Department of Mathematics Self-Study

Fitchburg State University

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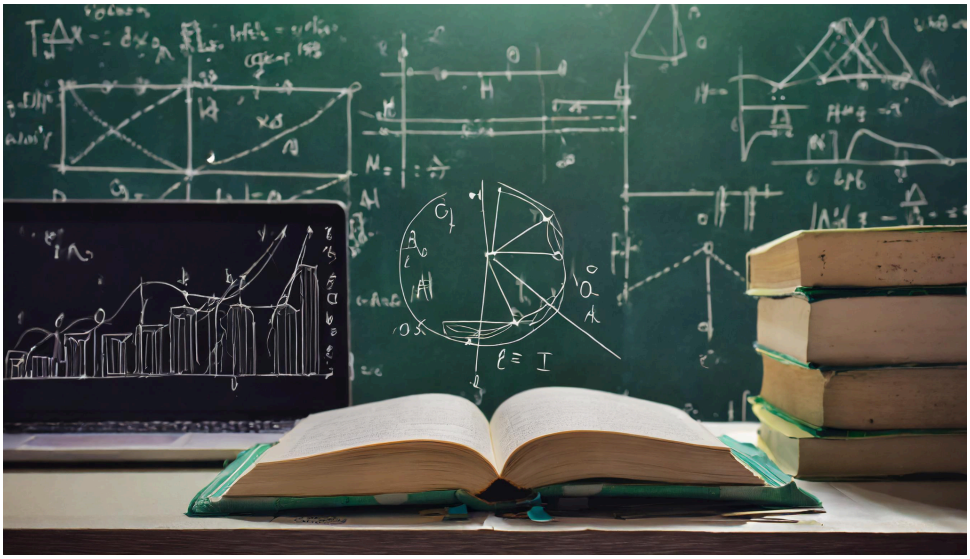

1. Overview and vision.....4

1.1 Overview of the Mathematics Department.....4

1.2 Vision, Mission and Objectives of the Department.....5

1.3 Relationship to the university mission, vision, and strategic plan.....6

1.4 Overview of program.....8

1.5 Internal demand of the program or department.....18

1.6 Recommendations and actions from previous five year review.....23

1.7 Changes and Initiatives since previous review.....24

2. Assessment.....25

2.1.1 Program reputation.....25

2.1.2 Students.....26

2.1.3 Faculty.....27

2.1.4 Staff Support.....29

2.1.5 Resources.....30

2.2 Program Processes.....31

2.2.1 Curriculum.....31

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1. Overview and vision

1.1 Overview of the Mathematics Department

During the last forty or more years, the Department of Mathematics has functioned both as a "service" department and a department with a viable undergraduate mathematics major program. Although the Department had either eleven or twelve faculty members for many years, during the period from approximately 2000 to 2010 it was staffed by nine or ten full-time members often with one of these members having a one-year temporary position. For academic year 2023-2024 the department has ten tenure-track full time faculty members, one full time temporary faculty member, an administrative assistant and a coordinator of foundational mathematics. Each semester there is also a need for several adjunct faculty members and the department has been fortunate to have a few excellent and dedicated long-time adjunct faculty members. See the Faculty Section for more details.

College policies and general governance of our academic workplace are determined by contract provisions and by proposals for change passed by the contractually established All University Committee (AUC) and approved by the President of the University. Faculty and librarian members of the AUC are annually elected by their colleagues to serve in this post. Administrators and students also serve on this committee. The Department traditionally has had at least one member on the AUC. Two of the standing subcommittees of the AUC, the Curriculum Committee and the Academic Policy Committee also have traditionally had Mathematics Department faculty representation. Our Department members have also participated in nearly every campus-wide curriculum and accreditation effort and in various other A campus-wide committee work or other initiatives. It was principally through the efforts of one of the members of our department that the University's Undergraduate Research Conference, now an annual program, was established AY 2009/2010. Members of the Department served on NECHE college-wide subcommittees preparing for the University's upcoming visit and evaluation by the NECHE accreditation team in AY 2021/2022. Members have also served as directors for campus-wide programs like the Center for Teaching and Learning, the Honors Program, and PASM.

The Mathematics Department is organized under the Agreement between the MSCA and the BHE (the Massachusetts State College Association and the Board of Higher Education) which mandates the election of a chair every three years and two departmental standing committees, the Curriculum Committee and the Peer Evaluation Committee. The Department currently has three additional standing committees for which the departmental faculty members volunteer. These are the Assessment Committee, Elizabeth Haskins High School Mathematics Contest Committee, and Seminar Committee. In recent academic years, this list has also included Search Committees. Other ad hoc committees have been formed as needed. The Department Chair along with the department administrative assistant and the departmental committees take

care of the business of the Department, which meets as a whole once a month. Since all faculty offices are in close proximity, faculty can and do communicate regarding day-to-day concerns and often can quickly resolve the minor issues that arise, through informal face-to-face communications and/or email.

1.2 Vision, Mission and Objectives of the Department

The defining characteristic of the Department and the major remains its devotion to its students and to high academic standards within service courses and major courses. The current mission of the Department is

"The mission of the Department of Mathematics is to foster our students' self-reliance in mathematics, to produce graduates who can bring together the theory and practice of mathematics, and to create in graduates strengthened ability for critical and logical thinking."

Through these principles, the Mathematics Department at Fitchburg State University aims to inspire a lifelong love of learning, promote mathematical literacy, and prepare our students to excel in a rapidly changing world where mathematical skills are increasingly essential. We are dedicated to nurturing the intellectual, personal, and professional growth of our students and contributing to the advancement of mathematics and its applications.

The Mathematics Department advances this mission by providing to Fitchburg State University students the best possible programs it can deliver for:

- The mathematics major program
- The mathematics major leading to initial licensure as a middle and secondary education teacher of mathematics
- The mathematics major with a concentration in Applied Mathematics
- The minor of Data Analytics
- The mathematics minor program
- The mathematics minor program for Early Childhood, Elementary and Special Education students.
- The mathematics service courses for students in disciplines which require particular quantitative knowledge and skills
- The mathematics courses which satisfy graduation requirements of the General Education Program
- The foundational mathematics program designed for students needing further preparation for college-level mathematics

While each of these components has a somewhat different purpose and objectives, the all-encompassing goal of the Department of Mathematics is to provide Fitchburg State students with the best possible teaching and learning environment, to ensure the academic integrity and academic quality of all mathematics programs and individual courses, and to actively encourage the academic growth and success of all students. The Department of Mathematics serves all

students at the University. Mathematics majors receive a comprehensive foundation in abstract and applied mathematics as preparation for a professional career or for further study. Minors in mathematics receive the mathematical foundation needed for advanced work in their major fields. Other students receive instruction in quantitative theory and skills appropriate for their chosen disciplines. The hope is that all students also receive an appreciation of mathematics as an intellectual endeavor.

1.3 Relationship to the university mission, vision, and strategic plan

The mission statement of Fitchburg State University reads:

"Fitchburg State University is committed to excellence in teaching and learning and blends liberal arts and sciences and professional programs within a small college environment. Our comprehensive public university prepares students to lead, serve, and succeed by fostering lifelong learning and civic and global responsibility. A Fitchburg State education extends beyond our classrooms to include residential, professional, and co-curricular opportunities. As a community resource, we provide leadership and support for the economic, environmental, social, and cultural needs of North Central Massachusetts and the Commonwealth. Fitchburg State envisions itself to "be nationally recognized for its excellence in teaching and learning in current and emergent fields, for its commitment to transforming lives through education, and for its dedication to public service."

The core values of the University as given on its website are *accessibility, affordability, community, enrichment, and excellence.*

The mission of the Department of Mathematics is to foster our students' self-reliance in mathematics, to produce graduates who can bring together the theory and practice of mathematics, and to strengthen our graduates' ability for critical and logical thinking.

The Mathematics Department advances the mission of the University by providing to Fitchburg State students the best possible programs it can deliver for all of the Department's constituencies – the mathematics major program (including concentration options in applied mathematics and middle and secondary education leading to initial licensure as a 5-8 or 8-12 mathematics teacher), the mathematics minor, the data analytics minor started in AY 2023/2024, the mathematics minor designed for the early childhood, elementary, and special education students, the mathematics service courses for students in disciplines which require particular quantitative knowledge and skills, the mathematics courses which satisfy graduation requirements of the General Education Program, and the foundational mathematics program designed for students needing further preparation for college level mathematics.

The Mathematics Department supports the mission of the University in several ways:

a) The Department has offered a mathematics major, which has compared favorably with majors at other liberal arts and comprehensive colleges. While we have a senior-level Capstone in Mathematics course in which students demonstrate writing and presentation skills in the study of problem solving and research on one or more topics outside the usual curriculum, we also now require the Freshman Seminar in Mathematics for all non-education students. This course introduces all students to possible careers, research, and paths through mathematics. This is a retention tool for our majors, which serves a different purpose to the general First-Year Experience course offered campus-wide. The mathematics offerings for the professional majors are considerable and have been continually re-evaluated. A list of service courses offered for particular majors can be found in section 1.5.1.
b) The Mathematics Department consistently attempts to keep an appropriate focus on mathematics content through the offerings of courses that are appropriate and up-to-date for the many different major programs it serves, and for its own mathematics majors.
c) The Elizabeth Haskins Mathematics Contest for area high school students has been an annual event for over forty years. Upwards of 500 students have come to this event in various years to compete for prizes, listen to talks on a variety of mathematical topics, and visit the campus.
d) A program of "Supplemental Instruction" was developed and initiated to assist instruction in MATH 1700, Applied Statistics, the most populated service course offered by the Department. This program continued to evolve and has expanded to most 1000-level service courses.
e) Prior to 2020, we hosted the AMC 8 and the AMC 10/12 exam for area middle and high school students. This year marks the first year since the pandemic that we have offered the AMC 10/12 at Fitchburg State University again. According to the Mathematical Association of America (MAA) website, these exams are multiple-choice examinations designed to promote the development of problem-solving skills. Local schools can provide the opportunity to take the exam to their own schools, but not all schools offer it. Since the exam cannot be given officially by individual families, hosting the exam at Fitchburg State provides the opportunity for some students to take it who would not otherwise have the opportunity; the mathematics department offers the exam as a service to the larger community.

In addition, the Mathematics Department supports the strategic plan of the university in many ways. In particular

> Goal 1: *Forge innovative paths to knowledge acquisition, career readiness, social mobility, and lifelong learning*
>
> The Department has designed a new minor in Data Analytics that is both innovative and develops skills in computing, data analysis, and interdisciplinary work that will directly affect career readiness. In both the Mathematics and Applied Mathematics

majors, there has been a greater emphasis on developing computing skills, again, which is very applicable to careers.

Goal 2: *Become a model student-ready university and narrow the achievement gap*

Because every student needs a mathematics (Quantitative Reasoning) course, the Department has been implementing mechanisms in our courses to address this goal. In Precalculus, we have had course-specific tutors in the year prior to this academic year and currently have embedded tutors in both the Precalculus and Calculus courses. See section 2.2.2 Students for more details. In nearly all of the other 1000-level courses, we have an additional contact hour per week to help all students with previous mathematical content on which they often need some supplemental instruction. There is some additional discussion of this in the Mathematics Readiness section.

1.4 Overview of program

The Mathematics Department serves all students at the University. Mathematics majors receive a comprehensive foundation in abstract and applied mathematics as preparation for graduate studies or for a professional career in either industry or as a middle or secondary education teacher. Minors in mathematics receive the mathematical foundation needed for advanced work in their major field. The Department also provides all students with courses for their major or with courses to fulfill the requirements of the General Education Program.

Mathematics students may pursue:

- A Mathematics program (analysis, algebra, geometry, number theory, and selected 'applied' fields).
- A concentration in Applied Mathematics (operations research, mathematical modeling, numerical analysis, graph theory, probability and statistics).
- Initial licensure as a middle or high school mathematics teacher (a mathematics major program which includes geometry, number theory, probability and statistics, pedagogy, and field experience in a school setting).

The core curriculum in the mathematics major provides considerable breadth in the discipline. All majors must complete the standard calculus sequence of MATH 2300: Calculus I, MATH 2400: Calculus II, and MATH 3350: Multivariate Calculus. Additionally, majors must take MATH 2600: Linear Algebra and MATH 2550: Symbolic Computational Mathematics, courses which expose the student to the techniques, theory and vast applications of linear algebra and to the applications and interconnections of technology and the discipline of mathematics. Additionally, and importantly, majors must take MATH 2500: Introduction to Mathematical Thought, which exposes the student to a wide variety of topics in the discipline including logic, set theory, and techniques of proof. Finally, MATH 1850: Freshman Seminar in Mathematics also provides the student with an overview of several topics and issues in the study of mathematics.

Depth in the curriculum is achieved in many ways. The applied mathematics track exposes the student to a deep involvement between mathematics and how it is applied. Courses such as MATH 3500: Methods of Applied Mathematics and MATH 3550: Ordinary Differential Equations are examples of particular applications. Also, majors in this track are required to complete a minor in one of several disciplines, a provision which promotes both depth and breadth. Another example of depth is in the area of analysis. Many students take Real Analysis, Complex Analysis and Numerical Analysis. Obviously, this last course, Numerical Analysis, also promotes depth in applications.

The following is an overview of the programs within the Mathematics Department

The Bachelor of Science in Mathematics major program consists of 47 credit hours of coursework. Twenty-six (26) of those required credit hours are for specified mathematics courses, three (3) are for a required course in computer science, three (3) are for a required speech course and for the remaining fifteen (15) credit hours, students may choose any five courses from among the 3000 and 4000 level mathematics electives offered, at least three of the electives chosen must be at the 4000 level. All upper level mathematics electives are 3-credit hour courses.

The Bachelor of Science Mathematics with a Concentration in Applied Mathematics consists of 43 credit hours of coursework in mathematics, 3 credit hours for a required speech course, and 3 credit hours for a required computer science course. Requirements mirror those of the mathematics major program described above with twenty-one (21) of the required credit hours identical to those of that program. Nine (9) additional credit hours for mathematics courses are specified with a choice of 12-credit hours (or four courses) in mathematics electives. At least three of these elective courses must be at or above the 3000 level. In addition, the program requires seven-eight (7-8) credit hours in General (or Calculus Based) Physics I and Physics II or MATH 3003 Advanced Statistics, and also requires a minor in biology, chemistry, computer science, economics, geography/earth science, psychology, or (soon to be added) data analytics. The program is designed to provide students with a strong mathematical background and an emphasis in a second field in which the student can integrate his/her mathematical knowledge.

