# Recommendations for Computer Science Education in Colleges of Education

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**Keywords:** Computer Science, Teacher Education, 21st-century Skills, Broadening Participation

**Abstract**

This report is for colleges of education that are interested in adding or increasing Computer Science Education (CSEd) offerings in teacher education programs, either preservice or in-service. The report is based on data collected through a workshop of national leaders in CSEd who are involved with teacher education. The workshop convened 51 people from across the country to collate resources, share experiences, and make recommendations for colleges of education. The attendees represented 25 colleges of education in 16 different states as well as stakeholders from non-profits, government, and industry. Results and recommendations are included.

## Introduction

Computer science provides a set of tools and skills for a fundamental human pursuit, solving problems. At their core, computing tools and skills are a means of automating information processing. For example, a computer can automate tedious tasks and process information faster than humans, like when searching records for a keyword. The better a person understands how to use computing tools, the more information processing they can offload to computers. For example, the field of data science allows us to understand large datasets by using computing tools to process more data than humans reasonably could. The underlying process is the same except that the task of information processing shifts from a person to a computer. Though these new tools and skills are based on how humans have solved problems for centuries, Computer Science Education (CSEd) symbolizes a major shift in how we teach students to solve problems.

Rationale for including CSEd in K-12 and, thus, in teacher preparation have ranged from helping students to develop 21st-century skills and basic computational literacies to providing specialized technical skills and broader access to high-paying and high-impact jobs in our technology-driven society. This broad range is an indicator of the ubiquity and importance of computing in our current and future lives and, thus, the value of CSEd. Whether for reasons

related to policy, digital citizenship, or professional development, many colleges of education are interested in adding or increasing CSEd offerings in teacher education programs, either preservice or in-service. This report assumes that CSEd can be relevant and applicable to a wide range of teacher education programs, not exclusively CS teacher programs, with the goal of improving the computational literacy of teachers and, eventually, their students. To support these efforts, a workshop of 51 national leaders in CSEd who are involved with teacher education was held to collate resources, share experiences, and make recommendations for colleges of education based on the lessons learned and progress made over the past decade.

The aim of this workshop was to offer options for integrating CSEd into teacher education programs, enabling colleges to capitalize on their unique strengths. Another objective was to pinpoint evidence-based resources that colleges can utilize to bolster their implementation of CSEd. Finally, the roles of multiple stakeholders in the preparation of these programs, such as faculty, students, administration, accrediting agencies, school partners, and community partners were considered. Again, the goal was to help colleges leverage their strongest advocates while considering the systemic impacts of changes. It is crucial for colleges of education to carefully select which recommendations from this report they choose to put into action, not try to implement all options. It is important to recognize that the colleges participating in the workshop, many of which possess five or more years of experience in integrating CSEd into teacher preparation, do not offer all the pathways included nor engage directly with all the stakeholders mentioned.

In the report, we consider both standalone and integrated approaches to CSEd. A standalone approach treats CS as a distinct discipline, and its primary goal is to develop CS teachers for standalone CS classes. An integrated approach treats CS as a fundamental literacy,

and its primary goal is to broaden the toolkit of all teachers to help all students develop computational literacy. This comprehensive approach views every teacher as having a level of involvement in CSEd, similar to how all teachers are considered to have a role in teaching reading.

## Method

This report acknowledges that teacher preparation programs are beholden to requirements and standards that may differ based on local and university standards. To make more broadly relevant recommendations, we ensured that workshop participants represented 25 different universities from a variety of institution types, including those that primarily serve populations underrepresented in CS, such as Community Colleges, Historically Black Colleges and Universities, and Minority-Serving Institutions. In addition, 16 different states in the US, each with different attitudes and policies about CSEd, were represented. Last, CSEd stakeholders from non-profits, government, and industry, such as the Aspen Institute, CSforAll, Georgia Dept of Education, Google, International Society for Technology in Education, and Maryland Center for Computing Education, also attended to have a larger CSEd ecosystem represented.

