Proposal for a new Master of Science degree in Applied Statistics
Department of Mathematical Sciences

1. **Date submitted:** October 9, 2017.

2. **Contact:** Mark S. Gockenbach, Professor and Chair, Department of Mathematical Sciences (msgocken@mtu.edu, 487-2068).

3. **Interdisciplinary support:** not applicable.

4. **General description and characteristics of program:** There is no accrediting agency for degree programs in Statistics. However, the American Statistical Association organized a working group that recently published the “Report of the ASA Workgroup on Master’s Degrees” (November 2012[1]). This report made the following recommendations:

   (a) Graduates should have a solid foundation in statistical theory and methods.

   (b) Programming skills are critical and should be infused throughout the graduate student experience.

   (c) Communication skills are critical and should be developed and practiced throughout graduate programs.

   (d) Collaboration, teamwork, and leadership development should be part of graduate education.

   (e) Students should encounter non-routine, real problems throughout their graduate education.

   (f) Internships, co-ops or other significant immersive work experiences should be integrated into graduate education.

   (g) Programs should be encouraged to periodically survey recent graduates and employers of their recent graduates as a means of evaluating the success of their programs and to examine if other programmatic changes are warranted.

The first five recommendations imply desirable learning goals and outcomes. We have designed the proposed degree program so that students will achieve the corresponding outcomes, as follows.

   (a) **Graduates can choose a statistical method that is appropriate for a given problem, can apply that method, and can draw appropriate conclusions.** All students must take a two-semester sequence on Mathematical Statistics, the basic theory of statistics. They take a survey course on traditional Statistical Methods, a cutting-edge course on Predictive Modeling, and a course on Computational Statistics. In addition, each student must take five elective courses on statistics.

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Graduates can use popular statistical software to solve realistic problems. Programming and the use of statistical software are taught directly in the required course on Computational Statistics (currently, the packages SAS and R are emphasized.) Most of the other required courses and electives (except the Mathematical Statistics sequence) involve significant use of statistical software for course homework and projects.

Graduates can summarize and explain the results of statistical analyses orally and in writing. Several of the required courses and electives assign significant projects with oral or written reports. For instance, Predictive Modeling requires two in-class presentations and a written report. Computational Statistics requires an in-class presentation and a final written report. Statistical Consulting gives students experience in communicating with clients.

Graduates have experience working in teams. One of the required courses (Predictive Modeling) assigns a team project. The elective course on Statistical Consulting also requires a team project. Many of the courses involve occasional group work.

Graduates know how to work with real data. They can clean the data, deal with missing data values, and generally appreciate the complexities of handling real-world data. Most of the required courses and electives (again, excluding the Mathematical Statistics sequence) assign problems or projects involving real data. Several of the courses require significant projects.

Students are encouraged, but not required, to complete an internship.

5. **Rationale:** “Statistician” is number seven on the Bureau of Labor Statistics (BLS) list of fastest growing occupations, with a predicted increase of 33% in positions over the period 2016-2026. (The average growth for all occupations is predicted to be about 7%.) According to the BLS, “[s]tatisticians typically need at least a master’s degree in statistics, mathematics, or another quantitative field. However, a bachelor’s degree is sufficient for some entry-level jobs.”

Across the United States, the number of statistics degrees awarded has been steadily increasing, as shown in the following chart:\footnote{Taken from Statistics Degrees Continue Strong Growth, Amstat News (American Statistical Association), 1 October 2015, http://magazine.amstat.org/blog/2015/10/01/statistics-degrees-continue-strong-growth/}
As these data show, there is strong demand for advanced degrees in Statistics, both from students and the job market. The proposed M.S. in Applied Statistics aims to prepare students for the job market, where the master’s degree is the most common entry-level degree.

6. Related programs:

(a) At Michigan Tech:
   i. M.S. in Data Science (interdisciplinary program). This is a broader curriculum, including work in computer science and application areas in addition to statistics. Depending on the individual student’s choice of electives, 10% to 50% of the coursework in the Data Science curriculum consists of statistics courses.
   ii. M.S. in Statistics (new degree, also proposed Fall 2017). This curriculum is somewhat more theoretical, requiring a two-semester graduate sequence on Mathematical Statistics, as well as a graduate-level course on Linear Models. Many graduate electives in Statistics are available to both programs.
   The M.S. in Statistics should definitely be preferred by students considering a PhD in Statistics.
   Note: The M.S. in Statistics is a new degree, but it is essentially the same as the current M.S. in Mathematics Sciences (Statistics concentration). It is being changed to a stand-alone degree to give it more visibility.

(b) At other institutions: Numerous institutions in the state and around the country offer a master's degree in Applied Statistics. Here are three examples from the state of Michigan:
   i. Michigan State University, M.S. in Applied Statistics. This degree requires five courses, three graduate electives in statistics, and three additional electives in statistics or a cognate discipline. Four of the required courses correspond directly to courses we require.
   ii. University of Michigan—Ann Arbor, M.S. in Applied Statistics. The prerequisite requirements are greater (a course in probability and a course in mathematical statistics) and therefore there is less overlap in degree requirements with our proposed program. There are five required courses, plus at least three electives in statistics or biostatistics and one or two electives in a cognate discipline.
   iii. Oakland University, M.S. in Applied Statistics. Requirements include a two semester sequence in Applied Linear Models, a two-semester Introduction to Mathematical Statistics, 20 credits of electives (at least 12 in Statistics or Biostatistics), and an applied statistics project.