The Bachelor of Science in Mathematics with Initial Teacher Licensure program is structured similarly to the mathematics major program described above with an exception to the number of ‘free’ electives requiring a minor in Middle and Secondary Education and coursework designed to introduce students to theories and practices in middle and secondary education. The mathematics portion of this program has two additional ‘required’ mathematics courses (Math 3000 Geometry and Math 4200 Probability and Statistics I). Hence the ‘free’ upper level mathematics electives are reduced in number to three (3), at least two (2) of which must be at the 4000 level. The middle and secondary education minor requires five (5) 3-credit hour courses in educational theory and practice, including two special courses in methods of teaching middle and secondary school mathematics. In addition, a state-required English Immersion course (3-credits), two 150-hour practicums in a middle or secondary school and a state required seminar course are required. Students who successfully complete this program

are awarded the Initial Teacher Licensure as a middle or high school mathematics teacher in the state of Massachusetts.

The minor in mathematics is composed of twenty-three (23) semester hours of mathematics courses, consisting of eight (8) credit hours in calculus, three (3) in either Linear or Abstract Algebra, and twelve (12) credit hours of mathematics electives. The electives must satisfy particular requirements with respect to course level and type of course. The level of mathematical attainment in this mathematics minor program is approximately equal to one half that in the mathematics major program.

The Data Analytics Minor is composed of twenty-two (22) semester hours of mathematics, computer science and geography courses, including two specified mathematics courses (7 credit hours), two specified computer courses (6 credit hours), and one geospatial information systems course (3 credit hours), as well as two related electives (6 credit hours).

The mathematics minor for Early Childhood, Elementary, or Special Education majors is a 23-24 credit hour program which includes seven 3 or 4-credit hour courses in mathematics. It is designed to integrate the three mathematics course requirements for most education majors into a program that gives the student a basic understanding of those concepts in higher mathematics that have special relevance to the mathematics taught in the elementary classroom.

Details of these programs can be found in Section 2.2.1 and a listing of the programs from the University catalog can be found in Appendix D. The above majors listed as Bachelors of Science can instead be taken as a Bachelor of Arts if a four-course language sequence is also taken.

1.4.1 Recommendations for Mathematics Majors

The Mathematical Association of America's Committee on the Undergraduate Program in Mathematics (CUPM) has been studying the curriculum of undergraduate mathematics majors in the U.S. since 1953. The CUPM reports are considered to be a primary source for "best practices" in the teaching and design of undergraduate mathematics programs and courses in this country. The most recent reports were 2004 and 2015. There were six recommendations made in *Undergraduate Programs and Courses in the Mathematical Sciences: CUPM Curriculum Guide 2004* (available at www.maa.org/cupm/), which will be examined in the following sections. In addition, there was a recommendation for Pre-service K-6 and middle school teachers that is addressed below. The Department's Assessment Committee restructured the Department's assessment plan around these goals as described in the section on program outcomes.

CUPM Recommendation 1

Mathematical science departments should

- *Understand the strengths, weaknesses, career plans, fields of study, and aspirations of the students enrolled in mathematics courses;*
- *Determine the extent to which the goals of courses and programs offered are aligned with the needs of students as well as the extent to which these goals are achieved;*
- *Continually strengthen courses and programs to better align with student needs, and assess the effectiveness of such efforts.*

Many faculty in the Department have been cited by current students as being very approachable and there is a constant stream of current students seeking help from their professors. The small student:faculty ratio with teaching and advising allows for good personal contact between instructor/advisor and students/advisees. Some of our incoming mathematics majors are not really prepared for, or committed to, a mathematics major. Therefore, an important part of advising has been to help students find their best choice of major. It is also not unusual for informal conferences to develop between an instructor and an advisor concerning a particular student. If a certain mathematics major needs a collective "push" to achieve excellence, the department collaborates to help the student. So, there is a good departmental knowledge of strengths, challenges, career plans, fields of study, and aspirations of the students enrolled in mathematics courses. As described in the Mathematics Department Academic and Assessment Plan:

> "We stay abreast of the needs of our students as a whole as well as of individual students and their goals. Whether our students' goals are to teach, attend graduate school, get a job in a mathematics field after graduation, or use mathematics as a foundation for logical thinking to step into another career path, our goal is to support our students in their endeavors. This involves not only providing these students with the knowledge they need to succeed in their specific goals, but also fostering a sense of belonging on campus and to the mathematics community as a whole."

See Appendix F for the entire Mathematics Department Academic and Assessment Plan.

The Assessment Committee of the department has created rubrics for assessing various portions of the Outcomes Assessment plan. The assessment process has started for some objectives. In addition, the process has brought the department to adopt "best practices" guidelines for student homework assignments, proofs and lab reports. In terms of curriculum, the Mathematics Department continually re-assesses the two-year plan of offerings of upper-level mathematics courses to meet the needs of current mathematics majors. The current scheduling plan can be found in Appendix D.13. Even with this rotating schedule, it is difficult to keep upper level electives running, due to low enrollment. The Department continues to lobby for these electives to run so that students can get the courses they need to graduate. The Applied Mathematics concentration and now the Data Analytics minor were implemented as a result of studying interests of majors and the job market. See section 2.2.1 for more details on recent curricular changes.

CUPM Recommendation 2

Every course should incorporate activities that will help all students progress in developing analytical, critical reasoning, problem-solving, and communication skills and acquiring mathematical habits of mind. More specifically, these activities should be designed to advance and measure students' progress in learning to

- *State problems carefully, modify problems when necessary to make them tractable, articulate assumptions, appreciate the value of precise definition, reason logically to conclusions, and interpret results intelligently;*
- *Approach problem solving with a willingness to try multiple approaches, persist in the face of difficulties, assess the correctness of solutions, explore examples, pose questions, and devise and test conjectures;*
- *Read mathematics with understanding and communicate mathematical ideas with clarity and coherence through writing and speaking.*

As can be seen by a perusal of the Mathematics Department Academic and Assessment Plan (see Appendix F), the above is covered in the primary goals of the Mathematics Department. In particular, two goals of the plan are:

> Goal 2: Each undergraduate mathematics major, upon graduation from Fitchburg State University, should be able to apply mathematics to a broad spectrum of complex problems and issues by formulating and solving problems.
>
> Goal 3: Each undergraduate mathematics major, upon graduation from Fitchburg State University, should be able to read, write, listen, and speak mathematically, as well as to be able to read and understand technically-based materials and to contribute effectively to group efforts.

While particular methods of teaching cannot be legislated due to issues of academic freedom, the philosophy of all members of the department support these goals. In particular, the department did specify that the Informal Geometry course be taught using the discovery method and that the Informal Number Theory and Informal Mathematical Modeling courses be taught using an interactive, group work approach as much as possible as well as stressing multiple representations and approaches to problems. Additionally, the new MATH 1100: Math in Society course involves problem-based and project-based learning. Approaches used by members of the Department include quizzes based on reading assignments, precise writing stressed in proofs and lab reports, oral presentations and group projects in several courses, not just mathematics seminar and other upper level courses.

CUPM Recommendation 3

Every course should strive to

- *Present key ideas and concepts from a variety of perspectives;*
- *Employ a broad range of examples and applications to motivate and illustrate the material;*

- *Promote awareness of connections to other subjects (both in and out of the mathematical sciences) and strengthen each student's ability to apply course material to these subjects;*
- *Introduce contemporary topics from the mathematical sciences and their applications, and enhance student perceptions of the vitality and importance of mathematics in the modern world.*

Again, issues of academic freedom forbid legislating certain approaches to teaching courses. However, the Academic and Assessment Plan support these recommendations. They are reflected in the general philosophy of all members of the department, which affects how each professor teaches their courses.

Math 3001: Scientific Computing and Visualization introduces some contemporary mathematics into the mathematics major. Math 3900: Mathematics Seminar often involves contemporary topics including graph theory with applications to computer science and other fields. Some professors who teach Math 3350: Number Theory include some crypto-analysis. Some professors who teach Math 2600: Linear Algebra include applications to computer graphics. Some professors who teach Math 2000: Informal Geometry include finding the cost of filling a swimming pool or paving a driveway as a topic. In addition, students undertaking independent study sometimes choose more contemporary topics, such as disease modeling.

The Applied Mathematics concentration requires a minor in another field and a capstone project, which definitely involves applications of mathematics to other fields.

CUPM Recommendation 4

Mathematical sciences departments should encourage and support faculty collaboration with colleagues from other departments to modify and develop mathematics courses, create joint or cooperative majors, devise undergraduate research projects, and possibly team-teach courses or units within courses.

The Applied Mathematics track and the new Data Analytics minor involved discussion with the various science departments. Members of the department have engaged several undergraduates in interdisciplinary research projects which have led to many student presentations with some potential for future publication.

CUPM Recommendation 5

At every level of the curriculum, some courses should incorporate activities that will help all students progress in learning to use technology

- *Appropriately and effectively as a tool for solving problems;*
- *As an aid to understanding mathematical ideas.*

Virtually all members of the Mathematics Department incorporate the use of technology in their courses, where appropriate. Fitchburg State supports the use of Google Docs/Slides/Sheets, Excel, PowerPoint, Matlab or interactive web pages. Before changing to a 3-course calculus sequence, labs using Maple were a required part of Calculus I and II. With the conversion to the 3-course calculus sequence came the development of a separate 3 credit Symbolic Computational Mathematics course, giving the students even more experience with the use of Matlab. Linear Algebra is often taught with computer assignments using Matlab or online tools. Professors of Applied Statistics give class assignments using MyStatLab, R, Google Sheets, Excel and/or TI calculators–as designated in the core syllabus. Projects, also required in Applied Statistics, often include the use of technology. Some Precalculus and Functions courses have graphing calculator assignments or Excel assignments. Technology assignments are regularly used in applied mathematics courses, Operations Research, Probability and Statistics and other upper level courses. Some professors use Geogebra in Informal Geometry, supporting students in learning to create geometric objects and learn from them using the app.

Many members of the department use MyLab Math for online assignments in service or introductory mathematics courses and others use WeBWorK. The major also requires a course in computer programming.

CUPM Recommendation 6

Mathematical science departments and institutional administrators should encourage, support and reward faculty efforts to improve the efficacy of teaching and strengthen curricula.

During the evaluation process, members of the Peer Evaluation Committee and the department chair regularly recognize the work of members of the department in the area of improving the efficacy of teaching and the strengthening of curricula. Recently Academic Affairs has instituted grants that can be used for assessment or curriculum development. Some members of the department have been successful in obtaining these grants. There has been recent targeted support for faculty to attend education-based conferences including those centered around STEM education and inquiry based learning.

The Department and University have purchased wireless tablets and iPads for use in the classroom and in online courses. Several of the Mathematics Department faculty members have made use of these in their teaching. An Apple TV is in nearly every classroom, which allows any iPad or Mac to connect wirelessly. One issue is there is no longer a laptop requirement for students so classes requiring such technology run into issues with students not being prepared. This needs to be addressed since several of our mathematics classes require regular use of a computer in class.

CUPM Recommendation for Pre-service Elementary and Middle School Teachers

Mathematical sciences departments should create programs of study for pre-service elementary and middle school teachers that help students develop

- *A solid knowledge—at a level above the highest grade certified—of the following mathematical topics: number and operations, algebra and functions, geometry and measurement, data analysis and statistics and probability;*
- *Mathematical thinking and communication skills, including knowledge of a broad range of explanations and examples, good logical and quantitative reasoning skills, and facility in separating and reconnecting the component parts of concepts and method;*
- *An understanding of and experience with the uses of mathematics in a variety of areas;*
- *The knowledge, confidence, and motivation to pursue career-long professional mathematics growth.*

The current mathematics requirements for K-6 pre-service teachers more than meet these requirements. Fitchburg State has a very strong requirement of three rigorous, in-depth mathematics content courses required of all Special Education and Elementary Education majors which cover all the topics outlined above with the exception of probability and statistics which is being added. A serious problem is keeping this requirement in the face of pressure from outside sources to accept the transfer of credit from community colleges with "mile wide and inch deep" courses. However, the Department has worked on getting local community colleges to align their pre-service courses with ours and has been successful in doing so with many feeder institutions.

Middle School mathematics pre-service teachers at Fitchburg State have to be mathematics majors and receive certification in Middle School or Secondary Mathematics. So the requirement for them also is far greater than the minimum recommended in the CUPM report.

At its August meeting in 2014, the Board of Governors of the MAA approved the Cognitive and Content Recommendations shown below in italics and also reaffirmed the principles of the *CUPM Curriculum Guide 2004.*

1.4.2 CUPM Cognitive Goals

Every mathematical sciences major should be designed to help students acquire "mathematical habits of mind." Students should develop the ability and inclination to use precise language, reason carefully, solve problems effectively, and use mathematics to advance arguments and increase understanding. These cognitive goals are not achieved in a single assignment or course; they must be approached within the context of each student's mathematical maturation throughout his or her undergraduate years. A well-constructed curriculum supports students in learning concepts, acquiring skills, and achieving cognitive goals. In the following paragraphs, we describe several cognitive goals in more detail.

CUPM Cognitive Recommendation 1:

Students should develop effective thinking and communication skills.

Major programs should include activities designed to promote students' progress in learning to

- *state problems carefully, articulate assumptions, understand the importance of precise definition, and reason logically to conclusions;*
- *identify and model essential features of a complex situation, modify models as necessary for tractability, and draw useful conclusions*
- *deduce general principles from particular instances;*
- *use and compare analytical, visual, and numerical perspectives in exploring mathematics;*
- *assess the correctness of solutions, create and explore examples, carry out mathematical experiments, and devise and test conjectures;*
- *recognize and make mathematically rigorous arguments;*
- *read mathematics with understanding;*
- *communicate mathematical ideas clearly and coherently both verbally and in writing to*
- *audiences of varying mathematical sophistication;*
- *approach mathematical problems with curiosity and creativity and persist in the face of difficulties;*
- *work creatively and self-sufficiently with mathematics.*

At Fitchburg State University Mathematics major students learn the skills in clear thinking and communication through the different course requirements and these goals are covered extensively in nearly every major course. For instance, in MATH 2500: Introduction to Math Thought, students learn exact definitions, proof of theorems, and logical conclusions. In MATH 4400: Operations Research and 4450: Mathematical Modeling they state problems carefully, make assumptions, identify and model features of a complex situation, modify models as necessary for traceability, and draw useful conclusions. Many upper division courses use in-depth projects which cover many of these ideas. Lastly in Math 3001: Scientific Computation and Math 4500: Numerical Analysis, visual and numerical perspectives are stressed.