The workshop was held over one day. Morning sessions were spent presenting different models and tactics to the entire group to serve as a jumping-off point for discussions in the afternoon. These sessions covered CSEd policy, long-term goals for CSEd in teacher preparation, accessibility, and Universal Design for Learning in the context of CSEd, preparing standalone CS teachers, teaching CSEd in educational technology courses, using online modules to teach CS to teachers, and two panels with non-CSEd faculty from either a university-wide (i.e., Georgia State University) or state-wide (i.e., Maryland) initiative to integrate CSEd into teacher preparation programs.

The afternoons included small group working sessions. Working group themes were created based on the expertise and experience of the participants and were organized around the following themes: integrated elementary CSEd, integrated secondary CSEd, standalone CS teachers, partnerships with district teachers and administration, partnerships with university faculty and administration, serving underserved groups, and curriculum development. Each workshop attendee chose two working groups in which to participate with instructions to collect resources and make recommendations for colleges of education who are in the beginning stages of considering CSEd in their teacher education programs. The authors then reorganized the content from the working groups based on patterns and themes that emerged from their discussions, which became the topics addressed in the rest of this report.

## Results and Recommendations

### Building Buy-in Throughout Colleges of Education

Just like any significant procedural shift, those engaged in this transition must comprehend the advantages and drawbacks of the changes and how their existing skills, knowledge, and values align with the inclusion of CSEd in teacher education. Thus, the first step in adding or increasing CSEd in teacher preparation programs must include buy-in from the people connected to the programs. Almost all CSEd implementations stem from either a CSEd advocate or a policy change that requires CSEd. Regardless of the source, those leading the initiative to add or increase CSEd in teacher preparation programs will rely on other faculty to create a sustainable change.

#### *Empowering Educators Through Solving Shared Problems*

The true power of CS tools is that they allow people to solve problems, so the focus of CSEd in colleges of education should also be on solving problems in education. By treating CSEd as a

pivot in the tools that teachers and faculty use to solve problems, we can empower educators with a new skill set for attaining existing instructional objectives as opposed to requiring them to cram one more thing into an already packed curriculum. Too often, teachers and faculty believe that CSEd is valuable for their students, but they do not see how it is connected to their core curriculum or testing requirements. Below is a list of problems that faculty might be solving that would be suitable for integrated CS.

- Based on the pedagogical need
  - What is their least favorite topic/activity?
  - What is their least interactive/engaging topic/activity?
  - What do their students struggle with the most conceptually?
- Based on the activity/topic type
  - What is an activity that requires many repetitions?
  - What is a topic that would benefit from the exploration of many concrete examples (e.g., tinkering)?
  - What is a topic that would benefit from a visualization or animation?
- Based on the computational thinking approach
  - What is a topic that requires abstraction/pattern matching (e.g., inductive reasoning)?
  - What is a problem that requires multiple steps of decomposition?
  - What is a problem/process that could be automated with an algorithm?

Because many educators are unfamiliar with CS, their first step toward CSEd often includes using activities that others have developed. From that point, they might modify or add to activities, eventually developing their own activities to solve problems and improve learning in their class. Educators who are new to CS might identify activities that they would like to create but do not have enough skill yet to create the activities themselves. In this case, we recommend working with CSEd faculty or CS teachers, through local Computer Science Teachers Association (CSTA) chapters for example, to provide the necessary CS expertise to

create new activities. Educators can also leverage open education resources, such as those listed below, to improve their expertise.

Several examples of integrated CS activities are available online, but they can be difficult to find. Some groups have started collecting these activities in repositories, such as integratedcomputing.org and https://projects.ctintegration.org/. Some sample activities from these websites include:

- A fashion design module for elementary school art
- An interactive Mad Libs activity for middle school language arts
- An electromagnetic wave activity for middle school science
- A curricular unit for fractions for 4th-grade math

The ScratchEd online community also has many more examples. There are also many curated lists of Scratch projects by discipline to explore. One caveat raised during the meeting was that these activities may lack supporting materials that help a beginner understand how to use them.

***Aligning faculty, student, and administrator values***

To buy in, people need to see how their values are reflected in the changes being made. CS advocates are passionate about CSEd for the same reason that teacher preparation faculty are passionate about their fields -- because they believe it will help students be successful in the future. Two recurrent concerns in teacher preparation programs, however, are that CSEd promotes techno-solutionism and can increase screen time for students, which is particularly a concern for younger children. CSEd advocates share these concerns. As a result, most CS instruction positions CS as one of many possible tools for solving problems, examines the strengths and limitations of techno-solutions, and explains when CS is not an appropriate tool. These concerns can also be used as design constraints when creating and selecting CSEd instructional curricula and approaches, such as using unplugged activities when additional screen

time is a concern or using web-based activities when the cost of technology may be a barrier.