7. Projected capacity: We are simultaneously proposing an accelerated option for Michigan Tech students to complete the B.S. in Statistics and M.S. in Statistics in five years. Combined capacity for the two programs is 10 students with no new resources, 25 students with an additional faculty position. The majority of new enrollment is expected from this degree.

8. Scheduling plans:

(a) Regular (3 semesters in residence). The degree requires ten courses (30 credits), which can be completed during three semesters in residence. A model schedule is provided below. Note that new students will be admitted only in the fall.

(b) Online/on-campus hybrid (2 semesters in residence). The required courses MA4760 and MA4770 (Mathematical Statistics I and II) will be offered in an online format starting with the 2018-19 academic year. By completing these courses online, students will be able to complete the M.S. in Applied Statistics with two semesters in residence. A model schedule is provided below.
(c) Accelerated (4+1 B.S./M.S. option) The M.S. in Applied Statistics will be available in an accelerated format to Michigan Tech students with any undergraduate major other than Statistics, provided the required prerequisites are satisfied. These are the three-semester sequence in calculus (MA1160, MA2160, MA3160), linear algebra (MA2320 or MA2321 or MA2330), introductory statistics (MA2710 or MA2720 or MA3710 or MA3715), and probability (MA3720). (Note that engineering students complete all of these course, with the exception of MA3720, as part of their degree requirements.)

We do not anticipate a significant enrollment from this option, but it does not cost anything to offer it. A model schedule is provided below.

9. Curriculum design: The M.S. in Applied Statistics will be offered under the Coursework option (no comprehensive examination). Here are the course requirements:

(a) Complete the following required courses.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA4760</td>
<td>Mathematical Statistics I</td>
<td>Fall</td>
</tr>
<tr>
<td>MA4770</td>
<td>Mathematical Statistics II</td>
<td>Spring</td>
</tr>
<tr>
<td>MA5701</td>
<td>Statistical Methods</td>
<td>Fall</td>
</tr>
<tr>
<td>MA5761</td>
<td>Computational Statistics</td>
<td>Fall</td>
</tr>
<tr>
<td>MA5790</td>
<td>Predictive Modeling</td>
<td>Fall</td>
</tr>
</tbody>
</table>

(b) Complete five electives, chosen from among the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA3740</td>
<td>Statistical Programming &amp; Analysis</td>
<td>Fall, Spring</td>
</tr>
<tr>
<td>MA4710</td>
<td>Regression Analysis</td>
<td>Fall</td>
</tr>
<tr>
<td>MA4720</td>
<td>Design &amp; Analysis of Experiments</td>
<td>Spring</td>
</tr>
<tr>
<td>MA5702</td>
<td>Statistical Consulting</td>
<td>Spring</td>
</tr>
<tr>
<td>MA5711</td>
<td>Mathematical Statistics I</td>
<td>Fall</td>
</tr>
<tr>
<td>MA5712</td>
<td>Mathematical Statistics II</td>
<td>Spring</td>
</tr>
<tr>
<td>MA5730</td>
<td>Nonparametric Statistics</td>
<td>Fall (alternate years)</td>
</tr>
<tr>
<td>MA5731</td>
<td>Linear Models</td>
<td>Fall</td>
</tr>
<tr>
<td>MA5732</td>
<td>Generalized Linear Models</td>
<td>Spring (alternate years)</td>
</tr>
<tr>
<td>MA5741</td>
<td>Multivariate Statistical Methods</td>
<td>Spring</td>
</tr>
<tr>
<td>MA5750</td>
<td>Statistical Genetics</td>
<td>Spring (alternate years)</td>
</tr>
<tr>
<td>MA5770</td>
<td>Bayesian Statistics</td>
<td>Fall (alternate years)</td>
</tr>
<tr>
<td>MA5781</td>
<td>Time Series Analysis and Forecasting</td>
<td>Spring</td>
</tr>
<tr>
<td>MA5791</td>
<td>Categorical Data Analysis</td>
<td>Spring (alternate years)</td>
</tr>
</tbody>
</table>

With prior approval of an advisor, cognate courses (at most two) may also be used as electives.

10. New course descriptions: None. The schedule of offered courses is being modified to meet the needs of the different model schedules; also, MA4760 and MA4770 will be offered online to allow for the hybrid online/on-campus option.

11. Model schedules:

Model schedule to complete degree in three semesters Students must enter with prerequisites (a three-semester sequence in calculus, linear algebra, introductory statistics, probability) already completed. Students are only admitted to begin in the fall semester.

