

**SIAM Education Committee Report**

**on**

**Undergraduate Degree Programs  
in Applied Mathematics**

**May 2014**

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**I. Overview**

With a global focus on preparing students to enter STEM (Science, Technology, Engineering and Mathematics) fields, undergraduate programs in Applied Mathematics have an important role to play in preparing the future workforce. The purpose of this advisory report is to describe the components of existing programs in Applied Mathematics. The intended audience includes people who may be interested in initiating new programs, improving existing programs, or policy-makers.

The National Research Council of the National Academies Report, “The Mathematical Sciences in 2025” discusses many issues related to Applied Mathematics. The section on the vitality of the mathematical sciences notes that major problems in core mathematics are getting solved, which is a payoff of long-term investment. Meanwhile, the range of applications has dramatically expanded and new types of mathematics and statistics are being used to probe these applications as computation and “big data” become ubiquitous.

A section devoted to connections between the Mathematical Sciences and other fields describes an enormous expansion of interactions. Decadal studies of most fields list problems containing a major mathematical sciences component. The study acknowledges the role of “dual citizens” with mathematical training but working in other fields and a need for better mechanisms to connect researchers in other fields with mathematical scientists with the mathematical institutes serving an important mechanism to connect them. Important trends in the Mathematical Sciences show that boundaries within the mathematical sciences are eroding; which encourages an inclusive view of what constitutes mathematics, including computation. Intra-disciplinary collaborations are on the rise with the NSF mathematical sciences institutes playing an important role.

Issues regarding people in the Mathematical Sciences enterprise include recruitment and retention of women and underrepresented groups and an acknowledgement that the market for mathematical sciences

talent is now global. The study calls for a major rethinking of postsecondary mathematical sciences education, including content, pathways, and delivery. Within the educational system, the mathematical sciences must play a key role in increasing the number of STEM majors and in modernizing their education. The study notes a key idea in applied mathematics education: to motivate mathematical ideas by how they are used. A changing academic context means that cost pressures are severe, and will affect the mathematical sciences disproportionately because of their role in service teaching.

A section on broadening the culture of the mathematical sciences states that mathematical scientists need a greater awareness of how mathematics is being used. To support this broadening, the reward system needs to evolve, to better appreciate interdisciplinary work and educational innovation. The study notes a growing overlap between core math, applied math, statistics and theoretical computer science and that training should reflect this expanding role.

The findings of the report say: “Mathematical sciences work is becoming an increasingly integral and essential component of a growing array of areas of investigation in biology, medicine, social sciences, business, advanced design, climate, finance, advanced materials, and much more. This work involves the integration of mathematics, statistics, and computation in the broadest sense, and the interplay of these areas with areas of potential application; the mathematical sciences are best conceived of as including all these components. These activities are crucial to economic growth, national competitiveness, and national security. This Finding has ramifications for both the nature and scale of funding of the mathematical sciences and for education in the mathematical sciences.”

Furthermore, the chair of the committee Tom Everhart (*Caltech Professor of Electrical Engineering & Applied Physics, Emeritus; Caltech President, Emeritus; Member of Board of Trustees at Caltech*) says “My eyes were opened to the power of the mathematical sciences today, not only as an intellectual undertaking in their own right but also as the increasingly modern foundation for much of science, engineering, medicine, economics, and business...They have demonstrated a great capacity to envision an emerging era in which the mathematical sciences underpin much of twenty-first century science, engineering, medicine, industry, and national security. I hope that this report persuades many others to embrace that vision.”

Each of these components in “The Mathematical Sciences in 2025” report points to clear ways the industrial and applied mathematics community can help meet these challenges. This report can help guide and support future programs in industrial and applied mathematics at the undergraduate level. *The Mathematical Sciences in 2025* report places significant emphasis on the expansion of mathematical modeling. Modeling can act both as a motivator for the study of mathematics, especially for students whose primary interest is in using their mathematical skills in applied settings. This emphasis is seen as important both for the students’ undergraduate studies per se, and as part of their preparation for careers outside academia.