A good resource for identifying shared values related to CSEd is CS Visions. It includes values related to personal agency and joy, computational literacy, school improvement, equity, and social justice, personal and community economic development, and technological innovation. While all of these are valid motivations, identifying shared values in your college of education will help align CSEd initiatives to these values and, thus, increase buy-in. People can either take the online quiz or the college can facilitate a collaborative activity using the unplugged activity. Another tool for cultivating buy-in is to take a faculty vote about which pathways or stakeholders will be central to CSEd initiatives.

## Pathways to CS Education and Professional Development for Teachers

Though we advocate for treating CSEd as a pivot in tools and skills, we must also recognize that CS is a distinct academic discipline, and learning CS concepts and skills takes time. Fortunately, CS was built upon the disciplines that we are already familiar with, such as math, science, and language. Thus, people already know a lot about CS without realizing it. In this section, we discuss how to leverage this prior knowledge to develop CS knowledge at different stages of teacher learning.

### *First Hours of Professional Development*

A common barrier to implementing CSEd is a lack of CS knowledge and skills among the faculty members. Even if faculty are on board with adding CSEd, they may feel powerless to achieve that goal without seeing a clear path toward learning CS, particularly if they lack confidence in their technological abilities. Faculty should begin in the same manner we encourage teachers and their students to start, that is, engaging in activities that enable them to find enjoyment in CS. This approach can provide relevant experiences that can be leveraged

when formally learning CS concepts and skills. Hour of Code activities, such as https://hourofcode.com/us, are a great place to start because they do not require prior knowledge, can be completed in an hour, and are designed to let beginners enjoy CS. Further, many school districts engage in Hour of Code activities each year, so it is valuable to prepare teachers for this. Google's CS First offers activities ranging from 1 to 12 hours. A recommendation is for colleges of education to similarly recognize and incentivize this type of professional development in their faculty.

In cases where lack of technology or limits on screen time are considerations, unplugged or physical computing activities are good options. Unplugged activities require no computers, and some examples include, CS Unplugged, Code.org Unplugged, and the Robot Turtles board game. Physical computing uses specialized technology without screens, such as robots and sensors. Some popular options for physical computing activities are Bee Bots, Sphero, Arduino, Micro:Bit, and Raspberry Pi, each of which provides lesson plans and activities with purchase. One suggestion from the working groups was that robots, like Bee Bots and Sphero, can be particularly impactful as educational tools for young children because they provide a tangible object for them to interact with, enhancing the learning experience. For readings to supplement these activities, below is a list of CT integration-related articles and resources from ISTE Blogs:

- Why You Should Integrate Computational Thinking Into Your Curriculum
- How To Craft a Computational Thinking Problem
- Understanding Problems with Computational Thinking: Decomposition
- Computational Thinking and Data Analysis Go Hand-in-Hand
- How Teaching About Algorithms Deepens Student Learning

***First Weeks of Professional Development***

After gaining some firsthand experience with CS activities, education faculty and teachers will

need to learn the concepts that drive CS. Numerous online resources are readily available at no cost to help individuals grasp fundamental concepts of CS. Some examples of these resources include three, free, self-paced micro-courses: Computing in Everyday Life, Computational Thinking (including an introduction to programming), and Methods for Integrated Computing. They are based on university coursework developed at Georgia State University and are aligned to ISTE's Integrated Computational Thinking Endorsement. In this way, participation in the courses can lead to teachers can earning nationally-recognized credentials. Another useful resource is this self-paced, instructor-supported course about computational thinking for all grade levels and subject areas, developed with support from Google. For more directed CS curriculum, self-paced, free full courses at elementary, middle, and high school levels can be found on Code.org. Code.org curriculum is used by teachers internationally to support standalone CS courses.

