Artificial Intelligence
Index Report 2023

CHAPTER 5:
Education

CHAPTER 5 PREVIEW:

Education

ACCESS THE PUBLIC DATA

Overview

Studying the state of AI education is important for gauging some of the ways in which the AI workforce might evolve over time. AI-related education has typically occurred at the postsecondary level; however, as AI technologies have become increasingly ubiquitous, this education is being embraced at the K–12 level. This chapter examines trends in AI education at the postsecondary and K–12 levels, in both the United States and the rest of the world.

We analyze data from the Computing Research Association's annual Taulbee Survey on the state of computer science and AI postsecondary education in North America, Code.org's repository of data on K–12 computer science in the United States, and a recent UNESCO report on the international development of K–12 education curricula.

Chapter Highlights

More and more AI specialization.

The proportion of new computer science PhD graduates from U.S. universities who specialized in AI jumped to 19.1% in 2021, from 14.9% in 2020 and 10.2% in 2010.

New AI PhDs increasingly head to industry.

In 2011, roughly the same proportion of new AI PhD graduates took jobs in industry (40.9%) as opposed to academia (41.6%). Since then, however, a majority of AI PhDs have headed to industry. In 2021, 65.4% of AI PhDs took jobs in industry, more than double the 28.2% who took jobs in academia.

New North American CS, CE, and information faculty hires stayed flat.

In the last decade, the total number of new North American computer science (CS), computer engineering (CE), and information faculty hires has decreased: There were 710 total hires in 2021 compared to 733 in 2012. Similarly, the total number of tenure-track hires peaked in 2019 at 422 and then dropped to 324 in 2021.

The gap in external research funding for private versus public American CS departments continues to widen.

In 2011, the median amount of total expenditure from external sources for computing research was roughly the same for private and public CS departments in the United States. Since then, the gap has widened, with private U.S. CS departments receiving millions more in additional funding than public universities. In 2021, the median expenditure for private universities was $9.7 million, compared to $5.7 million for public universities.

Interest in K–12 AI and computer science education grows in both the United States and the rest of the world.

In 2021, a total of 181,040 AP computer science exams were taken by American students, a 1.0% increase from the previous year. Since 2007, the number of AP computer science exams has increased ninefold. As of 2021, 11 countries, including Belgium, China, and South Korea, have officially endorsed and implemented a K–12 AI curriculum.

5.1 Postsecondary AI Education

CS Bachelor's Graduates

At the undergraduate level, most AI-related courses are offered as part of a computer science (CS) curriculum. Therefore, trends in new CS bachelor's graduates give us a proxy for undergraduate interest in AI. In 2021, the total number of new North American CS bachelor's graduates was 33,059—nearly four times greater than in 2012 (Figure 5.1.1).

New CS Bachelor's Graduates in North America, 2010–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

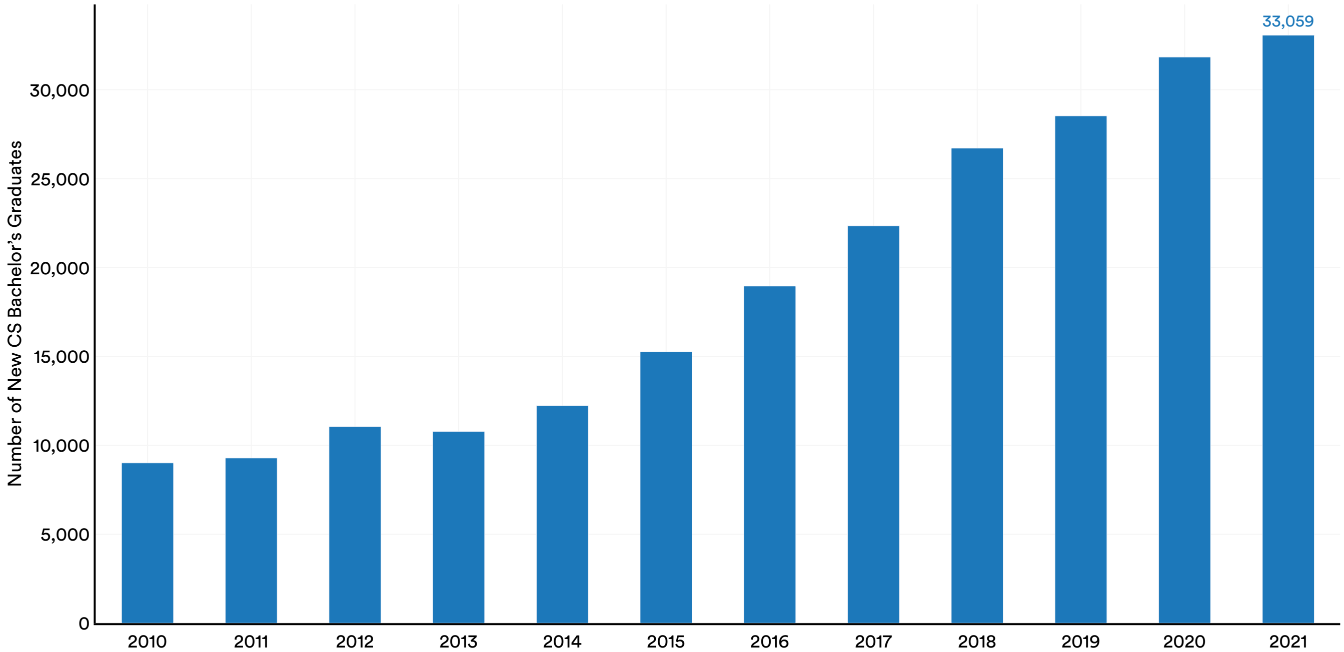

Figure 5.1.1

Figure 5.1.2 looks at the proportion of CS bachelor's graduates in North America who are international students. The number stood at 16.3% in 2021 and has been steadily increasing since 2012—the proportion of such students has risen 9.5 percentage points since 2012.