The expansion of modeling components in undergraduate mathematics curricula, and in the K-12 educational preparation for that undergraduate experience, has been the focus of two recent NSF-funded SIAM Workshops on *Modeling across the Curriculum*. The report on the first workshop (August, 2012) has been published and is freely downloadable from SIAM’s web site at: [www.siam.org/reports/modeling\\_12.pdf](http://www.siam.org/reports/modeling_12.pdf) Key discussion points in the undergraduate section of that report focused on the relative merits of infusion of modeling throughout the undergraduate mathematics curriculum, or creating specific modeling courses, or even modeling-based majors.

The second Modeling across the Curriculum workshop was held in January 2014. The report is currently (February 2014) in preparation and will also be published on SIAM’s web site. This second report will provide more detailed responses to some of the questions and recommendations from the first workshop and includes additional focus on modeling in the K-12 curriculum and the implementation of modeling related to the Common Core State Standards for Mathematics.

Preparation for careers outside academia has also been the subject of recent exploratory workshops and studies. In particular, the NSF-funded INGenIOuS program was a collaborative effort among the leading mathematical sciences professional societies: the American Statistical Association, the Mathematical Association of America, SIAM and the American Mathematical Society. The INGenIOuS (Investing in the Next Generation through Innovative and Outstanding Strategies) program had six initial themes related to different aspects of mathematical sciences workforce preparation, each was the subject of a white paper and these informed the discussions at the July 2013 workshop, which then evolved into six critical threads. These initial themes and resulting threads are summarized in the following table.

<b>INGenIOuS Initial Themes</b>	<b>Major Report Threads</b>
Recruitment & Retention Internships Job Placement Technology & MOOCs Documentation & Dissemination Measurement & Evaluation	Bridge gaps between business, industry, & government (BIG) & academia Improve students’ preparation for non-academic careers Build public awareness of role of math & stat in STEM & non-STEM careers Diversify incentives, rewards, & methods of recognition in academia Develop new curricular pathways Build & sustain professional communities

It is perhaps already evident that several threads relate closely to providing rich and relevant, and therefore applied, undergraduate experiences for all our students. They also reflect the need for some cultural changes in order to establish and institutionalize such curricular and experiential developments. The full report is available at <http://www.ingeniousmathstat.org/pdfs/INGenIOuS-report.pdf>

## **II. Components of an Undergraduate Applied Mathematics Program**

### **A. Survey Instruments**

To create typical profiles of undergraduate applied mathematics programs, we developed and administered a set of survey questions to a small set of colleges and universities varying in geographical region, size and focus. The survey, administered as a Google form, has two parts: program development, resources and challenges (see questions in Appendix A) and curricular data (see questions in Appendix B). We gathered data from 12 institutions and summarized the results below.

### **B. Interview responses about program development, resources and challenges**

**General and Specific Characteristics.** Applied math programs often differentiate themselves from general math programs by having heavier requirements in numerical analysis, computer science, and physical sciences. Some effective aspects of specific programs include: balance of compulsory theoretical courses with real-world applied courses; flexibility in the program; specialized programs, for example in statistics, actuarial science, mathematical biology; research opportunities; industrial connections; interdisciplinarity; social activities, including lunches, math club, pi-mu-epsilon, SIAM student chapter; studies abroad. Respondents tended to measure the success of their programs from the number and types of placements for their graduates, as well as the popularity of their courses.

**Capstone Requirements.** The most common form of capstone project is the senior honors thesis, generally required for honors students. A capstone project is generally not required of non-honors students. However, there are exceptions where a capstone project is required of all students, comprising, for example, either a literature review, independent research project with a faculty advisor, or group work on an industrial mathematics project.

**Industrial Opportunities.** Industrial opportunities generally take the form of internships for pay during the summers. In most cases, students must find these internships on their own initiative, sometimes with the help of a college career center. There are some exceptions. For example, some co-operative education programs place students in an industry position in their third year. Some capstone projects have industry sponsorship and guidance from an industrial advisor.

