mathematical concepts upon entering your courses.

(*The same items as in #5 were rated on a 7-point Likert scale, with indications of 1=None, 3=Basic, 5=Intermediate, 7=Advanced, along with the option of 'N/A or Unknown'.)*

The participant is now moved to #7.

7. In general, how much do your courses draw from the previously mentioned material that students should have learned in their math sequence?

(Answer with 5 point Likert scale, indicated as 1=Not at all, 2=Slightly, 3=Moderately, 4=Quite a bit, 5 =Very much.)

8. Please list any other basic mathematical concepts that you expect or wish students would understand upon entering your courses? (*Comment box included.)*

9. Which of the following best describes how you revisit mathematical concepts in class that students should have already learned in their math sequence?

- I assume they remember nothing and reteach from scratch anything they need to know for my course.
- I assume they need substantial refreshing of concepts for my course.
- I assume they need some moderate refreshing of concepts for my course.
- I assume they need only light refreshing of concepts for my course.
- I assume they remember most of what they learned and don't spend time on those concepts in my teaching.

10. n general, how much do your students seem to have retained from their first math series upon entering your course?

(Answer with a 5-point Likert scale, with indications 1=None at all, 2=A small amount, 3=A moderate amount, 4=A large amount, 5=Everything they learned.)

11. On average, how many hours <u>during class</u> in a given semester do you spend covering the mathematical concepts that students <u>should have already learned</u> in their math sequence? (If this varies by class, please provide the higher number across those classes.) (*Comment box provided.*)

12. On average, how many hours outside of class in a given semester do you spend covering the mathematical concepts that students should have already learned in their math sequence? This might include office hours or working with students as they complete a math-related project. (*Comment box provided.)*

13. In general, how satisfied or dissatisfied are you with the math sequence?

(Answer with a 6-point Likert scale, with indications 1=Strongly dissatisfied, 2=Moderately dissatisfied, 3=Slightly dissatisfied, 4=Slightly satisfied, 5=Moderately satisfied, 6=Strongly satisfied.)

14. Rate how much you agree or disagree with this statement: "The math sequence prepares students for my courses as it should."

(Answer with a 6-point Likert scale with indications 1=Strongly disagree, 2=Moderately disagree, 3= Slightly disagree, 4=Slightly agree, 5=Moderately agree, 6=Strongly agree)

15. What are your thoughts on how effective the math series is at preparing students for your classes and others? (*Comment box provided.)*

16. If the math series were to change, what are the most important changes that you would want to see? (*Comment box provided.)*

17. Any other comments concerning the math series or this survey? (*Comment box provided.)*

Appendix D Cadet Focus Groups

QEP Cadet Focus Group Questions

1. Thinking about the usefulness of your math sequence courses, explain the difference or similarities between how you felt regarding the usefulness of those courses when you were taking them initially and how you feel now as you are into your major?

2. How often do you employ skills learned in those courses in your in-major courses now?

3. What were the most rewarding aspects of the core math sequence?

4. What were the most and least rewarding aspects – or, the aspects you disliked the most – of the core math sequence?

5. What kinds of things do you think you would have enjoyed learning about that were not taught in your core math sequence?

6. What kinds of software programs, if any, do you wish you were more proficient at using?

7. If you were to recreate a course from scratch, what are the top 3 things you'd include in it?

8. What is used in real life?

QEP Math Sequence Focus Group Analysis

Three focus groups were conducted between November 30 th and December 2 nd , 2015. The focus groups were made up of cadets who participated in either the MA105/106 or MA125/126 sequence. One focus group was held at noon on the 30 th with seven cadets. The second focus group was held on the 2 nd at 11:00am with five cadets. The final focus group was held at noon on the 2 nd with six cadets. Each focus group lasted between 30 and 40 minutes. The cadets' participation was voluntary and they were given the opportunity to leave at any time during the focus group. The cadets were also advised that they may have any comments redacted to the best of our ability (since no names or identifiers were taken down). The focus groups were recorded with permission from the participants.

The focus group responses were coded into similar concepts through a line-by-line coding scheme. Similar concepts were then grouped into common themes. A theme contained at least 3 codes to substantiate it. The sample size was not large enough to ensure a reliable study, but it still provides valuable insight to cadets' opinions towards both math sequences. These data should be used to assist as a confirmatory or explanatory artifact in the process of triangulating other forms of evidence.