Year 1:

Fall: MA4760, MA5701, plus an elective chosen from the following:
* MA3740 Statistical Programming & Analysis
* MA4710 Regression Analysis
* MA5730 Nonparametric Statistics (offered in odd years)
* MA5731 Linear Models
* MA5770 Bayesian Statistics (offered in even years)

Spring: MA4770, plus three electives chosen from the following:
* MA3740 Statistical Programming & Analysis
* MA4720 Design & Analysis of Experiments
* MA5702 Statistical Consulting
* MA5741 Multivariate Statistics
* MA5750 Statistical Genetics (offered in odd years)
* MA5781 Time Series Analysis & Forecasting
* MA5791 Categorical Data Analysis (offered in even years)

Year 2:

Fall: MA5761, MA5790, plus one elective chosen from the following:
* MA3740 Statistical Programming & Analysis
* MA5730 Nonparametric Statistics (offered in odd years)
* MA5731 Linear Models
* MA5770 Bayesian Statistics (offered in even years)

Spring: Four electives chosen from among the following:
- MA4720 Experimental Design
- MA5702 Statistical Consulting
- MA5741 Multivariate Statistics
- MA5750 Statistical Genetics (offered in odd years)
- MA5781 Time Series Analysis & Forecasting
- MA5791 Categorical Data Analysis (offered in even years)

Model schedule for hybrid online/on-campus option  Students can take all necessary prerequisites (three semesters of calculus, linear algebra, introductory statistics, probability) at their home university, take MA4760 and MA4770 online from Michigan Tech, and then complete the degree with two semesters in residence, as follows:

Fall: MA5701, MA5761, MA5790, plus MA4710 or MA5730 or MA5770

Spring: Four electives chosen from among the following:
- MA4720 Experimental Design
- MA5702 Statistical Consulting
- MA5741 Multivariate Statistics
- MA5750 Statistical Genetics (offered in odd years)
- MA5781 Time Series Analysis & Forecasting
- MA5791 Categorical Data Analysis (offered in even years)

Model schedule for accelerated M.S.  Students must be admitted to the accelerated M.S. degree before graduation and preferably before the beginning of the senior year. The following courses, to be taken in the senior year, will count toward the M.S. degree and also toward the B.S. degree (though possibly only as free electives):

<table>
<thead>
<tr>
<th>Course</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA4710</td>
<td>Regression Analysis</td>
<td>Fall</td>
</tr>
<tr>
<td>MA4720</td>
<td>Design and Analysis of Experiments</td>
<td>Spring</td>
</tr>
</tbody>
</table>

The following model schedule completes the Mathematics major (General Mathematics concentration) and the M.S. in Applied Statistics in five years. A student from another major must complete the prerequisites, which are indicated in bold type.
Year 1

Fall: (14 credits)
* UN1015 (Composition)
* CH1150 (University Chemistry I)
* CH1151 (University Chemistry Lab I)
* MA1910 (Exploring Symmetry Groups) (free elective credit)
* MA1160 (Calculus with Technology I)

Spring: (16 credits)
* UN1025 (Global Issues)
* GE 2000 (Understanding the Earth)
* MA2160 (Calculus with Technology II)
* MA2330 (Introduction to Linear Algebra)
* General Education Critical and Creative Thinking Core course

Year 2

Fall: (16 credits)
* MA3160 (Multivariable Calculus with Technology)
* MA3210 (Introduction to Combinatorics)
* General Education Social Responsibility and Ethical Reasoning Core course
* HASS Communication/Composition course (3 credits)
* Free electives (3 credits)

Spring: (15 credits)
* MA1600 (Introduction to Scientific Simulation)
* MA2710 (Introduction to Statistical Analysis)
* MA3560 (Math Modeling with Differential Equations)
* HASS Humanities and Fine Arts course (3 credits)
* Free electives (3 credits)

Year 3

Fall: (16 credits)
* MA3310 (Introduction to Abstract Algebra)
* MA3720 (Probability) (free elective credit)
* HASS Social and Behavioral Sciences course (3 credits)
* Free electives (7 credits)

Spring: (16 credits)
* MA3450 (Introduction to Real Analysis)
* MA4410 (Complex Variables)
* HASS course (3 credits)
* Free electives (7 credits)

Year 4

Fall: (16 credits)
* MA4450 (Real Analysis)
* MA4710 (Regression Analysis)
* MA4945 (History of Mathematics)
* Free electives (7 credits)
Spring: (15 credits)
  * MA4310 (Abstract Algebra)
  * MA4720 (Design & Analysis of Experiments)
  * MA4908 (Number Theory with Technology)
  * Free electives (6 credits)

Year 5:
Fall: MA4760, MA5701, MA5761, MA5790
Spring: MA4770, plus three electives chosen from the following:
  * MA5702 Statistical Consulting
  * MA5732 Generalized Linear Models (offered in even years)
  * MA5741 Multivariate Statistics
  * MA5750 Statistical Genetics (offered in odd years)
  * MA5781 Time Series Analysis & Forecasting
  * MA5791 Categorical Data Analysis (offered in even years)

Note that this schedule assumes that students will take four courses per semester during year 5. To reduce this load, students can opt to take one or two courses in year 4 under the senior rule (if practical—this will work for the schedule of some students, and not for others).