**Other Student Research Opportunities.** Respondents reported that research opportunities are generally available for working with faculty. Research can often be used as credit towards the student's degree. Only a few schools actively send students to REU opportunities. REUs do not appear to be a large source of research opportunities.

**Student Recruiting.** Some departments, particularly well-known schools with established programs, do not feel a need to actively recruit students at high schools. Other schools do advertise their programs to high schools through brochures and posters. Besides web sites, use of social media was not mentioned as a recruiting tool. Activities sponsored by a school appear very effective in recruiting highly qualified students, including open days and open houses at admissions events, math contests, summer programs, and special courses. For example, at some schools, post-AP courses for high school students may be taken for university credit. This not only attracts students to the math programs, but also is very effective at attracting STEM students in general to the university. Math departments may also attract good students with undeclared majors or from other majors, for example by discussing applied math research in first-year courses and offering research opportunities. Since many first year students may not have chosen a major, interesting and exciting first year applied math courses appear to be a common way to attract qualified students.

**Attrition.** Schools did not view attrition as a problem. Attrition rates in applied math do not appear higher or lower than in other math programs. In addition, attrition after the first year is often compensated by new students joining the program after the first year, a natural consequence of students figuring out what major they want to pursue.

**Post-graduation.** The percentage of graduating students in each program that pursue post-graduate studies in a STEM field varies widely: 10 to 95 percent, with a mean of about 25 percent. Smaller schools typically reported higher percentages in the range 60-95%. For students pursuing industrial careers, major industries that seek applied math graduates include: financial, software/tech/internet, actuarial/insurance, aerospace, pharmaceutical, defense/government contractors, consulting, education, automobile/manufacturing, and oil and gas.

**Resources Needed.** In general, the most important resource needed to launch or maintain an applied math program, mentioned by almost all respondents, is faculty to teach specialized courses in applied math. Applied math courses tend to be upper division courses in the curriculum and are thus not normally taught by lecturers. Other important human resources include: computer support and someone able to make and maintain industrial connections. Other resources needed include computing labs and licenses for math software.

**Challenges of Developing a New Program.** An undergraduate major in applied math may start with an existing concentration or minor, which may demonstrate a market for a major program. It may also be natural to start an applied math program, whether major, minor, or concentration, when a critical mass of faculty begins to nucleate in applied math in a department. A significant challenge is obtaining funding for additional faculty to teach new courses, or differentiated courses in applied math, as invariably would be needed. Another significant challenge is designing a program that is differentiated from a regular math program, given the few course hours that are available after counting for general required courses and fundamental math courses. New courses need to be developed as well. Important issues to consider when designing a new program include: identifying key industrial needs; balancing content of courses while maintaining coherence; interdependency of individual courses; accreditation requirements; university administration requirements and internal politics.

**Questions for consideration for new programs:**

- How many courses should be required for a major/minor/concentration? How many should be particular courses versus electives? Too long a list of required courses could mean a student couldn't declare late and still complete the program.
- How should computing be integrated into the program? Many students learn to use computational tools such as MATLAB, Mathematica, Sage, COMSOL, etc. How much exposure should students have to computational thinking and programming (e.g., elementary algorithms and data structures)? Much of applied mathematics is intimately tied to computing. Early exposure to computing may enable students to take beginning computer science courses early enough to have time to take more advanced courses before graduation.
- What is the critical number of majors/minors to make a program successful? If a new program becomes highly successful, what agreements can be established to provide an appropriate number and variety of courses?
- What kinds of institutional support can help make a new program successful?

### C. Interview responses about curriculum

Typical programs of study consist of a set of required courses and a set of elective courses. The following are some typical course requirements for an applied mathematics major or minor/concentration. Sometimes there is also an applied mathematics track within the mathematics major.