When asked about their feelings towards the overall usefulness of the courses they had during the course sequence compared to those at the present time, three themes became apparent. The most common response was that the information learned in the sequence was never used (7). Five cadets commented that the information from the sequence was valuable, but only in real-world uses. An equal amount of cadets (5) said that the information was useful in other courses such as astronomy, economics, and biology.

Three themes emerged when the cadets were asked how often the skills learned in those classes are used currently in their major. Most cadets said that the skills were never used (7), while five commented that the information was only used in a limited amount in select courses. Four cadets further commented that statistics were most useful in real-world applications.

The focus group participants did not have much to say in regards to any rewarding aspects of the core math sequence. The ability to use stats to solve real-world problems with statistics was the most common answer (3).

Contrary to the minimum responses regarding positive aspects, comments towards negative aspects were quite numerous. Two themes emerged from the three focus groups. The first was that cadets felt they didn't learn much and/or were not challenged (14). Five cadets added that they felt there was no real-world integration of the information learned in the sequence. When asked what the cadets would have liked to see in the sequence, 12 said they would have liked to have seen a sequence that was appropriate and applied to their major. Eight cadets eluded to removing the use of calculators since they were not used afterwards. Cadets would have also like to have learned basic programming in languages such as Java or Python (8) and/or the use of Excel (7).

The final question asked the cadets to list three things that they would make sure are included in the new math sequence. The top three responses were 1) how to conduct data analyses using statistics, algebra, and/or calculus depending on the major, 2) move the math sequence to the third year, and 3) learn how to use a database.

After taking the initial math sequence, cadets recalled using confidence intervals, knowledge of outliers, the understanding of sample sizes and bias, and significance testing to better understand journals and other types of reported research. The use of algebra and calculus in real-world situations was not discussed. The overarching ideas gleaned from the focus groups relate to the idea of taking a math sequence that offers skills, such as programming/database management and data analysis that can be applied directly to the major and their everyday needs. The primary use of the information learned in the math sequence by non-STEM majors appeared to be for research and informed decision making.

Appendix E QEP Summer Institute

QEP SUMMER INSTITUTE

Lay Foundation:

- **Consulting Faculty (CF):**
  - Review math topics and objectives of QEP course.
  - Present idea for module to Applied Mathematics Faculty based on personal discipline that roughly aligns with QEP course (full alignment comes with module development)
- **Cadets:**
  - Learn about objectives of QEP and pedagogical concepts relevant to development of module
  - Practice module development by refining pre-existing, partially developed modules.
- **Applied Mathematics Mentor:**
  - Prepare partially developed modules, teach cadets relevant pedagogical concepts.

Initial Meeting

- **Consulting Faculty:** Present module problem/idea to cadets & Applied Mathematics Mentor within discipline context.
- **Cadets:** Take notes & ask questions of consulting faculty; write up summary of meeting.
- **Applied Mathematics Mentor:** facilitate cadet understanding where needed.

Prepare Module Draft

- **Consulting Faculty:** be available (email, phone, in person as needed) for questions.
- **Cadets:**
  - Outline module.
  - Determine milestones of progress and deadlines.
  - Begin development of student and instructor materials.
- **Applied Mathematics Mentor:** oversee cadet work, including
  - Appropriateness of outline,
  - Development of milestones, deadlines, and progress therein.
  - Appropriateness of developed materials (pedagogically sound? scaffolded well?)

Present Draft

- Cadets present current work to Consulting Faculty and Applied Mathematics Mentor. Progress is monitored and feedback given to cadets.

Module Finalized

- Cadets finalize student and instructor materials under guidance of Applied Mathematics Mentor, with Consulting Faculty responding to questions as needed.

Final Module Presented

- Cadets present finalized module to audience of all Consulting Faculty, cadets and Applied Mathematics Mentors

Appendix F: Summer Boot Camp Day by Day

QEP SUMMER BOOTCAMP

Day 1:

- Faculty play the a student role and experience three different modules, each led by a different trainer.
- Faculty study the intentionality and scaffolding of each module.
- Faculty are given a module to prepare & lead in an upcoming bootcamp day.

