The Future of Problem Solving with Data and Intelligence

Increasing Artificial Intelligence and Data Science Education Across the US

CSforALL

Catherine Born
Leigh Ann DeLyser

About CSforALL

CSforALL is the national hub of the computer science for all movement, with a mission to make high-quality computer science an integral part of K–12 education in the United States. Our work spans national and local levels to provide equitable and accessible K–12 computer science education to every student. We engage with diverse stakeholders leading computer science initiatives across the nation to support and facilitate implementation of rigorous, inclusive, sustainable computer science. For more information, see www.csforall.org or follow us on Twitter: @CSforALL.

Acknowledgements

We would like to thank those who have made this project possible.

Funding for this project was provided by the National Science Foundation through grant #2135878. 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 NSF.

A big thank you to the speakers at the June meetings, including Justin Lynch at the Office of Science and Technology Policy, Dr. Emmanuel Schanzer, Dr. Trena Wilkerson, Latoya Boland, Ishmael Robinson, Chike Aguh, Kristen Titus, Dr. Jose-Marie Griffiths, Joshua Elder, Dr. Sagar Samtani, Claire Perkins, Willa Potosnak, and Matthew Fan.

We are grateful to the June 29-30 meeting attendees for contributing their time and knowledge to a fruitful and productive discussion. The names of the workshop participants are listed in Appendix A of this report.

Another heartfelt thank you to the working group members who continued to meet, supported the work throughout the summer, and contributed a brief on topical areas within the purview of AI and DS education.

We dedicate this project to computer science, data science, and artificial intelligence educators and the education pioneers who had the forethought to introduce AI and DS to their students, working for years to build high quality CS education, and giving us something to build on.

Without your contributions, this report would not have been possible!

Suggested Citation

DeLyser, RL. & Born, C. (2021). The *Future of Problem Solving with Data and Intelligence: Increasing Artificial Intelligence and Data Science Education Across the US*. New York, NY: CSforALL.

Contents

"Increasingly at the core of innovation, scientific advancement, economic development, and a higher quality of living; artificial intelligence (AI) and data science (DS) are critical components of the continued growth of the United States. As AI and DS become ubiquitous, influencing every aspect of our lives, it is imperative that all Americans have access to the tools and knowledge that will shape our world. Expanding access to high quality artificial intelligence and data science education and keeping inclusion at the heart of our efforts will allow all children to thrive regardless of gender, race, geography, and neurology. To meet this goal, government and education must plan strategically, collaborating with the private and nonprofit sectors to ensure that high quality pathways are available to all students, especially those currently underrepresented in the industry."

Project Description

The Artificial Intelligence and Data Science Education Leadership meeting was held virtually on June 29-30, 2021 in service of three distinct goals: (1) to create clarity around the CS education movement and mechanisms for equitable change resulting in broadening participation in CS, AI, and DS pathways, (2) to review current movement goals and national CS standards to update guidance, and (3) to define movement trajectories and clear next steps that align with promising practices for equity and broadening participation in AI and DS pathways. The June 2021 meetings convened a diverse set of stakeholders, including industry leaders, K-12 CS education leaders, and postsecondary leaders as well as policymakers at the state and national levels.

This coordinated community of AI and DS leaders discussed ways to improve trajectories of students in the U.S. education system with an outcome of (1) better preparation of all students to live in a digital world where AI and DS significantly impact everyday life, (2) strengthen pathways for computing professionals with appropriate preparation to use AI and DS in their careers, (3) excite the next generation of AI and DS researchers to contribute to the landscape of technology in the world, and (4) broaden the participation of women, Black, Hispanic, Indigenous, and other underrepresented populations in the educational pathways that result in the outcomes listed.

During the meeting, stakeholders addressed key topical areas in AI and DS education, including diversity, equity, and access, teacher professional development (PD), digital citizenship, tools and resources, awareness of pathways, and building capacity at postsecondary institutions. Subsequent summer working group discussions honed in on the areas of diversity, equity and access, teacher PD, multi-stakeholder alignment, digital citizenship, and capacity building.

This report is the product of those conversations in the summer of 2021 and seeks to answer critical questions, describe challenges, and propose solutions in implementing AI and DS education in schools across the U.S. and outlines several ways to increase enrollment in undergraduate CS programs by 2028.

The June meeting and the subsequent working group discussions are intended to be a series of conversations that will take place now and into the future as a starting point for action. After publicly disseminating the report and materials from these conversations, CSforALL will host a community call with potential for ongoing work on this project.

This material is based upon work supported by the National Science Foundation (NSF) under Grant No. 2135878. 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 NSF.

CSforALL

Five years have passed since the national call for Computer Science for All was made at the highest levels. Building on early work by educators, researchers, school leaders, and communities, learners across the U.S. have been introduced to algorithmic thinking, coding, application development, web design, and other fundamentals of computer science (CS). Although universal implementation has a long way to go (Code.org, 2020), the momentum of the movement is undeniable, and enrollments at the postsecondary level in computing related degrees has been steadily increasing.

At the same time, the world has continued to evolve, creating a technological landscape where artificial intelligence (AI) and data science (DS) are not only careers in need of professionals with specialized knowledge, but also fundamental components of the technological platforms we increasingly rely on for many aspects of our lives. AI now selects resumes from candidate pools, makes choices about the news we see on and off social media, and increasingly interactive data is being used to communicate everything from our health in medical portals to statistics about our favorite players or foods. Recognizing and understanding how AI and data impact our lives is a critical literacy for our global technology and data-driven world.

Despite the surge in AI and DS in our lives, it still remains absent even from undergraduate programs in CS, except as an upper-course elective in many places. Additionally, AI and DS are often seen as interesting contexts for which to apply fundamental K-12 CS, instead of core competencies to be covered in their own right. Lack of universal inclusion of AI and DS in our educational pathways has contributed to the shortage of professionals ready to apply these skills.

In the Summer of 2021 CSforALL, with support from the National Science Foundation, convened a meeting of leaders, educators, researchers, and policymakers to discuss AI and DS education from primary through graduate school. At this meeting, we presented a challenge to the community: **What would it take to double the number of undergraduates pursuing computational-related degrees and to increase the percentages of those degree programs providing fundamentals in AI and DS to all learners?**

Central to achieving this goal is to ensure we are not limiting options for students in K-12 to experience fundamental CS education including AI and DS education. Attendees considered the current landscape of efforts, access, and participation gaps by historically marginalized youth and young women, as well as challenges and successes they have observed in their own settings, to come up with key recommendations for policymakers and implementers to achieve the goal. In this report we share details from seven working groups including a definition of each area of focus, area-specific recommendations from the experts, anda high-level synthesis of all recommendations here.

Executive Summary

We encourage policymakers, advocates, education leaders, and community members to consider how to ensure CS education is available for all learners in their community, how to best help learners and families understand choices for postsecondary education and careers, and how to ensure capacity for and instruction in AI and DS are a critical component of those academic pathways. We need to ensure our education systems not only provide equitable experiences for students no matter their race, gender, ethnicity, or ZIP code, but also that those experiences are on par with educational pathways from Mumbai, Beijing, Berlin, Copenhagen, and other places who are ensuring CS with AI and DS is a part of student's' preparation for college and career.

Recommendations to support Artificial Intelligence and Data Science Education

Build a clear understanding of implementation success and gaps through **data and landscaping**.	Support **infrastructure development** that brings technological access and capable devices to rural and disadvantaged communities to close the digital divide.
Support the development or identification of **high quality instructional materials and tools** for instruction and practice.	Create guidance for **primary through graduate school pathways** including both fundamental big ideas and subject specific learning.
Invest in **updates to career awareness resources**, focusing on role based competencies instead of industry based activities.	Support continued teacher and faculty development to **ensure instructional capacity at all institutions**.
Create **local guidance** for educational pathways and the local industries and roles available to pathway completers.	Ensure **industry and other stakeholders are engaged** in all aspects of the process — at the table, a part of pathways, and a critical contributor to capacity building efforts.

CSforALL

1
Recommendations

Diversity, Equity, Access

1 Enhance data and reporting on implementation and diversity in AI and DS education:

Having concrete data and information about the integration of AI and DS into existing curricula, including curricula in subjects outside of science, technology, engineering, and mathematics (STEM), as well as reporting on diversity in AI and DS pathways will allow policymakers to measure progress and outcomes related to implementing AI and DS education in schools.

- In the high school math and science data reporting from the U.S. Department of Education (DOE) Civil Rights Data Collection, disaggregate statistics and data science-based mathematics courses from the larger category of advanced mathematics.

- Include CS and types of CS* in the U.S. Department of Education Civil Rights Data Collection and initiate a U.S. DOE transcript study to understand the national landscape of CS, AI, and DS fundamental learning in K-12.

- Resource landscape reports through the NSF to understand how postsecondary programs integrate artificial intelligence and data science into degree programs outside of CS, including business and other related subjects."

2 Expand educational infrastructure:

- Allocate funding and federal support towards capacity building among educators through the provision of PD and training programs. Furthermore, consider support for a national AI teaching corps, which could provide incentives for teachers at low-income schools to build their knowledge and ability to deliver AI education.

- Create infrastructure through funding for both physical systems and capacity building in local leaders to make it possible for civil society organizations and other actors to build on local or regional success to national scale.

- Mirror and build on the NSF-funded CyberCorps for Service model to create an AI Tech Corps which would provide students with scholarships-for-service pathways to pursue AI education and apply it in federal, state, or local government positions as well as faculty positions after their postsecondary education.

3 Develop materials for instruction and practice that inspires students to pursue AI and DS pathways:

- Support local, regional, and national efforts through the NSF, Institute for Education Sciences, and Department of Defense (U.S. DOD) STEM education programs to develop and pilot curricula, especially those designed to be accessible and inclusive. This includes curricula developed by civil society organizations, school districts, and academia.

- Promote the use of low-tech examples and activities that can be layered into coursework, as well as the use of social justice examples as it pertains to AI and DS to connect technology education with topics that Gen Z finds engaging.

- Use career exploration as a hook to engage and inspire students to think about the role of AI, CS, and DS in their futures, including those who do not intend to pursue STEM degrees, potentially featuring how government uses these tools and the problems they are able to solve.

Teacher Preparation

State Policy Recommendations

In order to support teacher preparation, we recommend the following actions at the state and local levels:

1 Incorporate AI and DS into other subjects:

There are multiple ways to incorporate fundamental concepts and applications of AI and DS into curricula.

- Resource and require state departments of education to collaborate with community stakeholders to determine where in the school day AI and DS best fit and how curricula could be adjusted to accommodate AI and DS offerings for all students. This step could include creating a state-level committee or discovery task force to explore this integration, including opportunities for PD for all teachers, which provides connections to other subjects in science, social studies, etc.

2 Revise teaching credential requirements for pre-service and in-service teachers:

- States should explore options to include AI and DS in the required teaching credentials. Given existing variation, this could be included in either a math or a CS credential depending on local capacity and policies. This will give maximum flexibility for implementation, which will accelerate rather than hinder AI and DS education. Credentials may be part of a pre-service program, or they may be done later, with a long-term goal to develop comprehensive pre-service programs through partnerships with local postsecondary institutions to ensure teachers are prepared prior to entering the classroom. This may be done comprehensively through revising the undergraduate curriculum to include AI and DS topics within general courses and offering introductory CS coursework including AI and DS for pre-service teachers.

- States should consider adding CS to teacher credentialing requirements and specify the inclusion of AI and DS in CS teacher preparation. Computer science should also be added as a designated high-need area, if appropriate for an individual state.

- When possible, localities should support cross-disciplinary connections between subjects. For example, credentialing or certificates that extend current credentials could allow either math, science, or business educators to teach these topics in their classrooms.

3 Support teachers who pursue credentialing in CS, AI, and DS:

- States should create dedicated scholarships, reimbursements for training, or other financial assistance to further incentivize ongoing and advanced teacher development including professional development or graduate classes.

- States should incentivize credentialing which goes beyond reimbursing the cost of PD (e.g., loan forgiveness, stipends, associated graduate programs like STEM or math education) will help increase the number of qualified teachers in CS, including AI, and DS.

- Sustained PD support is necessary and must include use of computational software and hardware related to AI and DS, as well as IT support and infrastructure. For example, teachers may have questions during the school

year that follow a summer course. According to local contexts, this should be accounted for in budgeting for PD, by developing contracts with service providers, and evaluating offerings from PD partner organizations.

Federal Policy Recommendations

- The federal government should consider adding "data science" as a Graduate Assistance in Area of National Need (GAANN) topic, which already includes AI and other high-need subjects.