	<b>Major</b>	<b>Minor/Concentration</b>
<b>Required courses</b>	Calculus sequence Differential equations Linear algebra Introduction to proofs Real analysis Numerical analysis Applied math or Modeling Probability Statistics Abstract algebra Introduction to programming Int. object-oriented languages	Calculus sequence Differential equations Linear algebra Introduction to programming
<b>Recommended/elective courses</b>	PDEs Math biology Operations research Complex analysis Discrete mathematics Geometry	Differential equations Linear algebra Discrete mathematics Numerical analysis Applied math or Modeling Operations research

### III. Industrial Mathematics

Industrial mathematics often involves problems that are posed to members of the mathematics community by private companies. The companies might sponsor a group of students working as a team for a sustained period of time on a single problem. Competitions, such as the Moody's Mega Math Challenge and the Mathematical Competition in Modeling (MCM) / International Competition in Modeling (ICM) provide students with challenging applied problems to solve as a team in a matter of hours. Such contests encourage students to get involved in mathematical modeling through clubs or courses at their schools. Study Groups with Industry, first organized at Oxford in 1968, last one week. The problems posed by industry scientists and mathematicians involve graduate students, industry representatives and faculty as well as some advanced undergraduates.

SIAM's math in industry report (2012) has examples of skills in applied mathematics that recruiters for industrial positions look for in mathematics graduates. Skills desired by industry, as communicated by applied mathematicians working in industry include

- **Communication skills** - ability to communicate and "sell" your ideas to management and clients

- **Ability to work in interdisciplinary environments.** This means teamwork and being able to “speak the language” of non-mathematicians, e.g., marketing, software developers, application specialists, and in particular students need a sense of the business in which they are working. Even if the student cannot be directly prepared for every possible business, students need some experience to appreciate that business or other issues may be drivers of a company, not necessarily mathematics and science
- **Technical skills**, which fall into three overlapping domains: (a) **math skills**: broad training in the core of mathematics, and in addition: statistics, mathematical modeling, numerical simulation; (b) **computational skills**: experience in programming in one or more languages. Increasingly important: parallel computing, large-scale data mining, data visualization; (c) **application skills**: enough knowledge in a domain to bridge the gap between theory (math) and practical implementation (the application). Recommend internships to prepare students to develop this ability of “translating” between math and applications, and exposure to real-world problem solving. The latter can also be accomplished with industry speakers/visitors presenting real-world problems and working with students on solutions and/or critiquing solutions.

The INGenIOuS report cited above reflects all of these skills and the desirability of interdisciplinary teamwork. A similar set of desirable outcomes was also identified in the SIAM Report on Undergraduate Computational Science and Engineering, available at [http://www.siam.org/about/pdf/CSE\\_Report.pdf](http://www.siam.org/about/pdf/CSE_Report.pdf) and in shorter form as Turner, P., Petzold, L., Shiflet, A., Vakalis, I., Jordan, K., St. John, S. (2011). Undergraduate Computational Science and Engineering Education. *SIAM Review*, 53(3), 561-574, DOI: 10.1137/07070406X. [www.siam.org/journals/sirev.php](http://www.siam.org/journals/sirev.php).

## IV. Recruitment and Retention

Recruiting students into applied mathematics programs can happen formally and informally. Math clubs provide opportunities for students to get together and help recruit for the program. Research Experiences for Undergraduates (REUs) can provide research experiences for students at another campus, and for students at small schools can sometimes help them experience larger research universities. Travel funds help students attend conferences and begin to feel a part of the profession. Contests can bring students together to practice and have fun really applying their mathematics. Industrial mathematics programs also provide students with an interesting often team-based capstone experience different from a thesis and can draw students to the major. Social activities such as Math Tea or off campus trips with professors can also help build community. Some programs send letters to students after they declare their major, suggesting that applied mathematics pairs well with other majors in STEM and encouraging students to consider a double major or adding a minor in applied mathematics. Some programs send congratulatory letters to students who have performed well in courses, encouraging them to consider the major/minor.