New International CS Bachelor's Graduates (% of Total) in North America, 2010–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

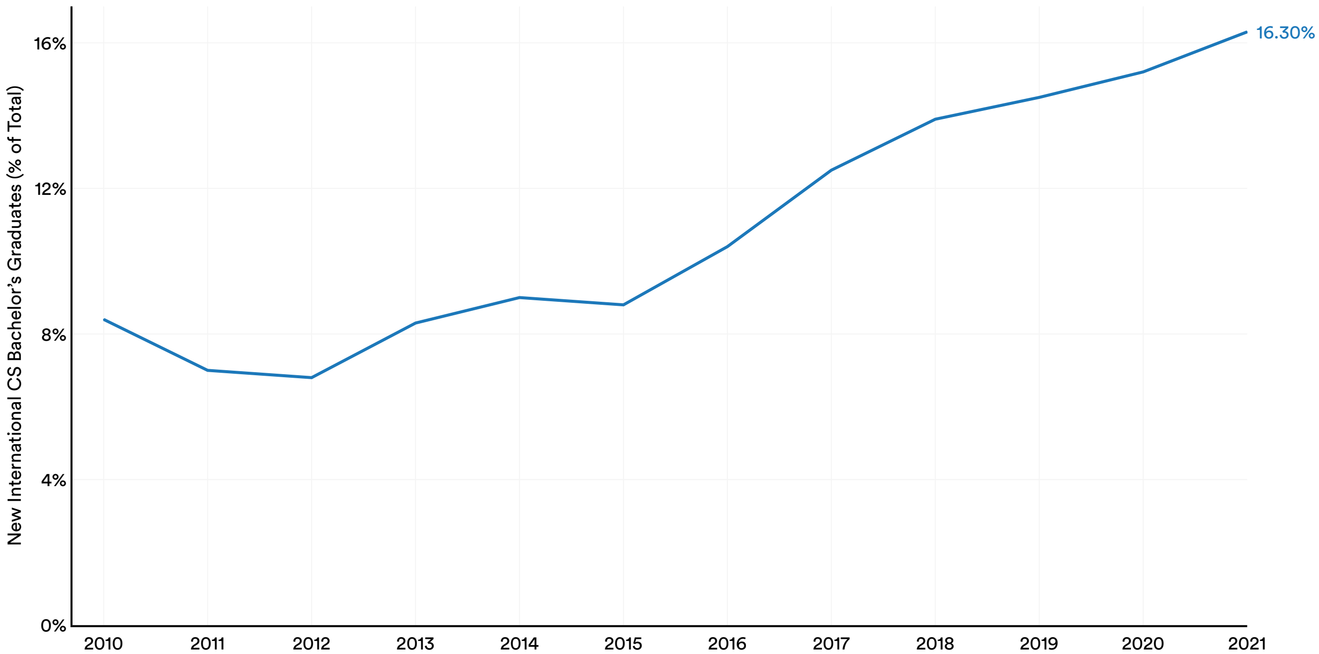

Figure 5.1.2

CS Master's Graduates

AI courses are also commonly offered in CS master's degree programs. Figure 5.1.3 shows the total number of new CS master's graduates in North America since 2010. In 2021 there were roughly twice as many master's graduates as in 2012. However, from 2018 to 2021 the total number of new master's graduates plateaued, declining slightly from 15,532 to 15,068.

New CS Master's Graduates in North America, 2010–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

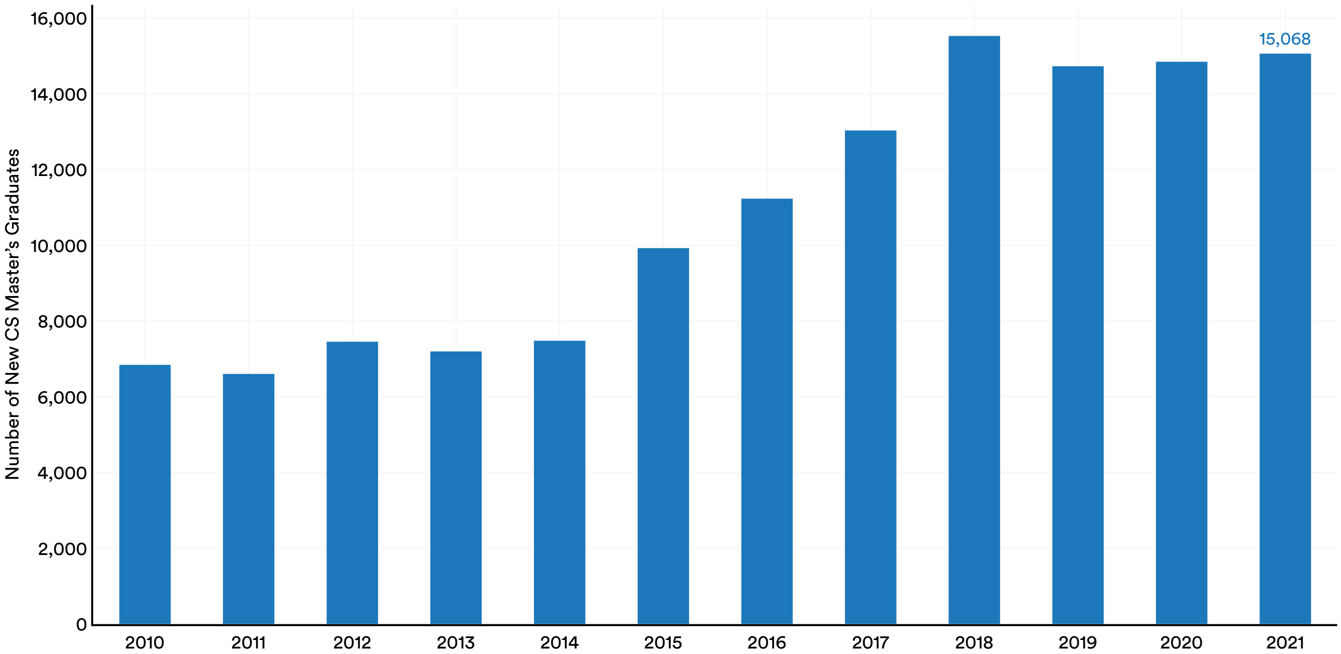

Figure 5.1.3

Interestingly, the number of CS master's students at North American universities who are international started declining in 2016 after rising in the early 2010s (Figure 5.1.4). Despite the decline, in 2021 the majority of CS master's graduates remained international (65.2%).