- The federal government should pass legislation requiring teacher preparation programs to include AI and DS-related instruction or coursework for any academic subject teachers who are required to teach AI and DS as a part of their license. For example, every elementary school teacher in states with required CS standards should be required to take coursework covering those standards.

- The federal government should consider increasing and/or dedicating targeted funding within existing grants programs that serve state and local education agencies in providing AI and DS professional development, including Teacher Quality Partnerships or SEED programs.

- The federal government should consider stipulating that NSF-funded national science centers include dedicated funding and activities for teacher PD through direct training or other community partnerships. Institutes, including the recently funded AI and DS institutes should include and report on educator training

conducted as a part of grant or BPC efforts. The EHR division should also work more closely with CISE, MPS, and others for sponsoring joint opportunities for educator development.

- The federal government should consider making PD funds under the Elementary and Secondary Education Act include eligibility for additional wrap-around services in addition to contract-based services, including funds for planning, training for administrators, instructional coaches, and counselors, stakeholder engagement, and outreach to community partners, as a part of holistic PD.

- The federal government should set aside additional funding to address national teacher shortages in STEM education, including for areas of national need like AI and DS.

- The federal government should create significant awareness and public relations efforts in support of these goals, including senior official tours to teacher training programs, and/or districts or schools that are undertaking innovative approaches to incentivize more teachers to train in these areas.

Tools and Resources

Little focus is given to pedagogical tools and resources, even though it is a crucial aspect of AI and DS education. Research, development, and funding must be secured for identified gaps in the areas of infrastructure access, materials for instruction and practice, software, hardware, and other technology for instruction, as well as tools for demonstrating success. Attendees encourage the community to:

1 Provide funding for infrastructure access: Students, teachers, and schools must have adequate access to infrastructure and devices, which is a prerequisite to effective instruction in computing and data. Funding must be provided for the expansion of 5G to universal access, including in both geographic terms (e.g. rural areas) and cost terms (e.g. low-income or otherwise disadvantaged students). While the Biden Administration has recently taken measures to expand high-speed internet infrastructure, it is crucial that sufficient bandwidth is provided to schools and community centers and that students and teachers have sufficient bandwidth for at-home use. Devices, such as tablets or desktop computers, are necessary for students and educators to enable serious academic work. Phone access is likely insufficient. Lastly, funding must be allocated to expand school budgets for technology, textbooks, and space on the Cloud. Policymakers can do this specifically by:

- Ensuring infrastructure funds reach rural and remote communities and create technical assistance for low resourced districts to create high-quality grant applications.

- Define a minimum bar for regional access to high-speed internet, and measure and report progress on a ZIP code-basis for meeting that standard.

- Include measures of access in the U.S. DOE Civil Rights Data Collection, and include indicators in the Educational Equity Report and school and district-level data views.

2 Incentivize the development of materials for instruction and practice:
Only around 30% of the intended CS curricula in the U.S. includes AI (Falkner et al., 2019, p.7). More resources need to be developed for instruction in AI and DS. Educators need access to instructional materials and pedagogical tools with exercises and demonstration examples that enable younger students to experience AI and DS, building intuition at early ages and learning age-appropriate core fundamentals. Creating avenues for educator-generated content to be highlighted and awarded through programs like the Presidential STEM teacher awards would allow teachers to contribute to the materials and curricula available in the AI education landscape.

Fund tools for demonstrating success by incentivizing the development and research of classroom assessment tools in emerging computer-based education, including AI, DS, and additional topics including quantum and cybersecurity.

Credentials in these emerging fields must also be created, including career and technical education (CTE), certificate programs, apprenticeships, OSTCP programming, and other career pathway programs.

Equally crucial is supporting research that produces evidence for additional classroom materials, especially in K-5 and 6-8, for AI and DS instruction, and supporting the integration of AI and DS into other K-12 subjects and disciplines. Building awareness among stakeholders of available resources is also important.

Students that are eager to pursue AI and DS in their free time also need access to extracurricular engagement opportunities, including summer programming, and other enrichment activities, such as robotics, data hack-a-thons, Bootcamps, etc.

A lack of viable data for educational purposes underscores the need for shared data sets and robust case studies for education and research. Stakeholders must collaborate to make data publicly available, shareable, and discoverable, creating a base of common knowledge for their colleagues to build upon and collaborate on.

Policymakers can address these problems specifically by:

- Implementing awards programs like the Presidential Awards for Mathematics and Science or the White House Champions of Change to recognize teachers and faculty producing high-quality materials and engaging students.

- Resource federal agencies like NASA and the U.S. DOD STEM programs to create or build upon repositories in order to collect resources for teachers. All repositories should have APIs to allow resources to be easily searched and retrieved by other providers.

- Create opportunities for teacher and faculty positions in the summer months to create and share lessons using data from Data.gov

3 Resource the development of software, hardware, and other technology for instruction: Students, including students with disabilities and other learning differences, should learn about a variety of software packages and tools, moving towards exposure or practice in real-world tools by high school graduation. To allow this progression, policymakers should incentivize the community to build age-appropriate software progressions throughout K-12, surface the AI and DS concepts in the Association for Computing Machinery (ACM) Computing Curriculum 2020 recommendations, and encourage the development and funds for pedagogical devices for implementing AI in classrooms, such as AI-powered robots, accessible to children and educators.

So educators may confidently teach the curricula and use the tools, PD opportunities must be aligned with the development of new tools and curricula.

Policymakers can address these challenges specifically by:

- Asking the NSF to include bullet points in solicitations and release Dear Colleague letters to point potential curriculum developers and instructor professional learning to grants appropriate for this work.

- State policymakers can continue to fund teacher PD and incentivize ongoing teacher learning, beyond CS basics, to allow teachers to deepen their knowledge and explore topics such as AI and DS.

Fundamental Artificial Intelligence and Data Science Education

In order to promote ubiquitous and fundamental AI and DS education, we must:

- Evaluate existing definitions for AI and DS within K-12 contexts. The National Academies should convene a working group to produce a series of publications on AI and DS education similar to the series produced for computational thinking.

- The U.S. DOE should highlight AI and DS in its STEM initiatives and hold webinars or other convenings with subject-matter experts to inform state departments of education about AI and DS education.

- The NSF and U.S. DOE should support workshops with faculty from various universities to review the new ACM Computing Curriculum recommendations and ensure AI and DS are a part of all CS programs. Faculty from other disciplines should be invited to the meeting, or convened in a separate workshop, to consider the integration of AI and DS in other domains.

We encourage all stakeholders to work together to:

- Participate in National Academies working groups to clarify and bridge definitions for fundamental AI and DS education and its relationship to digital citizenship or digital literacy standards that currently exist. Stakeholders should work together to come up with a working definition that builds upon previous frameworks and definitions.

- State leaders should partner with educators and experts to look at existing standards to see where AI and DS could fit, such as the International Society of Technology in Education (ISTE), Common Core, American Library Association (ALA), National Curriculum Standards for Social Studies (NCSS), and Next Generation Science Standards (NGSS) and produce recommendation reports for state departments of education about the gaps between current curriculum and desired outcomes.

- The NSF should showcase current projects and release a Dear Colleague letter highlighting available grant opportunities, connecting learners to existing AI and DS programs and curricula offerings at all levels.

- The NSF should encourage university BPC plans to include educator professional learning and collaboration with faculty, teachers, and curriculum designers of core academic subjects to design approaches to embed AI and DS and other emerging technologies into their current instruction.

Awareness of Pathways through Graduate School

In order to increase participation in pathways, especially among Black, Hispanic, and Indigenous youth:

- The U.S. Department of Labor (U.S. DOL) should update the O*NET Career Listings and associated support materials and assessments to recognize the growing influence of computational skills needed by most degrees and specific pathways for AI and DS specialists. We strongly recommend that the "Ability Profiler" be renamed to align with appropriate growth mindset language, potentially "Preparation Strength Profiler" or "Academic Preparation Profiler".

- The U.S. DOL in partnership with the U.S. Patent and Trademark Office should collaborate to connect USPTO profiles of inventors and educational pages with the careers featured on O*NET.

- The U.S. DOL, U.S. DOE, and Office of Science and Technology Policy should convene a working group including the ACM Education Board and Advisory Committee and Computing Research Association (CRA) to identify opportunities to landscape undergraduate programs and identify existing guidance for implementation of AI and DS education. The working group should release a report clearly articulating the gap between community goals to increase AI and DS education at the undergraduate level, ACM recommendations, and current implementation.

- The U.S DOL and U.S. DOE should collaborate to produce workshops or other PD for postsecondary advisors and career counselors to disseminate information about existing CS programs and appropriate undergraduate preparation. This must include staff and faculty at community colleges.

- The U.S. DOE should release clear guidance to the states to use Perkins or other federal funds for education or career preparation to provide (1) professional learning for middle school educators and counselors, (2) opportunities to upskill computer science and other STEM educators to integrate AI and DS into existing coursework, and (3) high school guidance and college counselors with professional learning and student and parent-facing materials to clarify appropriate pathways for students.

- The U.S DOL and U.S. DOE should partner with the Afterschool Alliance to share professional learning opportunities with out-of-school-time educators and mentors to ensure families and students in under-resourced schools can have access to this information through alternative means.

Capacity at Postsecondary Institutions

In order to increase institutional capacity for providing high-quality CS, AI, and DS education, the community recommends:

- Identify the clear areas and institutions where capacity building is difficult. The U.S. DOE should convene a working group, in partnership with ACM and Computing Research Association (CRA) and funded by the NSF, to develop an assessment of institutional capacity for computational degrees and the ability of the institution to offer AI and DS concepts within the degree programs.

- The NSF or U.S. DOE should provide support through workshops or other venues for non-R1 institutions to collaborate, identify challenges, and share resources for capacity building.

- Create incentives through the U.S. DOL or other federal agencies for employees who do reverse sabbaticals at institutions where faculty are needed. As many of these institutions are not in major cities, incentives are needed. For example, consider tax credits or other incentives to either the individuals or employers who complete a semester at colleges or universities with need.

- The U.S. DOL should explore how to connect universities with corporate social responsibility departments in order to discuss ways to leverage employees to guest lecture or provide adjunct capacity through remote teaching for colleges and universities not in major urban centers.

Multi-stakeholder Alignment

Recommendations

Public policy recommendations with supportive grant funding from significant federal resources provide the best possible opportunity to communicate the priority of data science and AI education for our nation. The following two domains capture the greatest opportunity for innovative and collaborative solutions to scale quickly:

Preparation: Curriculum innovation is needed to address the challenge. Not enough students have access to relevant coursework and most institutions can not independently justify the expense for curriculum development to address this need (or may not know how). Ensuring equitable access to relevant coursework (required for all vs. elective), will increase awareness and engagement of underrepresented groups. Key intervention points include:

- **Foundational Concepts:** The NSF and U.S. DOE should encourage undergraduate institutions to use BPC plans or grants to create program structures including foundational concepts and examples of artificial intelligence and data science in required coursework.

- Industry engagement: Incentivize Industry to provide release time to their staff to partner with universities on the development and delivery of new coursework that can be revised annually to keep up with the accelerating rate of digital disruption across our key industries.

Pathways: Developing pathways into, pathways out of, and alternative pathways to higher education will be critical for increasing the quantity of graduates with technical skill sets and foundational acumen in these areas. Respectively, these pathways include the areas of PK-12, higher education career services, and career & technical education, including apprenticeships. Key intervention points include:

- **State-level task forces are needed in all 50 states to align exit and entrance requirements.** In many cases, K-12 state standards and graduation requirements do not align to higher education admissions requirements, and often over-index on outdated or hand-written procedural competencies, especially in mathematics. Admissions requirements can also crowd-out

more modern content in data science or AI in K-12. Institutes of Higher Education (IHEs) should work to ensure high school courses in DS, AI, and CS are recognized in admissions eligibility, and K-12 state and local stakeholders should work collaboratively with higher education to develop modernized graduation outcomes. Federal agencies including the NSF and U.S. DOE should report on grantee or institutional alignment with recommended requirements and identify community progress needed to meet task force recommendations.

- **A national task force with funding to implement recommended solutions is needed to transform the career services function to deliver high-quality career counseling on a national basis.** The career services function in higher education is the nexus of industry and academia and is at best, under-funded, unevenly delivered, and in need of innovation specific to the tech industry. This should begin with a national study on the current state of the career services functions at different types of institutions: higher education, high school, and employment centers. This study should include best practices in general and, specifically, an understanding of what is needed in computer-related fields. Industry engagement is critical to reflect the value proposition for diversifying the tech workforce and overcoming the barriers they perceive as a deficiency in the current K-12 and higher education system which discourages those who are historically underrepresented in tech from pursuing high-demand, high-paying career pathways that are in desperate need of their perspective to create future technological solutions.