12. Library and other learning resources needed: None.


14. Description of available/needed equipment: The Tech standard computer lab image includes the statistical software packages R and SAS, and also standard office productivity software. This is sufficient for students in the M.S. in Applied Statistics. No other equipment is needed.

15. Program costs, years 1, 2, and 3: Projected enrollments are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th># of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018-19</td>
<td>5</td>
</tr>
<tr>
<td>2019-20</td>
<td>10</td>
</tr>
<tr>
<td>2020-21</td>
<td>20</td>
</tr>
<tr>
<td>steady state</td>
<td>25</td>
</tr>
</tbody>
</table>

Program costs consist of additional sections that must be offered to accommodate the projected enrollment. Note that no new courses will be offered, but certain popular courses will be offered twice per year instead of once per year to meet the demand.

<table>
<thead>
<tr>
<th>Year</th>
<th># additional sections</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018-19</td>
<td>2</td>
<td>$18,000</td>
</tr>
<tr>
<td>2019-20</td>
<td>3</td>
<td>$27,000</td>
</tr>
<tr>
<td>2020-21 and after</td>
<td>4</td>
<td>$36,000</td>
</tr>
</tbody>
</table>

16. Space: No new space is needed.

17. Policies, regulations, and rules:

  (a) Admission to the degree under the regular and hybrid online/on-campus schedules follows usual departmental and graduate school policies.
(b) For the accelerated M.S., Michigan Tech students must apply before graduation and, for purposes of advising, are encouraged to apply before the beginning of the senior year. A cumulative GPA of 3.0 is required.

18. **Accreditation requirements:** not applicable.

19. **Planned implementation date:** Fall 2018
Proposal for a new Master of Science degree in Statistics
Department of Mathematical Sciences

Introduction  The Department of Mathematical Sciences currently offers an M.S. degree in Mathematical Sciences that can be completed with one of four concentrations: Computational and Applied Mathematics, Discrete Mathematics, Pure Mathematics, and Statistics. We propose to spin off the Statistics concentration to a stand-alone degree program.

2. Contact: Mark S. Gockenbach, Professor and Chair, Department of Mathematical Sciences (msgocken@mtu.edu, 487-2068).
3. Interdisciplinary support: Not applicable.

4. General description and characteristics of program: There is no accrediting agency for degree programs in Statistics. However, the American Statistical Association organized a working group that recently published the “Report of the ASA Workgroup on Master’s Degrees” (November 2012). This report made the following recommendations:

(a) Graduates should have a solid foundation in statistical theory and methods.
(b) Programming skills are critical and should be infused throughout the graduate student experience.
(c) Communication skills are critical and should be developed and practiced throughout graduate programs.
(d) Collaboration, teamwork, and leadership development should be part of graduate education.
(e) Students should encounter non-routine, real problems throughout their graduate education.
(f) Internships, co-ops or other significant immersive work experiences should be integrated into graduate education.
(g) Programs should be encouraged to periodically survey recent graduates and employers of their recent graduates as a means of evaluating the success of their programs and to examine if other programmatic changes are warranted.

The first five recommendations imply desirable learning goals and outcomes. We have designed the proposed degree program so that students will achieve the corresponding outcomes, as follows.

(a) Graduates can choose a statistical method that is appropriate for a given problem, can justify the choice theoretically, can apply the method, and can draw appropriate conclusions. All students must take a two-semester sequence on
Mathematical Statistics and courses on Linear Models and Multivariate Statistics. These courses cover the basic theory of statistics. They must also take at least two graduate electives in statistics (most of which address applied statistics). These requirements are built on top of the expected prerequisites for the program, which include introductory statistics, probability, linear regression, and the design of experiments.

(b) **Graduates can use popular statistical software to solve realistic problems.** Students admitted to this program are expected to have some knowledge of statistical software, and all courses (with the exception of Mathematical Statistics) involve significant use of statistical software for course homework and projects. In addition, students can choose the elective course Computational Statistics to develop a stronger background in computing.

(c) **Graduates can summarize and explain the results of statistical analyses orally and in writing.** The required course on Multivariate Statistics assigns a significant project with an oral and written report. Several of the elective courses have similar requirements. For instance, Predictive Modeling requires two in-class presentations and a written report. Computational Statistics requires one in-class presentation and a final written report. Statistical Consulting gives students experience in communicating with clients.

(d) **Graduates have experience working in teams.** The project in Multivariate Statistics is a team project, allowing students the opportunity to develop collaboration and teamwork skills. The elective course on Statistical Consulting also requires a team project. Many of the courses involve occasional group work.

(e) **Graduates know how to work with real data.** They can clean the data, deal with missing data values, and generally appreciate the complexities of handling real-world data. Most of the required courses and electives (again, excluding the Mathematical Statistics sequence) assign problems or projects involving real data. Several of the courses require significant projects.

We have not included an internship requirement in the design of the degree. However, students are encouraged to pursue internship opportunities in the summer.

5. **Rationale:**

(a) We are creating the stand-alone degree for two reasons:

i. To give more visibility to our program (students interested in studying Statistics may not even notice a degree in “Mathematical Sciences with a concentration in Statistics”).

ii. To remove a possible disadvantage for our graduates (employers who want to hire a Statistician might be suspicious of a candidate with a degree in Mathematical Sciences).