Days 2 & 3:

- Faculty lead assigned modules to other faculty, acting as students, in smaller group settings.
- Opportunities will be given for feedback, discussion & reflection.
- Feedback will be collected by the organizers at the end of each day to help guide the next day's activities and discussion, specifically in areas in which participant's confidence is growing and areas in which doubts and concerns remain.

Day 4:

- Participants work in groups to prepare a new module.
- The day ends with presentations and discussions of the modules created.

Day 5:

- Interested faculty will lead another module.
- Faculty will conclude work on module development.
- Additional unstructured time of preparation for the course will be provided.

Appendix G – Course Trajectories

QEP PROPOSED COURSE TRAJECTORY – COURSE 1

Table 1 is an overview of the first course, including the lesson number(s), the mathematical/computational content, the subject of the contextualization, and other skills. There is still a lot of room to move things, based on the module development process.

Table 1: Rough Draft of Course Outline for Course 1

Approx. Lessons	**Mathematical and/or *Computational Skills***	**Subject Area/ Context (Activity)**	**Other Skills or Comments**
1 – 2	Basic Computation *Entering Data into spreadsheets* *Forming/Using Equations in spreadsheets* *Basics of calling / locking cells*	Money and Travel (Currency Exchange)	Collecting Data Developing Models Making Assumptions Learning about POGIL assignments Communicating Orally
3 – 8	Discrete Dynamical Systems *Entering Data into spreadsheets* *Recursive Equations in spreadsheets* *Autofilling (locked vs floating) in spreadhseets* *Graphing in spreadsheets* *Graphing Multiple Functions in spreadsheets* *Fitting a trendline in spreadsheets* *Looking at R^2 value in spreadsheets* Families of Functions / Models Recursive Models Longterm Behavior & Equilibria	Populations (M&Ms)	Collecting Data Developing Models Making Assumptions Communicating Mathematics Models vs Data
9 – 12	Practice fitting data (trendlines) Small datasets Noisy datasets Making predictions	Application TBD (history or econ trends?)	Interpreting results of analysis Contextualizing predictions Communicating findings
13	Data Fitting (Trendlines)	Application TBD	Assessment (Test or Quiz) *maybe lesson 8 instead?*
14 – 19	Piecewise Functions Making predictions Correlations between data sets Changing axes to plot correlation	Corn Syrup Consumption (and other topics)	Downloading govt data Understanding outside influences Communicating findings Quality of data sources Briefing skill (roundtable)
20	Data Fitting II (Prediction)	Application TBD	Assessment (Test?)
21 – 28	Statistics Mean vs Median Variance Common distributions Introduction to Confidence	Biology/bat Others TBD	Data Analysis Data Visualization
29	Stats Overview	Application(s) TBD	Assessment (test?)
30 – 31	Computer experimentation Intro to hypothesis testing	Application TBD	
32 – 35	Correlation Hypothesis testing	Biology Data	
36	Correlations	Mini-project Proposal (list of topics proposed)	Proposal Development
37	Correlation	Application TBD	Assessment (Test?)
−38	Mini-project presentations	Selected topics	Oral communication Data visualization
39 – 42	Review	Application(s) TBD	
Final Exam	Course Overview	Applications TBD	Assessment

QEP PROPOSED COURSE TRAJECTORY – COURSE 2

Table 2 is an overview of the second course, including the lesson number(s), the mathematical/computational content, the subject of the contextualization, and other skills. There is still a lot of room to move things, based on the module development process. This is significantly less developed than the first semester so far, but the process of developing this will be a key element of the duties of the Curriculum Committee in AY2016-2017.

Table 2: Rough Draft of Course Outline for Course 2

Approx. Lessons	**Mathematical and/or *Computer Skills***	**Subject Area/ Context (Activity)**	**Other Skills or Comments**
$1-7$	Intro to integration ideas *Review spreadsheets* *Numerical integration in spreadsheets* discrete vs cont. Polynomial integration	Revisit corn syrup Accumulation (econ) Area/ volume	Contextualizing results Communication Visualization
$8-11$	Multivariable functions Multivariable integration Integration review/overview	Application(s) TBD	Visualization
12	Integration	Application(s) TBD	Assessment (Test or Quiz)
$13-19$	Intro to derivatives Approx vs Instant r.o.c. Discrete vs cont. polynomial derivatives	Application(s) TBD (zipline activity?) business	Contextualizing results Visualization Communicating findings
20	Basic derivatives	Application TBD	Assessment (Test or Quiz)
$21-25$	Multivariate Differentiation	Applications TBD	TBD
$25-29$	Optimization Single & multivariable opt.	Application TBD	TBD
30	Optimization	Application TBD	Assessment (test?)
$31-40$	Bigger Modeling Problems	Real World + TBD	
$41-42$			Poster Sessions Final Posters
Final Exam	Course Overview	Applications TBD	Assessment (test)