- **Incentives for catalyzing innovation in Career & Technical Education, including Apprenticeships:** Existing Career & Technical Education (CTE) programs are a potentially high-leverage way to encourage students, starting in high school or earlier, to pursue careers in technical areas in high demand locally and nationally for lower cost than traditional four-year higher education. However, many state CTE programs are misaligned to in-demand careers, and have yet to develop strong support for careers in software development, data analytics, or AI. Many practitioners in these areas can often self-progress in software or coding languages beyond their training programs through job experience, making traditional graduate education less necessary. Specific mechanisms can include National Activities funding authorized under the Perkins Act.

2
Introduction

In our technology-driven world, incorporating computational thinking and computer science concepts into student learning has become increasingly important. Schools and districts across the country are taking note, and stakeholders including teachers, school administrators, industry leaders, universities, and policymakers are finding ways to implement computer science education in schools. While the movement is gaining momentum, only 45% of schools teach computer science at the high school level (Code.org, 2020).

2 Introduction

Computer science (CS) is a maturing discipline, and the notion of coding is only a basic skill. CS education needs to explore subtopics including artificial intelligence (AI) and data science (DS) into curricula in order to truly prepare citizens for this digital life. Over the past few decades, the fields of AI and DS have rapidly progressed, becoming ubiquitous and increasingly influencing every facet of our lives. AI has the potential to affect deep societal change, impacting our world for the better, driving humanity towards advancements in science, medicine, and education, while also creating economic opportunities and a better quality of life for many. There is no question that AI and DSwill have a lasting impact on our world in every domain. The importance of AI and DS education is predicated on several distinct imperatives - a global equity imperative as well as a moral and inclusion imperative.

A new era of global economic development requires rapid technological innovations in AI and DS. Human capacity in these fields allow countries to better innovate for the benefit of humanity. AI is also a key driver of economic growth and a foundation of the modern innovation economy. In fact, McKinsey estimates that AI has the potential to cumulatively increase global GDP by $13 trillion by 2030 (Bughin et al., 2019). Data has become a part of every industry, and employers are looking for these skills. Demand for a workforce with computing abilities has skyrocketed, while our education system is unable to fulfill this need for digital talent. In 2019, the U.S. saw more than 500,000 open computing jobs, while only around 71,000 students graduated with a CS bachelor's degree (Code.org, n.d.). Our current model of STEM education is not meeting the needs of today.

Developing AI talent has become a top priority across the globe. Countries are cultivating this talent by reforming their curricula to incorporate AI and investing in research. To that end, the U.K., Estonia, Argentina, and Singapore have introduced aspects of computing curricula to children as young as preschool (Pedro et al., 2019, p. 22). At the postsecondary level, France under President Macron has committed €1.5 billion to building more academia-industry collaborations and incentivizing partnerships between universities and AI research institutes (Campus France, 2018). Meanwhile, only around 30% of the intended CS curricula in the U.S. includes AI (Falkner et al., 2019, p.7). Students in the U.S. must have access to the same foundational preparation as those around the world. As a global guideline, ensuring U.S. institutions implement high-quality versions of the ACM CC2020 is an important step for global competitiveness of the U.S. postsecondary education system.

Furthermore, in order to build an equitable future for all of our children, we must create a more diverse and inclusive workforce of AI innovators, and instill a fundamental understanding of AI in all citizens. Giving the keys to innovation to everyone, regardless of race, social status, gender, neurology, and geography, will allow us to live up to our dreams of an equitable society where everyone has access to the systems that build wealth, allowing for job security and economic stability, and empowering our next generations with the knowledge and skills needed to succeed in the modern world. In addition to creating a better society, building a diverse workforce will turbocharge our economic engine and allow us to develop inclusive AI technologies that will make us smarter, healthier, and more efficient.

Given that AI and DS are the new frontier and the profound impact they will undoubtedly have on our economy, security, and our citizens' well-being, we must expand education at the K-12 and postsecondary levels to incorporate AI and DS. By teaching all of our students about these emerging fields and developing multiple pathways in them, we will better prepare our citizens for the modern world, create opportunities for all youth in the U.S., and give our children access to the same knowledge as children across the world. We have the responsibility to reform our systems, ensuring American education does not fall behind and providing the best opportunities for all youth in this nation.

According to NCES data, 58% of bachelor's degrees conferred in 2015 were awarded to women, compared with 42% awarded to men. However, in STEM fields, only 36% of bachelor's degrees were awarded to undergraduate women (NCES, 2019). In CS, the gender divide is even more pronounced. In 2015, only 18.7% of undergraduate women earned a bachelor's degree in CS (NCES, 2018), accounting for approximately 1.4% of the total number of women graduating with undergraduate degrees.

Modestly increasing the percentage of undergraduate women graduating with computer science degrees from 1.4% of all female graduates to 5% of all female graduates would increase the total number of CS graduates by 51%, from 79,598 to 120,488 computer science graduates (NCES, 2019).

Definitions

Computer Science (CS)
The study of computers and algorithmic processes, including their principles, their hardware and software designs, their implementation, and their impact on society (Tucker et al., 2006).

Artificial Intelligence (AI)
Artificial intelligence leverages computers and machines to mimic the problem-solving and decision-making capabilities of the human mind (IBM, June 2020).

Data Science (DS)
Data science combines the scientific method, math and statistics, specialized programming, advanced analytics, artificial intelligence, and even storytelling to uncover and explain ... insights buried in data (IBM, May 2020).

Our Vision

In order to address these imperatives, create opportunities for all, and support this vision of our future, we must:

Increase the number of students with computer and information science bachelor's degrees from 79,598 today (NCES, 2019) to 150,000 by 2028 and double the number of students receiving instruction in AI and DS within those degree programs. In particular, expand participation for students, including women as well as Black, Latinx, Indigenous, rural, first-generation, and low-income groups.

Supporting this primary goal, we challenge the community to:

- Ensure all current K-12 CS standards are met, including standards regarding algorithms and data, in order to inspire students to see AI in the world and feel confident to pursue further study.
- Encourage postsecondary graduates to either (1) work in a CS field in an AI-related position, or (2) apply AI in any STEM or other discipline they pursue,as well as creating opportunities for graduates to seek out continued learning opportunities.
- Create affordable opportunities for all students to pursue studies that include high-quality AI education.
- Prepare those who do not pursue postsecondary education to understand AI's fundamental principles and apply it to their careers.
- Create an ecosystem where private initiatives support the aforementioned goals.

Implementation

The AI and DS Education Leadership meeting was held virtually on June 29-30, 2021 and convened a diverse group of stakeholders, including industry leaders, K-12 CS education leaders, and postsecondary leaders, as well as policymakers at the state and national levels. In order to meet our goals, the meeting focused on:

1. **Creating clarity around the CS education movement**
2. **Identifying mechanisms for affecting equitable change**
3. **Define movement trajectories and clear next steps**

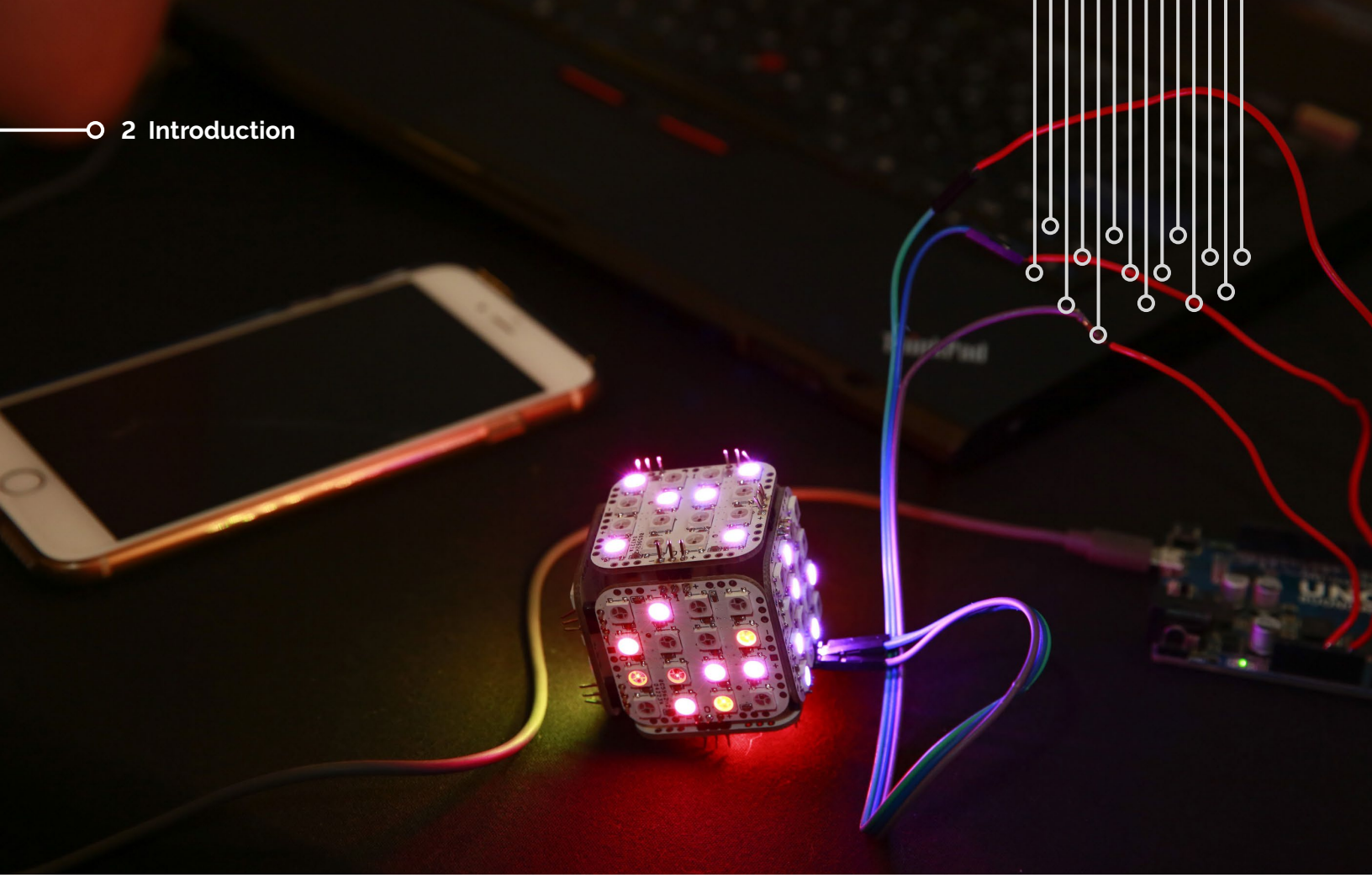
The two-day agenda included panel discussions and speakers, and breakout sessions:

Introduction with Dr. Leigh Ann DeLyser, Co-founder and Executive Director, CSforALL, and Justin Lynch, Office of Science and Technology Policy

A panel on Reforming our Math Systems with Dr. Emmanuel Schanzer, Program Director, Bootstrap; Director, CSPdWeek, Dr. Trena Wilkerson, President, National Council of Teachers of Mathematics, Latoya Boland, math educator, NYC Public Schools, and Ishmael Robinson, math teacher and administrator,

A session on Encouraging Innovation with Policy with Chike Aguh, Chief Innovation Officer, U.S. Department of Labor, and Kristen Titus, Executive Director, Cognizant U.S. Foundation,

Leveraging Individual Strengths and Collective Partnerships for Change with Dr. Jose-Marie Griffiths, President, Dakota State University;



Member, National Security Commission on Artificial Intelligence, and Joshua Elder, Director of Grants Management, Siegel Family Endowment,

A student panel with high school and university students from schools across the U.S.

During breakout sessions, meeting participants brainstormed priority topics related to the aforementioned goals. Participants identified the following key topical areas in AI and DS education: diversity, equity, and access; teacher professional development; digital citizenship; tools and resources; awareness of pathways; and building capacity at postsecondary institutions. Meeting attendees spent time during the subsequent breakout sessions first defining the topic areas, then outlining solutions.

After the June meetings concluded, we invited participants to continue the discussion in summer working groups, which honed in on diversity, equity, access; teacher PD; multi-stakeholder alignment; and digital citizenship.

This report is the product of those conversations in the Summer of 2021 and seeks to identify critical questions, describe challenges, and propose solutions in implementing AI and DS education in schools across the U.S.