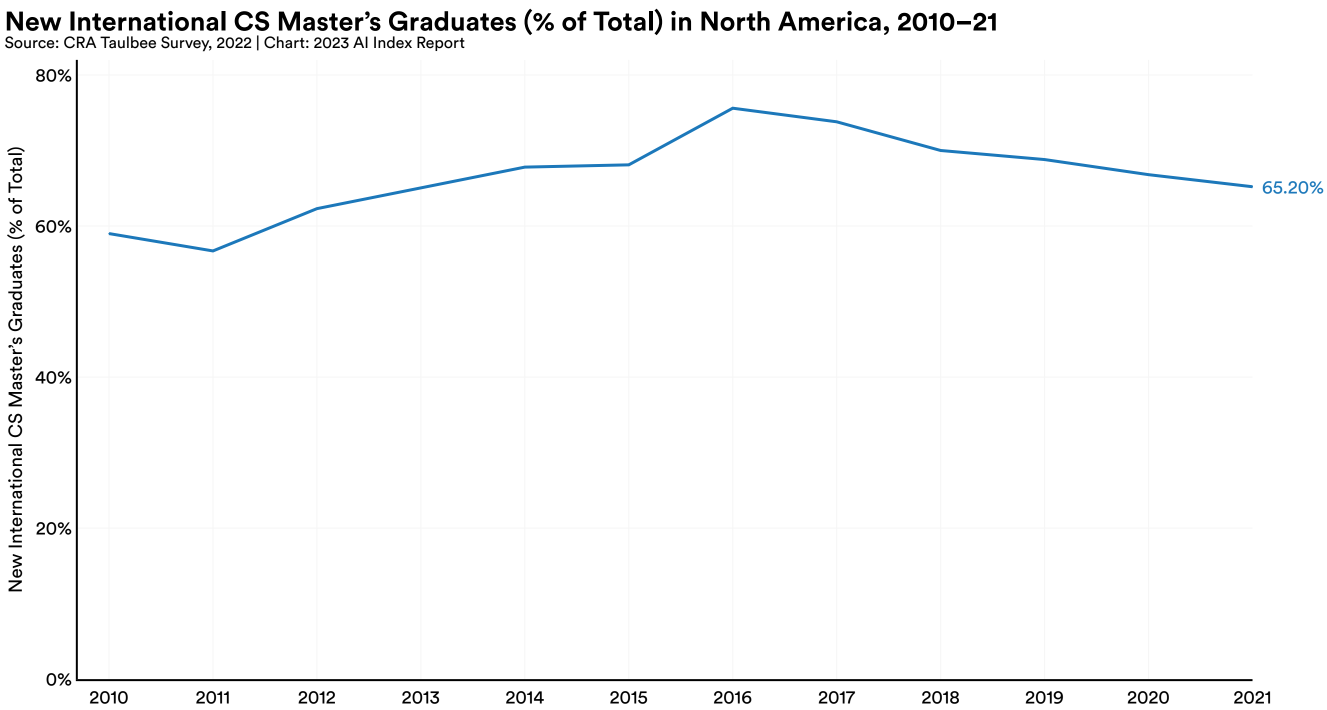

Figure 5.1.4

CS PhD Graduates

Unlike the trends in bachelor's and master's CS graduates, since 2010 there have not been large increases in the number of new PhD graduates in computer science (Figure 5.1.5). There were fewer CS PhD graduates in 2021 (1,893) than in 2020 (1,997) and 2012 (1,929).

New CS PhD Graduates in North America, 2010–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

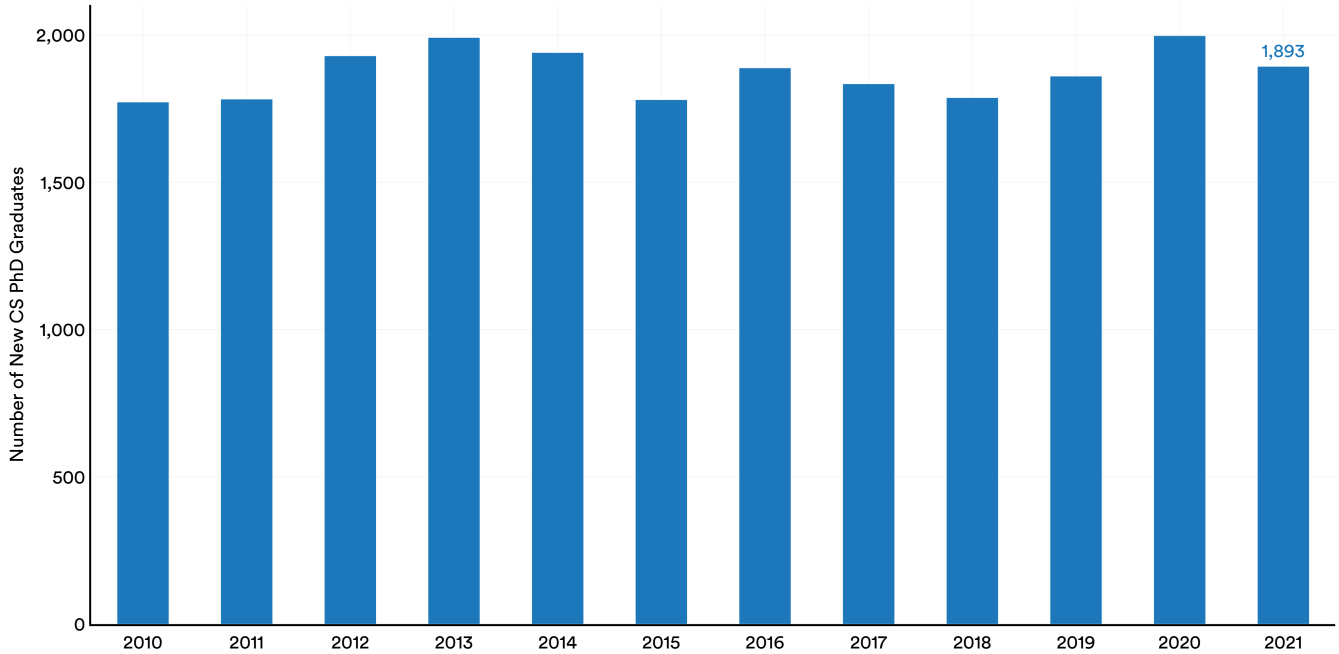

Figure 5.1.5

CS PhD graduates in North American universities are becoming increasingly international (Figure 5.1.6). In 2010, 45.8% of CS PhD graduates were international students; the proportion rose to 68.6% in 2021.

New International CS PhD Graduates (% of Total) in North America, 2010–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