Appendix H: Sample Module Content

<u>Cadet-centered materials of the sample module “DREAM TRIP!”</u>

- Motivation by a contextualized question
- Questions for cadets, leveraging guided inquiry, for discovery and development the mathematical and computational skills they need to address the motivate question.
- Guidance for the instructors
- Developed in conjunction with a member of the Modern Languages Department

<u>Motivation:</u>

Dream Trip!

VMI just received a very generous donation from the class of ‘87 for the sole purpose of allowing Cadets to spend a weekend in a foreign country. You need to submit a proposal to the Study Abroad Committee to apply for the funds.

Divide up into your groups. Introduce yourself with your name, where you are from, and your major. Tell the group where you would want to go. As a group, pick one country to visit.

What country did your group decide to visit?

As a group: Look up the costs necessary to get to your desired country. Look up the costs of things you would want to do while in that country. Keep track of these expenses. The Reporter should be ready at the end of this activity to share out what you plan to do and at what cost.

The Reporter of each group will give a very short presentation on how they are planning to spend money on their trip. Be sure to listen to the other groups to see if there are things that you forgot to include!

What expenses did you not think about? What currency/currencies were your expenses in? What is the currency exchange rate to USD?

As a group: Look up the costs of any expenses you missed. Record all expenses in a table in the currency you found them in. Convert all expenses to USD.

For homework, you are to INDIVIDUALLY write your proposal. This means each team member will write their own proposal, summarizing the work the group did in class. In less than one page, write a proposal for your trip. Include: I Why you want to make this trip. The total cost of the trip in USD. A break-down of the total cost (i.e., airfare, lodging, food, tourism, etc.). The amount you’ll need in foreign currency for your visit. On a second page, create an Appendix to your report that contains a table of your costs.

Dream Trip Module

Throughout the semester you will be working groups with assigned roles. The following three roles will be used often:

Leader Manages the group. Ensures that members are fulfilling their role, the assigned tasks are being accomplished on time, and all members of the group are participating in the activities.

Recorder Records the names and roles of the group members at the beginning of each day. Records the important aspects of the group discussions, observations, insights, etc.

Reporter Presents oral reports to the class on behalf of the group.

Dream Trip Proposal
Homework Assignment

Your homework assignment is to write up your work from today in the form of a proposal. As a reminder, here is the scenario you were studying today:

> *VMI just received a very generous donation from the class of '87 for the sole purpose of allowing Cadets to spend a weekend in a foreign country. You need to submit a proposal to the Study Abroad Committee to apply for the funds.*

For homework, you are to INDIVIDUALLY write your proposal. This means each team member will write their own proposal, summarizing the work the group did in class.

- In less than one page, write a proposal for your trip. Include:
  - Why you want to make this trip.
  - The total cost of the trip in USD.
  - A break down of the total cost (i.e., airfare, lodging, food, tourism, etc.).
  - The amount you'll need in foreign currency for your visit.
- On a second page, create an Appendix to your report that contains a table of your costs.

Bring a hard copy of your proposal to class. This assignment is due at the beginning of the next class period!

Dream Trip Module

Author: Cadet: Ross Schmeisser, '18, Mechanical Engineering
Applied Mathematics Faculty: Jessica Libertini and Karen Bliss
Disciplinary Expert: Mary Ann Dellinger, Modern Languages and Cultures

Class time: 1.5 days

Abstract: This learning module is designed to give cadets an easy entry into the course, to familiarize them with the classroom environment they can expect in the course, including elements of POGIL, and to practice communicating mathematics. Cadets discover and learn the basics of using a spreadsheet by estimating costs for a trip abroad, and then write a proposal outlining their trip and the expenses.

