

Revision Report: MSF

MSF Subcommittee responses (in blue) to reviewer comments are organized by section below.

Comments on overall report

Reviewer-0: I don't have time to give a formal review, but I gave it a quick skim and I think it's in good shape. The addition of probability, statistics, and linear algebra will be a strong point of this next revision. If forced to provide some constructive feedback, I would say the KA core for linear algebra goes further than needed -- it could be trimmed.

MSF response: That's a fair point about linear algebra. Since the outcomes are illustrative, we'll assume that not every course will include all of them.

Comments on *Preamble* section

Reviewer-2: I'm being pedantic, and suggest that the first time some acronym is used, it should be written out in full (like MSF). The KA acronym tripped me up later.

MSF response: KA is defined for the whole report at its beginning.

Reviewer-3: I recommend adding a clause in this list that references artificial intelligence as a branch of computing that requires strong mathematical foundations.

MSF response: See last sentence of first paragraph and first sentence of "Changes" section.

Comments on *Core Hours* section

Reviewer-1: I don't see the 'KA' acronym defined.

MSF response: KA is defined for the whole report at its beginning.

Reviewer-2: Maybe this will be obvious to your target audience. I am puzzled about what does 29 Knowledge units mean, and infer from the text that this is a total of 29 hours total time (for the degree) spent in teaching the material. Excluding time for assessments, projects, exams.

MSF response: We've added a third column and some explanation to help clarify.

Comments on *Knowledge Units* section

Reviewer-1: [referring to Discrete math] Shouldn't complexity definitions and some analysis be part of CS core? Leaving this information to an Algorithms course is too late. Covering in Data Structures is necessary too, but the MSF would cover complexity more in depth and teach how to use the Algebra, Numeracy, and Pre-Calculus skills to compute complexities. For example complicated nested while loop complexities is not traditionally covered in Data Structures.

MSF response: now added

Reviewer-1: [referring to Discrete math] Also, should we expose students to Automated Theorem Provers? Probably as useful as most CS core students may ever need.

MSF response: We are leaving this to the AI subcommittee to respond to.

Reviewer-1: [referring to Calc] Some of these topics (especially for KA Core) go quite a bit in depth. Should we consider also Monte Carlo/Metropolis type methods? Or leave it to Simulation electives?

MSF response: now added.

Reviewer-1: [referring to Stats] Would this require Calculus, Linear Algebra, and possibly numerical skills?

MSF response: We strongly recommend a calculus-based probability course as prerequisite to the stats course.

Reviewer-1: [referring to lin-alg] I find covering the concept of a matrix is critical for CS core. It is central in Matrix-vector and Matrix-Matrix Multiplication algorithms (and high performance optimizations), in adjacency matrices, many graph algorithms, etc. The presentation of a matrix as a linear operator is not important here. But the operations it enables is.

MSF response: now added.

Reviewer-1: [referring to lin-alg] The knowledge units below are what we often called Applied Linear Algebra which is often combined with a "Numerical" approach as the goal is usually computational. Even without "Numerical", this can be an entire course for Linear Algebra for CS. It might present some challenges in placing it within the curriculum as it requires some algorithmic maturity (e.g., understanding the complexity implications of some approaches). Still some subjects cannot be addressed without the Numerical part (e.g., Bézier curves, Gaussian elimination, or practical examples of SVD and PCA).

MSF response: yes, good point about needing maturity. However, the numerical part may not be as necessary in a more application-focused approach. Much of numerical linear algebra is quite specialized and highly technical (example: Golub textbook) and probably a challenge for CS undergraduates.

Reviewer-2: [referring to discrete math] I wonder whether there is room to introduce the concept of an algebra (rings/groups), mainly with the goal of introducing and illustrating the distributive law.

MSF response: There is a case to be made for introducing abstract algebra as some discrete math textbooks do. However, we have had to prioritize and as a result this topic among others might need to be incorporated into later, possibly elective, courses. For example, algebra could be included in a course on security as a prelude to material on cryptography.

Reviewer-2: [referring to discrete math] Given that this is targeted at a computer science cohort, I recommend to reduce the number of proof techniques, and instead introduce the key concept of an algorithm. For example, in Sussana Epp's book "Discrete Math with applications", algorithms form a thread linking proofs and logic.