In answering the common question of how much CS knowledge and skill education faculty and teachers really need to implement CSEd, one recommendation is, "just enough so that you can solve the problems that you want to solve." In other words, CS knowledge should evolve as the college's CSEd implementation strategies do. At first, it may be enough for faculty members to use existing resources to support integration in teacher preparation programs, and likewise, teachers can use these existing resources with their students. Teacher preparation faculty should not be intimidated by CS or their lack of formal training in CS. CS is rapidly evolving to be more intuitive and easier to understand, especially with the rise of generative AI tools, and many stalwart CSEd advocates had no formal training in CS. Of course, learning CS is not effortless, but the CSEd community has developed many resources to support education faculty, teachers, and students in learning new skills and developing new knowledge and skills.

***Different Pathways to Honor Different Starting Points and Goals***

Future teachers of CS programs have different prior knowledge and different goals for CSEd, which can influence how a program might be designed and delivered. The workshop participants used one or more of the following options:

- CS majors might add a teaching certificate or Master of Arts in Teaching (MAT).
- Preservice or in-service teachers could add a CS endorsement to their program of study.
- Preservice teachers may add micro-credentials to their program of study.
- They may also participate in short semesters (e.g., 3 weeks) or intensives (e.g., 2 full days) to introduce programming that could be built upon in disciplinary courses.
- CS can also be integrated into existing (e.g., methods) courses in teacher education (e.g., science, math, ELA) programs.

CSTA's Guidance for Schools of Education is a great resource for further guidance or case studies and guidance on how to start CSEd programs in colleges of education, including recommendations related to courses and field experiences. In addition, WeTeachCS Strategies for Effective and Inclusive CS Teaching is an online course that discusses CS teaching methods. For those interested in answering questions about specific aspects of CSEd or teaching practices, csedresearch.org provides overviews of research on CSEd, and csteachingtips.org provides strategies for general and more specific aspects of CS teaching.

**Partnerships and Engaging School Districts**

It is crucial to establish partnerships between colleges of education and local schools and districts to ensure the success of CSEd in teacher preparation. A common challenge in teacher preparation is that first-year teachers often feel unprepared and lack the confidence to teach CS in classroom settings. Similarly, in-service teachers frequently express a lack of professional development opportunities and instructional support in CSEd. Through partnerships, colleges of education can better support transitioning and in-service teachers in schools and, in doing so,

learn how to better prepare preservice teachers. Because partnerships provide opportunities for targeted and customized ongoing professional development, collaboration, and knowledge sharing, they ensure CSEd achieves shared goals. Below are tools for establishing effective partnerships.

### *Mutually Beneficial Partnerships*

It is essential that both schools/districts and colleges of education can mutually benefit from these partnerships, to ensure that the collaboration is sustainable. The following are some suggestions on how to work towards this goal.

**The goals and needs of all stakeholders should be considered and served.** For instance, colleges can partner with districts to provide additional support for first-year teachers or establish mentorships between preservice and in-service teachers. This collaboration allows colleges to a) gain insights into the challenges faced by new teachers, informing improvements in their preservice programs and b) identify professional development needs for CSEd. At the same time, districts can offer induction support, helping new teachers navigate their initial classroom experiences.

**All stakeholders must invest resources and expertise.** This investment should match each stakeholder's strengths and can involve allocating funding, facilitating professional development, and sharing facilities and technology resources.

**Readiness and capacity are crucial for sustainable partnerships.** Factors like administrative turnover, staff turnover, and institutional stability should be assessed to ensure successful and sustainable school-university partnerships. Evaluating the readiness for partnership will help determine if both parties have the necessary stability, commitment, and infrastructure to engage in a beneficial collaboration.

### *Unpacking Values as Part of the Process*

Shared values and goals will facilitate the alignment of instructional approaches, curriculum development, and assessment practices, leading to a more coherent and impactful CSEd experience for teachers and students. This requires all stakeholders to engage in discussions that unpack values and delve into the goals of CSEd. Below are some suggestions for how to go about recognizing and sharing values as a part of healthy partnerships.

**Teach each other about values and needs.** Bringing stakeholders, who are from different backgrounds and perspectives and work in various roles and contexts, together in the same room encourages dialogue and collaboration. By creating opportunities for interaction and shared problem-solving, colleges of education and schools/districts can bridge gaps in classroom preparation and practice and establish trust and understanding. For instance, education faculty can observe CS-integrated classrooms or activities in local schools to gain insights into effective instructional strategies and the unique demands of CSEd and reflect on their teacher preparation practices. By exchanging knowledge and experiences, support and resources can be tailored to meet the needs of teachers and students.