## V. Undergraduate Research

The Council on Undergraduate Research ([http://www.cur.org/about\\_cur/fact\\_sheet/](http://www.cur.org/about_cur/fact_sheet/)) defines undergraduate research as “An inquiry or investigation conducted by an undergraduate student that makes

an original intellectual or creative contribution to the discipline.” It lists the benefits of undergraduate research, which

- Enhances student learning through mentoring relationships with faculty
- Increases retention
- Increases enrollment in graduate education and provides effective career preparation
- Develops critical thinking, creativity, problem solving and intellectual independence
- Develops an understanding of research methodology
- Promotes an innovation-oriented culture

Many undergraduate programs offering either a concentration or a degree in applied mathematics required an undergraduate thesis, research project or internship. Others encourage this but do not require it. Some programs require a thesis for an honors degree, but do not require it for all students. Most programs seem to have some provision for independent study courses. Most accelerated BS/MS programs require a thesis.

Summer research experiences were recommended on many department websites, although no department required them for a major. One of the most common summer research experiences is the Research Experience for Undergraduates (REU) program sponsored by the National Science Foundation.

According to Mathematical Sciences REU listing

[http://www.nsf.gov/crssprgm/reu/list\\_result.cfm?unitid=5044](http://www.nsf.gov/crssprgm/reu/list_result.cfm?unitid=5044), in 2013, there are 65 REU sites. Of those, 40 mention applied mathematics or terms related to applied mathematics (such as computation, etc.) in their keywords.

Modes of research engagement include: working with faculty during year for credit, working with faculty during academic year for pay, summer research at home campus, industry internship/ job, or summer research at another campus.

## **VI. Professional Development for Undergraduate Students**

Applied mathematics programs prepare students for a variety of careers. Through academic research, industry-related projects and internships, students have opportunities to gain a variety of professional skills. A 2013 SIAM report outlines career options for applied mathematics students:

<http://www.siam.org/careers/thinking/pdf/brochure.pdf> .

Through an applied mathematics major, students can develop communication skills that can apply to many careers. Communication modes include writing mathematics (academic writing), preparing and delivering posters, preparing and delivering talks, interviewing for industry jobs and academic positions, and communicating across disciplines. Some schools have required courses that focus on a particular skill, such as public speaking or proof-writing. Schools also offer assistance with applications to graduate school and for fellowships, including preparation for the mathematics subject GRE examination.

Research experiences and industry internships provide environments that facilitate communication and collaboration about cutting edge mathematics problems with connections to real world applications.

Conferences provide a number of professional development opportunities for students, where they can

- Increase their breadth and depth of understanding of mathematics by attending talks.
- Network with students, faculty and industry representatives.
- Attend recruiting evenings and informational sessions for internships, REUs, jobs and graduate programs.
- Present posters and talks to practice mathematical communication.
- Experience being a part of the applied mathematics community.

## **VII. Student Connections in Mathematics Organizations**

Professional organizations provide many opportunities for students of applied mathematics. The following organizations offer student memberships for free or reduced pricing:

American Mathematical Society (AMS)  
American Statistical Association (ASA)  
Association for Women in Mathematics (AWM)  
Mathematical Association of America (MAA)  
Operations Research (INFORMS)  
Society for Industrial and Applied Mathematics (SIAM)  
National Association for Mathematician (NAM).

A department can form a student chapter of MAA, AWM, and SIAM and frequently receive funding for activities.

Conferences and publications of the organizations provide great ways for students to network, learn about professional mathematics culture, see research talks, and present their own research. There are student sessions at SIAM's Annual Meeting, and their biennial Computational Science and Engineering conferences, the Joint Math Meetings, and the MAA Mathfest. Most of the organizations have prizes to encourage promising students to pursue mathematics research and communication.