CUPM Cognitive Recommendation 2

Students should learn to link applications and theory.

Mathematics students should

- *encounter a range of contemporary applications that motivate and illustrate the ideas they are studying*
- *become aware of connections to other areas (both in and out of the mathematical sciences), and learn to apply mathematical ideas to problems in those areas.*
- *come to see mathematical theory as useful and enlightening in both pure and applied contexts.*

This recommendation is met by the courses in the Applied Mathematics concentration, many of which are taken by other math majors as well. The mathematics seminar course also often exposes students to contemporary applied mathematics (e.g. graph theory and applications)

Cognitive Recommendation 3:

Students should learn to use technological tools.

- *Mathematical sciences major programs should teach students to use technology effectively, both as a tool for solving problems and as an aid to exploring mathematical ideas.*
- *Use of technology should occur with increasing sophistication throughout a major curriculum.*

Although many courses required for mathematics major use technology (as previously explained), the course MATH 2550: Symbolic Computational Mathematics introduces students to a computer algebra system (CAS), a crucial technological tool to solve problems from Math 1300: Precalculus to calculus and other courses. Many upper division courses extend the ideas from MATH 2550 to using these ideas in more specialized ways. Additionally, statistic courses at both the lower and upper level leverage technology in both computational and visual ways.

CUPM Cognitive Recommendation 4

Students should develop mathematical independence and experience open-ended inquiry.

- *A mathematical sciences major should be structured to move students beyond the carefully choreographed mathematical experiences of the classroom.*
- *A major curriculum should gradually prepare students to pursue open-ended questions and to speak and write about mathematics with increasing depth and sophistication.*

With the exception of the Applied Mathematics concentration students are required to take MATH 3900 (Mathematics Seminar) which provides students the opportunity to work on one or more topics outside the core curriculum areas. Students are required to write and present on a topic in depth. For students in the applied concentration, MATH 3500 (Methods of Applied Mathematics) fosters students' learning of techniques for performing research. MATH 4600 Capstone in Mathematics is another research based course open to all students and required for applied mathematics.

1.4.3 Mathematics Readiness Program

This program is seriously affected by state and Department of education policies and initiatives. The most significant change from the Department of Higher Education (DHE) included the new placement criteria for students. In response to student completion, retention,

and persistence rates in foundational mathematics, the DHE proposed changes to have more students included in college-level, credit-bearing mathematics courses. Currently, any student with an adjusted high school GPA of 2.7 or above is able to sign up for a credit-bearing college course without Accuplacer or placement testing. Students in STEM fields are still required to pass the algebraic placement test for admission to some science classes and Precalculus. The Department made its own significant change with the revisions of our foundational mathematics courses. Additionally, we added the supplemental instruction or "just-in-time" remediation to a variety of our introductory-level college courses.

The full Mathematics Readiness requirement is listed in Appendix I

1.5 Internal demand of the program or department

1.5.1 Mathematics Requirements for Other Majors

All students, regardless of major, must complete at least one college level mathematics course to satisfy the General Education Program Requirement - either a QR (Quantitative Reasoning) or sometimes PL (Procedural and Logical Thinking) designation. Some majors specify which particular mathematics course or courses its students must take.

Specific mathematics courses required by various major programs are outlined below.

Major	Mathematics Course(s)
Biology	Two courses at or above the level of MATH 1300 Precalculus (MATH 1300, MATH 1700, and/or MATH 2300 recommended and in some cases required depending on the concentration).
Business Administration (changed since last review)	· MATH 1800 – Business Stats
Chemistry (new since last review)	· MATH 1300 – Precalculus · MATH 2300 – Calculus I · MATH 2400 – Calculus II
Digital Media	· MATH 1100 – Mathematics in Society OR · MATH 1700 – Applied Mathematics
Computer Information Systems	· MATH 1300 – Precalculus · MATH/CSC 1900 – Discrete Mathematics · MATH 1800 – Business Statistics
Computer Science	· MATH 1300 – Precalculus · MATH 1800 – Business Stats · MATH/CSC 1900 – Discrete Mathematics · MATH 2300 – Calculus I · MATH 2400 – Calculus II · MATH 2600 – Linear Algebra
Criminal Justice	· MATH 1700 – Applied Statistics

Economics	· MATH 1700 – Applied Statistics
Early Childhood Education	· MATH 1500 – Informal Number Theory · MATH 2000 – Informal Geometry
Elementary and Special Education	· MATH 1500 – Informal Number Theory · MATH 1600 – Informal Mathematics Modelling · MATH 2000 – Informal Geometry
Environmental and Earth Science	· MATH 1700 – Applied Statistics OR · MATH 2800 – Intro to Statistical Analysis · MATH 1300 – Precalculus OR · MATH 2300 – Calculus I
Exercise & Sports Science	· MATH 1700 – Applied Statistics
Honors Program	· HON 1700 – Honors Applied Statistics
Engineering Technology	· MATH 1300 – Precalculus · MATH 2300 – Calculus I
Nursing	· MATH 1700 - Applied Statistics
Political Science	· MATH 1700 - Applied Statistics
Psychological Science	· MATH 1700 - Applied Statistics
Public Health Science (new since last review)	· MATH 1700 – Applied Statistics
Sociology	· MATH 1700 - Applied Statistics
All other majors	· One QR course – most 1000-level Math classes have this designation

The Mathematics Department sends guidelines to all faculty and staff prior to each registration period to help ensure that students are directed to the most appropriate mathematics courses for their program and their level of preparation.

1.5.2 Assessment of Service to other programs

Much of the work of the Mathematics department during the review period has focused on courses that serve other programs on campus (including the general education requirements). The department has redesigned the developmental mathematics program and piloted a form of supplemental instruction. MATH 1100, MATH 1500, MATH 1700, and MATH 1800 have Supplementary Instruction (SI).

The following table displays data for students who entered the university as freshmen in Fall 2019 through Spring 2022. DFW rates and U grades are included here.

Semester	MATH 1100	MATH 1300	MATH 1500	MATH 1700	MATH 1800
Fall 2019	12.2	36.4	30	29.6	34.9
Spring 2020	6.9	34.3	50	22.1	45.5
Summer 2020		100		28.6	50
Fall 2020	27.1	42.9	41.5	44.5	51.1
Spring 2021	13.3	43.9	66.7	36.4	38.5

Summer 2021		50		42.9	
Fall 2021	42.9	59.7	28.6	32.2	49.2
Spring 2022	64.7	52.3	22.2	48.4	54.8
Summer 2022				33.3	25

Note: Although SI are required for MATH 1700 and MATH 1800, the rate is still high, perhaps due to COVID and online instruction. The data is inconclusive. More assessment is needed in the future. Additionally, the SI sections are all run differently with some being taught by the instructor of the course and others being taught by a different instructor.

1.5.3 Enrollment in service courses

Note: The foundational courses MATH 0100 Basic Math I and MATH 0200 Basic Math II were replaced by MATH 0300 Quantitative Preparation and MATH 0500 Algebraic Preparation respectively. They are supplemented by MATH 0400 and MATH 0401 Math Preparation Lab. These newer courses started running in Fall 2020. Also, MATH 1200 was discontinued running after Spring 2018 and has mostly been replaced by MATH 1100: Math in Society, which started in Fall 2019. Both MATH 2100: Technical Calculus and MATH 2200: Business Calculus are no longer being offered regularly.

Course Number	Course Name	SP17	FA17	SP18	FA18	SP19	FA19	SP20	FA20	SP21	FA21	SP22	FA22	SP23
0100	Basic Math I	51	105	25										
0200	Basic Math II STEM Track	60	174	69	169	62	167	13						
0200N	Basic Math II Non-STEM Track	51	127	54	123	41	65	23						
0300	Quantitative Prep								60	20	39	10	32	10
0400	Math Prep Lab								245	29	95	20	98	20
0401	Math Prep Lab									27	94	18	98	18
0500	Algebraic Prep								72	14		14	65	14
1100	Math in Society						110	68	110	25	55	18	106	22
1200	Finite Math	18	27	29										
1250	Intro to Functions	89	146	92	202	104	148	96	69	29	48	5	20	5
1300	Precalculus	114	180	130	153	102	96	77	93	55	69	73	74	73

1500	Informal Number Theory	28	58	40	154	40	128	34	52	12	33	10	75	10
1600	Informal Modeling	39	36	39	29	40	11	36	7	32	8	12	15	12
1700	Applied Statistics	364	483	382	425	426	544	346	268	167	234	155	420	155
1700	Honors Applied Statistics	16		9		24		15		11	16	14	14	14
1800	Business Statistics	61	94	130	149	108	144	140	69	42	71	58	138	58
2000	Informal Geometry	80	55	79	60	58	40	34	39	23	27	19	32	19
2100	Technical Calculus	15		10				10		14				
2200	Calculus for Business	53	52	51	50	50	54	49	40	34	21	14		14

1.6 Recommendations and actions from previous five year review

The Self Study Report for the 2017 Program Review contains 12 plans for change and the report of the external reviewer from this program review contains 19 recommendations. Some of these plans and recommendations overlap, some are somewhat casual, some have been done or are being worked on and some are not considered desirable by the Department. This report will address some but not all of these 31 ideas.

1. *Relocation of the Mathematics Center*
   The Math Center is now called the Academic Coaching and Tutoring Center, however, moving it has been considered but seems infeasible at this time.
2. *Careers and Internships*
   The Department continues to work on developing contacts with local businesses for the purpose of creating internships. The Department was part of a grant program whose express purpose was to develop guidelines for internships in collaboration with Career Services. One member of the Department spearheads these efforts.
3. *Creation of "dedicated" Applied Statistics courses*
   The topic of discipline specific statistics courses versus general such courses has been an issue in mathematics education for decades. Recommendations on this issue appear in several places in the 31 ideas referred to above. One department member regularly teaches an Applied Statistics section dedicated to social justice issues. Also, Business Statistics (essentially Applied Statistics with applications especially to business issues and problems) is regularly offered. Approximately 10 to 15 years ago some sections of Applied Statistics were regularly dedicated to nursing students in collaboration with the Nursing Department, but this specialized course is no longer offered. However, in general, it is felt that establishing several more different dedicated such courses is not necessarily desirable or feasible.
4. *Software in mathematics courses in general and statistics courses in particular*
   Again, this issue is mentioned in several places among the plans and suggestions for change. Applied Statistics courses use software. The specific software is not stated by the Department, allowing faculty to choose this. Maple is no longer the CAS used in other courses and has been replaced by Matlab.
5. *Expansion of the Supplemental Instruction Program*
   This program has been expanded from Applied Statistics courses to almost all entry level mathematics courses. Also, more instructors are teaching their own supplemental sections. The results of this expansion are still being assessed and data is difficult to analyze due to the events of 2020 – 2023.
6. *Hiring a statistics specialist*
   This has been done as Dr. Jessica Oehrlein joined the Department in the fall of 2021.
7. *Hiring a coordinator of developmental mathematics and supplemental instruction*
   This was accomplished and our new coordinator Samantha Walters-Sweeney began in the fall of 2023.
8. *Require the Freshman Seminar for all majors*
   This has been done.

9. *Review the requirement for a full year sequence in physics for the Applied Mathematics Concentration*
   This also has been done and students in this program now have the option of taking Advanced Statistics in lieu of Physics II.
10. *Make 4000 level courses mostly independent research*
    This suggestion by the reviewer is problematic due to load credits for faculty. While several faculty members engage majors in independent research the idea of turning most 4000 level courses into this format presents many problems and complications.

1.7 Changes and Initiatives since previous review

1.7.1 Interdisciplinary programs

The Department has made significant changes and interdisciplinary initiatives in the last five years particularly in the areas of statistics and data science. Four new courses have been created in these areas, MATH 2800: Introduction to Statistical Analysis, MATH 3001: Scientific Computation and Visualization, MATH 3003: Advanced Statistics, and DATA 2000: Principles of Data Analysis. Additionally, a Data Analytics Minor has been created that, while housed in the Department of Mathematics, has vast interdisciplinary connections with several other departments.

1.7.2 Delivery mechanisms

The national events and required limitations from March of 2020 up to and into 2023 influenced a sea change in college instruction in general and in the Mathematics Department at Fitchburg State, in particular. Remote and hybrid teaching exploded in the last three years. While little or no Department policies were established in this regard, many members engaged in various aspects of remote delivery and remote office hours. The use of remote office hours, although not required, has provided students with considerable extra access to their mathematics professors and has certainly significantly enhanced the educational process.

1.7.3 Service learning and community outreach

The Department has sponsored the Elizabeth Haskins Mathematics contest for local high schools as an annual event since 1980. This event has served as an enormous connection between the College and the local high schools with attendance in the range of 400 – 600 participants up to, roughly, 2018, which saw a dip in participants to around 350 coming from roughly 10 local high schools. The 2020 event was canceled. The 2021 event was conducted remotely with around 35 participants. The last two years the contest was again held in person with fewer than 100 participants each year. The Department is again planning the contest for April of 2024 and is currently experimenting with various strategies to increase the participants up to pre-2020 levels. Additionally, the Department sponsors alumni panels and seminars with on and off campus speakers.

2. Assessment

2.1 Program Inputs

2.1.1 Program reputation

The Mathematics majors receive a comprehensive foundation in abstract and applied mathematics as preparation for graduate studies or professional career. The major is designed to offer courses to gradually and intentionally lead students from basic to advanced levels of critical and analytical thinking. It closely follows the cognitive recommendations of the Mathematical Association of America (MAA) outlined in Section 1.4.2 in that the courses offer opportunities for students to develop their thinking and communication skills (verbal and written), make connections between theory and applications often using various technologies, and experience open-ended inquiry.