**Acknowledge differences in values but work towards shared goals.** While stakeholders may have varying values and priorities in CSEd, it is essential to find common ground. A good resource for identifying and sharing these values is CS Visions. This activity can aid joint decision-making processes, supporting the development of mutually agreed efforts and approaches to CSEd.

**Build from assets, not weaknesses.** Recognizing and celebrating the existing efforts and successes of individuals (e.g., preservice, and in-service teachers, teacher education faculty) and institutions (e.g., schools, districts, teacher education programs) in CSEd is crucial. By

highlighting their achievements, colleges of education and schools/districts can increase buy-in and motivation among stakeholders as a foundation for sustainable growth and improvement.

### *Know Your Accountability Systems*

Accountability systems play a significant role in school-university partnerships. In CSEd, state standards, initiatives, and assessments are accountability mechanisms that shape teaching practices. By understanding these accountability systems, colleges of education and schools/districts can navigate the expectations and requirements while leveraging flexibility and autonomy to promote CSEd.

**Identify success within each partner's context.** Understanding the accountability systems helps identify what each partner needs to demonstrate success. For example, colleges of education may need to align their teacher preparation programs with state K-12 CS standards. Schools/districts, on the other hand, may need to show student achievement in CS through assessments.

**Create sustainable accountability systems aligned with visions and goals.** Partnerships should establish accountability systems that serve the CS visions and goals of each partner. For instance, in the context of in-service teacher professional development, establishing clear expectations, evaluation criteria, and support mechanisms is critical. CS visions and goals can be incorporated into teachers' professional development plans and their teaching evaluation processes.

**Include key stakeholders in decision-making conversations.** It is crucial to involve key stakeholders, such as cooperating teachers, in-service teachers, placement coordinators, fieldwork supervisors, and school administrators in decision-making conversations. Their input and perspectives are invaluable in creating sustainable change.

### *Support for Supervisors/Mentor Teachers in CSEd Partnerships*

Supervisors/mentor teachers play a significant role in shaping the experiences and development of preservice teachers. With the necessary support, supervisors/mentor teachers can effectively guide preservice teachers in integrating computing activities across instructional contexts. The support helps preservice teachers gain practical experiences in CSEd and enables supervisors/mentor teachers to enhance their CS content and pedagogical knowledge and skills.

**Start with vernacular language, followed by modeling in various contexts.** Begin by engaging supervisors/mentor teachers, especially those who have limited CS experiences and backgrounds, in discussions using everyday language to convey the concepts and principles of computing to understand the underlying ideas before mapping them onto specific contexts. Additionally, modeling the integration of computing activities showcases practical examples and instructional strategies and provides supervisors/mentor teachers with a clear understanding of how those concepts and skills can be implemented within the existing curriculum.

**Backmap language onto the concepts.** Once supervisors/mentor teachers have engaged with computing activities, encourage them to back map the language onto the underlying concepts. This process helps teachers recognize the connections between everyday language and CS concepts and further deepens their understanding and makes similar connections in their instruction.

**Utilize high-leverage teaching practices**. Supporting and guiding mentor teachers in employing high-leverage teaching practices, such as explicit instruction, collaborative and inclusive learning, and constructive feedback, is critical in promoting CS learning. By incorporating these practices, mentor teachers can help preservice teachers acquire essential pedagogical knowledge and teaching strategies for their classroom teaching.