(b) “Statistician” is number seven on the Bureau of Labor Statistics (BLS) list of fastest growing occupations, with a predicted increase of 33% in positions over the period 2016–2026. (The average growth for all occupations is predicted to be about 7%.) According to the BLS, “[s]tatisticians typically need at least a master’s degree in statistics, mathematics, or another quantitative field. However, a bachelor’s degree is sufficient for some entry-level jobs.”

Across the United States, the number of statistics degrees awarded has been steadily increasing, as shown in the following chart²

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As these data show, there is strong demand for advanced degrees in Statistics, both from students and the job market. The proposed degree program, which already exists under a different name, has a record of preparing students for the job market and for PhD programs.

6. Related programs:

(a) At Michigan Tech:

i. M.S. in Data Science (interdisciplinary program). This is a broader curriculum, including work in computer science and application areas in addition to statistics. Depending on the individual student’s choice of electives, 10% to 50% of the coursework in the Data Science curriculum consists of statistics courses.

ii. M.S. in Applied Statistics (new degree proposal; currently under review). This curriculum is more applied and is not intended for students intending to continue for a PhD in Statistics. Many graduate electives in Statistics are available to both programs.

(b) At other institutions: Numerous institutions in the region and around the country offer a master’s degree in Statistics. Here are three regional examples:

i. Michigan State University, M.S. in Statistics. This program requires 30 credits of coursework, with four required courses. Three of these required courses are very similar to our required courses on Mathematical Statistics (I and II) and Linear Models.

ii. Western Michigan University, M.S. in Statistics. This program requires 32 credits of coursework, with five required courses. Three of these courses are similar to ours (two courses on statistical theory and one on linear models), and a fourth (Design of Experiments) is a prerequisite for our program. (Students admitted to our program who have not previously taken Design of Experiments are directed by their advisor to take the course as an elective.)

iii. University of Wisconsin, M.S. in Statistics. Five courses are required, including two semesters of theory (similar to our required courses Mathematical Statistics I and II) and two semesters on regression and the analysis of variance (which have significant overlap with our required courses on Linear Models and Multivariate Statistics). The UW degree requires a course on statistical consulting, which is an elective for our program.
7. **Projected enrollment:** We expect a combined enrollment of about 15 students in the M.S. and PhD programs.

8. **Scheduling plans:** Regular.

9. **Curriculum design:** The M.S. in Statistics will be offered under the Thesis Option, Report Option, and Coursework (with exam) Option. Here are the course requirements:

(a) Complete the following required courses:

- MA5711 Mathematical Statistics I  Fall
- MA5712 Mathematical Statistics II  Spring
- MA5731 Linear Models  Fall
- MA5741 Multivariate Statistics  Spring

(b) Complete at least two electives, chosen from among the following:

- MA5702 Statistical Consulting  Spring
- MA5730 Nonparametric Statistics  Fall (alternate years)
- MA5732 Generalized Linear Models  Spring (alternate years)
- MA5750 Statistical Genetics  Spring (alternate years)
- MA5761 Computational Statistics  Fall
- MA5770 Bayesian Statistics  Fall (alternate years)
- MA5781 Time Series Analysis and Forecasting  Spring
- MA5790 Predictive Modeling  Fall
- MA5791 Categorical Data Analysis  Spring (alternate years)
- MA6700 Advanced Topics in Statistics  Spring (alternate years)
- MA6701 Probability  Fall (alternate years)

Additional coursework, as needed (three credits for the Thesis Option, six credits for the Report Option, and 12 credits for the Coursework Option, can be chosen from the above list or from 4000 and 5000-level courses in mathematics. Note that coursework on computational mathematics, especially numerical linear algebra and optimization, would be advantageous for students who want more emphasis on computational statistics.

**Accelerated M.S. option**  The accelerated M.S. is open only to Michigan Tech undergraduates majoring in Statistics. Students must be admitted to the accelerated M.S. degree before graduation, and ideally before the beginning of their senior year. The following courses will count toward both the B.S. and M.S. degrees:

- MA4710 Regression Analysis  Fall
- MA4720 Design and Analysis of Experiments  Spring

**Recommended electives**  If possible, accelerated M.S. students should take the following electives while undergraduates:

- MA4330 Linear Algebra  Fall
- MA4450 Real Analysis  Fall

These additional mathematics courses will help prepare students for the graduate sequence in Mathematical Statistics (MA5711, MA5712) and the required courses on Linear Models (MA5731) and Multivariate Statistics (MA5741). They are especially recommended for students who may wish to pursue a PhD in Statistics following the accelerated M.S.
10. **New course descriptions**: None. The schedule of offered courses is being modified to meet the needs of the accelerated master’s degree option.