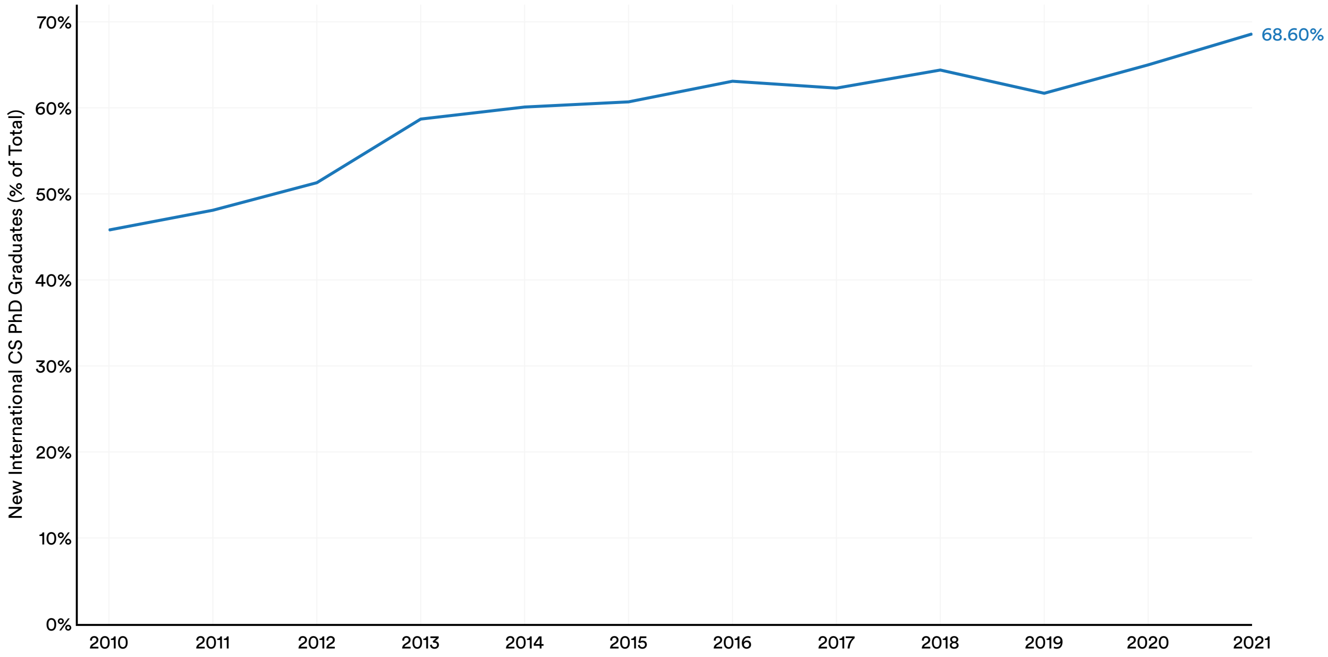

Figure 5.1.6

Moreover, now a significantly larger proportion of new CS PhD students are specializing in AI (Figure 5.1.7). In 2021, 19.1% of new CS PhD students in North American institutions specialized in AI, a 4.2 percentage point increase since 2020 and 8.6 percentage point increase since 2012.

New CS PhD Students (% of Total) Specializing in AI, 2010–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

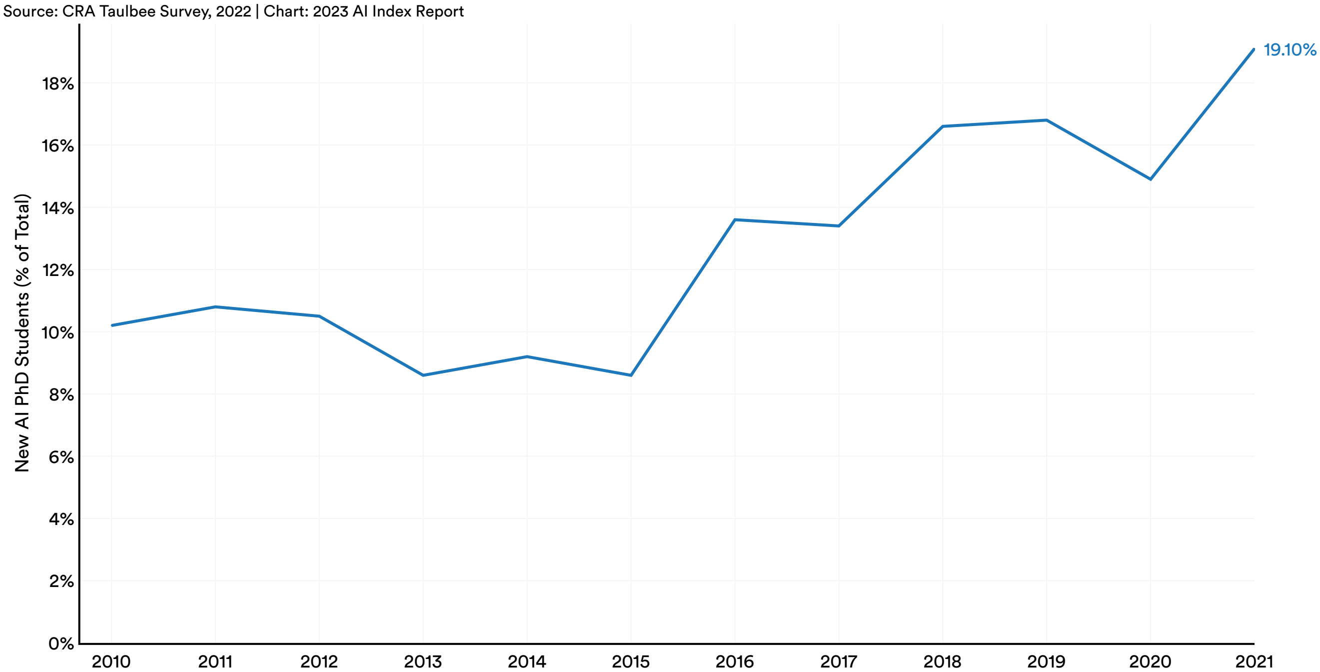

Figure 5.1.7

Where do new AI PhDs choose to work following graduation? Mirroring trends reported in last year's AI Index report, an increasingly large proportion of AI PhD graduates are heading to industry (Figures 5.1.8 and 5.1.9). In 2011, for example, roughly the same percentage of graduates took jobs in industry (40.9%) as in academia (41.6%). However, as of 2021 a significantly larger proportion of students (65.4%) went to industry after graduation than to academia (28.2%). The amount of new AI PhDs entering government was 0.7% and has remained relatively unchanged in the last half-decade.

