Highlights from the 2022 Math-Stats Foundations Survey

Mathematical & Statistical Foundations Subcommittee
2023 ACM / AAAI Curricular Task Force
December 2022

1.0 Summary

As part of its task to craft curricular guidelines, the Mathematical and Statistical Foundations (MSF) subcommittee of the 2023 ACM / AAAI Curricular Task Force sought input from the community in various forms. MSF analyzed mathematical requirements in other Knowledge Areas (KAs), sought direct input from the CS theory community, drew from various reports (example: the Park City report on data science) and, critically, used the data from two surveys, one distributed to faculty, designed and distributed by, and one to industry practitioners designed and distributed by ACM. Since the latter is described in other documents, we focus on the former and summarize results here.

2.0 History and timeline

- October 2021: Survey discussing and planning.
- June 2022: First draft and edits.
- June 2022: Coding in Qualtrics.
- September - November 2022: Survey distribution through email.
- By December 2022: 597 responses received.
- January-March 2023: analysis

3.0 Topic #1: Who responded?

3.1 Data summary for topic #1

- 91.7% said “I am a faculty member in an academic computing department”
- Type of institution:
    - Doctoral granting, research-intensive: 58.3%
    - Bachelor's and Master's degree granting university: 19.2%
    - Four-year liberal arts (undergraduate only): 20.2%
    - Two-year college: 3.8%
- Type of department:
    - Computer science: 59.6%
    - Computer science and mathematics: 10.4%
    - Computer science and computer engineering: 8.5%
    - Other: 9.8%
- 25% regularly teach discrete structures, 75% do not
- 23% teach a theory course other than discrete
- Amongst people who teach courses with mathematical content or need math prerequisites:
    - AI (classic and modern) 13.6%
    - Machine learning 12.66%
    - Computational Complexity 11.41%

    - Logic 10.53%
    - Data analysis, data science 10.46%

3.2 Highlights from topic #1

- Strong showing from CS depts/programs (>90%), which means results are relevant to CS programs
- Strong showing from CS faculty who teach math beyond discrete, which again lends support to the “beyond discrete” part of the survey. Amongst these, nice balance amongst various mathematical areas, as above.

4.0 Topic #2: What do we learn about Discrete Structures?

4.1 Data summary for topic #2

- 85% of respondents report the Discrete Structures is a required course in all tracks in their department
- 63% report that Discrete Structures is taught in their (computing) department, 25% in math.
- The prerequisite is evenly distributed between calculus (27%), precalc (22%), and algebra (26%), with the remaining split between gen-ed math and Calc-II.
- When asked to use low-medium-high in ranking the importance of key elements (Applications, Programming assignments, Homework problems, Proofs presented by instructor, student-proofs, Algorithms):
    - The top 3 rated “high” are HW problems, instructor-proofs, student-proofs.
    - But at the same time, the combined low-and-medium score for these three are: 23%, 37%, 52%.
- The top three textbooks:
    - Rosen, Discrete Mathematics and Its Applications: 40%
    - Epp, Discrete Math with Applications: 11.4%
    - Irani (for Zybooks). Discrete Structures for Computer Science: 8.5%
- The top 10 topics taught (ranked):
    - Sets and set operations
    - Propositional logic: truth tables, connectives (operators), inference rules
    - Proof techniques (induction, proof-by contradiction)
    - Relations
    - Set cardinality
    - Recursive mathematical definitions
    - Propositional logic: formulas, normal forms
    - Permutations, combinations, counting, pigeonhole principle
    - Predicate logic
    - Graphs: basic definitions
- The top 5 topics thought to be needed in follow-on courses:
    - Sets and set operations
    - Recursive mathematical definitions
    - Graphs: basic definitions
    - Propositional logic, basic
    - Proof techniques

- The top challenges faculty teaching Discrete face (ranked):
    - Poorly prepared students
    - Not motivated to apply themselves to developing theoretical skills
    - There isn't enough time or grading support to properly teach students proof writing skills
    - Discrete structures has too many disconnected topics to do justice to each
    - Students struggle to see the connection between discrete structures and the rest of computer science
    - There are not enough follow-on courses that show students why discrete math is needed
- Pedagogy: approximately evenly split between "mostly lecture" and "students work problems in groups"
- DFW rate:
    - 45.3% report a rate >= 11%
    - Only 28% report a less than 5% DFW rate
- Further theory beyond discrete structures:
    - 42%: Multiple subsequent theoretical courses
    - 30% require a single course

4.2 Highlights from topic #2

- Variety of prerequisites: what could it mean? Is it just about establishing sufficient mathematical ability?
- The top 10 topics can form the list of topics recommended. They seem to align well with the top 5 topics thought to be needed in follow-on courses. There are follow-on courses (72%).
- We need to say something about poorly prepared students such as: remedial coursework, back-end curricular design. The DFW rate is high, but not as high as for calculus.