11. **Model schedule**:

   **Year 1**:
   
   Fall: MA5711, MA5731, plus an elective chosen from the following:
   * MA3740 Statistical Programming and Analysis
   * MA4710 Regression Analysis
   * MA5761 Computational Statistics
   * MA5730 Nonparametric Statistics (offered in odd years)
   * MA5770 Bayesian Statistics (offered in even years)
   * MA5790 Predictive Modeling
   
   Spring: MA5712, MA5741, plus an elective chosen from the following:
   * MA4720 Design & Analysis of Experiments
   * MA5702 Statistical Consulting
   * MA5750 Statistical Genetics (offered in odd years)
   * MA5732 Generalized Linear Models (offered in even years)
   * MA5781 Time Series Analysis and Forecasting
   * MA5791 Categorical Data Analysis (offered in even years)

   **Year 2**:
   
   Fall: Further electives and/or thesis research.
   
   Spring: Further electives and/or thesis research.

Note that most students pursuing this degree are supported on teaching or research assistantships and complete the degree in two academic years.

**Model schedule for accelerated M.S.** The following schedule completes the B.S. and M.S. in Statistics in five years.

**Year 1**

Fall: (14 credits)
* UN1015 (Composition)
* CH1150 (University Chemistry I)
* CH1151 (University Chemistry Lab I)
* MA1910 (Exploring Symmetry Groups) (free elective credit)
* MA1160 (Calculus with Technology I)

Spring: (16 credits)
* UN1025 (Global Issues)
* GE 2000 (Understanding the Earth)
* MA2160 (Calculus with Technology II)
* MA2710 (Introduction to Statistical Analysis)
* General Education Critical and Creative Thinking Core course

**Year 2**

Fall: (16 credits)
* MA3160 (Multivariable Calculus with Technology)
* MA3740 (Statistical Programming and Analysis)
* General Education Social Responsibility and Ethical Reasoning Core course
* HASS Communication/Composition course (3 credits)
* Free electives (3 credits)

Spring: (16 credits)
* MA2330 (Introduction to Linear Algebra)
* MA3750 (Introduction to SAS Programming)
* HASS Humanities and Fine Arts course (3 credits)
* Free electives (6 credits)
* Approved cognate course (3 credits)

Year 3

Fall: (16 credits)
* MA3720 (Probability)
* MA4710 (Regression Analysis)
* HASS Social and Behavioral Sciences course (3 credits)
* Free electives (4 credits)
* Approved cognate course (3 credits)

Spring: (16 credits)
* MA3450 (Introduction to Real Analysis)
* MA4720 (Design & Analysis of Experiments)
* HASS course (3 credits)
* Free electives (4 credits)
* Approved cognate course (3 credits)

Year 4

Fall: (16 credits)
* MA4760 (Mathematical Statistics I)
* MA4790 (Predictive Modeling)
* MA4945 (History of Mathematics)
* Free electives (7 credits)

Spring: (14 credits)
* MA4770 (Mathematical Statistics II)
* MA4780 (Time Series Analysis and Forecasting)
* Free electives (8 credits)

Year 5:

Fall: MA5711, MA5731, plus two electives chosen from the following:
* MA5761 Computational Statistics
* MA5730 Nonparametric Statistics (offered in odd years)
* MA5770 Bayesian Statistics (offered in even years)

Spring: MA5712, MA5741, plus two electives chosen from the following:
* MA5702 Statistical Consulting
* MA5750 Statistical Genetics (offered in odd years)
* MA5732 Generalized Linear Models (offered in even years)
* MA5791 Categorical Data Analysis (offered in even years)
Note that this schedule assumes that students will take four graduate courses per semester during year 5. To reduce this load, students can opt to take one or two graduate courses in year 4 under the senior rule (if practical—this will work for the schedule of some students, and not for others).

12. **Library and other learning resources needed:** None; current resources are adequate.

13. **Faculty resumes:** [www.math.mtu.edu/~msgocken/StatisticsCVs](http://www.math.mtu.edu/~msgocken/StatisticsCVs)

14. **Description of available/needed equipment:** The Tech standard computer lab image includes the statistical software packages R and SAS, and also standard office productivity software. This is sufficient for students in the M.S. in Statistics. No other equipment is needed.

15. **Program costs, years 1, 2, and 3:** No additional costs are expected. This degree is already being offered under the title “M.S. in Mathematical Sciences.” There is no intent to significantly increase enrollment, and therefore no increased costs are expected.

16. **Space:** No new space is needed.

17. **Policies, regulations, and rules:** Admission to the degree follows usual departmental and graduate school policies.

18. **Accreditation requirements:** Not applicable.

19. **Planned implementation date:** Fall 2018
Proposal for a new PhD in Statistics
Department of Mathematical Sciences

Introduction  The Department of Mathematical Sciences currently offers a PhD in Mathematical Sciences that can be completed with one of four concentrations: Computational and Applied Mathematics, Discrete Mathematics, Pure Mathematics, and Statistics. We propose to spin off the Statistics concentration to a stand-alone degree program.