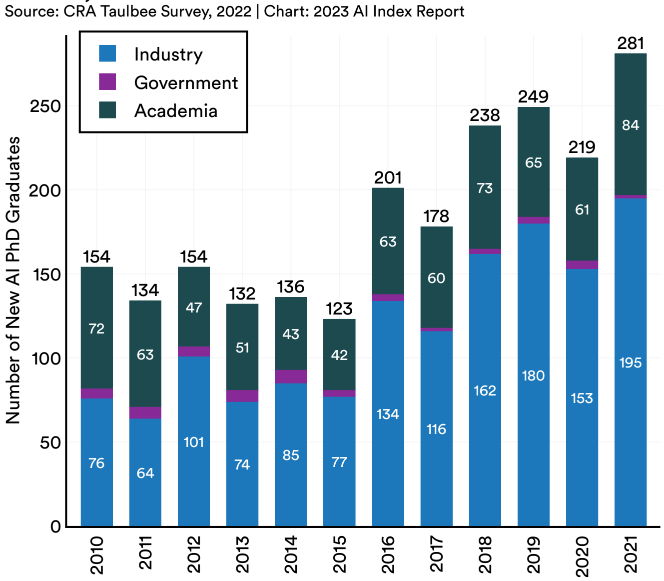

Figure 5.1.8

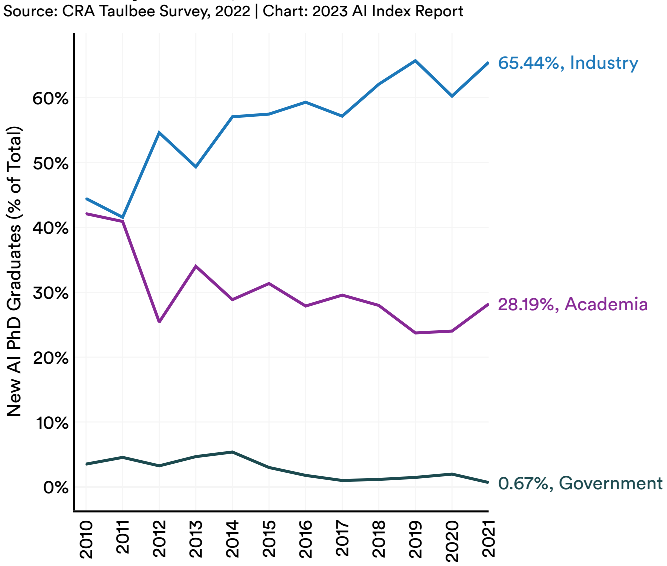

Figure 5.1.9

1 The sums in Figure 5.1.9 do not add up to 100, as there is a subset of new AI PhDs each year who become self-employed, unemployed, or report an "other" employment status in the CRA survey. These students are not included in the chart.

CS, CE, and Information Faculty

To better understand trends in AI and CS education, it is instructive to consider data on computer science faculty in addition to postsecondary students. Figure 5.1.10 highlights the total number of CS, CE (computer engineering), and information faculty in North American universities. The amount of faculty has marginally increased in the last year, by 2.2%. Since 2011 the number of CS, CE, and information faculty has grown by 32.8%.

Number of CS, CE, and Information Faculty in North America, 2011–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

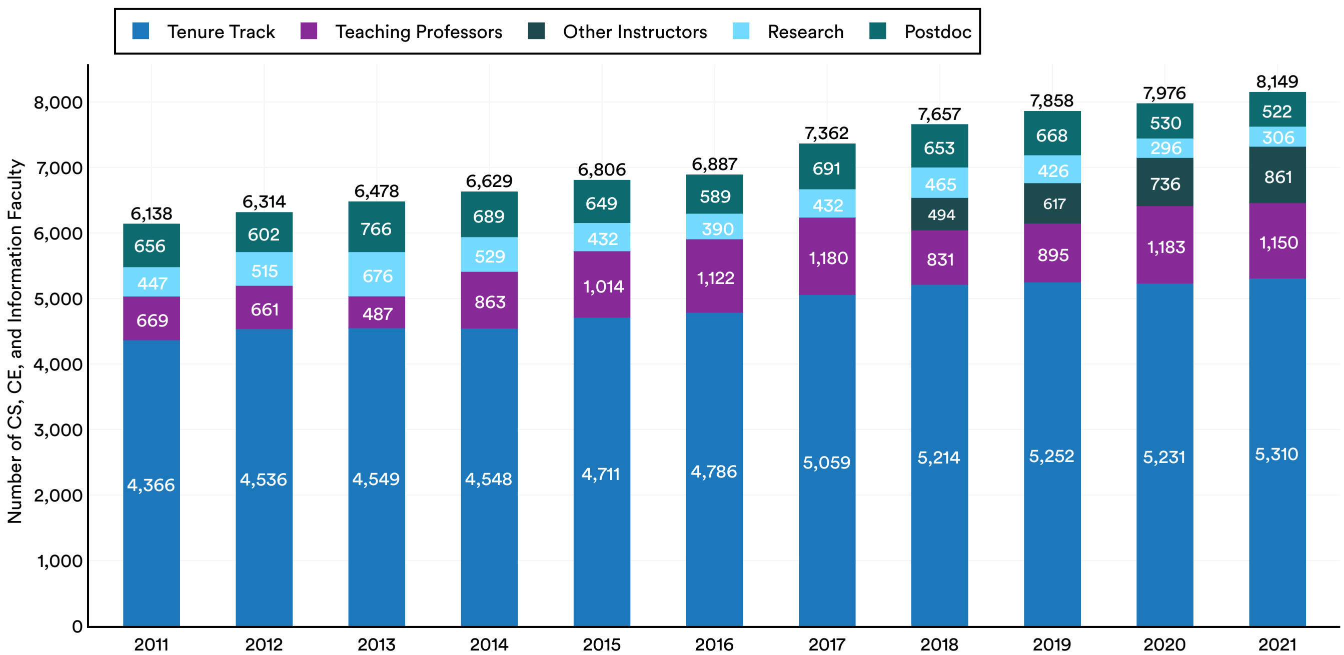

Figure 5.1.10

In 2021 there were a total of 6,789 CS faculty members in the United States (Figure 5.1.11). The total number of CS faculty in the United States increased by only 2.0% in the last year, but by 39.0% since 2011.