When considering possible publication of research by undergraduates, note that *SIAM Undergraduate Research Online* (SIURO) is a web-based publication devoted to undergraduate research in applied and computational mathematics

## **VIII. Outreach and Teacher Preparation/Development in K-12**

Academic departments engage with K-12 outreach and teacher professional development most successfully when activities are closely matched to the surrounding community. Successful outreach programs may target students or teachers or both together; professors experienced in outreach recommend having more than one person manage the program. Some outreach programs use a graduate TA or RA line for the logistical coordinator; others are operated entirely by faculty and staff. We recommend talking extensively with local teachers and administrators before designing any program.

One area where industrial and applied mathematics students and faculty may be particularly helpful is in working with teachers to incorporate mathematical modeling into their mathematics curriculum. In the Common Core State Standards the eight standards for mathematical practice include several ideas that relate to applied mathematics and mathematical modeling:

[CCSS.Math.Practice.MP1](#) Make sense of problems and persevere in solving them.

[CCSS.Math.Practice.MP2](#) Reason abstractly and quantitatively.

[CCSS.Math.Practice.MP3](#) Construct viable arguments and critique the reasoning of others.

[CCSS.Math.Practice.MP4](#) Model with mathematics.

[CCSS.Math.Practice.MP5](#) Use appropriate tools strategically.

[CCSS.Math.Practice.MP6](#) Attend to precision.

[CCSS.Math.Practice.MP7](#) Look for and make use of structure.

[CCSS.Math.Practice.MP8](#) Look for and express regularity in repeated reasoning.

SIAM has had two workshops to discuss mathematical modeling across the curriculum from early grades to undergraduate curriculum. The reports from these workshops are freely available at the SIAM website <https://www.siam.org/reports/>

#### **Examples of long-standing, department- or college-based programs for students:**

Saturday Morning Math Group, The University of Texas at Austin

<http://www.ma.utexas.edu/users/smmg/index.html>

*GRA organizer; monthly 3-hour meetings; M/HS students; lectures + hands-on*

Purdue's Department of Computer Science K-12 Outreach

[http://www.cs.purdue.edu/external\\_relations/k-12\\_outreach/programs/](http://www.cs.purdue.edu/external_relations/k-12_outreach/programs/)

*various programs for different age groups; faculty/staff coordinators; university-wide*

MIT offers a wide range of K-12 outreach programs

<https://due.mit.edu/initiatives/k-12-outreach>

*over a dozen different programs for students listed*

Oakland University K-12 STEM Camps

<http://www.oakland.edu/?id=28966&sid=527>

*week-long science camps for elementary, middle, high school students*

Clarkson University *IMPETUS* for Career Success Roller Coaster camps

<http://web2.clarkson.edu/projects/impetus/>

*school-year and week-long summer program on math and physics using roller coaster theme, grades 7 – 12.*

#### **Examples of department-based or college-based programs for teachers:**

Georgia Tech Intern Fellowships for Teachers

<https://www.ceismc.gatech.edu/gift>

*summer, paid research experience for STEM teachers in labs/industry*

Harvey Mudd College Professional Development and Outreach Group

<http://www.math.hmc.edu/pdo/>

*ongoing lecture series*

MIT Science and Engineering Program for Teachers

<http://web.mit.edu/scienceprogram/program.html>

*week-long immersion course (teachers pay tuition to attend)*

Montana State University Teaching Engineering Applications in Mathematics & Science

<http://www.coe.montana.edu/teams/>

*networking K-12 teachers in reservation communities, focusing on grade 6-8 teachers*

**National networks:**

National Association of Math Circles (for students)

<http://www.mathcircles.org/>

Math Teachers' Circle Network (for teachers)

<http://www.mathteacherscircle.org/>

## **IV. Conclusion**

We hope that this report will provide information for people interested in developing a new program in industrial or applied mathematics or enriching an existing one. New trends in industrial and applied mathematics, which include increasing focus on computational mathematics and interdisciplinary connections between STEM fields, would be interesting areas to investigate for a future report.

## Appendix A: Interview Survey

The survey that was used to gather some information to inform this report is attached for information purposes. Responses are no longer being solicited.