**Provide ongoing support through grants and partnership resources.** Successful teacher induction needs ongoing support. Offering customized professional development opportunities allows teachers to deepen their knowledge and skills in CSEd. See Appendix A for a list of organizations that support CS integration in teacher education. External funding opportunities can also yield access to resources for teachers to support the integration and innovation of CSEd in teaching practices. Some funding opportunities to provide resources include CSforAll Research-Practitioner Partnerships, Noyce Scholarships for teacher development, and Research Experiences for Teachers. External course providers and industry partners (e.g., Microsoft TEALS pairs industry professionals with teachers to co-teach CS) may also be beneficial resources. Some examples of these partnership frameworks include:

- CS Visions Framework for Research-Practice Partnerships
- National Network of Education Research-Practitioner Partnerships (NNERPP)
- P-12 School-University Co-Constructed Partnerships Framework
- Activity Theory for K-12 School-University Partnerships
- CSTA CSEd for administrators' guide

**Supporting Students from Underrepresented Groups**

As we work toward CSEd in teacher preparation programs, we want to ensure that we are closing representation gaps and diversifying CS. Currently, learners who are women, people of color, from rural areas, and from lower-income families are underrepresented in CS. Supporting underrepresented groups can come in a variety of forms including:

- Learning about the experiences and additional barriers students from underrepresented groups face in CSEd
- Teaching and supporting students to advocate for themselves
- Developing the capacity of institutions to listen to and respond to student, community, and educators and their advocacy
- Considering goals that reflect students' and educators' values and their communities (not

just those of employers and professional programmers)

One good starting point for district leaders, principals, and teachers is the CS equity guide from CSforCA. This guide integrates resources and suggestions to help education leaders bring equitable CS into their schools. Another good starting point for teachers and institutions is CUNY's CITE framework. This framework aims to support faculty and teachers in applying equity-minded perspectives and developing more expansive computing education opportunities for teachers and ultimately, their students. Table 1 summarizes the core principles of CUNY's CITE Framework that focus on supporting teachers to learn and teach about, with, through, and against technology.

**Table 1. Overview of CUNY's CITE Framework principles to equip teacher candidates to teach and learn about, with, through, and against technology.**

| | **About** | **With** | **Through** | **Against** |
|---|---|---|---|---|
| **To support teachers' learning** | Teachers engage in conversations about technology, digital citizenship, and its impacts (from a user and teacher perspective | Teachers learn with technology to help them explore concepts for themselves | Teachers express themselves and their learning through their creation and modifications of computational artifacts | Teachers think critically about technologies to disavow, discontinue, and dismantle unjust tech that shapes education, their own lives, and lives of students |
| **To support teachers' pedagogy** | Teachers strategically bring these conversations to their students | Teachers teach with technology to support student learning and participation | Teachers prompt their students to express themselves through creation and modification of computational artifacts | Teachers strategically bring these conversations to their students |

Several other resources can be found in more specific areas pertaining to accessibility, culturally

relevant and sustaining pedagogies, translanguaging pedagogy, and critical or justice-centered computing. A few of these are described in the next sections.

***Accessibility***

To improve accessibility, incorporating tenants from The Universal Design for Learning framework is central to CSEd (Universal Design for Learning). For example, the UDL4CS provides several resources for teachers and institutions to meaningfully include students with disabilities in CSEd. AccessCSforAll also works to increase participation in CS for students with disabilities. Such work emphasizes the importance of leveraging assistive technology for students when teaching CS and vetting tools for students' abilities, cultural and linguistic experiences, and bias and stereotyping in representation.

***Culturally Relevant and Sustaining Pedagogies***

Culturally relevant and sustaining pedagogies mean connecting learning to students' prior experiences. Several resources exist for integrating and developing culturally relevant and sustaining pedagogies alongside CSEd, such as (a) NYS Culturally Relevant / Sustaining Education Framework, (b) NYC DOE CSforAll Equity page, (c) Intersecting equity lenses and projects (compiled by STEM Teaching Tools for Science teaching and learning).

***Critical and Justice-Centered Computing***

Critical and justice-centered approaches in CSEd aim to address societal systems that create inequities and use CS as a channel for engaging with the world's political, moral, and ethical challenges. Such approaches also foreground equity in decision-making about CSEd to consider equity in who, how, what, and why CS is taught (Santo et al., 2019). For additional information, the Kapor Center's Culturally Responsive-Sustaining CS Education Framework discusses six tenants for supporting underrepresented students and the Critically Conscious Computing:

Methods for Secondary Education textbook provides free and ever-evolving information about critical computing.

***Translanguaging pedagogy***

Translanguaging pedagogy offers several ways to develop more expansive CSEd by drawing value from learners' diverse linguistic backgrounds and language practices when teaching CS. Several resources exist to integrate translanguaging pedagogy alongside computer science education. These include (a) The City University of New York – NYS Initiative on Emergent Bilinguals (CUNY-NYSIEB) project, (b) The Translanguaging Classroom and (c) Participating in Literacies and Computer Science (PiLa-CS).