5.0 Topic #3: Perceptions

5.1 Data summary for topic #3

- Faculty perceptions about student perceptions:
    - 80.3% agree: “Students' perceptions depend greatly on the particular instructor teaching the math/stats course”
    - 65.3% agree (agree or strongly agree) with “Students generally do not see the point of taking them but tolerate them”
    - 62.3% agree: “Students later in the curriculum appreciate the importance of having taken these courses”
    - 55.5% agree: “Students generally find math/stat courses unappealing because they don't feature applications relevant to CS”
    - 50% agree: “Alumni acknowledge the value of being forced to do theory even if they didn't like it at the time”
    - 45.2% agree: “Students are generally negative about their experiences in these courses”

    - Infer: CS community needs to find applications and communicate better the need for investment in math

- Faculty opinions: (agree/disagree both given since they are often even):
    - 46.1% agree, 35.4% disagree: “Requiring these courses poses a deterrent to enrollment/retention in CS.”
    - 75.1% agree, 14.9% disagree: “These courses represent essential knowledge without which students in our program are unlikely to succeed in later CS courses”
    - 36.6% agree, 38% disagree: “Students generally understand why the content of these courses is relevant to CS”
    - 39% agree, 38.1% disagree: “Students generally understand why these courses are required”
    - 16.4% agree, 50.6% disagree: “Students generally appreciate being required to take these courses.”
    - 49.3% agree, 19.4% disagree: “Alumni generally appreciate having been required to take these courses”

5.2 Highlights from topic #3

- What emerges is that student perceptions about the importance of theory are important and can be addressed through frequent communication.

6.0 Topic #4: Beyond Discrete Structures

6.1 Data summary for topic #4

- Required math courses: what fraction of respondents require the following?
    - Calculus I: 83.6%
    - Calculus II: 62.5%
    - Multivariate Calculus or Calculus III: 24.6%
    - Differential equations: 13.8%
    - Linear algebra: 62.5%
    - Gen-ed statistics: 22%
    - Stronger intro probability/stats: 45.3%
- Results when respondents were asked to rate the importance of various topics:

Topic	**Important for jobs**	**Important for grad school**	**Average**
Precalculus: functions, trig functions, polynomials, exponentials	88.9%	97.3%	93.1%
Basic single-variable calculus: derivatives, integration	78.6	95.6%	87.1%

Intermediate calculus: sequences, series, Taylor series	47.9%	79.1%	63.5%
Multivariate: partial derivatives, vector calculus	53%	80%	66.5%
Exposure to differential equation	26.5%	48.2%	
Basic linear algebra:	95.4%	100%	97.7%
Intermediate linear algebra: eigentheory, PCA, SVD	62%	88.7%	75.4%
Basic probability	96.6%	99.4%	98%
Intermediate probability:Markov chains, bounds, stochastic processes, generating functions	50%	80.11%	65%
Complex numbers and vectors	34.9%	60.3%	47.6%
Statistical inference	84.8%	92.5%	88.7%
Numerical methods	47.3%	61.2%	54.3%
Signal processing, Fourier analysis	25.3%	44.2%	34.75%
Linear programming	46.8%	66.9%	56.9%
Nonlinear optimization	38.32%	58.48%	48.4%

6.2 Highlights from topic #4

- The low Calc-3 requirement suggests that we make a case to math departments about including CS-relevant calculus in Calc-1 and Calc-2
- Precalc, Calc-1, linear algebra and prob-stats stand out in the above table, raising implications about formally requiring them, especially given the rise of modern AI, data science and quantum computing.
- The grad-school numbers are often significantly higher than their equivalent “needed on the job” numbers.