Form can be accessed here:

[https://docs.google.com/forms/d/18Og5b8Sx9pneoOF\\_FWIKIWv19UCkFa8KUyxYcqBpbJ8/viewform](https://docs.google.com/forms/d/18Og5b8Sx9pneoOF_FWIKIWv19UCkFa8KUyxYcqBpbJ8/viewform)

**Instructions:** Please remember to click SUBMIT at the bottom of the page to save your input data.

- 1) Date of telephone interview
- 2) Name of interviewer
- 3) University/college being surveyed
- 4) (For interviewer to find): Number of undergraduates at the institution
- 5) Name of interviewee
- 6) Position of interviewee
- 7) In what ways does your department offer undergraduate experiences in applied mathematics?
  - Applications in courses (such as Differential Equations or Statistics)
  - Applied Math courses
  - Applied math concentration
  - Applied math minor
  - Applied math major
  - Industrial mathematics courses
  - Other:
- 8) Which majors have required courses in applied mathematics taught by people in your dept (mathematicians/statisticians/etc)?
  - mathematics
  - statistics
  - operations research
  - mathematical biology
  - computer science
  - biology
  - chemistry
  - physics
  - engineering
  - Other:
- 9) If you have an applied mathematics major, how many students graduate each year with this major?

- 10) At what URL can we find your course listings that include applied mathematics?
- 11) At what URLs can we find your requirements for major/minor/concentrations?
- 12) Does your institution offer a graduate program in applied mathematics?
  - Masters
  - PhD
  - None of the above
  - Other:
- 13) Do your undergraduates take statistics and/or operations research as part of your applied mathematics program?
- 14) What are the research options available for your undergraduate students in applied math?
- 15) Please describe experiences in industry your students have (such as internships, group projects, summer jobs, class projects, gov't labs). Is this work for pay or credit?
- 16) Please describe thesis, senior project or capstone experiences required for your students.
- 17) What aspects of your applied mathematics program/offering are most successful?
- 18) What percentage of your students pursue a graduate degree in a STEM field? (please enter in decimal form)
- 19) What kind of jobs or companies do your graduates go to?
- 20) What does your school do to attract students into your programs in applied mathematics?
- 21) Have you had any problems with attrition from applied mathematics programs and if so, to what would you attribute it?
- 22) If you have developed an applied/industrial mathematics program, please briefly describe it?
- 23) What are some of the challenges of developing a new program?
- 24) What resources (e.g. faculty, staff, space, equipment, etc.) are needed from administrators to launch/maintain an applied mathematics program?
- 25) Can you name other universities that you know that have particularly unique and successful programs in applied mathematics?
- 26) Thank you very much for talking with us about your program. Is there any other information that it would be helpful for us to know as we develop case studies about applied mathematics programs?

## Appendix B: Curricular Data

Form can be accessed here:

[https://docs.google.com/forms/d/1fcqK7uHjHyxrqZPCOE002HSTI\\_IFN2j3JIVq471yZ9w/viewform](https://docs.google.com/forms/d/1fcqK7uHjHyxrqZPCOE002HSTI_IFN2j3JIVq471yZ9w/viewform)

**Instructions:** Please enter information from university/college websites concerning curriculum requirements. Please click the SUBMIT button on the last page to save your input data. If the program offers various degree options, please enter information in applicable PARTS listed below. Please leave blank any PARTS of this survey that are not applicable. For applied math MAJOR, please enter information in PART I. For applied math MINOR, please enter information in PART II. For applied math CERTIFICATE, please enter information in PART III. For applied math CONCENTRATION, please enter information in PART IV. For applied math OTHER degree, please enter information in PART V.