Skills: Cadets should already be comfortable entering data into a spreadsheet and creating scatter plots. The new skills presented in this module include:

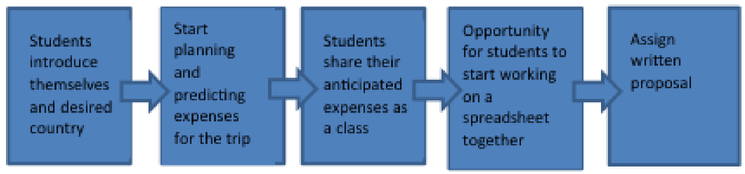
1. Learning to work within a group structure.
2. Learning basic Excel functionality, such as:
   (a) how to input functions,
   (b) row and column lock, and
   (c) the `sum` function.
3. Learning to become self-sufficient users of spreadsheets.
4. Finding and importing data.
5. Contextualizing mathematics and viewing it as an important tool to help answer real questions.
6. Written/Oral Communication.

Materials:

- PowerPoint presentation (provided)
- Instructor guides (one for each day)
- Student handout (provided)
- Push-pins: instructor may want to supply push pins in order to hang the student's spreadsheets in the front of the room. (See Day 2 for additional details.)

Dream Trip Module
Day 1

Overview



Details:

0. *Optional pre-class assignment:* Have the students start thinking of a foreign country they would like to visit prior to the first class. This request could be sent via email or Canvas.

1. Arrive to class early enough to load the PowerPoint presentation.

2. Break up the class into groups of 2-3 cadets. For this module the cadets will be following POGIL roles. It is recommended that each group has one leader, one recorder, and one presenter.

3. (3 minutes) Assign roles to cadets within each group. Give them a handout of the POGIL roles for this activity. Ask them to each read about their role and be prepared to discuss with their group.

4. Show the cadets the Introduction slide that states the problem for the day:

   > VMI just received a very generous donation from the class of '87 for the sole purpose of allowing Cadets to spend a weekend in a foreign country. You need to submit a proposal to the Study Abroad Committee to apply for the funds.

   Consider asking one of the cadets to read it aloud.

5. (5 minutes) Group activity:

   (a) Move on to the next slide, which provides directions for what the students are to achieve in the next five minutes:

   - Divide up into your groups.
     - Introduce yourself with your name, where you are from, and your major.

    - Tell the group where you would want to go.
    - As a group, pick one country to visit.

(b) If you plan to use some "gather back together as one group" gesture throughout the semester, explain it now and use it to re-group at the end of three minutes.

(c) Let them know they have only five minutes for introductions. Remind them that it is the leader's job to keep the group on task.

(d) At the three-minute mark, let the students know they have only two minutes remaining and should start having a discussion about which country they will choose. Remind the leaders again that part of their role is keeping time.

6. Re-group the entire class, move on to the next slide, and ask each group to share which country they plan to visit. Make sure the cadet who speaks is the group's reporter. Consider asking the reporter to name his/her teammates.

7. (20 minutes) Group activity:

(a) After each group has presented, move to the next slide and start the next activity.

- As a group:
  - Look up the costs necessary to get to your desired country.
  - Look up the costs of things you would want to do while in that country.
  - Keep track of these expenses.
- The Reporter should be ready at the end of this activity to share out what you plan to do and at what cost.

Remind them to maintain their POGIL roles, and encourage them to look on the internet as needed.

(b) Let the students look up various attractions and sights in their country. At this point just have the cadets list the things they would like to do and see. Walk around and listen to the types of expenses that one may have on a trip like this. Cadets may overlook things like travel expenses, lodging, food etc. As the instructor, encourage conversation and critical thinking in the group. Make sure that major items (lodging, airfare, food, etc.) are each represented in the classroom by at least one group. If no groups have identified a major expense, for example lodging, then you may need to nudge a group by casually asking them "Where are you sleeping?"

(c) Give the class several warnings about time. Remind them the reporter will need to share out the group's results.

(d) As you walk around the room during this activity, it is very important to keep reminding them of their specific roles through prodding. For example, "So, I see (name) is taking notes–you must be the recorder. Who is your reporter? I look forward to hearing (name's) presentation!" This will set the tone for the rest of the semester and have the class working together.

8. (1 minute per group) Move to the next slide and ask groups to share out.