2. Contact: Mark S. Gockenbach, Professor and Chair, Department of Mathematical Sciences (msgocken@mtu.edu, 487-2068).
3. Interdisciplinary support: Not applicable.
4. General description and characteristics of program: Graduates are expected to achieve the five learning goals established for our M.S. in Statistics, along with two additional goals.
   (a) Graduates can choose a statistical method that is appropriate for a given problem, can justify the choice theoretically, can apply the method, and can draw appropriate conclusions.
   (b) Graduates can use popular statistical software to solve realistic problems.
   (c) Graduates can summarize and explain the results of statistical analyses orally and in writing.
   (d) Graduates have experience working in teams.
   (e) Graduates know how to work with real data. They can clean the data, deal with missing data values, and generally appreciate the complexities of handling real-world data.
   (f) Graduates can carry out research in statistical science.
   (g) Graduates can access and read statistical literature.

Students are required to complete the coursework from our M.S. in Statistics, to do advanced courses in Probability and in Statistics, and to complete two “breadth” courses in mathematics or another cognate discipline. The Qualifying and Comprehensive examinations are used to ensure that the first learning goal is achieved. Goals (b)–(e) are achieved through coursework, while the last two goals are achieved through the process of writing a dissertation.

5. Rationale:
   (a) We are proposing the stand-alone degree for two reasons:
      i. To give more visibility to our program (students interested in studying Statistics may not even notice a degree in “Mathematical Sciences with a concentration in Statistics”).
      ii. To remove a possible disadvantage for our graduates (employers who want to hire a Statistician might be suspicious of a candidate with a degree in Mathematical Sciences).
“Statistician” is number seven on the Bureau of Labor Statistics (BLS) list of fastest growing occupations, with a predicted increase of 33% in positions over the period 2016-2026. (The average growth for all occupations is predicted to be about 7%.) According to the BLS, “[s]tatisticians typically need at least a master’s degree in statistics, mathematics, or another quantitative field. However, a bachelor’s degree is sufficient for some entry-level jobs.”

Across the United States, the number of statistics degrees awarded has been steadily increasing, as shown in the following chart.

As these data show, there is strong demand for advanced degrees in Statistics, both from students and the job market. The proposed degree program, which already exists under a different name, has a record of preparing students for both the academic and non-academic job markets.

6. Related programs:

(a) At Michigan Tech: none.

(b) At other institutions: Numerous institutions in the region and around the country offer a PhD in Statistics. Here are three regional examples:

i. University of Michigan, PhD in Statistics. This program requires six graduate courses in probability and statistics (chosen from a list of eight courses), a two-part qualifying exam, and a dissertation.

ii. Michigan State University, PhD in Statistics. This program requires 13 courses in probability and statistics, a preliminary exam that covers probability and statistics, and a dissertation.

iii. University of Wisconsin, PhD in Statistics. This program requires 12 courses in probability and statistics, a qualifying exam, an oral preliminary exam, and a dissertation.

Our course requirement of ten courses is more than required by University of Michigan, but less than required by Michigan State University and the University of Wisconsin. In each case, there is significant overlap in the content of required courses. All programs require a year of Mathematical Statistics, at least one graduate course in Probability, and courses on statistical methods.

7. Projected enrollment: We expect a combined enrollment of about 15 students in the M.S. and PhD programs.

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8. **Scheduling plans:** Regular.

9. **Curriculum design:**

   (a) Complete courses essentially equivalent to the requirements for our M.S. in Statistics:
   
   i. MA5711 and MA5712 (Mathematical Statistics I and II)
   
   ii. MA5731 (Linear Models)
   
   iii. MA5741 (Multivariate Statistics)
   
   iv. Two graduate electives in Statistics

   (b) Complete the following additional coursework:

   i. MA6700 (Probability)
   
   ii. MA6701 (Advanced Topics in Statistics)
   
   iii. Two graduate courses in mathematics or another cognate discipline

   (c) Pass the written Qualifying Examination on Linear Algebra and Mathematical Statistics before the end of the second year in the PhD program. (A student who fails to pass the Qualifying Examination by the stated deadline can complete a master’s degree but cannot continue in the PhD program.)

   (d) Pass the written Comprehensive Examination on Mathematical Statistics and Linear Models. (By Graduate School rules, the Comprehensive Examination must be passed by the end of the fifth year in the PhD program. We recommend that it be passed by the end of the third year.)

   (e) Write and defend a dissertation describing original research.

10. **New course descriptions:** None.

11. **Model schedule:** For students entering without a master’s degree in Statistics, the PhD is expected to take about five years:

    Years 1 & 2: Complete M.S. coursework, pass Qualifying exam.
    
    Year 3: Complete MA6700 and MA6700, pass Comprehensive exam, begin research.
    
    Year 4: Complete cognate coursework, continue research.
    
    Year 5: Complete research, write and defend dissertation.

    Note that we do encourage students to begin dissertation research before year three when possible.

    **Model schedule for students entering with an M.S. in Statistics** For such students, the PhD is expected to take three to four years:

    Year 1: Complete MA6700 and MA6700, pass Qualifying exam, begin research.
    
    Year 2: Complete cognate coursework, pass Comprehensive exam, continue research.
    
    Year 3 (& 4, if needed): Complete research, write and defend dissertation.

12. **Library and other learning resources needed:** None; current resources are adequate.