3
Working Group Topics

Diversity, Equity, Access

Definition

The rapid expansion of AI and DS and their increasing ubiquity is having unprecedented industrial, economic, and social impacts. AI and DS are transforming our lives as well as the pathways to prosperous futures. In order to access opportunities in an AI and data-driven world, it is imperative that all young people, regardless of race, social status, gender, neurology and geography, gain a fundamental understanding of AI and DS, and how these fields will impact their lives. However, there is still a long way to go in achieving equity in AI and DS education and pathways. Equity in AI and DS pathways will require carefully implemented policy and must be considered at the heart of any policy recommendations that affect AI and DS education.

Since CS education has not yet reached every K-12 school in the U.S. (Code.org, 2020), it is likely that AI and DS education are also not universal. Additionally, while many postsecondary institutions may offer electives in AI and DS for their CS majors, few require rigorous study in AI and DS as a core component of their degree program. While there is a lack of robust data on AI and DS education demographics specifically, the data for CS education is telling. In 2019, only 5.52% of AP Computer Science test takers were Black while only 16% were Hispanic (College Board, 2021).

The trend continues at the postsecondary level, where only 18% of Bachelor's Degrees in Computer and Information Sciences were awarded to Black and Hispanic students in 2018 (NCES, October 2019).

National studies of K-12 CS education suggest that at the high school level, availability of courses significantly correlates to community wealth (Fletcher & Warner, 2021), leaving AI and DS education expected to exist in only a subset of those locations. Some out-of-school-time programs offer opportunities for students to explore AI and DS education such as the NSF-funded project between the American Museum of Natural History and MIT to include AI in the science student mentoring program run by the museum. While important, programs such as these cannot possibly serve all students in the community through after-school or informal settings. While fundamentals of AI are rooted in the Computer Science Teachers Association standards, and initiatives like AI4K12 have created more specific definitions, there is a lack of explicitness in state CS standards as to where and how AI and DS

NASA STEM

NASA STEM is an educational program run by the U.S. space agency, NASA, that offers learning and engagement opportunities for students and educators including career exploration, contests, internships and fellowships, as well as events and activities focused on space education.

should be taught. The larger community needs guidance for implementation to ensure the content reaches all students, and high-quality materials and examples that engage a broad diversity of students.

Those from historically marginalized communities are at the greatest risk of the negative impacts of bias in AI and irresponsible uses of data, further exacerbating the situation. A 2018 report from the National Institute of Standards and Technology (NIST) evaluating 189 software algorithms used by police departments and federal agencies to identify suspected criminals found that African American and Asian faces were 10 to 100 times more likely to be falsely identified than Causasian faces (NIST, 2019). Automated prediction and decision-making systems trained on non-representative or biased datasets are used to determine who gets accepted into colleges, who gets interviewed for jobs, who gets approved for loans, and who gets held in jail. They have been shown to be biased against people from historically marginalized groups, thereby limiting their access to education, information, and economic opportunity, and in some cases contributing to wrongful imprisonment. Students' interest in and their opportunities to participate in AI education may be limited by the existence of these biases. Thus, detecting and combating bias in AI, as well as developing fair, accountable, and trustworthy AI systems are paramount to equitable AI education.

Any national AI and DS education effort that seeks to advance economic and social equity must account for challenges facing broad-based

accessible and inclusive AI and DS education and address these barriers through concrete strategies, some of which are outlined below.

Challenges and Barriers

- **Fundamental artificial intelligence education:** Most Americans lack basic awareness about what AI is, and how it is already a part of their lives. To the extent they are encountering AI, it is often in the media and pop culture contexts, which often misrepresent reality in terms of what AI is and what its capabilities are. Stakeholders who are most at risk of bias in AI and algorithms are often unaware of the impact it has on their lives, as well as the challenges it will create as the economy continues its digital transformation. These stakeholders include students, who are making critical decisions about their future careers; businesses and institutions; local and state governments; and families and teachers who are in a position to mentor their students through career choices and digital citizenship.

- Raise awareness and knowledge of AI fundamentals among all stakeholders and students.

- **Need for capacity:** In many K-12 schools, community colleges, and universities, there is a lack of instructors with the foundational knowledge and high-quality curriculum to teach students about AI. In addition to instructional staff, institutional leaders such as administrators and education leaders are not prioritizing nor have the resources to engage in capacity building for AI education. Compounding the need for human and curricular capacity, institutions who serve the most marginalized youth often lack equitable access to high-speed internet and devices.

- **Curriculum and standards are in early phases:** The acceleration of CS education standards and curricula at the K-12 level is focused primarily on concepts often taught in introductory CS and emphasizes simple algorithms. Much of the curricula for AI or DS is implemented in small research projects, or through teacher-created materials. The need for teachers to locate, integrate, and perhaps even create their own materials serves to exacerbate economic and social disparities, as Black and Brown students are significantly less likely to attend K-12 schools or community colleges with CS teachers who have a background in AI or DS. It can be challenging for families to find opportunities when they do exist (Roshan et al., 2014), especially if they lack understanding of the difference between different types of CS topics.

CAPE: A Framework for Assessing Equity throughout the Computer Science Education Ecosystem (2021)

According to the Association for Computing Machinery, only 47% of U.S. high schools offered one or more CS courses as of 2020. In the same report, researchers found that access to CS coursework is highly correlated with affluence, and thus CS opportunities, such as advanced courses or multiple CS course options, is not equitably distributed (Fletcher & Warner, 2021).

Recommendations

1 Enhance data and reporting on implementation and diversity in AI and DS education:

Having concrete data and information about the integration of AI and DS into existing curricula, including curricula in subjects outside of STEM, as well as reporting on diversity in AI and DS pathways will allow policymakers to measure progress and outcomes related to implementing AI and DS education in schools.

- In the high school math and science data reporting from the U.S. Department of Education Civil Rights Data Collection, disaggregate statistics and data science-based mathematics courses from the larger category of advanced mathematics.

- Include CS and types of CS* in the U.S. Department of Education Civil Rights Data Collection and initiate a U.S. DOE transcript study to understand the national landscape of CS, AI, and DS fundamental learning in K-12.

- Resource landscape reports through the NSF to understand how postsecondary programs integrate AI and DS into degree programs, including business departments and other related subjects.

Types of Computer Science

NYC instituted a way to track the implementation of CS education in K-12 schools. Because CS is not only offered in stand-alone CS classrooms, but also integrated into disciplines like math, science, or elementary classes, the district needed a way to track more than just course codes in order to measure CS offerings. When courses and student registrations are entered in the district's data system, there is a check box for whether the course contains CS content. In addition, schedulers choose from a series of topics including robotics, web design, programming, and others to indicate what type of CS topics are covered. This has allowed the district and researchers to evaluate the types of CS that are taught and how schools are implementing CS across the landscape (Villavicencio et al., 2018).

2 Expand educational infrastructure:

- Allocate funding and federal support towards capacity building among educators through the provision of PD and training programs. Furthermore, consider support for a national AI teaching corps, which could provide incentives for teachers at low-income schools to build their knowledge and ability to deliver AI education.

- Create infrastructure through funding for both physical systems and capacity building in local leaders, making it possible for civil society organizations and other actors to build on local or regional success to national scale.

- Mirror and build on the NSF funded CyberCorps for Service model to create an AI Tech Corps which would provide students with scholarships-for-service pathways to pursue AI education and apply it in federal, state, or local government positions as well as faculty positions after their postsecondary education.

3 Develop materials for instruction and practice that inspires students to pursue AI and DS pathways:

- Support local, regional, and national efforts through the National Science Foundation, Institute for Education Sciences, and U.S. Department of Defense (U.S. DOD) STEM education programs to develop and pilot curricula, especially those designed to be accessible and inclusive. This includes curricula developed by civil society organizations in addition to school districts and academia.

- Promote the use of low-tech examples and activities that can be layered into coursework, as well as the use of social justice examples as it pertains to AI and DS so as to connect technology education with topics that Gen Z finds engaging.

- Use career exploration as a hook to engage and inspire students to think about the role of AI, CS and DS in their futures (including those who do not intend to pursue STEM degrees), potentially featuring how government uses these tools and the problems they are able to solve.

Teacher Preparedness

Definition

Students must be prepared for careers in new areas of science and technology, and also flourish in a world that is increasingly influenced by artificial intelligence (AI) and data science (DS). In order to accomplish this, we must empower educators through effective and ongoing professional development (PD). To develop approaches for bringing AI and DS into their classrooms, educators must be comfortable with the science and tools and acquire pedagogical expertise. Critical to the alignment of educator development is a clear understanding of what concepts and skills are valued, and therefore updated standards and frameworks are a key prerequisite to any major professional learning initiatives. In the area of AI and DS, PD can take a variety of forms:

- Asynchronous online learning or coursework
- Workshops & conferences
- Professional learning communities
- In-service & pre-service training
- Micro-credentials
- Continuing education

These forms of PD connect to existing curricula, nurture the relationship educators have with science and technology, and/or support professional learning communities. Notwithstanding its form, all good PD is collaborative, authentic, relevant to educators and their classroom, and includes continued support after initial training. Complementary to the professional learning itself, the community must consider the incentives or accountability for educators to update their knowledge and instruction.

This document does not seek to promote a preferred method of teacher preparation nor a particular pathway, but rather make policy recommendations on PD that will support the mission to increase the number of students with computing-related majors from 75,000 today to 150,000 by 2028. Subsequently, this will double the number of students receiving instruction in AI or DS within those degree programs.

More broadly, there is an added need beyond PD for teachers, and programs should include learning opportunities for school administrators, counselors, instructional coaches, and families. When defining PD in policy, adding considerations to ensure eligibility for a broader set of stakeholder involvement and learning may be critical for effective implementation.

Recommendations

State Policy Recommendations

In order to support teacher preparation, we recommend the following actions at the state and local levels:

1 Incorporate AI and DS into other subjects:

There are multiple ways to incorporate fundamental concepts and applications of AI and DS into curricula.

- Resource and require state departments of education to collaborate with community stakeholders to determine where in the school

day AI and DS best fit and how curricula could be adjusted to accommodate AI and DS offerings for all students. This step could include creating a state-level committee or discovery task force to explore this integration, including opportunities for PD for all teachers, which provides connections to other subjects in science, social studies, etc.

2 Revise teaching credential requirements for pre-service and in-service teachers:

- States should explore options to include DS and AI in the required teaching credentials. Given existing variation, this could be included in either a math or a CS credential depending on local capacity and policies. This will give maximum flexibility for implementation, which will accelerate rather than hinder DS and AI education. Credentials may be part of a pre-service program, or they may be done later, with a long-term goal to develop comprehensive pre-service programs through partnerships with local postsecondary institutions to ensure teachers are prepared prior to entering the classroom. This may be done comprehensively through revising the undergraduate curriculum to include AI and DS topics within general courses and offering introductory CS coursework including AI and DS for pre-service teachers.

- States should consider adding CS to teacher credentialing requirements and specify the inclusion of DS and/or AI in CS teacher preparation. CS should also be added as a designated high-need area, if appropriate for an individual state.

- When possible, localities should support cross-disciplinary connections between subjects. For example, credentialing or certificates that extend current credentials could allow either math, science, or business educators to teach these topics in their classrooms.

3 Support teachers who pursue credentialing in CS, AI, and DS:

- States should create dedicated scholarships, reimbursements for training, or other financial assistance to further incentivize ongoing and advanced teacher development including PD or graduate classes.

- States should incentivize credentialing which goes beyond reimbursing the cost of PD (e.g., loan forgiveness, stipends, associated graduate programs like STEM or math education) will help increase the number of qualified teachers in CS including AI and DS.

Landscape Reports - Expanding Computing Education Pathways (ECEP) Alliance

Landscape reports are one viable step in implementing CS programs in schools. Prior to implementation of policies, it is necessary for state departments of education to analyze existing conditions specific to their state or geographic region that would influence the incorporation of CS, as well as AI and DS, education in schools. A landscape report would involve conducting research on challenges and education gaps, opportunities, and existing efforts that could bolster initiatives, as well as answering critical questions on the current conditions in the state. (ECEP, n.d.)

- Sustained PD support is necessary and must include use of computational software and hardware related to AI and DS, as well as IT support and infrastructure. For example, teachers may have questions during the school year that follow a summer course. According to local contexts, this should be accounted for in budgeting for PD, by developing contracts with service providers, and evaluating offerings from PD partner organizations.

Federal Policy Recommendations

- The federal government should consider adding Data Science as a Graduate Assistance in Area of National Need (GAANN) topic, which already includes artificial intelligence and other high-need subjects.
- The federal government should pass legislation requiring teacher preparation programs to include AI and DS-related instruction or coursework for any academic subject teachers who are required to teach AI and DS as a part of their license. For example, every elementary school teacher in states with required CS standards should be required to take coursework covering those standards.
- The federal government should consider increasing and/or dedicating targeted funding within existing grants programs that serve state and local education agencies in providing DS and AI professional development, including Teacher Quality Partnerships or SEED programs.