    - The Reporter of each group will give a very short presentation on how they are planning to spend money on their trip.
    - Be sure to listen to the other groups to see if there are things that you forgot to include!

    This part is designed to let groups show the other groups expenses they may have missed. This is also to get practice presenting work to the class. You will also want to encourage active listening skills, so advise your cadets to present the material reflectively, citing the similarities and differences of their presentation relative to those before them–for example a good presentation might be: "Like the group going to Barcelona, we also included our prices in euros and included airfare and food, but we forgot lodging. Since we'll be in Paris, we've included a visit to the top of the Eiffel Tower, the Louvre, and a boat ride. We've also included our RER train tickets into town from the airport as well as a 2-day 5-zone metro pass."

9. Discuss the questions on the next three slides briefly. Consider whether it makes more sense to talk about them as a class or for the cadets to discuss them within their groups, and adjust accordingly.

    - What expenses did you not think about?
    - What currency/currencies were your expenses in?
    - What is the currency exchange rate to USD?

    This question may have been raised in the discussion already, or a cadet may have asked about it during the exploration phase. It is important that not all expenses may have been in USD, while some may have been.

    The students should use the internet to find the current exchange rate for their country to USD. The following URL is a good place to check answers/ to find current rates. `http://www.x-rates.com/table/?from=USD&amount=1`

10. (remainder of class minus 5 minutes) Group activity:

    (a) Move to the next slide and let the cadets know how much time they have remaining.

    As a group:

- Look up the costs of any expenses you missed.
- Record all expenses in a table in the currency you found them in.
- Convert all expenses to USD.

(b) Note: some students may have already had experience with spreadsheets, and may naturally migrate in that direction.

(c) If the students haven't naturally migrated to Excel (or other spreadsheet), nudge them to use Excel as a tool to keep track of their calculations.

(d) Also, note that many students who are not familiar with spreadsheets will use it just as a table and compute all their numbers on a calculator or by hand and manually entering the results into the spreadsheet, instead of leveraging the internal computational capabilities of the spreadsheet software. If you see cadets calculating outside of the spreadsheet, let them know that spreadsheets have a calculator built into them, and encourage them to use the internet to find out how to add numbers or sum a column of numbers. This should get them moving in the right direction.(They needn't be perfect yet, as they will have an opportunity on Day 2 to learn about ways to improve their use of spreadsheets.)

(e) Lastly, if you have groups that are comfortable with using the computational functionality in their spreadsheet, you may push them to begin to consider how they can improve the visual appearance of their spreadsheet through the use of borders, colors, etc. Again, rather than show them directly, encourage them to search online–for example, suggest "Gee, it would be nice if you could make these look like different columns–any ideas? Oh, (name), (that, e.g. adding borders to the columns) sounds like a great idea! Your spreadsheet can probably do that; see if you can find anything online about that..."

(f) Here's one example of how a spreadsheet might look.

	Cost of my Dream Vacation		
	debit	Amount (USD)	Amount (forgein currency)
Pre-Trip Costs	Flight		--
	Lodging		--
Trip Costs	Breakfast 1		
	Lunch 1		
	Dinner 1		
	Breakfast 2		
	Lunch 2		
	Dinner 2		
	Transportation		
	Entertainment		
	Sight-seeing		

Total (USD)	

Exchange Rate

11. (5 minutes) Gather the class again and move on to the last slide, which gives their homework.

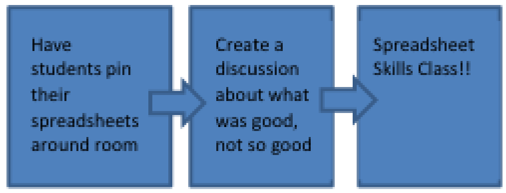
    For homework, you are to INDIVIDUALLY write your proposal. This means each team member will write their own proposal, summarizing the work the group did in class.

    - In less than one page, write a proposal for your trip. Include:
      - Why you want to make this trip.
      - The total cost of the trip in USD.
      - A break down of the total cost (i.e., airfare, lodging, food, tourism, etc.).
      - The amount you'll need in foreign currency for your visit.
    - On a second page, create an Appendix to your report that contains a table of your costs.

    Give each cadet a handout that has the assignment on it.