13. **Faculty resumes:** [www.math.mtu.edu/~msgocken/StatisticsCVs](http://www.math.mtu.edu/~msgocken/StatisticsCVs)

14. **Description of available/needed equipment:** The Tech standard computer lab image includes the statistical software packages R and SAS, and also standard office productivity software. This is sufficient for students in the PhD in Statistics. No other equipment is needed.

15. **Program costs, years 1, 2, and 3:** No additional costs are expected. This degree is already being offered under the title “PhD in Mathematical Sciences.” There is no intent to increase enrollment, and therefore no increased costs are expected.
16. **Space:** No new space is needed.

17. **Policies, regulations, and rules:** Admission to the degree follows usual departmental and graduate school policies.

18. **Accreditation requirements:** Not applicable.

19. **Planned implementation date:** Fall 2018
Policy Announcement from the Office of Graduate and Postdoctoral Studies (OGPS) at the University of Michigan Medical School

New PIBS Admissions Policy: GRE Scores Will Not Be Required in Applications to PIBS, effective for the 2018-19 Admissions Season (i.e. those applying for the Fall 2019 PIBS Class).

18 August 2017

The role of the Graduate Record Exam (GRE), a standardized test, in STEM graduate admissions has been questioned in several research papers, editorials, and journalistic pieces, many of which can be found in this shared folder. It has also been a regular topic of discussion at PIBS admissions meetings for years. Some of our faculty find that these papers present a compelling case for eliminating our requirement that all PIBS applicants take the GRE General Test and submit their scores. Others consider the GRE to be valuable enough, as a predictor of success in graduate school, to justify our current requirement. Similar conversations are taking place within STEM training programs across the country.

Over the past few years, the institutional rules that necessitated the GRE requirement in PIBS admissions have changed. The Rackham Graduate School no longer requires graduate programs at the University of Michigan to collect GRE scores, and GRE scores are no longer required in applications for NIH T32 training grants, NIH individual fellowships, or NSF GRFP fellowships. Both Rackham and NIH have publicly expressed reservations about the use of the GRE in graduate admissions.

In the light of these changes, now is a good time to examine our current policy and determine whether it is well aligned with the evidence from science-education studies, with our admissions philosophy, and with our institutional values. This year, the PIBS community engaged in a public discussion to bring ourselves up to speed with the relevant literature and the full range of informed opinions on the GRE. Volunteers from among our faculty researched the issue and wrote white papers distilling the best arguments for and against the requirement that all PIBS applicants submit GRE scores. Those white papers were shared with the entire PIBS community of faculty, staff and trainees. Earlier this month, we held an open town-hall meeting, in which we heard comments from mentors and trainees with a wide range of experiences and opinions. Video recordings of that meeting can be seen here. In addition, many faculty, staff and trainees individually contacted or met with PIBS Director Scott Barolo to share opinions, experiences, ideas, and favorite papers on the topic.

We sincerely thank everyone who engaged with this process and helped to educate our training community about the evidence relevant to the GRE and PhD admissions.

Key factors in the OGPS decision are the following:

1. Evidence from STEM graduate education studies. Different published studies reach different conclusions about the value of the GRE as a predictor of success in graduate school. There is evidence to be found that indicates a weak-to-moderate correlation between GRE scores and some metrics of graduate student success, most notably grades in first-year graduate courses. Other studies fail to corroborate this conclusion, finding little to no predictive value in GRE scores. The white papers summarize the evidence on both sides. Overall, while we
cannot rule out the possibility that GRE scores contain some valuable information, the predictive power of that information appears to be weak at best, and the signal-to-noise ratio is very low.

The American Physical Society and the American Astronomical Society, which represent highly quantitative fields, have questioned or recommended the elimination of the GRE requirement in graduate admissions. This, together with the recent decision by Harvard University’s Department of Astronomy to neither require nor accept GRE General Test scores, and the policy of the University of Michigan’s Department of Chemistry to not require GRE scores, suggests that the GRE is not indispensable for STEM PhD admissions, even in highly quantitative disciplines.

2. **Evidence of inherent bias in GRE scores.** GRE scores are significantly skewed to the disadvantage of women, students from underrepresented minority groups in STEM, and students of lower socioeconomic status.

3. **Significant expenditures of applicants’ money, time and effort required to take and prepare for the exam.** These costs, summarized in the white papers, are a disproportionate burden for less privileged students, making test scores less standardized than they may appear and raising questions of equity of access. Furthermore, requiring students to invest money and effort in a test whose usefulness our faculty cannot agree on is a questionable policy.

Based on the evidence and arguments outlined above, our decision is the following:

**PIBS applicants will no longer be required to submit GRE scores, effective in the 2018-19 admission season.**

This change applies only to PIBS. PhD programs within the PIBS umbrella that also hold separate, direct PhD admissions may create or maintain separate policies for their direct-admissions process. Please refer to each PhD program’s website for their individual admissions policies.

OGPS and PIBS would like to sincerely thank every member of our community who stepped forward to get involved in this process. We hope to keep this discussion going: please feel free to continue to share your opinions, new evidence, and ideas for improving this imperfect but vitally important process.

Sincerely,

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