Number of CS Faculty in the United States, 2011–21

Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

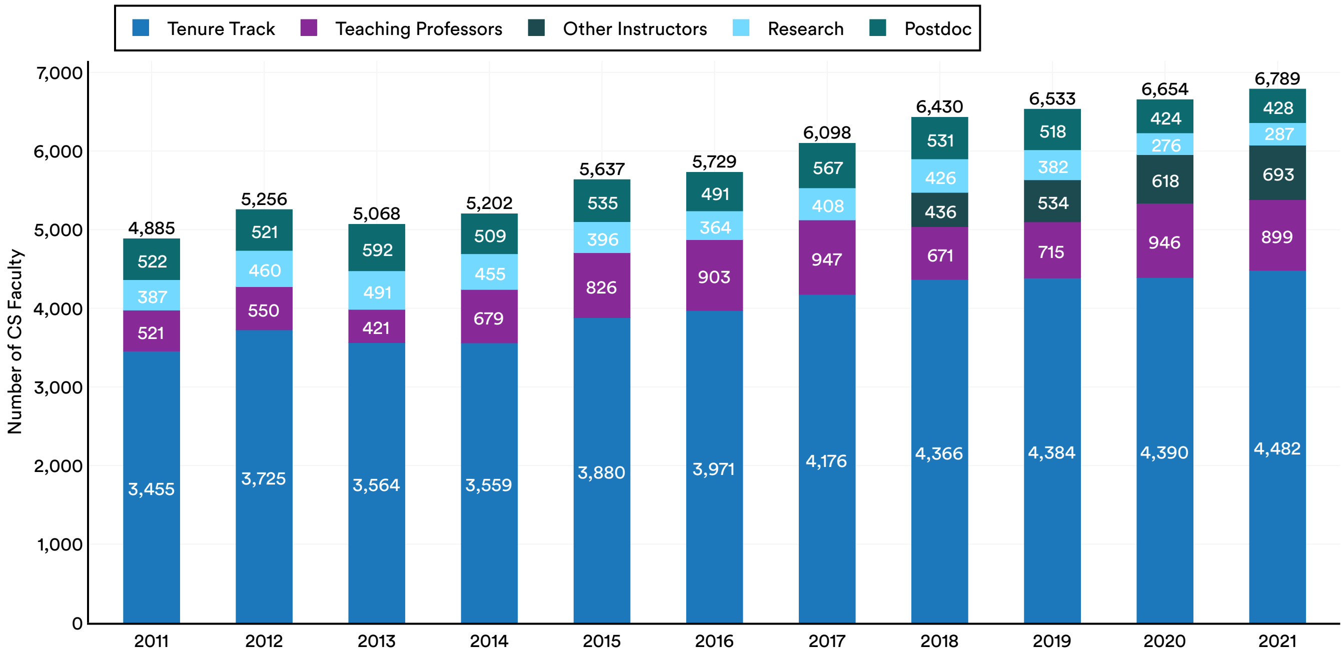

Figure 5.1.11

Figure 5.1.12 reports the total number of new CS, CE, and information faculty hires in North American universities. In the last decade, the total number of new faculty hires has decreased: There were 710 total hires in 2021, while in 2012 there were 733. Similarly, the total number of tenure-track hires peaked in 2019 at 422 and has since dropped to 324 in 2021.

New CS, CE, and Information Faculty Hires in North America, 2011–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

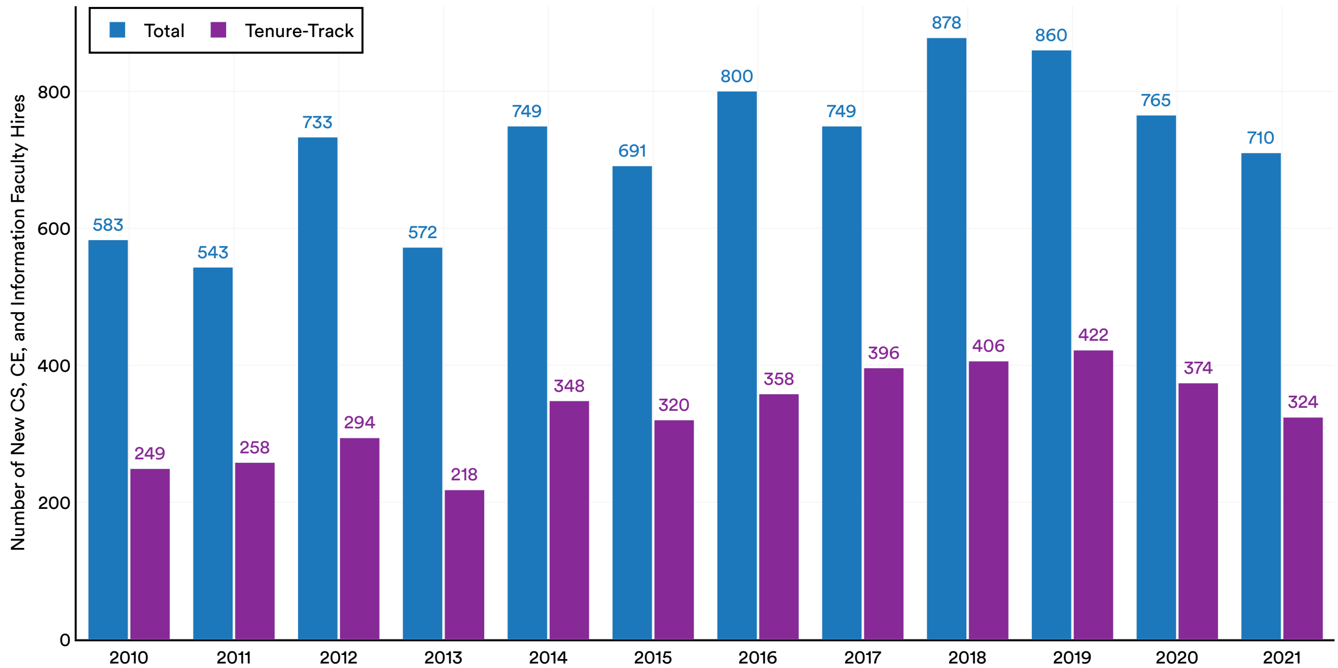

Figure 5.1.12

In 2021, the greatest percentage of new CS, CE, and information faculty hires (40%) came straight from receiving a PhD (Figure 5.1.13). Only 11% of new CS and CE faculty came from industry.

Source of New Faculty in North American CS, CE, and Information Departments, 2011–21

Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

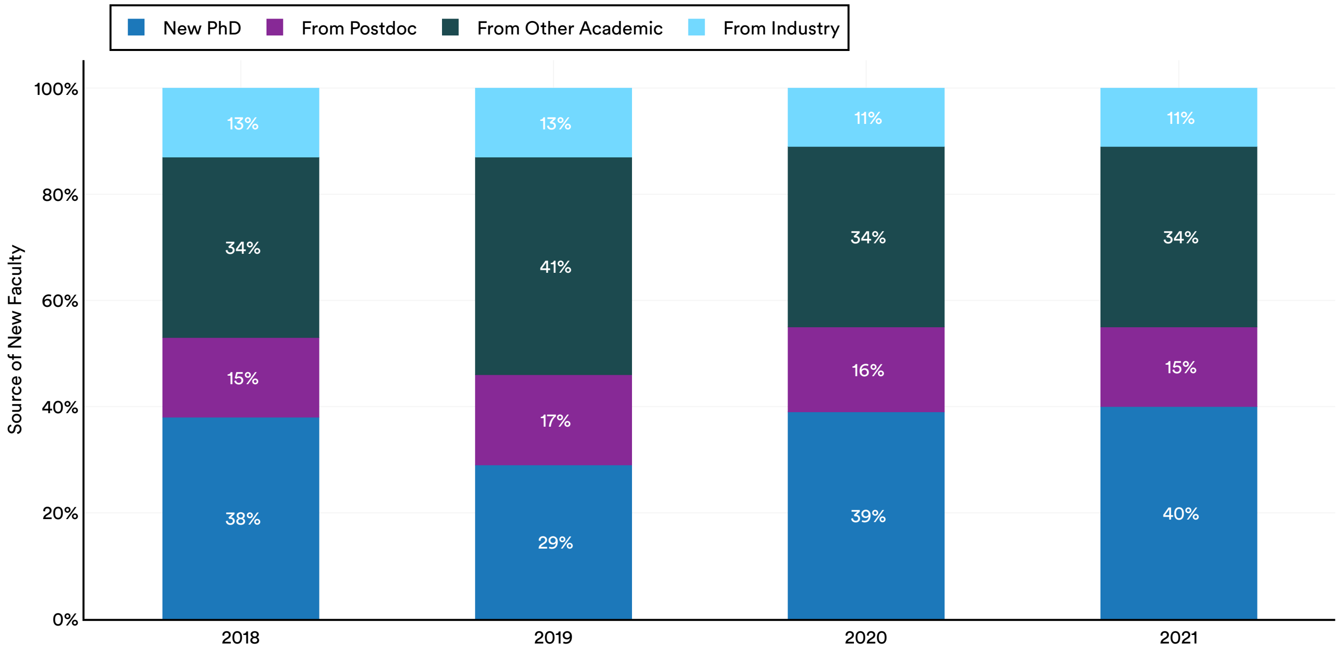

Figure 5.1.13

The share of filled new CS, CE, and information faculty positions in North American universities has remained relatively stable in the last decade (Figure 5.1.14). In 2021, 89.3% of new faculty positions were filled, compared to 82.7% in 2011.