- The federal government should consider stipulating that NSF-funded national science centers include dedicated funding and activities for teacher professional development through direct training or other community partnerships. Institutes, including the recently funded Data Science Institutes and Artificial Intelligence institutes should include and report upon educator training conducted as a part of grant or BPC efforts. The EHR division should also work more closely with CISE, MPS, and others for sponsoring joint opportunities for educator development.

- The federal government should consider making professional development funds under the Elementary and Secondary Education Act include eligibility for additional wrap-around services in addition to contract-based services, including funds for planning, training for administrators, instructional coaches, and counselors, stakeholder engagement, and outreach to community partners, as a part of holistic PD.

- The federal government should set aside additional funding to address national teacher shortages in STEM education, including for areas of national need like AI and DS.

- The federal government should create significant awareness and public relations efforts in support of these goals, including senior official tours to teacher training programs, and/or districts or schools that are under-taking innovative approaches, etc. to incentivize more teachers to train in these areas.

Tools and Resources

Definition

Tools and resources in AI and DS education is a broad category with implications in four areas: 1) student, teacher, and school access to infrastructure including at-home and community internet connectivity, 2) availability of instructional materials and support for school and out-of-school settings, 3) availability of software, hardware, and other technology for instruction and exercises, and 4) creation of tools for assessment and demonstrating success in these emerging fields, including classroom assessment and aligned PD opportunities including earned credentials.

Recommendations

Little focus is given to pedagogical tools and resources, even though it is a crucial aspect of AI and DS education. Research, development, and funding must be secured for identified gaps in the areas of infrastructure access; materials for instruction and practice; software, hardware, and other technology for instruction; as well as tools for demonstrating success. Attendees encourage the community to:

1 Provide funding for infrastructure access:

Students, teachers, and schools must have adequate access to infrastructure and devices, which is a prerequisite to effective instruction in computing and data. Funding must be provided for the expansion of 5G to universal access, including in both geographic terms (e.g. rural areas) and cost terms (e.g. low-income or otherwise disadvantaged students). While the Biden Administration has recently taken measures to expand high-speed internet infrastructure, it is crucial that sufficient bandwidth is provided to schools and community centers, and that students and teachers have sufficient bandwidth for at-home use. Devices, such as tablets or desktop computers are necessary for students and educators to enable serious academic work. Phone access is likely insufficient. Lastly, funding must be allocated to expand school budgets for technology, textbooks, and space on the Cloud. Policymakers can do this specifically by:

- Ensuring infrastructure funds reach rural and remote communities and create technical assistance for low resourced districts to create high quality grant applications.
- Define a minimum bar for regional access to high speed internet, and measure and report progress on a ZIP code-basis for meeting that standard.
- Include measures of access in the Civil Rights Data Collection, and include indicators in the Educational Equity Report and school and district level data views.

2 Incentivize the development of materials for instruction and practice:

Only around 30% of the intended CS curricula in the U.S. includes artificial intelligence (Falkner et al., 2019, p.7). More resources need to be developed for instruction in AI and DS. Educators need access to instructional materials, pedagogical tools with

exercises and demonstration examples that enable younger students to experience AI and DS, building intuition at early ages and learning age-appropriate core fundamentals. Creating avenues for educator-generated content to be highlighted and awarded through programs like the Presidential STEM teacher awards would allow teachers to contribute to the materials and curricula available in the artificial intelligence education landscape.

Fund tools for demonstrating success by incentivizing the development and research of classroom assessment tools in emerging computer-based education, including AI, DS, and additional topics including quantum and cybersecurity.

Credentials in these emerging fields must also be created, including CTE, certificate programs, apprenticeships, OSTCP programming, and other career pathway programs.

Internet Subsidies and Expansion of High-Speed Internet Infrastructure

In August 2021, Congress approved legislation that would allocate $64 billion to subsidizing internet access for low-income households and expanding high-speed internet access to millions of U.S. households that remain unconnected (Schlesinger & Tracy, 2021). Federal, state, and local investments in infrastructure are key to closing the digital divide and supporting the goals of universal CS education including AI and DS.

Equally crucial will be supporting research that produces evidence for additional classroom materials, especially in K-5 and 6-8, for AI and DS instruction, and supporting the integration of AI and DS into other K-12 subjects and disciplines. Building awareness among stakeholders of available resources is also important.

Students that are eager to pursue AI and DS in their free time also need access to extracurricular engagement opportunities, including summer programming, and other enrichment activities (such as robotics, data hack-a-thons, Bootcamps, etc.).

A lack of viable data for educational purposes underscores the need for shared data sets and robust case studies for education and research. Stakeholders must collaborate to make data publicly available, shareable, and discoverable, creating a base of common knowledge for their colleagues to build upon and collaborate on.

Policymakers can address these problems specifically by:

- Implementing awards programs like the Presidential Awards for Mathematics and Science or the White House Champions of Change to recognize teachers and faculty producing high quality materials and engaging students.
- Resource federal agencies like NASA and the U.S. DOD STEM programs to create or build upon repositories in order to collect resources in places. All repositories should have APIs to allow resources to easily be searched and retrieved by other providers.
- Create opportunities for teacher and faculty positions in the summer months to create and share lessons using data from Data.gov.

3 Resource the development of software, hardware, and other technology for instruction: Students, including students with disabilities and other learning differences, should learn about a variety of software packages and tools, moving towards exposure or practice in real-world tools by high school graduation. To allow this progression, policymakers should incentivize the community to build age-appropriate software progressions throughout K-12, surface the AI and DS concepts in the ACM Computing Curriculum 2020 recommendations, and encourage the development and funds for the purchase of pedagogical devices for implementing artificial intelligence in classrooms, such as artificial intelligence-powered robots, accessible to children and educators.

So that educators may confidently teach the curricula and use the tools, PD opportunities must be aligned with the development of new tools and curricula.

Policymakers can address these challenges specifically by:

- Asking the NSF to include bullet points in solicitations and release Dear Colleague letters to point potential curriculum developers and instructor professional learning to grants appropriate for this work.

- State policymakers can continue to fund teacher PDand incentivize ongoing teacher learning (beyond CS basics) to allow teachers to deepen their knowledge and explore topics such as AI and DS.

Fundamental Artificial Intelligence and Data Science Education

A call for fundamental AI and DS education to promote an empowered and informed U.S. citizenry.

Definition

Today's students must be prepared to thrive as consumers, workers, creators, and citizens in an age where AI, DS, and algorithms will impact every area of life. A fundamental understanding of how AI and DS are used throughout society, the types of problems they address in the world, and the ethics and challenges in their use are required for all students regardless of the college major, career, or industry they plan to enter. Fundamental AI and DS education is a prerequisite for responsible citizenship in the digital age, especially for those who will eventually design, develop, and deploy AI algorithms and systems or create the data tools used by the public. Fundamental AI and DS education must be a core part of digital literacy and integrated across all academic subjects where appropriate.

Currently there is no widely used definition that operationalizes fundamental AI and DS among educators, students, school administrators, researchers, university faculty, policymakers, and workforce stakeholders. Organizations such as AI4K12 and the Association for Computing Machinery (ACM) have recently released guidance for educators and faculty to address this issue. The guidance is new, and implementation is just getting started. In many schools, AI and DS are either briefly explored or treated as an elective for deep study in existing frameworks that define "digital citizenship" such as in International Society for Technology in Education (ISTE) student standards or K-12 state standards. This ambiguity can facilitate confusion among

Creating a Definition for Computational Thinking

Over the last decade, the National Academies have worked to create a community and research-based definition of computational thinking. Starting with a landmark report in 2010 entitled Report of a Workshop on the Scope and Nature of Computational Thinking (National Research Council, 2010), and followed by Report of a Workshop on the Pedagogical Aspects of Computational Thinking (National Research Council, 2011), and other materials including a recent meeting on Incorporating Computational Thinking in Elementary Mathematics Curriculum (National Academies, 2021), the National Academies explored computational thinking from multiple dimensions. These workshops and subsequent reports and meetings help the community to come to a shared understanding, provide resources for curriculum development and educators, and create important documents to drive national discussion.

stakeholders, foster a lack of mutual understanding, and eventually prevent the development of high-quality AI and DS education for students in the U.S. Some educators and developers of curricula are working to integrate teaching about AI and DS into learning standards beyond CS, including reading, English Language Arts, social studies, science, mathematics, or as introductory coursework in undergraduate programs. This approach seeks to broaden access to all students, and ensures AI and DS are taught from a multidisciplinary perspective, but these early efforts will need intentional resources and support to reach all students.

By providing equitable access for all students to foundational teaching about AI and DS, we can ensure an informed citizenry who will help shape innovative, ethical, and respectful uses for this transformative set of technologies. In addition to creating empowered and informed citizens, AI and DS fundamentals can inspire students with real-world problems and challenges to pursue computational degrees or graduate study.

Recommendations

In order to promote ubiquitous and fundamental AI and DS education, we must:

- Evaluate existing definitions for AI and DS within K-12 contexts. The National Academies should convene a working group to produce a series of publications on AI and DS education similar to the series produced for computational thinking.

- The U.S. DOE should highlight AI and DS in its STEM initiatives, and hold webinars or other convenings with subject-matter experts to inform state departments of education about AI and DS education.

- The NSF and U.S. DOE should support workshops with faculty from various universities to review the new ACM Computing Curriculum recommendations and ensure AI and DS are a part of all CS programs. Faculty from other disciplines should be invited to the meeting, or convened in a separate workshop, to consider the integration of AI and DS in other domains.

Data Science at the NJCU School of Business

The New Jersey City University School of Business is one model of integrating data literacy and data science into higher education courses in a business school. In addition to offering the first Master's in Financial Technology degree program in the state of New Jersey, the School of Business has also recently launched an undergraduate major and a minor as well as a master's program in business analytics and data science. Students in these programs learn cutting-edge analytical skills, including popular machine learning techniques such as deep learning, and use software tools that are currently popular in the industry. In addition to the full programs, the School of Business also has a general education course in data literacy with the objective of introducing freshmen students to key concepts in data science and data driven decision making. This course and these programs are designed to provide students the skills needed to gather, store, analyze, and interpret large amounts of data to facilitate data driven decision-making. Graduates of the programs will be thoroughly prepared to hit the ground running when they enter the workforce.

We encourage all stakeholders to work together to:

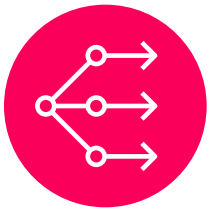
- Participate in National Academies working groups to clarify and bridge definitions for fundamental AI and DS education and its relationship to current digital citizenship or digital literacy standards that currently exist. Stakeholders work together to come up with a working definition building upon previous frameworks and definitions.

- State leaders should partner with educators and experts to look at existing standards to see where AI and DS could fit such as International Society of Technology in Education (ISTE), Common Core, American Library Association (ALA), National Curriculum Standards for Social Studies, Next Generation Science Standards (NGSS), etc. and produce recommendation reports for state departments of education about the gaps between current curriculum and desired outcomes.

- The NSF should showcase current projects and release a Dear Colleague letter highlighting the opportunities to apply for grants to fund opportunities for learners to connect to existing AI and DS programs and curricula offerings at all levels.

- The NSF should encourage BPC plans to include educator professional learning and collaboration with faculty, teachers and curriculum designers of core academic subjects to design approaches to embed AI and DS topics and other emerging technologies into their current instruction.

Awareness of Pathways Through Graduate School



Definition

Because AI and DS are subfields of computer science and both relatively new and developing fields, the pathways for education and careers in these areas are still being explored and defined. As a result, a lack of awareness, misinformation, and misperceptions persist when it comes to pathways in CS careers among students, educators, and guidance counselors. In many cases, learners interested in CS, AI, and DS-related fields, lack an understanding of the roles, responsibilities, and opportunities available in the field as well as how that relates to their educational pathway and how to best prepare for their desired career in the field. Recent research by the Gates Foundation shows that lack of career pathway awareness especially impacts minoritized youth including Black, Hispanic, and Indigenous populations (Bill and Melinda Gates Foundation, n.d.).

On the part of industry and employers, there is a concern that an undergraduate education is not consistent in the implementation of computational degree programs and does not require fundamental concepts needed for careers, employment, and the job search in CS, AI and DS-related fields. Additionally, as the fields are new and emerging, a high value is placed on obtaining a graduate degree, especially for those pursuing positions of leadership or in cutting-edge technological industries.

The current system favors students at elite institutions who have resources, including portfolios, specialized faculty, connections, and a network that allows them to access and ascend to high-ranking positions.