The major also aligns with most of the MAA content recommendations. For example, it includes the Calculus series and Linear Algebra as well as an introduction to proof course and Abstract Algebra as some of the required coursework. Another required course, Symbolic Computational Mathematics, introduces students to Computer Algebra Systems (CAS). The major requires five mathematics electives at the 3000-4000 level with 9 credits required to be at the 4000 level. The elective courses such as Geometry, History of Mathematics, Probability and Statistics, Differential Equations, Operational Research offer students the opportunities to engage with various concepts and methods from data analysis, computing, mathematical modeling and historical perspectives.

The mathematics major is intentionally designed to offer space in students' programs to pursue different areas of interest either by completing a minor, a second major or a concentration. All concentrations (applied mathematics, middle or secondary education) require students to complete a minor. Applied mathematics concentration students can choose a minor of interest to them in consultation with their advisor. On the other hand, middle or secondary education concentration students have to complete a specialized minor, Middle and Secondary Education, along with licensure specific coursework. This design of teacher preparation program is relatively unique in the sense that students in this concentration will both complete their mathematics major requirements and all the state mandated licensure requirements that will allow them to secure their initial license upon graduation. This design allows students to pursue a path utilizing their mathematics major if they eventually decide not to teach in 5-12 school settings.

As a response to growing interest in data sciences, we, along with our colleagues in Computer Science and Environmental, Geographic and Public Health Sciences, recently launched an interdisciplinary minor, Data Analytics. It is designed to serve students who want to develop computational, graphical and analytical skills related to data. The minor provides students with

basics in statistical and mathematical analysis, computational skills with relevant software as well as experience in geospatial and GIS analysis field.

In order to keep abreast with the needs of the field, our students, and the larger community, the department is contemplating redoing the curriculum to include a required statistics course and is working to provide students with additional internship opportunities in various settings. In addition, we are also looking into various paths for students who are interested in teaching mathematics in middle or high school level in addition to the current model of completing a concentration along with the mathematics major.

2.1.2 Students

Incoming students must meet the admission requirements of the university. The number of majors has shown a decrease from the peak of 53 in AY17 to 18 in AY23, consistent with the national enrollment trends in the mathematics and education majors. Although the incoming freshman numbers have been steady since AY20, for the last three years the number of transfer students which is the main feeder of our major has been at the lowest levels since AY13. A similar trend has been observed with the number of students pursuing a minor, decreasing to half of the number of students since AY17. The biggest decrease in this category has been observed with our number of students pursuing the minor for education majors, from 24 in AY17 to 2 in AY23. This decrease is relatively proportional to the decrease of the number of students pursuing education majors who are eligible for this minor.

Our students are primarily Caucasian, with a relatively equal number of female and male students in AY17 to a disproportionate level in AY23 (12 male to 6 female). In AY23, 14 students identified as White while only 1 as Asian, 1 as Black and 1 as Hispanic. Our department acknowledges the importance of and is committed to increasing the diversity of our students. As we plan our recruitment and retention efforts, we will continue to be intentional and creative about trying to increase the number of students from different backgrounds.

Student involvement in the Department happens through activities including in-class tutoring, serving on departmental committees, serving as departmental student ambassadors, and running the math club. For example, as a department policy there are two student representatives on the curriculum committee. In addition, we hold annual holidays and spring celebrations to which all our current students and alumni are invited. This allows a strong bond between the students and faculty in a non-academic environment. Our student-run Math Club has not been active in the past few years, but we are actively encouraging students to revive it.

In 2007, the Mathematics Department established a chapter of Pi Mu Epsilon, the national honorary mathematics society. Several current students, faculty members and alumni have been inducted as members. In recent years, many of our students have given presentations at conferences hosted by regional and national mathematical organizations. Several of our students have completed or are currently involved in a senior honors thesis in pure or applied mathematics as part of the honors program. Our faculty members are professionally active in

national and regional mathematics associations, in research, in the university and local communities, and in fostering student involvement in the mathematics community.

Many of our students are able to complete an internship or independent research project as part of their curriculum. Students in the Applied Mathematics concentration take a capstone course in which a research project is completed. Some students have been involved in grant projects and engage in research with the faculty on various topics. For example, Dr. Levy secured funding to work with one of our students on disease modeling and traveled with him to Africa as part of this project. Similarly, Dr. Wehe worked with a student who was a double major in mathematics and psychology to duplicate a happiness study considering the impact of the Covid-19 pandemic. The student presented the findings of her study in a conference with several faculty and peers in attendance. Drs. Buell, Higdon and Staab also advised several students during this timeframe to complete independent research projects. Many of the projects were presented at our local and and other regional undergraduate research conferences.

Students are also strongly recommended to complete internships in the areas of their interest. For example, one of our most recent graduates completed a paid internship at State Street corporation where she subsequently secured a full time position upon graduation. All of our licensure track students complete a semester-long practicum (field-experience) and often offered a full time position following their graduation as well.

Details of the faculty-led student projects and independent studies are provided in the faculty CVs in Appendix B.

2.1.3 Faculty

The full-time mathematics faculty members of the Department have varied backgrounds and academic interests. We currently have 11 members of the full-time faculty, including 1 faculty member on a one-year temporary position. Of the 11 faculty members, 7 are women and 4 are men. One of the faculty members is a person of color and the background of the faculty represents a broad geographic distribution of the U.S. and world. Since the last review, we added one member to our faculty, which has brought new ideas and interests to the department. The research interests of the faculty include mathematics education, statistics education, graph theory, mathematical knowledge for teaching, advanced mathematical thinking (particularly proof), teacher education, field experiences, co-teaching, representation theory and combinatorics, assessment, algebraic group theory, symmetric spaces, lie groups and lie algebras, summability theory, mathematical biology, infectious disease modeling, winter climate modeling & prediction, population modeling, distribution modeling, statistical modeling, undergraduate education, linear algebra, numerical analysis, orthogonal polynomials, image processing, fluid mechanics, dynamical systems, numerical analysis, partial differential equations, mathematical pedagogy, combinatorial matrix theory, matrix completion problems, history of mathematics, differential equation, and analysis. Many of the faculty members regularly attend national mathematics conferences, with some having recently given presentations at these conferences, and are involved in various other professional development

activities. There is a strong focus across the faculty on undergraduates, with faculty guided research and general close contact with mathematics majors and alumni. Other activities of the faculty include heading the Massachusetts Eta Chapter of Pi Mu Epsilon, leading the AMS Committee on Professional Ethics, and extensive committee work for Fitchburg State University. More details are categorized in the sections below and can be found in Appendix B, which includes a complete list of the faculty members and their vitae.

The Department also employs several part-time faculty members each semester and has been fortunate to have a few excellent and dedicated long-time adjuncts. The adjunct faculty members teach most of our foundational mathematics course sections as well as some 1000-level course sections each semester. The foundational courses are module-based courses where students work at their own pace. For non-foundational courses, the instructors have full responsibilities, although some Supplementary Instruction structures have been established for introductory 1000-level courses since our last review. Many adjuncts give useful input on the courses they teach as well as departmental policies. The resumes of our current adjuncts are also included in Appendix B.

Faculty Teaching Activities

Faculty in the Department embrace several teaching philosophies and continuously focus on honing their teaching skills and improving student learning and experiences in their classes. In this regard, faculty are engaged in and leading several professional development and teaching activities. For example, three faculty were recently selected to be part of the Faculty Academy, a three-year professional development on the understanding and implementation of Pedagogy of Real Talk. Similarly, one of the most recently hired faculties is a Project NExT fellow, a professional development program for new or recent Ph.D.s in mathematical sciences to support them in many aspects of the academic life including improvement of teaching and learning of mathematics. We should note that many of the faculty members in our department were part of this program at some point in their careers. In addition, another faculty member has been involved in developing WeBWorK, a web-based interactive system designed to make homework in mathematics and the sciences more effective and efficient, and has run several workshops for faculty to adopt this system in their courses and contribute to it.

Faculty commitment to teaching is also evident in the investment and development of the Open Educational Resources (OER) for mathematics courses over the last several years. Collectively, faculty compiled three open source textbooks to be used in our courses for the general population and K-8 teacher candidates' content courses. In addition, a faculty member recently secured funds to develop OER materials for two other courses, one for the general population and another for advanced math majors. Finally, it is worth noting that most of the faculty intentionally use OER materials in their classes to best support our students.

Faculty scholarship, professional experience, university and professional service, and community engagement

Our faculty members are very active outside of teaching. Since the last review, they have collectively published 23 journal articles and have given numerous presentations at local, regional, national and international conferences. Many have also attended and run professional development workshops, participated in grant activities and organized mathematics activities and conferences in various formats.

One faculty member, who alone published 8 journal articles since last review and was also a recipient of the university's faculty scholarship award, has secured two NSF grants (totaling ~$459,000) to explore various aspects of ethics in STEM, particularly mathematics. She also secured three distinct grants to fund workshops and travel. Another faculty member was recruited to serve as an external reviewer for a $1M NSF S-STEM grant and a Co-PI of another NSF S-STEM grant (pending funding). Another faculty member secured several internal grants to support his research with students, one in particular in the form of a 3-credit course release. In addition, three faculty members secured OER funds to compile course textbooks and materials. Lastly, another faculty member secured about $54,000 from the Department of Higher Education to facilitate the co-requisite instruction and co-design of the new lab facility for foundational mathematics.

The Department is also very focused on service to the university community, the community surrounding the university, the state, and the nation at large. See section 1.1 for details on service to the university and department.

Service to the community includes enrichment activities for K-12 students in the area. Statewide contributions include involvement in Massachusetts Transfer Pathways, STEM education collaboration and the development of Alternative MTEL assessment for mathematics subtest. Regionally, faculty took leadership roles in organizations (i.e. NE-COMMIT and MAA NES) and organized and hosted conferences, talks and workshops. Nationally, faculty have been involved in judging poster sessions, editing and reviewing journal articles, organizing and participating in research groups, and collaborating on creating problems for WeBWorK. One faculty member is involved in research internationally, including mathematical modeling of Ebola outbreaks in Africa.

We have a vibrant, constantly changing department. We are open to new ideas and are committed to improving our teaching and curriculum in collaboration within and outside of the Department.

2.1.4 Staff Support

The Mathematics Department is supported by one full-time administrative assistant shared with the Computer Science department and one full-time staff member serving as the instructional coordinator for foundational mathematics. The administrative assistant, Ms. Ann Larsen, is responsible for daily administrative operations, managing the department budgets, running financial reports, assisting the department chair with entering the course schedules, making

changes to course schedules and classroom assignments, and occasionally assisting the chair with event planning and catering. Ms. Larsen is also the first person a student or an external constituent interacts with when they visit the department for information or questions.

Instructional coordinator for foundational mathematics, Ms. Samantha Walters-Sweeney, is responsible for coordinating and teaching mathematics preparation courses, supporting supplementary instruction for select courses, managing and staffing mathematics computer labs, and closely monitoring student progress in these courses. She also oversees the implementation of foundational mathematics curricula and teaching in comparison to national trends considering the institutional context.

2.1.5 Resources

Financial

The Department budget has ranged from $45,459 to $55,878 over the last 6 years. Funding for faculty (both full-time and adjunct) is not included in the Department budget. The majority of the budget is allocated for the mathematics associates and in class tutoring. The second largest expense item in the budget is administrative expenses. A flat $950 is allocated for operational expenses while a flat $1,000 is reserved for consultants. A detailed breakdown of the budget allocations is provided in Appendix C. We often request additional strategic funds such as academic or innovation funds from the provost's office for larger expenses such as purchase of softwares or equipment. Each faculty member receives a minimum of $350 for travel per year from the Provost's office and are also contractually entitled to continuing scholarship funds usually between $800 and $900 each year . Faculty members also have the opportunity to apply for several internal grants to support professional development activities or supplement travel expenses. We also benefited from external grants such as Dr. Buell's NSF grants within the last six years.

Space

The Mathematics Department is located on the third floor of Edgerly Hall shared with the Computer Science Department. Faculty offices are all located on the same floor including two adjunct offices with room for four adjuncts. The department also shares a seminar room with the Computer Science Department that includes a table for ten and flat TV with computer connection. Finally, we have a cabinet for teaching supplies plus an additional closet of manipulatives (used mainly for math education courses) in another academic building where these courses are taught.

Mathematics classes recently have been held across campus in Thompson Hall, Edgerly Hall, Percival Hall, Conlon Industrial Arts, Condike and McKay. These classrooms hold between 25 and 50 students each and all have either a blackboard or whiteboard. Nearly all of the rooms

have tier 1 media capabilities (computer, Apple TV, VCR/DVD and projector) with laptop hookup available and many rooms also have document cameras which are used by some faculty members. There are also at least 5 computer lab classrooms, including Edgerly 106 which houses the foundational mathematics classes. The renovation of Thompson Hall allowed for the creation of four Active Learning classrooms.

Equipment

The Department has a number of teaching related manipulatives, abaci and various types of calculators available for faculty use.

A list of all the equipment and materials used in classroom teaching and research is provided in Appendix C.

2.2 Program Processes

2.2.1 Curriculum

Curriculum Development

Every academic department at FSU is required, by contract, to have a curriculum committee. The curriculum development of the Mathematics Department is facilitated by the Mathematics Department Curriculum Committee (MDCC). This committee consists of faculty members selected, on an annual basis, by the Mathematics Department Chair as well as student members selected by the MDCC. The MDCC selects a chair at the start of each academic year to compile agenda items and run MDCC meetings. The MDCC collects ideas from inside and outside the Mathematics Department, discusses these ideas, gathers data and feedback as needed, develops and votes on proposals. Once a proposal passes through the MDCC it is brought to a Mathematics Department meeting for a follow up vote and then forwarded to the AUC (All University Committee) to be put through governance. Once a proposal passes through governance, it is forwarded to the president of the university for final approval.

Every academic department at FSU is also required, by the University, to have an assessment committee to assess curricular goals and objectives of the department. The Mathematics Department Assessment Committee (MDAC) consists of faculty members selected, on an annual basis, by the Mathematics Department Chair. The MDAC selects a chair at the start of each academic year to facilitate assessments and meetings. The MDAC works in tandem with the MDCC to advise changes in policy and curriculum. See more details on curricular assessment in Section 2.3.