Share of Filled New CS, CE, and Information Faculty Positions in North America, 2011–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

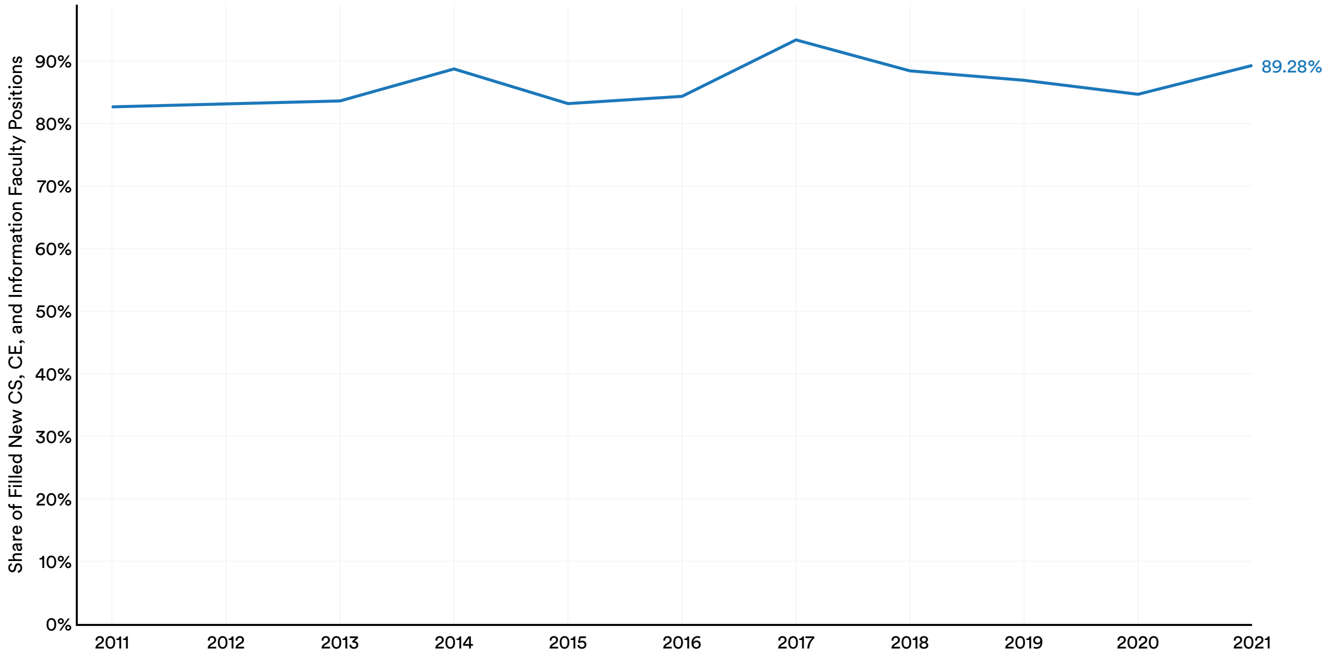

Figure 5.1.14

Among open CS, CE, and information faculty positions in 2021, the most commonly cited reason for their remaining unfilled was offers being turned down (53%) (Figure 5.1.15). In 22% of cases, hiring was still in progress, while 14% of the time, a candidate had not been identified who met the department's hiring goals.

Reason Why New CS, CE, and Information Faculty Positions Remained Unfilled (% of Total), 2011–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

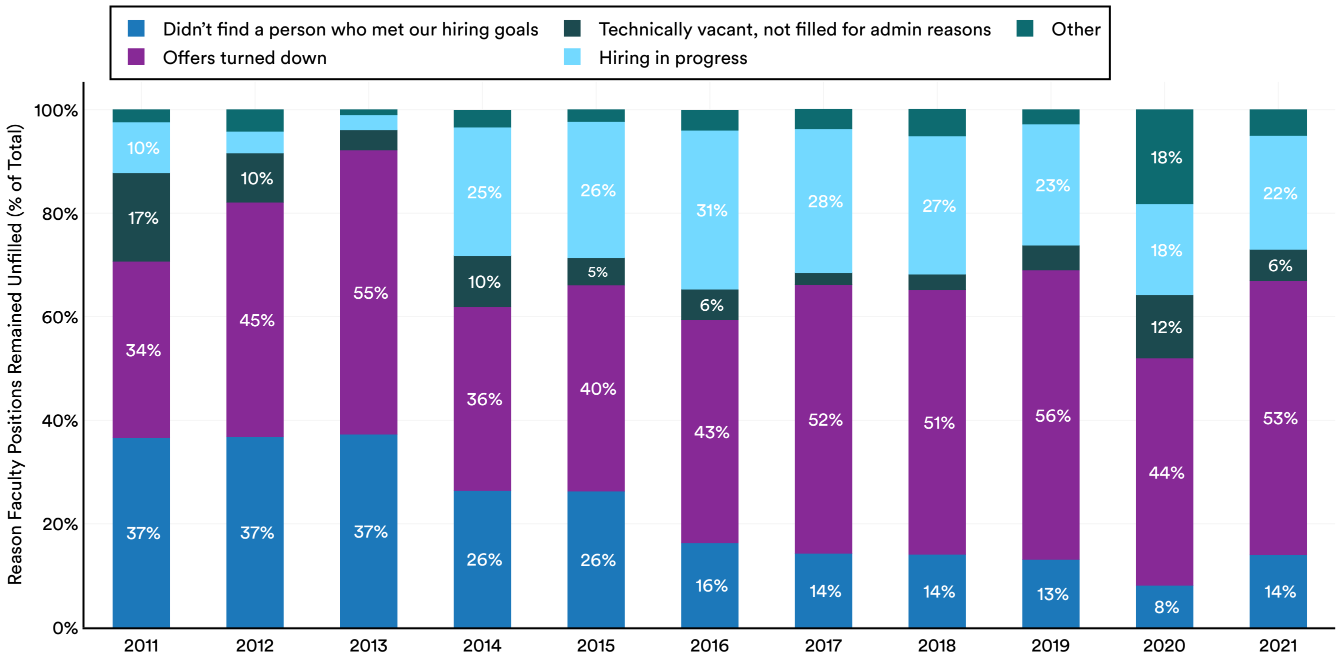

Figure 5.1.15

Figure 5.1.16 highlights the median nine-month salaries of CS faculty in the United States by position since 2015. During that period, the salaries for all classes of professors have increased. In 2021, the average full professor in computer science made 3.2% more than they did in 2020, and 12.8% more than they did in 2015. (Note: These figures have not been adjusted for inflation.)

