

## Challenges and Opportunities for Computer Science

What are the challenges and opportunities facing undergraduate computer science education today? What are their implications for the adoption/adaptation of CS2023 curricular guidelines? How can CS2023 help address them? We attempt to explore these questions from several institutional perspectives – students, faculty, curricular content, instructional resources, assessment methods, packaging and delivery, and ensuring the long-term vitality of computer science education.

### Students

- Computer science has had a long-term problem with diversity of participation. Given that computer science, as a discipline, touches all walks of life and all populations, it benefits from vigorous participation by all populations regardless of their demographic identities. *Everyone belongs in computer science*. Programs should not only make every effort to send out this message but also promote the active participation of all populations in the discipline.

In CS2023, a curricular practice article has been included on accessibility in computer science education. CS2023 commissioned a special issue of *ACM Inroads* on the practice of computer science education in various geographic regions of the world. (See *ACM Inroads*, Special Issue, 15, 1 (March 2024)).

- Employers everywhere seek professional dispositions (often called soft skills) among graduates (e.g., persistence, being self-directed, adaptive). In response, it has become necessary to make explicit what has always been implicit—the need for students to appreciate the importance of professional dispositions to their future professional success and develop them while still students.

In CS2023, within each knowledge area, the professional dispositions most relevant to the knowledge area have been identified.

### Faculty

- In many institutions, explosive growth in enrollment has put significant strain on faculty resources in terms of class sizes, course loads, etc. Managing faculty load is critical for the vitality of faculty, both in terms of the quality of their teaching and their professional development.
- Recruitment and retention of faculty has been a challenge, given the demand for graduates with advanced degrees in computer science. A trend that has gathered momentum in the last decade is the creation of teaching-track faculty. Institutions must strike the right balance between meeting instructional needs and supporting the professional development of teaching faculty to ensure that they stay current.

### Curricular content:

- Computer Science is a rapidly evolving discipline. This has been both a boon and a bane – boon because of new opportunities and bane because of the accompanying

challenges. Updating courses and curricula to stay current places significant demands on the resources of computer science educators and should be so acknowledged and supported.

In CS2023, emerging technologies have been highlighted (e.g., quantum computing) and rapidly evolving areas have been significantly expanded (e.g., machine learning). A curricular practice article has been included on quantum computing education.

- Generative AI, like other emerging technologies, has the potential to revolutionize computer science education. It will impact course content, pedagogy, and assessment techniques. Harnessing generative AI in service of the goals of formal education will be one of the most significant challenges for the community over the next few years.

In CS2023, a chapter has been included that lists educated guesses on the implications of generative AI for the various knowledge areas. The capabilities of generative AI are expected to rapidly improve. So, how well these speculations are borne out in the future remains to be seen. A curricular practice article has been included on the implications of generative AI for introductory programming.

- Theoretical and mathematical underpinnings make computer science a science. They are essential for long-term career success whereas tools and technologies prepare students for immediate employability. Striking the right balance between these dual objectives will continue to be a challenge, given the increasing need for mathematics in computer science (e.g., in machine learning) and often inadequate mathematical preparation of students entering computer science programs.

In CS2023, mathematical requirements have been individually identified for each knowledge area. This provides for flexibility: mathematically underprepared students can better navigate the curriculum and faculty can either require a prerequisite mathematics course or cover the necessary mathematics as part of a computer science course.

- Given the pervasiveness of computing applications, a computing solution is not just technical in nature. It must incorporate issues related to society, ethics, and the profession as well. Interweaving these issues into technical coverage so as to make them unavoidable in a curriculum is a challenge every educator must take up in fulfillment of responsible citizenry.

In CS2023, issues of society, ethics, and the profession (SEP) have been explicitly enumerated in as many knowledge areas as possible to highlight their importance across the curriculum and help educators incorporate them into their courses. Curricular practice articles have also been included on responsible computing, ethics, and CS for good.

- Computational thinking is now considered the fourth basic skill alongside reading, writing and arithmetic. This provides an opportunity for computer science programs to offer courses for non-majors, both as a service and a recruiting tool. Similarly, interdisciplinary options (CS + X) provide opportunities for computer science educators to collaborate and create programs that will also enhance the learning experience of computer science

students. Resource availability is the primary constraint for availing both these worthwhile opportunities.

In CS2023, a curricular practice article has been included on CS + X.

### **Instructional resources:**

- Increasingly, entire computer science courses and curricula are being moved onto the cloud and to using freely available software and services online. While the benefits of such moves are many, the pitfalls are many as well, including loss of control over the resources and data, privacy issues, etc. A careful consideration of both benefits and pitfalls by all stakeholders should precede such moves.
- The free availability of a variety of big data presents an invaluable opportunity for educators to scale assignments and projects and use real-life problems in their courses to better motivate students.

In CS2023, a curricular practice article has been included on “CS for Good,” a great example of using computing to solve real-life problems.

- Some of the critical resources relevant to emerging areas in computing may not be equitably available to the global computer science community. For example, quantum resources are export-regulated, which hinders quantum computing education.
- The availability of cutting-edge textbooks in languages other than English and the affordability of textbooks are ongoing challenges for computer science educators.

### **Assessment Methods:**

- Generative AI tools are rendering existing assessment methods ineffective. In addition, tools that detect plagiarism based on generative AI are still evolving.
- Current assessment techniques are not well-suited to provide personalized feedback efficiently and at scale.

### **Packaging and Delivery:**

- Online delivery of courses has matured since the COVID-19 pandemic. The success of computer science courses delivered online, whether synchronously or asynchronously, critically rests on the level of maturity of the student. Taking this into account is not only in the best interests of the student but also the discipline and the profession.
- Computer science has been rapidly fragmenting, spinning off Software Engineering, Data Science, Security, and lately, Artificial Intelligence, as separate disciplines. This should be seen as both an opportunity and a challenge: an opportunity to amortize costs by sharing resources and costs; and a challenge to differentiate the disciplines sufficiently from each other so that students can make educated choices. A variety of options are available for differentiation, from certificates and minors all the way up to distinct majors.

Computer Science education research has lately been gathering momentum. It is now a mainstream area of doctoral research. Professional conferences catering to it are increasing in number and ranking. This portends well for computer science education by providing a feedback

loop for improvement that could not have come sooner. It signals the maturing of computer science education.