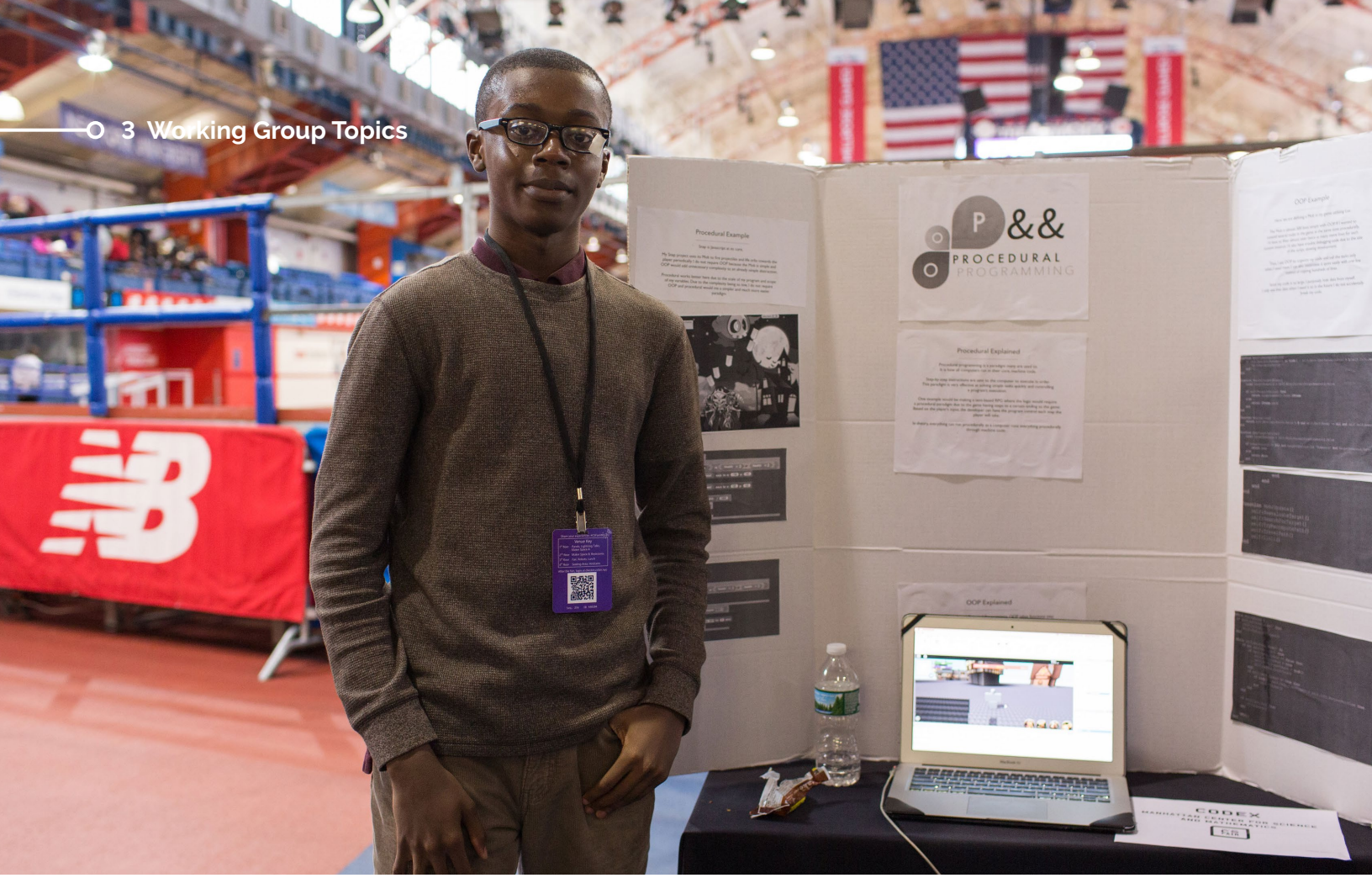
Recommendations

In order to increase participation in pathways, especially among Black, Hispanic, and Indigenous youth:

- The U.S. Department of Labor (U.S. DOL) should update the O*NET Career Listings and associated support materials and assessments to recognize the growing influence of computational skills needed by most degrees and specific pathways for AI and DS specialists. We also strongly recommend that the "Ability Profiler" be renamed to align with appropriate growth mindset language, potentially "Preparation Strength Profiler," or "Academic Preparation Profiler".

- The U.S. DOL, in partnership with the U.S. Patent and Trademark Office (USPTO), should collaborate to connect USPTO profiles of inventors and educational pages with the careers featured on O*NET.

- The U.S. DOL, U.S. DOE, and OSTP should convene a working group including the ACM Education Board and Advisory Committee and Computing Research Association (CRA) to identify opportunities to landscape undergraduate programs and identify existing guidance for implementation of AI and DS education. The working group should release a report clearly



articulating the gap between community goals to increase AI and DS education at the undergraduate level, ACM recommendations, and current implementation.

- The U.S. DOL and U.S. DOE should collaborate to produce workshops or other professional development for postsecondary advisors and career counselors to disseminate information about postsecondary programs and appropriate undergraduate preparation. This must include staff and faculty at community colleges.

- The U.S. DOE should release clear guidance to the states to use Perkins or other federal funds for education or career preparation to provide (1) professional learning for middle school educators and counselors, (2) opportunities to upskill CS and other STEM educators to integrate AI and DS into existing coursework, and (3) high school guidance and college counselors with professional learning and student and parent-facing materials to clarify appropriate pathways for students.

- The U.S. DOL and U.S. DOE should partner with the Afterschool Alliance to share professional learning opportunities with out-of-school-time educators and mentors to ensure families and students in under-resourced schools can have access to this information through alternative means.

Capacity at Postsecondary Institutions

Definition

In recent years, computing programs at universities across the United States have experienced an increase in student enrollment in programs granting computing degrees. For example, the number of students graduating with a Bachelor's Degree in Computer and Information Sciences increased by 50% from 27,406 in 2012 to 71,420 in 2017 (NCES, 2018). However, booming enrollments without increased institutional capacity limit space in programs, making computing programs increasingly competitive and creating homogenous cultures in CS departments including programs in DS and AI. Without increasing the capacity to allow students to study CS, AI, and DS, the U.S. cannot possibly meet workforce needs or goals of broadening participation in computing. In order to meet the demand for enrollment in computing programs at the postsecondary level, universities must increase capacity, starting with securing funding to hire faculty and invest in infrastructure such as computing equipment and classrooms. However, many schools have faced challenges in hiring faculty for computing courses, due to the same shortages of experts in these fields, creating competition for the same graduates with industry, and a multitude of well-paid opportunities in computing outside of academia.

Therefore, in order to ensure that all institutions, including minority-serving institutions, provide students with access to computing education at the postsecondary level, it is necessary to increase the capacity of CS, AI, and DS education. In addition to adding new faculty, opportunities should be provided to current faculty to increase their knowledge of the most recent AI innovations.

Recommendations

In order to increase institutional capacity for providing high-quality CS, AI, and DS education, the community recommends:

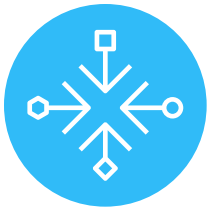
- Identify the clear areas and institutions where capacity building is difficult. The U.S. DOE should convene a working group, in partnership with ACM and CRA and funded by the NSF, to develop an assessment of institutional capacity for computational degrees and the ability of the institution to offer AI and DS concepts within the degree programs.

- The NSF or U.S. DOE should provide support through workshops or other venues for non-R1 institutions to collaborate, identify challenges, and share resources for capacity building.

- Create incentives through the U.S. DOL or federal agencies for employees who do reverse sabbaticals at institutions where faculty are needed. As many of these institutions are not in major cities, incentives are needed. For example, consider tax credits or other incentives to either the individuals or employers who complete a semester at colleges or universities with need.

- The U.S. DOL should explore how to connect universities with corporate social responsibility departments in order to discuss ways to leverage employees to guest lecture or provide adjunct capacity through remote teaching for colleges and universities not in major urban centers.

Multi-stakeholder Alignment



Definition

While other sections of this policy brief address proposed actions for specific stakeholder groups, such as industry, higher education, non-profits, and K-12 institutions, this section addresses specific proposals for where these groups must collaborate. Educational institutions remain the nexus point to produce step function changes. However, in the absence of public policy and funding that would allow higher education to assume that role, it is unlikely that the myriad of action items will coalesce into a defined strategy.

Problem Statement:

Higher education institutions have sufficient enrollment to double the number of computer science and AI-related degrees awarded each year. However, students lack sufficient awareness of how these majors contribute to overall workforce readiness in a digital economy or how their current course of study will be disrupted by AI over time. If only a fraction of those students elected a CS, AI, or DS-related major, we could accomplish the stated goals for this study. For example:

- Data shows that if undergraduate institutions continue graduating students who are prepared to enter the tech industry at the current rate that by 2028 the United States will only have 17% of the needed tech workforce.
- We know that 58% of all bachelor's degrees are awarded to women and 32% are awarded to Black and Hispanic students and that these demographic groups are dramatically underrepresented in CS and related tech disciplines.
- With the goal of doubling the number of CS and tech-related degrees, it is critical that solutions focus on how to recruit and retain these underrepresented groups in CS major

Department of Labor (DoL) Apprenticeship: Closing the Skills Gap

In 2020, the U.S. DOL awarded nearly $100 million in grants to 28 public-private apprenticeship partnerships meant to equip over 92,000 U.S. workers with skills needed in critical industries. These apprenticeships are offered as an alternative to a bachelor's degree, equipping workers with skills that lead to well-paid jobs (DOL, 2020). One such apprenticeship grant awarded $6 million to North Carolina State University (NCSU) in order to support 5000 workers with coursework, skills training, and certification in AI. The project at NCSU involved multiple stakeholders including nine industry partners (such as IBM and CISCO), four educational partners (including North Carolina Community College), as well as recruitment-related agencies and the North Carolina Chamber (Kulikowski, 2020).

Multi-stakeholder alignment and misalignment: There is clear alignment across stakeholder groups on the need to 1) graduate more students in computer science, AI and tech-related disciplines, 2) increase the diversity of the tech field, and 3) ensure that students stay current as the field of technology quickly changes and evolves.

In spite of these shared objectives, these stakeholders are misaligned in terms of how to achieve these objectives. Each stakeholder looks to the others to increase engagement and/or solve the problem, yet none have been given the specific accountability, incentives, and/or time to do so. Most programs actually work against the development of collaborative solutions by causing stakeholders to compete with one another for grant dollars instead of incentivizing collaborative solutions that leverage the best of those organizations working in this space already. Additionally, the community lacks a shared collective impact strategy or theory of change that connects the various individual activities into a reinforcing pathway for learners. That leaves us without a comprehensive strategy to advance data science and AI education on a national scale.

An instance where multi-stakeholder alignment can have significant benefits, for example, is in the growing discipline of AI for cybersecurity. Both areas have conventionally been siloed, with academia and industry often having varying expectations and definitions. However, AI has significant potential to address critical cybersecurity tasks, including asset identification, vulnerability management, threat detection, and control allocation. Providing clear preparation, including foundational coursework, and pathways such as those listed above can help to produce the next generation of “Cyber-AI” professionals, a key clear need from recent U.S. executive orders and federal initiatives.

Higher Education Regional Alliance

The Higher Education Regional Alliance (HERA) in Southeastern Wisconsin is a collaboration between network partners as well as 18 Southeastern Wisconsin two- and four-year postsecondary institutions. Stakeholders in HERA’s network are working to close equity gaps in postsecondary education, increase degree-completion rates, and prepare young people for work in the modern world. This summer, HERA, in partnership with the MKE Tech Hub Coalition and industry members, awarded a Foundations in Data and Artificial Intelligence badge to 70 high school, college, and university students that completed a pre-internship program on data and artificial intelligence impact and ethics. Participating high schools and universities plan to award credit for successful completion of this program.