## Conclusion

A growing number of students, parents, educators, and administrators are beginning to view CS as a fundamental literacy, such as health literacy or financial literacy. In literacy, people must learn how to consume information or products and apply them to their lives. Computational literacy is the same, allowing people to intelligently consume technological solutions and create their own solutions. In fact, many people already use programming, AI, or data science to solve problems in their lives without realizing it, whether it is using formulas in Excel, interacting with an assistant like Siri, Alexa, or Google Assistant, or using public databases to track cases of coronavirus in your community. Applying a wide range of approaches to CSEd, such as those included in this report, will support the diversity of computational literacies, knowledge, and skills needed to participate in a technology-driven society.

In addition to a diversity of paradigms, teacher preparation programs should also consider a diversity of pathways to developing teachers' CS knowledge and skills. Colleges of education use a multitude of approaches from short courses to full courses, week- or weekend-long

intensive professional development, self-paced online courses, and professional learning communities. This instruction should start with accessible activities related to learners' prior knowledge and skills before focusing on CS disciplinary content.

Perhaps the most effective aspect of successful CS professional development is that learners receive ongoing instruction and support. Because CS represents a major shift in process (i.e., towards automating information processing), people need time to discover how the tools can apply to their lives across different tasks. When they have identified applications in their lives, they can more readily internalize their knowledge and skills. The goal of CS professional development is not that faculty, teachers, or students can independently solve problems with CS overnight, or even over a year. Instead, the goal is that they recognize opportunities to solve problems with CS and work towards developing the knowledge and skills to create those solutions iteratively and over time.

To serve this goal, we encourage colleges of education to think of CSEd as a pivot in tools rather than a standalone initiative to pursue. While CS can also be treated as a standalone discipline, we hope that all colleges of education eventually consider CS a fundamental literacy taught in all teacher preparation programs as a tool to solve problems across disciplines. As such, CS advocates and college administrators should collaborate with education faculty to identify specific issues in teacher preparation programs that can be resolved through CS integration. Perhaps there is a concept that teachers struggle to explain that a computer simulation or visualization could address. Perhaps teachers are looking for a new activity to increase engagement or support projects in the classroom, and CS would be an effective tool. Ultimately, CS is a set of powerful tools for solving problems, increasing efficiency, and offloading tedious tasks. We recommend colleges of education consider leveraging these tools across their

programs. It is hoped that the resources and recommendations described here can be of use to those developing and considering adding CSEd to their teacher education programs.

## Acknowledgment

This material is based upon work supported by the National Science Foundation under grant #2016010. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

## Appendix A: Organizations That Support CS Teacher Education

- Computer Science Teachers Association (CSTA) - A large organization for CS teachers, non-CS teachers using CS tools, and those who support their efforts, which also has many area- or state-based chapters. They set the most widely accepted standards for CS teachers and several resources for those involved in teacher development.

- CSforAll - A central resource for educators and researchers looking to advance CSEd. They have a repository of curriculum providers, and resources focused on supporting CSEd in colleges of education.

- Expanding Computing Education Pathways (ECEP) - An alliance of stakeholders from various states committed to increasing access to CS education. Many of their resources include strategies for making change and landscape reports to better understand policy and strategies within your state and get ideas from other states.

- Kapor Center - An organization for advancing CS and STEM education for students of color. Many of their publications focus on culturally relevant and sustaining pedagogy in CSEd and addressing inequities.

- The National Center for Women & Information Technology (NCWIT) - An organization for advancing women in CSEd. They provide several programs at the K-12 and Higher Education level for women in technology.

- International Society for Technology in Education (ISTE) - An organization for supporting the use of technology in education that is likely familiar to many colleges of education already. Recently, they have added computational thinking to their scope, including standards for Computational Thinking Competencies.

- ACM Special Interest Group on CSEd (SIGCSE) - A large professional organization for practitioners and researchers of CSEd. Perhaps the most useful resource from SIGCSE is the Technical Symposium--a conference of over 1000 people focused on teaching and researching CSEd.