Some recent curricular development activity in the Mathematics Department is highlighted here. Dr. Nermin Bayazit spearheaded changes to our Secondary and Middle Level Education concentrations including creating a new pre-practicum methods course, MATH 3010: Methods of Teaching Mathematics (5-12) I and moving middle level math education students from the Education Department to the Mathematics Department. The latter change required the creation of new practicum courses MATH 4020/4030 Practicum in Middle School (5-8) Math I & II. Dr. Bayazit also collaborated with several other departments to create a new Minor in Middle and Secondary Education thereby streamlining the structure of all Middle and Secondary Education programs.

Our new faculty member, Dr. Jessie Oehrlien, led the development of a new Data Analytics Minor in collaboration with the Computer Science Department and the Environmental, Geographic and Public Health Sciences Department. Before doing so she compiled a list of requirements from data science programs (minors and majors) from approximately 30 public institutions in the U.S.. This interdisciplinary minor was designed to serve students who want to develop computational, graphical and analytical skills related to data. The minor provides students with basics in statistical and mathematical analysis, computational skills with relevant software as well as experience in the Geospatial and GIS analysis fields. Students who complete this minor will be able to analyze data sets in a manner that includes basic statistics, grouping and plotting, perform computational tasks on data, perform geospatial and GIS-related analysis of an appropriate dataset and draw conclusions from the analysis. This minor aligns with the goal of increasing innovative and interdisciplinary programs as outlined in the current versions of both the University's Academic and Strategic Plans. The course requirements for this minor can be found in Appendix D.11 of this self study. The Data Analytics Minor includes two new courses: MATH 2800: Introduction to Statistical Analysis and DATA 2000: Principles of Data Analysis. The latter course came with the creation of the new DATA prefix. Another new course, MATH 3003: Advanced Statistics, serves as an elective for this minor.

The field of Data Science is growing and still in its infancy. Academic programs in data analytics have been increasing over the past several years as the demand for data analysts in industry continues to skyrocket. See sources below.

- Miller, Kelsey (updated Dec. 2023). 11 Data Science Careers Shaping Our Future.
- Abadi, Mark (2019, January) The 50 best jobs in America for 2019, Business Insider.
- Current database search of entry-level Data Science jobs in Worcester County.

Hence the creation of the FSU minor in Data Analytics is very timely.

Other changes to the mathematics curriculum include requiring MATH 1850: Freshman Seminar in Mathematics for regular mathematics majors. This course was originally designed for the applied mathematics concentration only.

Other new courses offered since the last program review include:

- *MATH 3001/CSC 3003: Scientific Computing and Visualization* which serves as a math or computer science elective and offers students the opportunity to visualize and solve

mathematics and science problems using appropriate computational software as well as write their own programs.
- *FYE 1018: First-Year Experience: Mathematics* which is a mathematical-focused version of the foundation level course designed for the University's new General Education Program.
- *MATH 4950: Internship* which allows mathematics majors to get credit for internships.

Last but not least, the mathematics minor for education students was adjusted to require introductory level statistics and an introductory level proofs course.

Curriculum Requirements and Description of Curriculum

See section 1.4 for an overview of curriculum requirements. Specific requirements for all mathematics majors and minors can be found in Appendix D. The MDCC has been discussing a potential restructure of the mathematics major including adding a statistics/data requirement.

As discussed in Section 1.2, the mission of the Department of Mathematics is to foster our students' self-reliance in mathematics, to produce graduates who can bring together the theory and practice of mathematics, and to create in graduates strengthened ability for critical and logical thinking. The following are cognitive goals for our mathematics majors:

1. Develop effective thinking and communication skills
2. Learn to link applications and theory
3. Learn to use technological tools
4. Develop mathematical independence and experience open-ended inquiry

The relationship of these goals to the courses and curriculum is included below, beginning with common requirements among the concentrations.

The inclusion of the calculus sequence, *Math 2300: Calculus I, Math 2400: Calculus II*, and *Math 3350: Multivariate Calculus* in the program is standard practice among institutions of higher learning. The ideas and techniques of calculus are used in most applied mathematics courses and in advanced level courses in analysis.

The 3-credit course *Math 2550: Symbolic Computational Mathematics* is designed to sustain and expand student exposure to mathematics technology in our curriculum. This portion of the curriculum teaches students to use a computer algebra system as an exploratory and problem-solving tool.

Math 2500: Introduction to Mathematical Thought introduces students at an early stage to both rigorous treatment of mathematics and certain basic mathematical ideas that occur in many branches of mathematics. This course is designed to teach the fundamental strategies and styles used in mathematical proofs. Assignments demanding precise and clear writing of proofs

are the norm for this course. So, students learn to think logically and read, write, listen and speak mathematically.

Math 2600: Linear Algebra includes an introduction to solutions of linear equations in *n*-dimensional space. In addition to exposing students to a variety of applications, Linear Algebra provides a first introduction to abstract mathematical systems through the study of vector spaces. The students learn that the techniques used in real space can be extended to more abstract solutions.

Math 4300: Abstract Algebra course is required for all math majors with the exception of those in the applied math concentration. Concepts introduced in this course are shared with all branches of mathematics and help students to see similarity in diversity and perceive an underlying global theme in mathematics. Assignments demanding precise and clear writing of proofs are the norm for this course. Students learn to emulate a professional mathematician's approach to the abstract thinking processes involved in proving theorems and the precision required in expressing these proofs in formal written form. They also learn to have a better understanding of the breadth of the mathematical sciences and their deep interconnecting principles.

Math 3900: Mathematics Seminar is required for all math majors with the exception of those in the applied math concentration. It exposes students to mathematics outside of the core curriculum and the topic varies depending on the instructor. It encourages student research and exploration including reading mathematical articles. Students give oral presentations and engage in mathematical expository writing. Thus, students learn to read, write, listen and speak mathematically and read and understand technically-based materials.

Math 1850: Freshman Seminar in Mathematics is required for all math majors with the exception of those in the middle or secondary education concentration. This course exposes students to mathematics applications in research and industry via guest speakers giving them early opportunities to explore research and career interests.

The upper level course requirements allow students some flexibility in choosing courses germane to their interests while guaranteeing exposure to a reasonable amount of sophisticated and rigorous mathematics. When the requirements are completed, students will have engaged in complex mathematical problem solving, expository mathematical writing, oral presentations, group and individual projects, and will have used technology for many assignments in a variety of contexts including having students submit work formatted in LaTeX.

Independent Study offers flexibility for the mathematics major to take courses outside of the standard offerings. Some of our students intending to go to graduate school take one or more independent studies at the rigorous graduate level in algebra, analysis, or topology to help them prepare. Other students simply seek knowledge of an area that has interested them that is not available in electives. Additional flexibility is available through the offering of a topics course,

experimental courses that may run for up to two semesters prior to being submitted through governance for formal approval as a regular course offering.

Curriculum for Initial Licensure in Mathematics, Grades 5-12

Fitchburg State University's undergraduate and post-baccalaureate mathematics middle and secondary level teacher preparation programs lead to the Initial Licensure to teach mathematics for grades 5-8 and 8-12 respectively, in the Commonwealth of Massachusetts. Under the regulations of the Massachusetts Department of Elementary and Secondary Education (DESE), all candidates for Initial Licensure must pass the Communication and Literacy and Mathematics subject area exams of the Massachusetts Tests for Educator Licensure (MTEL). Fitchburg State University has adopted the policy that students may not enroll in a teaching practicum until they have passed these exams. The current test objectives for the Mathematics subject area secondary level exam are (1) number sense and operations; (2) relations, functions and algebra; (3) geometry and measurement; (4) probability, statistics, calculus and discrete math; (5) integration of knowledge and understanding. The current test objectives for the Mathematics subject area middle level exam are (1) number system and quantity; (2) algebra, functions and modeling; (3) geometry and measurement; (4) statistics and probability (5) mathematics curriculum framework: concepts and skill AND statistics, probability and algebra. The math requirements for these concentrations include courses on geometry, probability and statistics and mathematical modeling to align with these objectives.

Furthermore, these programs require over 100 hours of pre-practicum hours in varied settings embedded in their coursework, beginning with Introduction to Education and ending with Math Methods of Teaching Mathematics II. In addition, the students are required to complete a supervised semester long practicum of at least 300 hours. The practicum must be supervised jointly by someone from the sponsoring program and a supervising practitioner with at least three years of teaching experience under an appropriate Initial or Professional License. The program supervisor and supervising practitioner must complete a performance assessment of the teacher candidate using the professional standards. Candidates are observed by the university supervisor several times during their student teaching practicum. Lessons and lesson plans are evaluated and various teaching materials and assessments are used as evidence to make a recommendation on whether or not the candidate will be endorsed for licensure. The Fitchburg State mathematics secondary programs have national certification from the Council for the Accreditation of Educator Preparation (CAEP).

Mathematics Major with Applied Mathematics Concentration

In addition to the standard mathematics requirements, this concentration includes physics and applied mathematics courses as well as completion of a minor in another field. The descriptions and goals of the required applied mathematics courses are explained below.

Math 3500: Methods of Applied Mathematics is designed for students to learn the basic techniques necessary for performing research in an application of Mathematics to another field of study. The students also learn to use a Computer Algebra System for analysis and visualization. The goal is to give the students a firm foundation for pursuing further study in

Applied Mathematics, as well as have a good appreciation for the use of Computer Algebra Systems to aid the analysis and visualization of mathematical problems. In addition to gaining a thorough understanding of the topics covered, this course aims to improve students' mathematics communication skills both in written and oral form.

Math 3550: Ordinary Differential Equations addresses linear first and second order differential equations, methods of solution, and applications. Numerical, series solutions and higher order linear equations are also considered as well as Laplace transform solutions.

The requirement of *Math 4400: Operations Research* or *Math 4450: Mathematical Modeling* emphasizes the mathematics used in applications to the physical, social and life sciences. Operations Research includes linear programming, network modeling, dynamic programming and stochastic models. Mathematical Modeling includes some of these concepts but studies applications of mathematics more broadly. In both courses students are exposed to using computer programs to help solve problems.

Math 4600: Capstone in Mathematics is a three-credit course designed for seniors in applied mathematics to develop and complete a senior project. This is the capstone course in Applied Mathematics and the project should be a synthesis of the student's previous courses. The students consult regularly with the instructor on their project and work in conjunction with other students as needed. Last year, the Mathematics Department changed the name and expanded the description to encourage any mathematics student to take it.

The required minor in another field is designed to complement the mathematics major and enable the students to integrate the mathematics within that field and prepare them for an interdisciplinary career. For example, a minor in economics would be appropriate for a student wanting to pursue a career in actuarial sciences, and a minor in computer science would prepare the student for computing positions in industry.

<u>The Mathematics Minor</u>
The minor in mathematics includes a core of three courses along with four elective courses. The Calculus I and II requirement gives the students a solid background in differential and integral calculus. The Linear or Abstract Algebra requirement exposes the students to abstract mathematical thought and gives them a good base in reading and writing mathematical proofs. The electives students choose further enhance and broaden their mathematical abilities and problem solving skills. The skills they obtain should complement their major studies and will give them an advantage when applying for jobs.

<u>The Mathematics Minor for Early Childhood, Elementary and Special Education</u>
This minor includes mathematics courses specially designed for education majors as well as a variety of other mathematics courses aimed to give students a deep understanding of the concepts they will teach and how these concepts grow into more advanced mathematics.

The requirements of *Math 1500: Informal Number Theory* and *Math 2000: Informal Geometry* dig deep into the mathematics taught in the elementary classroom and stress explanations and multiple representations of concepts and solutions. The students do a lot of writing and explaining in both of these courses. Furthermore, Informal Geometry is a discovery learning lab based course which uses a wide variety of manipulatives that the students will one day use in their own classrooms.

The requirement of *Math 2500: Introduction to Mathematical Thought* exposes the student to set theory and mathematical logic which is essential to successfully communicating mathematics. In Calculus I, the students learn about the ubiquitous concept of instantaneous rate of change and gain the mathematical maturity to take higher level courses. The *Math1700: Applied Statistics* requirement not only aligns with state standards but also gives students the background to understand and make effective assessments and data driven changes.

Students completing this program have a solid understanding of the mathematical theory that unifies the concepts taught in the elementary schools. They understand how theories in arithmetic are generalized to algebraic theories and how these concepts are further developed and expanded in other mathematical fields such as calculus, statistics, or geometry.

This program allows students to become mathematics specialists in elementary school. Improvement of mathematics programs in the elementary schools is a continuous goal of not only the Massachusetts' Department of Elementary and Secondary Education, but of every state and national education conference or professional organization. Education students completing this minor will be prepared to take a leadership role in improving the teaching of mathematics in the elementary school classrooms.

Plans of study, two year rotations, handbooks

We have 4 separate plans of study for Mathematics (no concentration), Mathematics with Applied Math Concentration, Secondary Education with Initial Licensure (8-12), Middle Education with Initial Licensure (5-8). Each includes general education requirements and requirements for the math major and concentration as appropriate. These can be found in Appendix D.

Major requirements are offered every year but some upper level electives are offered on a biennial basis. See Appendix D.13 for the 2-year rotation plan.

Internships and Research

In addition to regular coursework, mathematics majors have the opportunity to do research, internships and practica. As noted earlier, our Secondary and Middle Education majors are required to complete a student teaching practicum to earn their degree.

Our senior seminar in mathematics course is open to all majors and required for the applied math concentration. It involves a semester-long interdisciplinary research project. Some students have done research outside of class and/or in the summer. In particular, our faculty member Ben Levy secured funding to do research with students that involved mathematical modeling using differential equations. One student in particular traveled with Dr. Levy to Africa to work on disease modeling research. Two other students worked, under Dr. Levy's advisorship, on a Nashua River research project in collaboration with other departments.

There is currently no internship requirement for our students but our recently developed internship course allows them to get math credit for internships. A few mathematics majors have completed internships recently. One in particular did an internship at State Street in Boston in summer of 2022. They reported it to be a very professional experience with a lot of hands-on experience (met with executives, collaborated with constituents locally and internationally). Immediately thereafter they secured a State Street Rotational Development Program position open to interns. State Street also pays for graduate coursework after 6 months which this student plans to take advantage of.