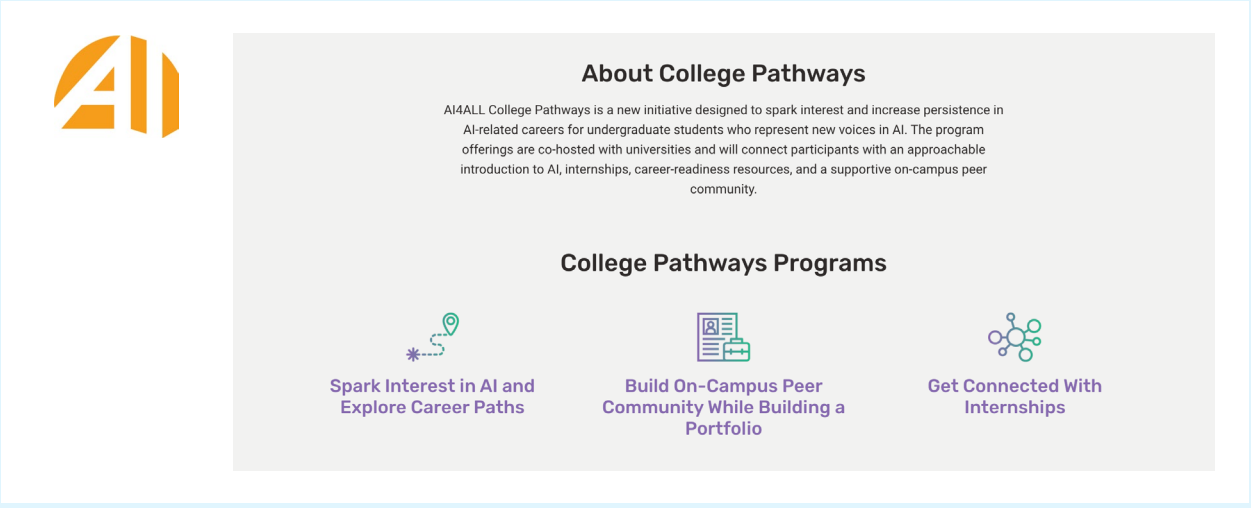
Recommendations
Public policy recommendations with supportive grant funding from significant federal resources provide the best possible opportunity to communicate the priority of data science and AI education for our nation. The following two domains capture the greatest opportunity for innovative and collaborative solutions to scale quickly:

Preparation: Curriculum innovation is needed to address the challenge. Not enough students have access to relevant coursework and most institutions can not independently justify the expense for curriculum development to address this need, or may not know how to implement changes. Ensuring equitable access to relevant coursework (required for all vs. elective), will increase awareness and engagement of underrepresented groups. Key intervention points include:

- **Foundational concepts:** The NSF and U.S. DOE should encourage undergraduate institutions to use BPC plans or grants to create program structures including foundational concepts and examples of AI and DS in required coursework.

AI4ALL

AI4ALL is a non-profit organization based in the U.S. with a mission to increase diversity in AI education, research, development, and policy. AI4ALL's College Pathways Program is designed to support undergraduate students pursuing AI-related fields. AI4ALL also offers summer programs for high school students, as well as an Open Learning program with free, interdisciplinary curricula for high school teachers of all subjects. AI4ALL acts as a bridge for higher education and industry for their summer camps and college pathways programming.



- **Industry engagement:** Incentivize Industry to provide release time to their staff to partner with universities on the development and delivery of new coursework that can be revised annually to keep up with the accelerating rate of digital disruption across our key industries.

Pathways: Developing pathways into, and out of, higher education will be critical for increasing the quantity of graduates with technical skill sets and foundational acumen in these areas. Respectively, these pathways include the areas of PK-12, higher education career services, and career and technical education, including apprenticeships. Key intervention points include:

- **State-level task forces are needed in all 50 states to align exit and entrance requirements.** In many cases, K-12 state standards and graduation requirements do not align to higher education admissions requirements, and often over-index on outdated or handwritten procedural competencies, especially in mathematics. Admissions requirements can also crowd out more modern content in DS or AI in K-12. Institutes of Higher Education (IHEs) should work to ensure high school courses in DS, AI, and CS are recognized in admissions eligibility, and K-12 state and local stakeholders should work collaboratively with higher education to develop modernized graduation outcomes. Federal agencies including the NSF and U.S. DOE should report on grantee or institutional alignment with recommended requirements and identify community progress needed to meet task force recommendations.

Multidisciplinary Section: Diversity Higher Education Consortium

In July 2021, Intel Corporation sponsored a virtual Diversity Higher Education Consortium that welcomed college and university staff and faculty for a technical training meant to foster collaboration between industry and academia. The one-day hands-on training covered AI, among other important topics.

Sample Case Study (Microinternships)

Break Through Tech has a program called a Sprinternship® which is a 3-week corporate paid micro-internship for freshman and sophomore women and other groups underrepresented in technology which takes place during an academic recess other than during the summer internship season. The program is a collaboration between industry and academia to deliver an experience that makes this target population more competitive when applying for summer internships. Over 1000 students have participated in this program in New York and Chicago, and it has dramatically improved their success in landing a paid tech summer internship and securing jobs once they graduate. With the proper incentives and government funding, the program could be replicated in cities around the nation.

- **A national task force with funding to implement recommended solutions is needed to transform the career services function to deliver high-quality career counseling on a national basis.** The Career Services function in higher education is the nexus of industry and academia and is, at best under-funded, unevenly delivered, and in need of innovation specific to the tech industry. This should begin with a national study on the current state of the career services functions at different types of institutions: higher education, high school, and employment centers. This study should include best practices in general, and, specifically, an understanding of what is needed in computer-related fields. Industry engagement is critical to reflect the value proposition for diversifying the tech workforce and overcoming the barriers they perceive as a deficiency in the current K-12 and higher education system which discourages those who are historically underrepresented in tech from pursuing high-demand, high-paying career pathways that are in desperate need of their perspective to create future technological solutions.

- **Incentives for catalyzing innovation in Career & Technical Education, including Apprenticeships:** Existing Career & Technical Education (CTE) programs are a potentially high-leverage way to encourage students, starting in high school or earlier, to pursue careers in technical areas in high demand locally and nationally for lower cost than traditional four-year higher education. However, many state CTE programs are misaligned to in-demand careers, and have

yet to develop strong support for careers in software development, data analytics, or AI. Many practitioners in these areas can often self-progress in software or coding languages beyond their training programs through job experience, making traditional graduate education less necessary. Specific mechanisms can include National Activities funding authorized under the Perkins Act.

Resources & Case Studies

- A National Academies Roundtable on postsecondary DS education highlighted the need for greater socio-economic, racial, and gender diversity in the field, and that early exposure in K-12 may be a promising opportunity to expand participation and additional alignment work will be needed.

- The AI4K12 Initiative is working with state departments of education who are developing pathways for AI and DS education. A preliminary Executive Summary was published and state delegations continue to report out on progress quarterly.

- Some states, like Wisconsin, have passed [unfunded] legislation to require Academic and Career Planning services in grades 6-12 but require support to ensure students are technologically literate before investing in postsecondary education and training.

Cornell Tech: Break Through AI

Break Through Tech's AI program is a new initiative targeted at increasing the number of undergraduate women in AI and ensuring that they are highly competitive when applying for tech jobs. By providing a bridge program for university women, this collaborative effort seeks to build resilient pathways for them in the technology sector. The program requires collaboration between universities and industry partners. It is focused on industry skills training and the creation of a real-world portfolio based on industry challenges and professional mentoring. The program model, if funded by the government, could be replicated in cities around the country.

4
Conclusion

It was less than a decade ago when the notion of "Computer Science for All" was in its infancy. At that time, it was considered forward thinking and a leap of faith for many educators, administrators, families, and policymakers. Since then, educators and students from across the country have championed computer science, working tirelessly to expand access to high-quality CS curricula and implementing it in classrooms across the U.S. They have shown us that CS is not a subject reserved for the students with privilege and some kind of innate talent, but instead an engaging and accessible topic that brings our technological and innovative world into the classroom. The enthusiasm for CS education from every corner of the United States has inspired us all to dream big, set big goals, and carefully consider how our rush to implement impacts students differently by ZIP code, gender, race, ethnicity, or socio-economic status.

4 Conclusion

Computer science is also not complete as an emerging discipline. It is maturing to have shades and colors, subdomains, sticky problems, and societal impacts. Pure logic and algorithms no longer exist in only textbooks or dusty corners of multi-institutional closed networks (ARPANET); they are in our pockets, screens, and live between our most personal and professional communications between friends, relatives, colleagues, and strangers. We've seen the rise and prominence of subdomains such as cybersecurity, artificial intelligence, and others, as well as the increase of multidisciplinary fields including data science. As the professional discipline changes, the education pathways preparing learners for entry into the domain will need to be reviewed and adjusted to continue to provide fundamentals and early exposure and experience with subdomains.

AI and DS have the ability to impact society on a global scale, and require diverse thinkers to build the next generation of technologies that will shape our lives. In this report we lay out a challenge to the United States to ***double the number of students enrolled in computational degrees and increase the percentage of those degree programs featuring Artificial Intelligence and Data Science learning***. This is only possible if we inspire a generation of students in K-12, provide them the fundamental learning in order to complete those degrees on time, and ensure equity of access to pathways resulting in postsecondary enrollment that mirrors the demographics of our country.

The recommendations in this report are focused on policymakers, advocates, and community leaders. They seek to raise awareness of the issues facing education systems across the U.S. and express the importance of AI and DS-specific education at all levels. They offer suggestions to build the capacity of teachers, institutions, and educational pathways in order to meet the demand to be created by increased awareness, and they suggest how to resource the increase in opportunities for students at every level.

In a world where other countries are surging ahead in their ability to provide high-quality CS education, including AI and DS education, we must adjust and improve our educational pathways in order to provide the same opportunities to our students. As global CS education continues to develop, the United States must be careful to not set the bar too low, leave our most vulnerable communities behind, and bake inequity into the system. Together we can not only reach CSforALL, but implement an educational pathway that prepares the solvers of tomorrow, ensuring a global citizenry ready to meet the challenges ahead.

List of Meeting Attendees and Contributors

Ehrik Aldana
Co-Founder and Chief Operating Officer,
The AI Education Project

Tasha Austin
Director,
Deloitte AI Institute for Government

Phaedra Boinodiris
IBM's AI for Good initiative

Latoya Boland (Speaker/Participant)
Mathematics Teacher,
NYC Department of Education

Catherine Born
AI and Data Policy Intern,
CSforALL

Arnaub Chatterjee
Senior Vice President,
Acorn AI at Medidata Solutions

Fay Cobb Payton
Program Director,
National Science Foundation

Dan Cosley
Program Officer,
National Science Foundation

Bryan Cox
Computer Science Program Specialist,
Georgia Department of Education*

Michael Davis
National Science Foundation

Dr. Leigh Ann DeLyser, Ph.D. (Speaker)
Co-Founder and Executive Director,
CSforALL

Sarah Dunton
Director,
Expanding Computing Education Pathways (ECEP) Alliance

Zarek Drozda
Data Science Fellow,
U.S. Department of Education*

Dr. Emily Edwards, Ph.D.
Executive Director of IQUIST at UIUC and academic co-lead of National Q-12 Education Partnership

Joshua Elder (Speaker)
Director of Grants Management,
Siegel Family Endowment

Dr. Jeff Forbes, Ph.D.
Program Director,
National Science Foundation

Dr. Christina Gardner-McCune, Ph.D.
Associate Professor,
University of Florida; Co-chair, AI4K12.org

Dr. Diana Gehlhaus, Ph.D.
Research Fellow,
Georgetown Center for Security and Emerging Technology (CSET)

Kayla Goode
Research Analyst,
Georgetown Center for Security and Emerging Technology (CSET)

Dr. Shiyan Jiang, Ph.D.
Assistant Professor,
North Carolina State University at Raleigh

Dr. Roshni Kasad, Ph.D.
Senior Director,
College Pathways, AI4ALL

Dr. Allyson Kennedy, Ph.D.
Assistant Program Director,
National Science Foundation

Appendix A

Alex Kotran
Co-Founder and President,
The AI Education Project

Dr. Sanmi Koyejo, Ph.D.
Assistant Professor,
University of Illinois at Urbana-Champaign

Lance Lantier
Director of Research and Analysis,
National Security Commission on Artificial Intelligence (NSCAI)*

Justin Lynch (Speaker)
Policy Advisor, Research and Analysis,
Office of Science and Technology Policy*

Karen Matthys
Co-Founder and Co-Director,
Women in Data Science (WiDS);
Executive Director, External Partners,
Stanford University Institute for
Computational and Mathematical Engineering

Monica McGill, Ed.D.
President and CEO,
CSEdResearch.org

Carolina Ortiz
Sr. HR Business Partner,
Acorn AI at Medidata Solutions

Dr. Victor Piotrowski, Ph.D.
National Science Foundation

Tess Posner
CEO,
AI4ALL

Dr. Davina Pruitt-Mentle, Ph.D.
Lead for Academic Engagement,
National Institute of Standards and
Technology (NIST)*

Emily Reid
VP of Open Learning,
AI4ALL

Ishmael Robinson (Speaker)
Math Supervisor,
Saint Paul Public Schools

Dr. Sagar Samtani, Ph.D. (Speaker)
Assistant Professor,
Indiana University

Esmerita Sepulveda-Lusky
Senior Director, People & Business Partner,
Acorn AI at Medidata Solutions

Dr. Emmanuel Schanzer, Ed.D. (Speaker)
Founder and Program Director,
Bootstrap; Director, CSPdWeek

Laura Schmidt
Chief Talent Development Officer,
Milwaukee Tech Coalition

Dan Schneider
Curriculum Development Manager,
Code.org

Dr. Allison Scott, Ph.D.
Chief Executive Officer,
Kapor Foundation

Natasha Singer
Technology Reporter and Writer

Dr. Judith Spitz, Ph.D.
Founder and Executive Director,
Break Through Tech

Dr. Nigamanth Sridhar, Ph.D.
Program Director,
National Science Foundation

Ora Tanner
Co-Founder and Chief Learning Officer,
The AI Education Project

Keisha Tennessee
Computer Science Coordinator,
Virginia Department of Education (VDOE)*

Dr. Jodi Tims, Ph.D.
Executive Director of Khoury Programs in the Global Network, Professor of the Practice,
Northeastern University

Dr. Dave Touretzky, Ph.D.
Research Professor,
Carnegie Mellon University; AI4K12.org

Gelyn Watkins
Program Strategy Manager,
Women and Tech Innovation,
Pivotal Ventures

Li Yang
Program Director,
National Science Foundation

Carlos Zavala
Assistant Vice President,
Cognizant Foundation

Chrissy Ziccarelli
Director of Program Implementation,
Girls Who Code

* This agency does not necessarily endorse the opinions or ideas expressed in the report.