MSF response: This is certainly an option for some programs. However, our current structure is to leave algorithmic material for a course on Algorithms. In general, individual programs may find it suitable to move knowledge units around within courses in a manner that's different from our outline.

Reviewer-2: [referring to prob-stats] I suggest to have in both subjects (this one and the next) a comparison of probability vs statistics.

MSF response: now added

Reviewer-2: [referring to prob-stats] I'd like to suggest adding hypothesis testing. The current topics purely focus on "descriptive statistics", and many modern applications of statistics are used for decision making. Hypothesis testing forms the basis of simple decision making.

MSF response: now added

Reviewer-2: [referring to calc] Given a focus on machine learning, I recommend adding some introduction to automatic differentiation.

MSF response: Given that calculus is taught by math departments, this might be a tough sell.

Reviewer-2: [referring to calc] Given a focus on computing, I recommend adding integration by Monte Carlo sampling.

MSF response: now added

Reviewer-2: [referring to calc] I would prefer to see continuous optimisation instead of parametric representations. The application of calculus to optimisation is one of the key ideas in machine learning. Illustrative learning outcomes: gradient descent, stochastic gradient descent, Newton's method

MSF response: now added

Reviewer-2: [referring to calc] Similar to the previous comment on parametric representations, I think Optimization should be a main topic of Calculus, and not a minor application of multivariate calculus. May need a reorganisation to present multivariate calculus first, then optimisation.

MSF response: now added

Reviewer-3: [referring to prob] This seems challenging: what are the expected outcomes for programs following CS Core trying to cover all these notions in so much less time

MSF response: This is indeed probably true of the entire set of curricular recommendations. We would rather be inclusive of recommendations and leave it to individual programs to trim and fine-tune.

Reviewer-3: [referring to calc] Could consider adding some specific CS-related applications to the learning outcomes (like for the other topics)

MSF response: now added

Comments on *Professional Dispositions* section

Reviewer-3: A disposition that I would suggest we include is Skepticism and validation, Students should cultivate a habit of questioning proposed claims and applying multiple approaches to test and validate mathematical statements.

MSF response: now added

Reviewer-3: [referring to growth-mindset] This is very important. It might be useful to make it even more actionable in terms of "anyone can learn the mathematics that is foundational for computer science"

MSF response: now added

Comments on *Math Requirements* section

Reviewer-1: Agreed. Yet, a large percentage of students have either forgotten this or never understood it well. The pandemic did not help with this either. I find that a good 10 hours of lecture in Discrete Math courses goes toward reviewing these “prerequisites”.

MSF response: now added

Comments on *Course Packaging* section

Reviewer-3: Are there some example courses you could point to?

MSF response: We do have some examples but the current draft is focused on topics and hours. There is on-going discussion about a follow-on report on sample implementations but that is yet to be finalized.

Responses to public comments

Comment #1. The mathematics contribution should include multivariate calculus, linear algebra and perhaps optimisation as well of course as probability theory and some number theory (for hashing, cryptography, for instance).

MSF response: Multivariate, linear algebra, optimization and probability are covered, respectively, in MSF-Calculus (KA-Core 6), MSF-Calculus (KA-Core 7), MSF-Linear, and MSF-Probability. It is true that number theory is not covered in discrete math. For the latter, our survey of faculty drove the priority of topics in discrete mathematics. Number theory simply was not amongst the high-priority topics desired by faculty.

Comment #2: Statistics section seems quite inadequate. What about the concept of bias, sampling and adequacy of a sample, statistical systems such as R, and so on. To include statistical inferencing, regression analysis, Bayesian statistics.

MSF response: This is a good point. We have included some of this in the KA-Core part of MSF-Statistics.

Comment #3. “While pathways, including computer science-adjacent degrees or tracks, can be created to steer students past math requirements towards software-focused careers,” → In this and similar areas (e.g., pre-med), this advice is often translated into “let’s push the kids who have been failed by the system — who are usually minoritized — into lower-prestige, lower-income careers like health techs or IT techs.” I strongly suggest eliminating this advice, especially in light of the research mentioned above. It is a colossal moral failure to do this when <https://www.insidehighered.com/news/students/academics/2023/09/26/instructional-practices-proved-crucial-college-completion>. We could train math instructors better instead.

MSF response: this comment is no longer in the MSF section.