Course delivery methods

Courses for the mathematics majors and minors use a variety of methods for content delivery including but not limited to interactive lecture, group work, presentations, seminars and projects. The Department has expanded its use of OER and/or free resources for classes including developing some of their own. See the sections on faculty for more details on this. During the pandemic the Department used a combination of face to face, online, and hybrid classes but now all mathematics day classes are back to face to face.

Effectiveness of curriculum

In fall 2023 surveys were administered to FSU mathematics majors, alumni and faculty. See Appendix H for surveys.

Eight students responded to the mathematics major survey and results are shown below for questions related to the programs cognitive goals:

- 87% were satisfied or very satisfied with their development of thinking/communication skills
- 100% were satisfied or very satisfied with their experience linking applications and theory
- 87% were satisfied or very satisfied with their experience in learning to use technology tools
- 50% were satisfied with their development of mathematical independence and open ended inquiry experience.

All respondents said they were satisfied or very satisfied with the overall mathematics program, advising and interactions with mathematics faculty members. Respondents highlighted faculty-good teachers and welcoming environment as strengths of the Department and lack of availability of electives and tutoring for high level courses as weaknesses. Five out of the eight students said they would recommend the FSU Mathematics Program to others. Three students responded to the mathematics minor survey and results were on par with the majors' responses.

Ten faculty members (7 full time and 3 part time) responded to the faculty survey.

- All respondents said they were satisfied or very satisfied with the overall mathematics Program and all full time faculty were satisfied or very satisfied with advising.
- Respondents highlighted faculty commitment and support as a strength of the Department. Some applauded faculty members' expertise and flexibility in working with students' interdisciplinary interests. The tight network with current students and alumni was also mentioned.
- Some weaknesses mentioned were not enough majors and full time faculty members and lack of a variety of electives. Some suggestions for improvements were more advertising and recruitment and more full time faculty members.

All faculty respondents said they would recommend the FSU mathematics program to others.

The alumni that responded were generally positive of the program in that almost all say they use mathematics in their current employment and mostly felt like Fitchburg State prepared them for their careers. Details of the alumni survey are given in Section 2.3.

2.2.2 Students

Learning expectations and learning supports

Cognitive goals from the Department Assessment plan were stated and addressed in Section 2.2.1. Content goals from the Department Assessment plan are stated below. See Appendix F for more details.

1) Mathematical sciences major programs should include concepts and methods from calculus and linear algebra.
2) Students majoring in the mathematical sciences should learn to read, understand, analyze, and produce proofs at increasing depth as they progress through a major.
3) Mathematical sciences major programs should include concepts and methods from data analysis, computing, and mathematical modeling.
4) Mathematical sciences major programs should present key ideas and concepts from a variety of perspectives to demonstrate the breadth of mathematics.
5) Students majoring in the mathematical sciences should experience mathematics from the perspective of another discipline.
6) Mathematical sciences major programs should present key ideas from complementary

points of view: continuous and discrete; algebraic and geometric; deterministic and stochastic; exact and approximate.
7) Mathematical sciences major programs should require the study of at least one mathematical area in depth, with a sequence of upper-level courses.
8) Students majoring in the mathematical sciences should work, independently or in a small group, on a substantial mathematical project that involves techniques and concepts beyond the typical content of a single course.
9) Mathematical sciences major programs should offer their students an orientation to careers in mathematics.

The curriculum as described in Section 2.2.1, supports nearly all of these goals and the Department is currently discussing changes to fill in the gaps. See Section 3 and Appendix D.14 for more details.

Academic supports outside of the Department include the Academic Coaching and Tutoring Center, Disability Services, and Career Services. Academic support within the Department includes office hours (which are often expanded beyond the usual 3 hour/week university requirement), appointments, and frequent one on one advising and reaching out to struggling students. Currently there are embedded tutors for Precalculus and Calculus I. These tutors attend classes and run individual and group sessions for students in these classes. These embedded tutors may or may not be sustained pending funding. Furthermore, nearly all of our faculty members have an open door policy in which any major or minor can walk in anyone's office to get help and students are often reminded of this. Last but not least, many of our faculty members offer remote options for commuters and after hours support including email consultations and online meetings via google meet or zoom. There are members of the Department that students are referred to for advising on applied mathematics, data analysis, mathematics education, and internships/career advising. Members of the Department also provide research and/or independent study support depending on their expertise and the students' interests. Students are encouraged to attend and/or participate in regional and national mathematics conferences and mentored appropriately. In addition, the Department connects current students with alumni via alumni panels and social events, giving them valuable perspectives and networking opportunities.

Retention initiatives

Retention of our majors largely comes from the high level of individual attention they get from their mathematics faculty and advisors. Given the relatively small size of the Department and number of majors, everybody knows everybody and good relationships are developed. There are frequent interdepartmental discussions about the successes and struggles of individual mathematics majors and extra support and encouragement is provided as appropriate. Mathematics majors are given multiple opportunities to become involved in departmental activities including tutoring, serving on committees, presenting at conferences and attending departmental social events where they can mingle and network with mathematics faculty

members and alumni. Departmental student honors and awards serve as further incentive to stay with the program. These include the FSU Honors Program (which is currently coordinated by mathematics professor Catherine Buell), Pi Mu Epsilon national mathematics honorary society membership opportunities, monetary awards, and awards honoring students for excellence.

2.2.3 Faculty

Teaching responsibilities

Full time faculty teaching responsibility consists of 12 credits per semester. Approximately three-quarters of the sections taught in each semester are devoted to service courses. Hence, each faculty member typically gets one mathematics major course and two or three service courses to teach in any given semester. Because the courses in our Calculus sequence are each four credits and the seminar courses are one-credit courses, several of our faculty routinely carry overloads and hence are compensated at a later time with a course reduction. The Mathematics faculty members also do independent/directed studies with students. Directed studies are occasionally offered if a student misses a course when it was offered, but still needs it for graduation. Several faculty have offered independent studies for students who are interested in mathematics research. These activities are indicative of the support and encouragement departmental faculty extend to our students. These extras are especially notable because this work yields very little compensation. (For a 3-credit directed or independent study course a faculty member is compensated at the rate of 0.25 -credit per student.). Furthermore, many of our faculty members do alternative professional responsibilities (APRs) for credit. Recent APRs include Department Chair (6 credits per semester), Honors coordinator (6 credits per semester), Director or Center for Teaching and Learning (6 credits per semester), Program Area Chair for Secondary and Middle Level Education (9 credits per year), Graduate 5-12 Education Chair (3 credits per year), Research Award (3 credits), Alternate MTEL APR (6 credits), Davis Foundation Grant for College and Career Readiness APR (3 credits), Academic Innovation Fund Grant for High Impact STEM Activities (3 credits). The Department is very active in APRs and several of these positions have been ongoing spreading our department very thin in terms of full time faculty teaching. Hence the Department is relying more heavily on part time faculty. Some of our full time and part time faculty also teach courses through the School of Graduate Online and Continuing Education (SGOCE) during the summer and/or the semester in the evenings and/or online.

Advising

The Chair of the Mathematics Department assigns incoming students to faculty advisors so that each faculty member will have approximately the same number of advisees, subject to several informal criteria. We assign all of our Secondary and Middle Level Initial Certification students

to one member of the department, giving this member the heaviest advising load in the department with other faculty members averaging about 5 advisees in any given semester. Additionally, if students request a particular member of the Department for their advisor, they are generally accommodated. Furthermore, all mathematics minors currently have a mathematics advisor they may go to for questions and guidance.

Professional development initiatives

The Mathematics Department and individual faculty members have recently participated in several professional development initiatives. Highlights are as follows: One of our faculty members, Peter Staab, is a member of the WeBWorK development team and runs the local WeBWorK network at FSU. WeBWorK is an open source online homework system with a database of mathematics and science problems created by individuals from all over the nation. In addition to working on upgrades to the program, Dr. Staab has participated in and run corresponding workshops at the national level and for faculty users at FSU both in and outside of the Mathematics Department. Some of our faculty members have done OER (Open Educational Resource) development training via ROTEL (Remixing Open Textbooks through an Equity Lens) grant, including one with a DEI (Diversity Equity and Inclusion) focus. This has led to the development of OER texts for our courses, one of which was recently published and can be found at https://rotel.pressbooks.pub/statsproblemsets/ . Two of our faculty members, Amy Wehe and Sarah Wright, completed training to teach our new FYE (First Year Experience) course and another faculty member, Nermin Bayazit completed Anti-racism training as part of her membership in the Education Unit at FSU. Department faculty member Catherine Buell has participated in and runs workshops and panels on mathematics and social justice and ethics in mathematics. Furthermore, several of our faculty members have participated in CTL (Center for Teaching and Learning) Course Redesign Summer Institutes.

Faculty Retention Initiatives

Faculty retention initiatives at the university level include new faculty mentorship programs, grants and awards to support various types of projects, years of service recognitions and more. The school of HNS (Health and Natural Sciences) has also helped support faculty members in such endeavors and fostered collaboration among other departments in the HNS school. At the department-level, faculty members are provided with letters of support, workshops, travel funding and course coverage as needed to enable them to participate in scholarship, professional development, grant activities and APRs. The Department has also supported innovation in teaching including standards based grading and inverted classes. Faculty members within the Department have assisted each other in many ways from sharing course materials and best practices to covering each other's classes. The Department has a great camaraderie and engages in social gatherings together. The sense of community within the department contributes a great deal to retention of its faculty members.

Sections 1.4 and 1.7 details the most recent changes made to improve the quality of the mathematics program at FSU. For example, the creation of an interdisciplinary data analytics minor gives our students opportunities to secure careers in this cutting edge field. The secondary and middle education programs were streamlined into a common minor and a second course for methods of teaching mathematics was added to enhance the preparation of our pre-service middle and secondary level mathematics teachers. The addition of an internship course and faculty liaison has provided career support for students. Also, in the year of our last self study the Mathematics Department had just switched a standard computing software from Maple for Matlab which is preferred in research and by industry. Since then Matlab has been incorporated into Math 2550: Symbolic Computational Mathematics and many of our upper-level courses and research with students. This gives our students valuable technology experience needed to succeed in their careers.

2.3.1 Program Outcomes –The Program

Alumni Surveys solicited by the University

The university surveys alumni to gather information about post-graduate employment, education, and other activities. Over the past five years, six alumni have responded to that survey. Two students responded in their first year after graduation (in 2019) and four responded in their third year (one each in 2018, 2019, 2020, and 2022). Four out of six respondents rated the quality of faculty instruction at Fitchburg State University as excellent, and none rated instruction below “fair” on a likert scale. Again, 4 out of 6 respondents rated the level of individual instruction at Fitchburg State University as excellent. Five out of six respondents rated the “Quality of advisement,” the “Curriculum linked to job related skills and knowledge” and “Preparation to meet the demands of my job” and “Preparation to continue my education” as “good” or “excellent.”

All of the respondents in their third year after graduation rated their degree as enhancing their ability to “think analytically and logically,” “acquire new skills and knowledge on your own,” “use the knowledge, ideas, or perspectives gained from your major field,” “orally communicate well,” “to judge information/ideas/actions/conclusions based on sources/methods/reasoning,” “understand and appreciate cultural and ethnic differences between people,” “understand and apply quantitative principles and methods,” “understand and appreciate cultural and ethnic differences between people,” “understand and apply quantitative principles and methods” as “well” or “very well.” Three-quarters of respondents rated Fitchburg State University as “well” or “very well” on all other categories in which they responded: ability to “write effectively,” “use information technology in intellectual and/or professional pursuits,“ “Ability to understand international perspectives on economic, political, social, and cultural issues,” “gain an understanding of or appreciation for the arts,” “understand scientific method.” The respondents in their first year since graduation did not respond to any of these categories.

All respondents rated Fitchburg State University in the following areas, and 5 out of 6 of respondents rated the university as preparing students “well” or “very well” in each of these areas: your ability to “work as a member of a team or group,” “get along with people of diverse backgrounds and perspectives,” “lead others effectively,” “evaluate and choose between alternative courses of action,” and “Your awareness of contemporary issues and their cause and consequences”

All of the respondents to the university survey of alumni were mathematics majors, 4 identified themselves as female and two as male, four identified their race/ethnicity as white/caucasian and two as “other.”

Alumni Survey solicited by the Mathematics Department

The Department also conducted their own survey of alumni of the department. That survey was sent to 128 alumni for whom the department has email addresses. Of those, 27 responded to the survey, including 4 who graduated in the 1980s, 2 from the 1990s, 6 from the 2000s, 10 from the 2010s, and 4 from the 2020s. Of those who are currently employed, 8 are teaching in High/Middle Schools, 6 are working in software or related fields, 3 are employed in financial services, and 2 are employed in data science fields. Two of the respondents are currently unemployed. Of the respondents, two have earned 2 Ph.Ds (with another nearly finished), 3 have MBAs, and 7 have a masters degree in teaching.

All employed respondents said they use mathematics in their professional life. More specifically, they use stats/data analysis, critical thinking/logic, modeling, and mathematics they teach to others (mostly Calc and below). The majority of respondents (26 out of 27) said Fitchburg State prepared them for their careers. In particular, respondents indicated that the following academic experiences at Fitchburg State that have helped them the most since graduation are:

- Projects and open-ended questions
- Technical communication
- Linear Algebra
- Proofs (for teaching)
- Inspiration to be a mathematician
- Problem solving
- Working in groups
- Education classes/practicum classes

Only one respondent out of the 27 would not recommend Fitchburg State University. That alumnus graduated over 30 years ago, so may not be evaluating the current state of the University.

Quotes from responses to the following question below: Identify any particular aspects of your academic experience at Fitchburg State that were a major help to you in your professional life and briefly explain how.