Working Groups

Beth Rudden
Distinguished Engineer & Principal Data Scientist,
Cognitive & AI Services, IBM

Irene Lee
Research Scientist,
Massachusetts Institute of Technology (MIT)

Dr. Ji Yun Son, Ph.D.
Professor of Psychology,
California State University, Los Angeles;
CourseKata

Irena Trifunovic
Community & Partnerships Manager,
Open Learning at AI4ALL

Suyen Machado
Educator,
Los Angeles Unified School District;
UCLA Introduction to Data Science (IDS)

Jinna Hwang
High School Math Teacher,
SMC-Connect; CourseKata

Dr. Karen Givvin, Ph.D.
Researcher & Adjunct Professor, UCLA;
CourseKata

Appendix B

AI and DS Education Meeting Agenda

Agenda: Day 1

Tuesday, June 29, 2021 from 1:00 - 5:00 p.m. Eastern Time

Agenda Item	Time	Description
Opening Remarks: The Big Challenge of Artificial Intelligence and Data Science Education	1:00 – 1:25 p.m.	Setting the challenge and introducing the goals of the meeting. **Speakers:** **Dr. Leigh Ann DeLyser** Co-Founder and Executive Director, CSforALL **Justin Lynch** Policy Advisor, Office of Science and Technology Policy
Panel: Reforming Our Math Systems	1:25 – 2:10 p.m.	AI and Data Science (and even Computer Science) education will require collaboration between multiple disciplines to implement. The panelists discuss education reform from the context of Mathematics, Computer Science, and Data Science. **Panelists:** **Dr. Emmanuel Schanzer** Program Director, Bootstrap; Director, CSPdWeek **Latoya Boland** Math Educator, NYC Public Schools **Dr. Trena Wilkerson** President, National Council of Teachers of Mathematics **Ishmael Robinson** Math Teacher and Administrator
Day 1: Breakout Sessions	2:15 – 4:00 p.m.	During this breakout session, participants meet with others from their grade-band institutions (K-6, 7-12, Undergraduate, Graduate) and identify system-wide barriers to reaching AI and Data Science Education goals. This is a highly interactive and participatory process and attendees interact with colleagues, funders, industry representatives, and policymakers to define a specific set of themes to pursue.
Encouraging Innovation with Policy	4:00 – 4:45 p.m.	Policy can be an important lever in the reform of education and workforce preparation. The speakers share insights from city, state, and federal perspectives and inspire participants to consider how policy can advance Artificial Intelligence and Data Science Education goals. **Speakers:** **Chike Aguh** Chief Innovation Officer, U.S. Department of Labor **Kristen Titus** Executive Director, Cognizant U.S. Foundation
Day 1: Wrap	4:45 – 5:00 p.m.	Day 1 recap, foreshadow remainder of agenda

Appendix B

Agenda: Day 2

Wednesday, June 30, 2021 from 1:00 - 5:00 p.m. Eastern Time

Agenda Item	Time	Description
Day 2: Opening Remarks	1:00 – 1:10 p.m.	
Leveraging Individual Strengths and Collective Partnerships for Change	1:10 – 2:00 p.m.	Change at scale cannot happen through only one individual advocate. It requires an infrastructure to support change and multiple sectors contributing to the work. The speakers discuss how public and private sectors can come together to form an infrastructure for change. **Speakers:** **Dr. Jose-Marie Griffiths** President, Dakota State University; Member, National Security Commission on Artificial Intelligence **Joshua Elder** Director of Grants Management, Siegel Family Endowment
Day 2: Leveraging Federal Support for Research and Implementation	2:00 – 2:10 p.m.	**Speaker:** **Dr. Sagar Samtani** Faculty, Indiana University
Day 2: Breakout Sessions	2:15 – 3:30 p.m.	Participants choose one of the topics from Day 1 to construct recommendations for policy and partnerships to improve in order to reach 2028 goals described on Day 1.
Breakout Group Share-outs	3:30 – 4:00	A nominee from each breakout group will share the most salient points from their discussion.
The Future: Listening to Students	4:00 – 4:45 p.m.	**Student Panelists:** **Matthew Fan** St. Mark's School of Texas, Class of 2022 **Claire Perkins** University of Texas at Austin, Class of 2022 **Willa Potosnak** Duquesne University, Class of 2022 **Moderator:** **Catherine Born** AI and Data Policy Intern, CSforAll
Day 2: Wrap and Closing Remarks	4:45 p.m.	

Appendix C

References and Citations

Bamforth, E. (2021, August 6). *NSF to Fund University AI Research Centers in Adult Education, STEM LEARNING*. EdScoop. https://edscoop.com/nsf-university-ai-research-stem-learning-adult-education/.

Bill and Melinda Gates Foundation. (n.d.). *How can we help young people navigate the journey from high school to college and career, ensuring that they are set for success in life?* Equitable Futures. https://www.equitablefutures.org/.

Bughin, J., Seong, J., Manyika, J., Chui, M., & Joshi, R. (2019, November 20). *Notes from the AI Frontier: Modeling the impact of AI on the World Economy*. McKinsey & Company. https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-modeling-the-impact-of-ai-on-the-world-economy.

Campus France. (2018, April 24). *Artificial Intelligence: France will Spend €1.5 Billion Euros*. https://www.campusfrance.org/en/intelligence-artificielle-plan-macron-Ai-for-humanity.

Code.org. (n.d.). *Why Computer Science?* Code.org. https://code.org/promote.

Code.org. (2019). *Micro-credentials: Addressing Certification and Professional Learning in Computer Science*. https://advocacy.code.org/micro-credentials.pdf

Code.org, CSTA, & ECEP Alliance. (2020). *2020 State of Computer Science Education: Illuminating Disparities*. https://advocacy.code.org/stateofcs

College Board. (2021, February 23). *AP Computer Science*. College Board AP Program Results. https://reports.collegeboard.org/archive/2019/ap-program-results/ap-computer-science.

Dou, R., Hazari, Z., Dabney, K., Sonnert, G., & Sadler, P. (2019). Early informal STEM experiences and STEM identity: The importance of talking science. Science Education, 103(3), 623-637.

Falkner, K., Sentance, S., Vivian, R., Barksdale, S., Busuttil, L., Cole, E., ... & Quille, K. (2019, November). An international comparison of k-12 computer science education intended and enacted curricula. In *Proceedings of the 19th Koli Calling International Conference on Computing Education Research* (pp. 1-10).

Expanding Computing Education Pathways (ECEP) Alliance. (n.d.). *Landscape Reports*. https://ecepalliance.org/resources/landscape-reports.

Fletcher, C. L., & Warner, J. R. (2021). *CAPE: a framework for assessing equity throughout the computer science education ecosystem*. Communications of the ACM, 64(2), 23-25.

IBM Cloud Education. (2020, June 3). *What is Artificial Intelligence (AI)?* IBM. https://www.ibm.com/cloud/learn/what-is-artificial-intelligence.

IBM Cloud Education. (2020, May 15). *What is Data Science?* IBM. https://www.ibm.com/cloud/learn/data-science-introduction.

Kulikowski, M. (2020, February 18). *Grant from the U.S. Dept. of Labor to Support AI Apprenticeships*. NC State News. https://news.ncsu.edu/2020/02/labor-apprenticeships-grant/.

National Academies. (2021). *Meeting on Incorporating Computational Thinking in the Elementary Mathematics Curriculum*. National Academies of Sciences, Engineering, Medicine. https://www.nationalacademies.org/event/09-14-2021/incorporating-computational-thinking-in-the-elementary-mathematics-curriculum#sectionEventMaterials.

National Center for Education Statistics (NCES). (2018, September). *Digest of Education Statistics, 2018. Degrees in computer and information sciences conferred by postsecondary institutions, by level of degree and sex of student: 1970-71 through 2016-17*. https://nces.ed.gov/programs/digest/d18/tables/dt18_325.35.asp.

National Center for Education Statistics (NCES). (2019, February). *Status and Trends in the Education of Racial and Ethnic Groups. Indicator 26: STEM Degrees*. https://nces.ed.gov/programs/raceindicators/indicator_reg.asp.

Appendix C

National Center for Education Statistics (NCES). (2019, October). *Digest of Education Statistics, 2019. Bachelor's degrees conferred by postsecondary institutions, by race/ethnicity and field of study: 2016-17 and 2017-18*. https://nces.ed.gov/programs/digest/d19/tables/dt19_322.30.asp.

National Center for Education Statistics (NCES). (2019, September). *Digest of Education Statistics, 2019. Degrees in computer and information sciences conferred by postsecondary institutions, by level of degree and sex of student: 1970-71 through 2017-18*. https://nces.ed.gov/programs/digest/d19/tables/dt19_325.35.asp.

National Center for Education Statistics (NCES). *Digest of Education Statistics, 2019*. (2019, September). Bachelor's, master's, and doctor's degrees conferred by postsecondary institutions, by sex of student and discipline division: 2017-18. https://nces.ed.gov/programs/digest/d19/tables/dt19_318.30.asp.

National Institute of Standards and Technology (NIST). (2019, December 19). *NIST Study Evaluates Effects of Race, Age, Sex on Face Recognition Software*. NIST. https://www.nist.gov/news-events/news/2019/12/nist-study-evaluates-effects-race-age-sex-face-recognition-software.

National Research Council. (2010). *Report of a workshop on the scope and nature of computational thinking*. National Academies Press.

National Research Council. (2011). *Report of a workshop on the pedagogical aspects of computational thinking*. National Academies Press.

National Science Foundation (NSF). (n.d.). *CyberCorps Scholarship for Service (SFS)*. NSF. https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504991.

National Science Foundation. (2021, July 30). *NSF Artificial Intelligence Research Institutes*. Artificial Intelligence at NSF. https://www.nsf.gov/cise/ai.jsp.

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development*.

Roshan, P. K., Jacobs, M., Dye, M., & DiSalvo, B. J. (2014, November). *Exploring How Parents in Economically Depressed Communities Access Learning Resources*. In GROUP (pp. 131-141).

Schlesinger, J. M., & Tracy, R. (2021, August 11). *U.S. Government Wants a Greater Role in How Americans Access Internet*. The Wall Street Journal. https://www.wsj.com/articles/u-s-government-set-for-greater-role-in-how-americans-access-internet-11628674423.

Tucker, A., McCowan, D., Deek, F., Stephenson, C., Jones, J., & Verno, A. (2006). *A Model Curriculum for K–12 Computer Science: Report of the ACM K–12 task force curriculum committee* (2nd ed.). New York, NY: Association for Computing Machinery.

United States Department of Labor. (2020, February 18). *U.S. Department of Labor Announces Nearly $100 million in Apprenticeship Grants to Close the Skills Gap*. News Releases, Employment and Training Administration. https://www.dol.gov/newsroom/releases/eta/eta20200218.

Villavicencio, A., Fancsali, C., Martin, W., Mark, J., & Cole, R. (2018). *Computer Science in New York City: An Early Look at Teacher Training Opportunities and the Landscape of CS Implementation in Schools*. Report. Research Alliance for New York City Schools. https://steinhardt.nyu.edu/sites/default/files/2021-01/CS4All_Report_final_1.pdf

csforall.org
@CSforALL