1) Name of person submitting data

2) University/college being surveyed

### **PART I - Curriculum for applied math MAJOR**

3) Core mathematical sciences courses required

- Calculus courses
- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Geometry
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- Other:

4) Recommended mathematical sciences courses for applied math program (In addition to core requirements above, suggested courses for degree)

- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs

- Real analysis
- Numerical analysis
- Complex analysis
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- PDEs
- Math biology
- Operations research
- Industrial math
- Other:

5) Required computer or computational sciences courses

- Introductory programming language
- Intermediate object-oriented programming
- Low-level programming course (e.g. C)
- Data structures
- Algorithms
- Computational sciences or engineering
- Informatics or data mining
- High-performance computing
- Other:

6) Required natural sciences courses

- Physics
- Chemistry
- Biology
- Earth sciences
- any course above
- Other:

7) Other required STEM courses for applied math program

**PART II - Curriculum for applied math MINOR**

8) Core mathematical sciences courses required

- Calculus courses
- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs

- Real analysis
- Numerical analysis
- Complex analysis
- Geometry
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- Other:

9) Recommended mathematical sciences courses for applied math program  
(In addition to core requirements above, suggested courses for degree)

- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- PDEs
- Math biology
- Operations research
- Industrial math
- Other:

10) Required computer or computational sciences courses

- Introductory programming language
- Intermediate object-oriented programming
- Low-level programming course (e.g. C)
- Data structures
- Algorithms
- Computational sciences or engineering
- Informatics or data mining
- High-performance computing
- Other:

11) Required natural sciences courses

- Physics
- Chemistry
- Biology
- Earth sciences
- any course above
- Other:

12) Other required STEM courses for applied math program

**PART III - Curriculum for applied math CERTIFICATE**

13) Core mathematical sciences courses required

- Calculus courses
- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Geometry
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- Other:

14) Recommended mathematical sciences courses for applied math program

(In addition to core requirements above, suggested courses for degree)

- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra

- Number theory
- PDEs
- Math biology
- Operations research
- Industrial math
- Other:

15) Required computer or computational sciences courses

- Introductory programming language
- Intermediate object-oriented programming
- Low-level programming course (e.g. C)
- Data structures
- Algorithms
- Computational sciences or engineering
- Informatics or data mining
- High-performance computing
- Other:

16) Required natural sciences courses

- Physics
- Chemistry
- Biology
- Earth sciences
- any course above
- Other:

17) Other required STEM courses for applied math program

**PART IV - Curriculum for applied math CONCENTRATION**

18) Core mathematical sciences courses required

- Calculus courses
- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Geometry
- Topology
- Applied math or math modeling
- Probability
- Statistics

- Abstract algebra
- Number theory
- Other:

19) Recommended mathematical sciences courses for applied math program

(In addition to core requirements above, suggested courses for degree)

- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- PDEs
- Math biology
- Operations research
- Industrial math
- Other:

20) Required computer or computational sciences courses

- Introductory programming language
- Intermediate object-oriented programming
- Low-level programming course (e.g. C)
- Data structures
- Algorithms
- Computational sciences or engineering
- Informatics or data mining
- High-performance computing
- Other:

21) Required natural sciences courses

- Physics
- Chemistry
- Biology
- Earth sciences
- any course above
- Other:

22) Other required STEM courses for applied math program

**PART V - Curriculum for applied math OTHER degree**

23) Formal title of OTHER degree program

24) Core mathematical sciences courses required

- Calculus courses
- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Geometry
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- Other:

25) Recommended mathematical sciences courses for applied math program

(In addition to core requirements above, suggested courses for degree)

- Differential equations
- Linear algebra
- Discrete mathematics
- Introduction to proofs
- Real analysis
- Numerical analysis
- Complex analysis
- Topology
- Applied math or math modeling
- Probability
- Statistics
- Abstract algebra
- Number theory
- PDEs
- Math biology
- Operations research
- Industrial math
- Other:

26) Required computer or computational sciences courses

- Introductory programming language
- Intermediate object-oriented programming
- Low-level programming course (e.g. C)
- Data structures
- Algorithms
- Computational sciences or engineering
- Informatics or data mining
- High-performance computing
- Other:

27) Required natural sciences courses

- Physics
- Chemistry
- Biology
- Earth sciences
- any course above
- Other:

28) Other required STEM courses for applied math program