- “Linear algebra for sure, but I think in general just helping to develop generalized problem solving skills whether those were from pure or applied math classes…”
- “The Applied Mathematics program was extremely beneficial to my professional life…having to write mathematical papers for each project prepared me, in a way that I would never trade the world for, to communicate technical information effectively”
- “A lot of the skills I learned in the advanced statistics course were super helpful for grad school and are skills I still use today in my current position”
- “I found the courses to be rigorous and allowed me to experience productive struggle”
- “I also learned skills such as effective communication, logic and perseverance”

Some of the students who went to graduate school said they felt unprepared in some ways. For example, we do not require Real Analysis which is a requirement for many math graduate programs. Also, students who went to graduate school for statistics said they felt unprepared for the difficulty level in their graduate-level statistics courses including the technology used. Since then the Department has added more statistics courses to the curriculum and is considering incorporating a statistics requirement. Along with this comes the use of more (statistical) technology. Other potential program changes would have more students taking Real Analysis. See Appendix D.14 for more details. Many students mentioned Matlab as an asset which gives credit to the Department decision to switch to this software during our last self study. Internship opportunities and help finding math jobs was suggested and is something the Department has been working on.

The weaknesses respondents mentioned are:

- Didn’t feel prepared for grad school – real analysis, more proofs, level of challenge
- More computational tools
    - Only 50% said they developed skills to use technological tools in FSU math courses, although of the 14 2010s or 2020s graduates, 9 said the courses did allow them to develop this skills
- Wanted internships in mathematics

The respondents gave the following advice to the mathematics department:

- More programming
- Do an internship
- Work on time management

In summary, both sets of survey results indicate that alumni overwhelmingly felt prepared for their life after graduation. It appears that the department has improved in providing students with more experience in the use of technology in the past 13 years. In fact, the number of course offerings in the department utilizing the use of technology has increased greatly in that time, including in the past five years. All of the surveys given in Fall 2023 are given in Appendix H.

2.3.2 Program Outcomes – Students

Student Learning Outcomes

This information in this section is taken from the Mathematics Department Assessment Plan. The assessment goals are included in full in Appendix F. The assessment plan can be found in the department reports, which you can find on the Fitchburg State University website. The assessment goals state that students who graduate with a degree in mathematics from Fitchburg State University will have effective thinking and communication skills, will link applications and theory, will have experience using technological tools, and will have increased their mathematical independence and open-ended inquiry. These goals originated from the cognitive goals stated in the "Curriculum Guide to Majors in the Mathematical Sciences" published by the Mathematical Association of America (MAA) on their website. The goals adopted by the Fitchburg State University Mathematics department are stated in more detail below, for easy reference.

PLO 1: Students should develop effective thinking and communication skills.

a) state problems carefully, articulate assumptions, understand the importance of precise definition, and reason logically to conclusions;
b) identify and model essential features of a complex situation, modify models as necessary for tractability, and draw useful conclusions;
c) deduce general principles from particular instances;
d) use and compare analytical, visual, and numerical perspectives in exploring mathematics;
e) assess the correctness of solutions, create and explore examples, carry out mathematical experiments, and devise and test conjectures;
f) recognize and make mathematically rigorous arguments
g) read mathematics with understanding;
h) communicate mathematical ideas clearly and coherently both verbally and in writing to audiences of varying mathematical sophistication;
i) approach mathematical problems with curiosity and creativity and persist in the face of difficulties;
j) work creatively and self-sufficiently with mathematics.

PLO 2: Students should learn to link applications and theory.

a) Mathematics students should encounter a range of contemporary applications that motivate and illustrate the ideas they are studying
b) Students should learn to apply mathematical ideas to problems in those areas.
c) Students should come to see mathematical theory as useful and enlightening in both pure and applied contexts.

PLO 3: Students should learn to use technological tools.

a) Mathematical sciences major programs should teach students to use technology effectively, both as a tool for solving problems

b) Mathematical sciences major programs should teach students to use technology effectively, as an aid to exploring mathematical ideas.
c) Use of technology should occur with increasing sophistication throughout a major curriculum.

PLO 4 Students should develop mathematical independence and experience open-ended inquiry.

a) A mathematical sciences major should be structured to move students beyond the carefully choreographed mathematical experiences of the classroom.
b) A major curriculum should gradually prepare students to pursue open-ended questions
c) to speak and write about mathematics with increasing depth and sophistication.

Summary of Findings

One of the action plans from the previous self study of the mathematics department was to revise the mathematics department assessment plan.

In AY 2018, the Assessment Committee decided to base our new Assessment Plan on the cognitive goals in the Curriculum Guide to Majors in the Mathematical Sciences and details are given in section 1.4. The Mathematics Department agreed that these were appropriate goals for the students majoring in mathematics at Fitchburg State University.

We spent AY 2018, 2019, and 2020 working through the language of the guide to see if it fit our needs, adjusting the language as needed for clarity, passing it through the department, mapping the plan to existing courses in the mathematics department, creating a rubric for Goal 1 of the new Assessment Plan, and beginning to work on inter-reliability and calibration using the Goal 1 rubric. The Assessment Committee also developed a rubric for presentations, which were used to assess mathematics students' presentations at the Undergraduate Conference of Research and Creative Practice at Fitchburg State University. The assessment goals, the curriculum map, and the rubrics the committee created during those years can be found in Appendix F.

In AY 2021, the Department was in the first cohort of departments at Fitchburg State University to take part in a project funded by a grant from the Davis Educational Foundation to create an "Action Plan" for each department that would be used in marketing and other outwardly facing uses to describe what skills students who major in mathematics can expect to have when they earn their BA and what actions they should take each year in order to be successful in a career after graduation. Since this work was so closely related to the work of the Assessment Committee, the committee spent the year looking at our Assessment Goals and condensing and revising them so they were easier for entities outside of the department to understand. The final version of the Mathematics Department Action Plan can be found on the Fitchburg State University website.

In AY 2022, the Assessment Committee asked faculty for examples of student work that required students to engage in work Goal 1(a),(c), (f), (h) and Goal 2. The Assessment Committee was not able to attend any sessions where students were presenting their work verbally that year, so we asked faculty members in a survey whether or not they required students to verbally communicate mathematical ideas. That survey can be found in Appendix H.4. In the future, we plan to attend student presentations students given during their classes and use the rubric the Assessment Committee developed in AY 2018 to assess their presentations. The Assessment Committee also developed a survey in AY 2022 to assess PLO 2 by asking students about their views of mathematics and its applications. That survey can be found in Appendix F.2. The Assessment Committee received several assignments from faculty members that semester that could be used to assess Goal 1(a), (c), (f), and (h) and the "in writing" portion of Goal 1(h). The committee assessed several of those assignments before the end of AY 2022. The results of that assessment can be found in the departmental report for AY 2022.

In AY 2023, the Assessment Committee continued assessing using the work submitted to the committee by the faculty in AY 2022. At the end of that year, the committee asked for assignments that could be used to assess PLO 1(b), (d), (e), (g) and Goal 3. We received a few of these and plan to assess those PLOs in AY 2024. The results of the assessment we completed in AY 2023 can be found in the department report for AY 2023. Some examples of student work can be found in Appendix E.

Ongoing Changes Made to the Program in Response to the Assessments

One thing the Assessment Committee recognizes they need to work on is providing feedback on their work to the rest of the faculty in the department. Although the department report contains a report from the assessment committee each year, that report is not widely disseminated in the department. Faculty have indicated that they would like to know how they are doing in attaining the department goals, and would like to use the information to improve their teaching in their classes.

In addition, the Assessment Committee would like to evaluate student work on each goal near the beginning of their mathematical learning at Fitchburg State and also later in their mathematical career at the university, so we can assess improvement on the goals. For instance, PLO 1 focuses on thinking about and communicating mathematics in general. This goal can be assessed in many classes, such as calculus and linear algebra, near the beginning of a student's studies at Fitchburg State, and in abstract algebra, which all mathematics students take shortly before graduation. In contrast, PLO 2, which is about linking application and theory, can also be assessed at a beginning level in precalculus and calculus I and II, but there is no guarantee that students take a higher level course requiring an application of mathematical theory (ie. an applied mathematics course).

This is an issue the department has been discussing. One possible solution is to create “buckets” with courses of different types, so all students take a beginning and an advanced course in each bucket (eg. Applied Courses, Proofs Courses, and Probability and Statistics Courses) instead of our current structure, which requires that majors take some foundational classes and then choose a certain number of courses at a certain level. Most of our courses fit into one of these buckets (with the possible exception of History of Mathematics), so such a structure would likely not change our course offerings to a large degree. However, such a structure would not give a student as much flexibility to focus on a particular mathematical area, if they are striving to prepare for a particular field (industry vs. graduate school in mathematics).

The mathematics department is interested in feedback regarding this idea, as well as any other ideas that can help students attain the PLOs and also retain some freedom in their schedule. A sketch of a possible course structure the department is considering can be found in Appendix D.14.

2.3.2. Student – Career Placement and Continuing Education Opportunities

In the university survey mentioned earlier in this section, half of the six respondents were currently employed or had a job offer in a field closely related to their degree. Two of the remaining students had been accepted to a graduate program at Fitchburg State University. All respondents found a position of employment within 3 months of graduation, and half of the respondents have been promoted at their place of employment at least once. Four out of the 6 respondents indicated they were satisfied or very satisfied with the course of their career thus far. Four respondents were employed in the education sector and one in the biotech/pharmaceutical industry.

Two of the respondents have joined the American Mathematical Society (AMS), which is a national professional association focused on research in mathematics. Two of the respondents indicated that they had attended conferences and workshops, one had given a talk, and one indicated they had engaged in professional development training.

2.3.3. Inclusiveness of Trend Data Reflection/Analysis

Each year, a few incoming freshmen declare mathematics as their intended major. The number of students who have declared mathematics as their major is very fluid. Several students change to a different major, and several students either add mathematics as a major or switch to mathematics after taking a calculus course or two. For this reason, the “time to degree completion” is not meaningful for the mathematics major.

3. Analysis and Action Plan for the Future

3.1 Comparative strengths and distinctiveness, and areas of improvement across all program levels

The Department determined that the various program levels include our foundational mathematics courses, service and general education courses, and our major-level courses. We will provide a brief description of each of these classifications, and delineate strengths and distinctiveness, and areas of improvement for each.

Foundational Mathematics Courses

Here we are considering our MATH 0300: Quantitative Preparation and MATH 0500: Algebraic Preparation, as well as, the MATH 0400/0401: Math Preparation Lab. Students are enrolled in these courses if they have a high-school GPA under 2.7 or did not score high enough on the Quantitative and Analytical Skills (QAS) or Advanced Algebra and Functions (AAF) Accuplacer tests to enroll in their required mathematics courses.

Strengths and Distinctiveness

Since the time of our last program review, the Department instituted changes to our foundational math program including modifying its naming scheme from a "developmental math" program with "Basic Math" courses to the current courses listed above. This was one attempt to remove some of the stigma that can be associated with enrollment in these courses. Additionally, we incorporated a lab-style format with a dedicated mathematics lab space and shifted these courses from two-semesters to one-semester–allowing more students to complete college-level mathematics in their first year. Since students are working at their own pace, they can feel comfortable spending more time on material that they need the extra time on. Pearson MyLab Math has features built in on homework for students to view an example set up exactly like the problem they are working on or to work through a problem with hints then redo with different numbers. Also the "Ask my instructor" feature will send an email to the instructor with the exact problem they are working on.

In response to growing student needs, and issues with student success and completion in these courses, we added additional hours for students to work in the lab and made programmatic changes as to how students proceeded through the material. We modified benchmarking systems to help students progress through the program and modified the In-Progress (IP) program to help students succeed. An initial study of the effectiveness of the Placement System and the Foundational Mathematics classes was done by Dr. Oehrlein during 2023 and a summary is available in Appendix G, however as we note below, more assessment needs to be done.

We were one of the first universities to pilot and move into fully integrating the BHE's High School GPA requirements (listed above) for placement into foundational math courses versus credit-bearing courses.

Areas of Improvement

We are hoping to assess student placement into these foundational mathematics courses in regards to time for completion, student needs, and student success in their follow-up course. In Section 3.3, we provide details on our weakness regarding assessment of this portion of our program, and assessment is certainly an area for improvement. We want to make intentional changes to continually improve student experiences here. Initial data seems to suggest that the MATH 0500: Algebraic Preparedness is serving as a leveling course for those with low AAF scores into MATH 1300: Precalculus; however, it is less clear if MATH 0300: Quantitative Preparedness is doing the same for other courses.

A small percentage of students do not like that the work is online and self-paced, they prefer direct instruction. But the course is held in-person in a dedicated math space, and having 4.5 hours in-person a week allows time for students to meet with instructors and associates so they can get some one-on-one direct instruction.

Service and General Education Courses

The Department's courses in this classification encompass the large number of service classes offered for other majors on campus, as well as an assortment of courses designed to support the general education curriculum and minors. These courses include MATH 1100: Mathematics in Society, MATH 1700: Applied Statistics, MATH 1800: Business Statistics, MATH/CSC 1900: Discrete Mathematics, MATH 2800: Statistical Analysis, MATH 1500: Informal Number Theory, MATH 1600: Informal Mathematical Modelling, MATH 2000: Informal Geometry, MATH 1300: Precalculus, and DATA 2000: Principles of Data Analysis.

Strengths and Distinctiveness

A strength of our department has been, and continues to be, our ability to adapt to the changing needs of our students, our fellow departments, and the university. In first-semester courses, designed for incoming students, we instituted supplemental instruction to support student learning as we shifted to the new GPA requirements for placement. MATH 1500, MATH 1700 and MATH 1800 all have an additional co-requisite hour to supplement student knowledge in foundational mathematics.

With the change in the General Education Program at Fitchburg State, we identified a need for a Quantitative Reasoning course that would fit a general education/liberal arts model. We designed MATH 1100, and we were deliberate to include "just-in-time" remediation sections, and three faculty members wrote and edited an open-source textbook for the class, inquiry-oriented activities, and project-based evaluations. We have moved many other courses at this level in the program to open-source course materials.

In response to the needs of our Business, Engineering Technology (ENGT), and Biology/Chemistry peers, we reevaluated the courses we offered and have stopped offering an Introduction to Functions course, which was a feeder course for Business Calculus (which is no longer required for Business Major). We also pared down our overall offerings by removing Technical Calculus (no longer required by ENGT). In response to our Biology/Chemistry and Computer Science peers, we developed MATH 2800 to provide a deeper dive into statistical analysis and tools that would service STEM students over the traditional Applied Statistics offerings.