    This activity is designed to set a precedent of connecting math work to the real world and should be taken seriously. This writeup does not have to be very long, though it should be a professional proposal. Students will be showing each other their spreadsheets during the beginning of the next class, so be sure to emphasize that each spreadsheet needs to look clean and readable with easily understood labels.

Dream Trip Module
Day 2



Details:

1. As the students come into class, have them pin their spreadsheets up around the classroom.
2. (5 minutes) Once class has started have the students look at the similarities and differences between their spreadsheets and the spreadsheets of the other groups.
3. Start a class discussion about which were nicely organized and if they had seen some that could use a little improvement (and ask why).
4. Continue the discussion by asking what tools they used to calculate the cost of the trip. It is likely students will have used their calculators or an online converter to convert to USD. However, some students may have used the spreadsheet.
5. Next ask them: if they had 1000 expenses on this trip, would they want to use the same method?

   Ideally we want the students to see that doing all of these calculations by hand would be awful. Therefore, we can use a spreadsheet to do the calculations for us.
6. Pull up the Excel file `Dream_Trip_Excel.xlsx` and show students row and column lock, how to use equations, sum function etc. Better yet, if a team was ahead the day prior, arrange to use theirs.
7. Use this as a pivot point to go into a class about spreadsheet skills.

Throughout the semester you will be working groups with assigned roles. The following three roles will be used often:

Leader Manages the group. Ensures that members are fulfilling their role, the assigned tasks are being accomplished on time, and all members of the group are participating in the activities.

Recorder Records the names and roles of the group members at the beginning of each day. Records the important aspects of the group discussions, observations, insights, etc.

Reporter Presents oral reports to the class on behalf of the group.

Dream Trip Proposal
Homework Assignment

Your homework assignment is to write up your work from today in the form of a proposal. As a reminder, here is the scenario you were studying today:

> *VMI just received a very generous donation from the class of '87 for the sole purpose of allowing Cadets to spend a weekend in a foreign country. You need to submit a proposal to the Study Abroad Committee to apply for the funds.*

For homework, you are to INDIVIDUALLY write your proposal. This means each team member will write their own proposal, summarizing the work the group did in class.

- In less than one page, write a proposal for your trip. Include:
  - Why you want to make this trip.
  - The total cost of the trip in USD.
  - A break down of the total cost (i.e., airfare, lodging, food, tourism, etc.).
  - The amount you'll need in foreign currency for your visit.
- On a second page, create an Appendix to your report that contains a table of your costs.

Bring a hard copy of your proposal to class. This assignment is due at the beginning of the next class period!

Appendix I: QEP Strategic Communications and Key Document Integration

To keep the VMI community informed on the progress of the QEP, from selection up through final submission of this document, several meetings have been held with either the full faculty or with representatives of each department. A listing of some of those meetings is given below.

Date	Meeting / Purpose
11/24/2014	Faculty meeting to discuss QEP proposals
08/24/2015	Selected QEP topic and QEP Director announced to Department Heads, followed by announcement in general faculty meeting
09/24/2015	Meeting of QEP Director with representatives from all departments
12/01/2015	Meeting of QEP Director with representatives from all departments to update on QEP progress
01/13/2016	QEP Director presents QEP Draft to VMI's faculty and staff
02/1/2016	QEP Director presents QEP Draft to Board of Visitors
05/02/2016	QEP Director and Dean meet with representatives from all departments
08/26/2016	QEP Director briefs QEP Final Draft to Department Heads, Faculty Representatives, and Key Staff at QEP Summit
08/31/2016	QEP Director briefs the Academic Board
09/01/2016	Dean summarizes discussion from QEP Summit to Institute Planning Committee (IPC)
09/09/2016	QEP Director briefs the Core Curriculum Oversight Committee
09/13/2016	Forthcoming Dean Brief of QEP Final Draft to Board of Visitor members

The QEP has been integrated into VMI's Key Planning Documents

SCHEV 6-Year Plan FY 2016 and Update FY 2017

Sept 2016
- VMI's Academic Program Operations Plan, AY15-16
- VMI's Academic Program Operations Plan, AY16-17

Communications to the broader VMI Community
- QEP Article in September Issue of the *Institute Report*
- Forthcoming QEP article in October Issue of the *Institute Report*