Finally, in recognition of both an emerging field for mathematics, but also in interdisciplinary fields, we created a Data Analytics minor and a new introductory course (DATA 2000) to address this growing field and opportunity for students across multiple majors to add to their knowledge of data and its usage.

Areas of Improvement

Similar to our situation with foundational mathematics classes, we are hoping to assess student placement into these mathematics courses to promote student success. We have a faculty member who graciously dove into this placement data to begin the conversation about how we can do better. A summary of this study is available in Appendix G. In Section 3.3, we provide details on our weakness regarding assessment of this portion of our program, and assessment is certainly an area for improvement.

MATH 1300: Precalculus has been a course we have continually modified to adapt to fit all the roles it is supposed to cover, while still preparing students for Calculus. While we have made changes, this is still a place of improvement for us, especially since MATH 1300 has served as both a retention and recruitment tool for mathematics students. The university states they believe that retention and recruitment is best fostered by full-time faculty members in introductory courses. We are fortunate to have many passionate and experienced part-time faculty; however, in MATH 1300, we've gone from a pattern of full-time to part-time faculty due to lack of staffing. We see this as an area to improve because this class is one pathway for new students into the major. The DFW rates presented in the table below are there for information; however, there were many variables at play beyond just the full-time/part-time status of the instructor. Note: NA in the table below is not available

Semester	# of Sections	% Taught by FT Faculty	DFW rate	Semester	# of Sections	% Taught by FT Faculty	DFW rate
Spring 2018	5	100%	NA	Spring 2021	3	33.3%	43.9%
Fall 2018	6	100%	NA	Fall 2021	3	0%	59.7%
Spring 2019	4	100%	NA	Spring 2022	3	0%	52.3%
Fall 2019	4	100%	NA	Fall 2022	3	66.7%	18.6%

Spring 2020	4	100%	34.3%	Spring 2023	3	100%	32.6%
Fall 2020	3	66.7%	42.9%				

The trend of the inability to schedule full-time faculty in introductory courses includes MATH 1100, which was designed with the intention of a full-time faculty member teaching it. Due to the lack of hiring, we have not been able to staff these courses as desired. While course demand is down (see chart on the number of sections of MATH 1300 above) because of the lack of new hires, we have lost full-time faculty in our introductory-level courses.

Major-Level Courses

In our major-level courses, we include classes required for our major, which also may be required in other STEM majors. These courses include MATH 2300: Calculus I, MATH 2400: Calculus II, and MATH 2600: Linear Algebra. In addition, we include MATH 2500: Introduction to Mathematical Thought, MATH 2550: Symbolic Computational Mathematics, and all 3000 and 4000-level courses and electives.

Strengths and Distinctions

In responding to trends in higher-education and student-demand, the department has made intentional changes and additions to our curriculum. First, we've incorporated more early mathematical study into all of our concentrations, meaning all students take our first-year seminar in mathematics and the introduction to proofs course. Students in these classes are exposed to advanced mathematical practice, the diversity of the field, research topics, and provide a broader foundation for study and exploration. Second, we have added a multitude of classes to our major including more data-driven classes in symbolic computation, data visualization and analytics, and advanced statistics.

We have continued to offer high-level electives to students bringing back some 3000/4000 level courses that had not been offered in some time. Most of our students have had the opportunity to be part of a major project or research project through either their classes, seminar course, independent work with a faculty member, or our new internship initiatives.

One of our greatest strengths are our active and committed faculty who go above and beyond for our students in providing them opportunities outside of the classroom, as well as an enriching academic and scholarly atmosphere. We demonstrate this by our rapport with students, our peers at the university, and our excited and engaged alumni who come back and meet with our current students and with us.

Areas of Improvement

As mentioned above, given our lack of replacement hires for retirements and departing faculty, we have had part-time faculty teaching some major-level courses. Again, we are fortunate to have long-term, dedicated part-time faculty; however, full-time faculty have access to additional

resources for students, research opportunities, and need to be part of creating our relationships with majors. Additionally, these courses also serve for recruiting into the major and minors and retaining our students.

Ultimately a weakness of our program, highlighted in this section is the low-enrollment in the major. This has resulted in the inability to run upper-level courses (both required courses and electives) due to enrollment. Often, the dedicated faculty member agrees to do all the work in that course and teach it as a directed study (worth 0.25 or 0.33 credits vs 3 credits). Finally, with more students we believe we could improve our student engagement outside of class like in a Math Club or additional colloquium–but as a student-driven activity.

3.2 Opportunities to Extend Existing Strengths and Resources

If we're seeing improved completion rates in the foundational math courses, we want to keep that momentum going for students. We will continue our communication with other departments, providing information for those faculty advising these students. More direct advising from instructors in the foundational courses and the faculty teaching the credit bearing courses these students will enter, may help relieve some of the anxiety that can hold these students back. We will continue to adapt our course offerings to reflect the needs of students in our own department and others across campus.

Now that we have some experience with the new course developed for the Quantitative Reasoning requirement in the new General Education program, it is time for some updates. A faculty member will take on the work of updating and extending the materials for the course. She will consult with students who have taken the course, faculty who have taught the course, and colleagues in other disciplines whose students take the course. We will keep the materials free to students and open to other educators and maintain the "just in time remediation" structure that we believe is beneficial to students.

We continue to evaluate our Precalculus course. This course serves many purposes and a variety of students. We maintain open discussions with faculty teaching the course and those teaching future courses, in mathematics and other disciplines. We frequently evaluate the material covered and the preparation and needs of the students.

The sequence of courses for Elementary and Early Childhood educators (MATH 1500, 1600, 2000) aims to give students the expertise and skills they need to succeed in classrooms and other educational settings, and also to prepare students to pass the MTEL exam. We have found students finishing those classes are missing an understanding of probability and statistics that they will need both as teachers and to succeed on the MTEL exam. We are currently working to add this material into these courses.

We have successfully adapted, compiled, and written many OER materials for our courses. There is interest in continuing to expand this work. These faculty can be supported by the department chair with thoughtful and careful course scheduling and by the institution with course releases and stipends, as well as continued professional development.

3.3 & 3.4 Weaknesses found during the self-study and Opportunities for addressing weaknesses

We highlighted areas of weakness in Section 3.1; however, we can summarize these findings. First, we highlight the increase of adjuncts placed into courses, in particular introductory major-level courses and first-semester courses designed to be taught by full-time faculty. We have seen our number of tenure-track faculty members leave or retire without being replaced. (We have been denied three replacement hires.) Although the number of students have declined over this period, the rate of faculty lines decrease has outpaced this.

Additionally, our faculty members have been chosen for Alternative Professional Responsibilities (APRs), which further compounds our availability of full-time faculty due to course-releases associated with assignments. But these assignments are to direct campus-wide programs from coordinating PASM, directing the Center of Teaching and Learning, and coordinating the Honors Program. These positions are respected at the university and serve the wider university as well. The department should not be penalized for this overall strength.

To address this weakness, we need to have more tenure-track lines renewed. Regarding the APRs, we don't expect our department to be leave-proof; however, for the sake of our program and students, we believe the university would allow three-year temporary hires as Visiting Assistant Professors or Teaching Postdocs. Our faculty are good mentors, and new folks fresh out of graduate school are often looking for teaching positions. We would get a better pool of candidates to fill-in gaps by our involved faculty doing APR, open the door for new courses for our students, and help build and mentor new faculty. This provides consistency and stability for students and colleagues.

We mentioned the decline in the number of mathematics majors; however, this is particularly noticeable in our middle/secondary education program–which is usually over 50% of our major. There is a national decline of the number of both in- and pre- service teachers, and the covid era of teaching further negatively impacted potential candidates and discouraged students considering teaching as a profession. Currently, 30-40% of our majors pursue licensure, the sharp decline can partially be explained by this. To address this weakness, there has been concerted efforts at the state and federal level. One of such efforts is to offer various scholarships to recruit and retain STEM teachers that most of our students are eligible and encouraged to apply for. We already have one such scholar and will continue working with our students to utilize these resources. Our newly established pathways program with one of our community college partners, Mount Wachusetts Community College, has just been activated and designed to offer a smooth transition between the community college to our mathematics

licensure program to complete it in four years with 120 credit hours. We expect to see the impact of this collaboration in the next couple of years.

Finally, we address the assessment issue highlighted in several subsections of Section 3.1. Between 2017 and 2019, we made substantial changes to our foundational-level and introductory-level courses. We piloted a corequisite structure in our Applied and Business Statistics (MATH 1700 and MATH 1800); redesigned our foundational mathematics courses (MATH 0300 and 0500) from a one or two-semester model to a one-semester course for all while changing the pedagogical approaches in them; created and implemented a new corequisite in the first course for our elementary education majors, MATH 1500; full-instituted the DHE HS-GPA pilot, and created and instituted a new quantitative reasoning course. Due to a multitude of pressures from the university and the state, in making all these changes, we have lost much data to assess these solutions. Then, of course, data between 2019 and 2021 are categorically differ due to the covid-era of teaching. Parsing the data during this time to get meaningful information has thus become more complicated and our goal to assess student success and accurate placement is nearly blind. A faculty member submitted an innovation grant to go through this data; however, the grant was rejected.

The opportunity to address this weakness is clear–the administration must support the mathematics department with time and resources to do this assessment. Our faculty have already started, on their own, this depth of data collection and analysis. This is a student-success initiative and the administration needs to recognize that instituting changes without a plan for assessment does not benefit our students nor our faculty.

3.5 Future Direction of the Mathematics Program

The mathematics program has always been mindful of the ever changing world, demands, and workforce outside of Fitchburg State that our students will find themselves in. Given the work positioning our program to start internships for students, we have set the foundation for student exploration in that space. Additionally with the hiring of new faculty, we have been able to expand our offerings in statistics, data science and data analytics, again answering and noticing trends in the field. However, we maintain that a program grounded in fundamentals, problem solving, creativity, and core mathematical practice will benefit students no matter what the future problems will be that we can and cannot perceive now. However our program is not positioned to be able to move forwards due to the lack of staffing which hinders the diversity of classes we can offer to both the university and their changing needs, and our program's changing needs.

3.6 Action Plan for next five years

The action plan for the next five years has several core components, we discuss each individually; however, they are certainly intersectional.

A. Increasing the Number of Majors and Enrollment in our Programs

We are interested in increasing the enrollment in our major and minor programs. There is not a set timeline nor do we have enough information from admissions and institutional research regarding the future numbers at the university.

To achieve this goal, our faculty have and will continue to work to recruit new majors and minors in courses–which means we need a continued and growing presence in MATH 1300: Precalculus, MATH 2300: Calculus I, and MATH 2600: Linear Algebra. Other methods of recruiting students will be explored, like expanding our relationship with Mount Wachusett Community College (MWCC) to guide transfer students into our program. We already have a transfer agreement with MWCC for Middle and Secondary Education mathematics majors. We created a marketing video; however, we will continue to seek the guidance of our marketing and admission partners.

Additionally, to attract students we will rely heavily on action item B and action item C to make sure we are meeting student interests and market trends, while still providing a unique, substantive, challenging, creative, nurturing, and mathematically sound education for our students. To achieve this plan we will need faculty–as this is the primary currency for retaining and recruiting students. We will need marketing and admissions to reach out on our behalf and educate students about various opportunities, like those STEM grants for future teachers, and learn the unique value of a Fitchburg State mathematics experience. This request for marketing and admissions to take a stronger role working with departments has been a call across the university.

B. Diversifying the Offerings of the Department

We currently provide a strong foundation for students in our program and offer an applied mathematics concentration as well as two education concentrations leading to licensure. While we feel this is the most important curricular aspect of our program, providing additional coursework to further explore specializations and other areas of interest would only have positive effects for our students.

One easy step we can take is to expose students early to these specializations and some of the types of problems, thinking, and applications that this study would support. Introducing this and gauging students' interests in the Freshmen Seminar would provide more time to strategize opportunities, whether that be a course we pilot as a special topic or an off campus internship type experience.

In order to offer additional electives and special courses with any type of regularity, we need more students and more full time faculty.

C. Bolstering Opportunities for Capstone and Early Research Experiences

In our last review, our Applied Mathematics Concentration students were the only students required to take a 1-credit MATH 1850, our freshman/sophomore seminar in mathematics, as well as a 3-credit senior seminar in mathematics. Our mathematics and secondary education students took a 1-credit junior/senior seminar in mathematics. We have since started requiring MATH 1850 for mathematics and applied mathematics students, and changed the 3-credit seminar to MATH 4600 Capstone in Mathematics (opening it for all students). We retained our required 1-credit MATH 3900 Seminar in Mathematics. While our self-study mentioned several research projects, we are hoping these will become a more foundational experience for all students–with the goal of early research experiences. We must seek out current models of early integration of creative and research experiences in classes. These early experiences in STEM have been shown to help with retention. We envision this work could be attached to a course, directed studies, or internships–and modifying curriculum to be able to support our students' interests. We have also started recommending students for internship experiences; however, this is a complicated and time-consuming process for our students right now.

We hope that as we continue to reassess our curriculum, these opportunities will be built into the larger framework and a draft of a proposed curriculum change is in Appendix D.14. Ultimately, we would want all students to have a three-credit research experience or a culmination of 3 credits throughout their time with us. A major hurdle for these experiences is faculty and student time. Many of our students work, and some full-time. So finding experiences that can complement their current schedules or support them to do research would be necessary. Faculty working with students on these projects are also only compensated with 0.25 credits–if at all. The institution, while hosting Handshake (a job/internship site), needs to step up in the process of helping all students secure external opportunities by using their research and outreach to generate them for students.

D. Assessment for Incoming Students and Meeting Student Needs

Our foundational mathematics program and introductory mathematics courses are a sizable portion of what we do, an overall strength of our department, and a considerable service to the university and collective student body. We need and want this to continue. While we suspect the changes to the structure of the foundational math program and the addition of supplemental instruction sections to the introductory courses is likely a positive change, we need better access to and understanding of the data. We are confident that there are adjustments to be made to promote student success in these courses, their next course, and their education as a whole.

We have the human capital for this: A brilliant statistician, a faculty member specializing in ethics in mathematics, an expert in mathematics education, and many other dedicated faculty with various expertise. We need support from the University to do this work to better inform our future practices