Median Nine-Month Salary of CS Faculty in United States, 2015–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

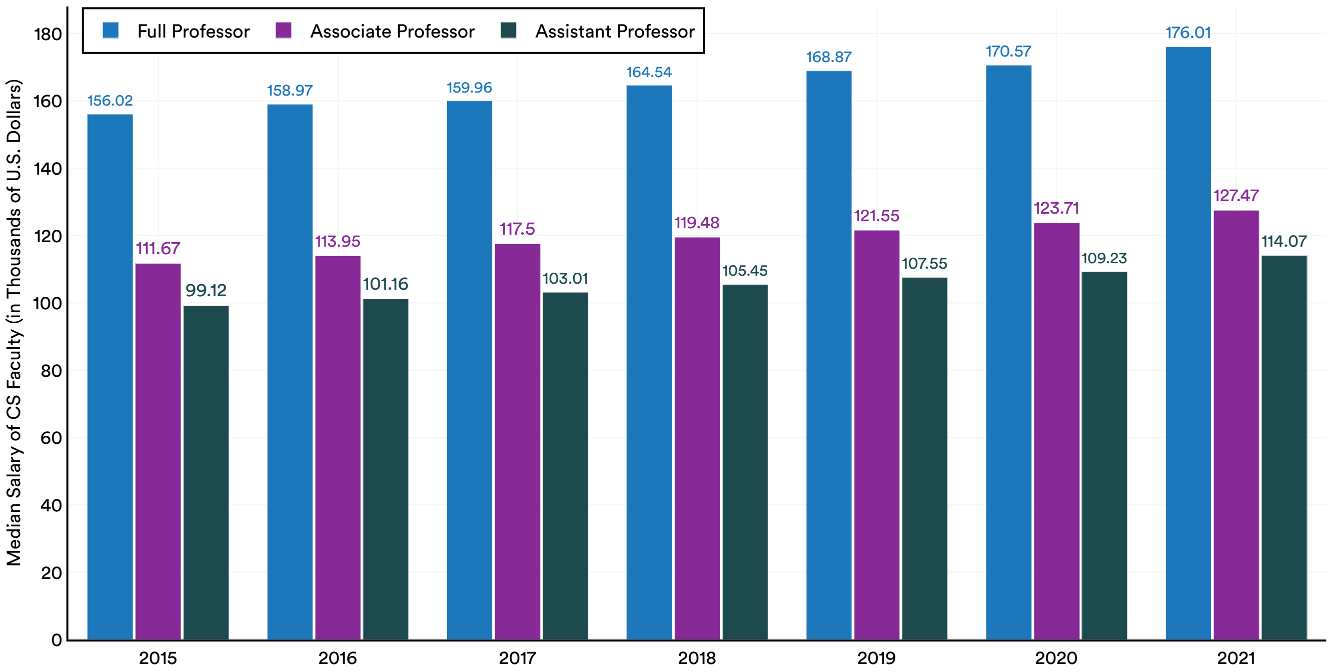

Figure 5.1.16

What proportion of new CS, CE, and information faculty tenure-track hires are international? The data suggests that it is not a substantial proportion. In 2021, only 13.2% of new CS, CE, and information faculty hires were international (Figure 5.1.17).

New International CS, CE, and Information Tenure-Track Faculty Hires (% of Total) in North America, 2010–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

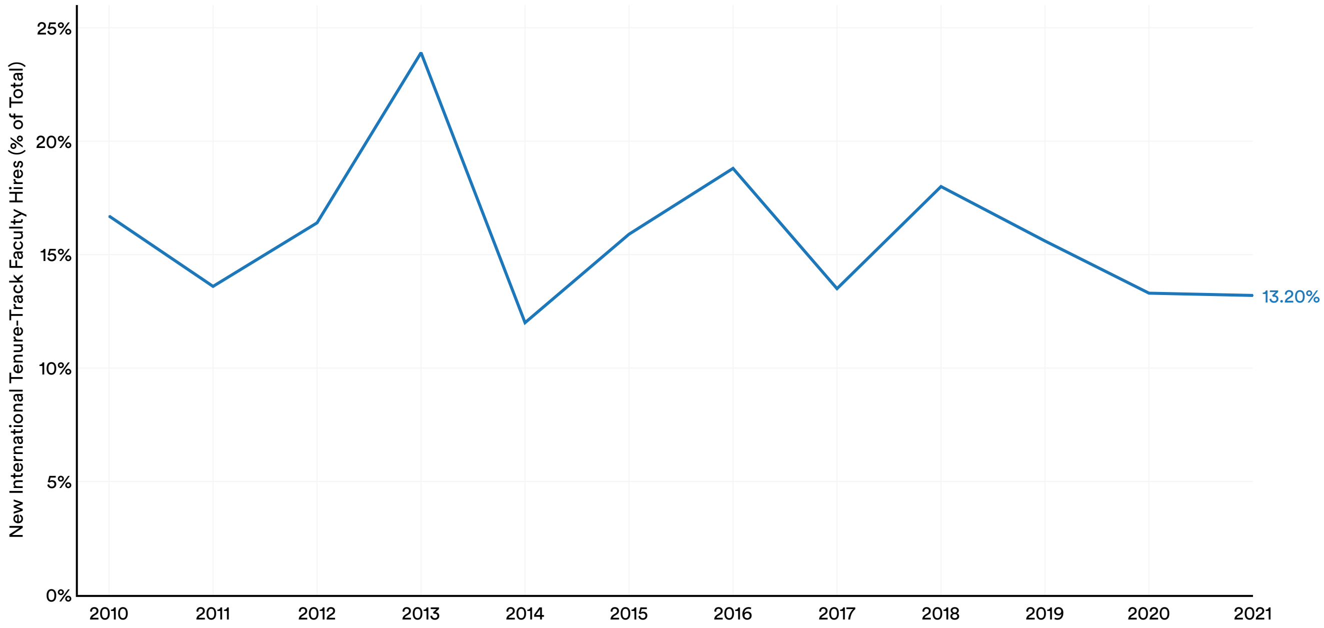

Figure 5.1.17

The majority of CS, CE, and Information faculty losses in North American departments (36.3%) were the result of faculty taking academic positions elsewhere (Figure 5.1.18). In 2021, 15.2% of faculty took nonacademic positions, which is roughly the same amount as those who took such positions a decade prior, in 2011 (15.9%).

Faculty Losses in North American CS, CE, and Information Departments, 2011–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

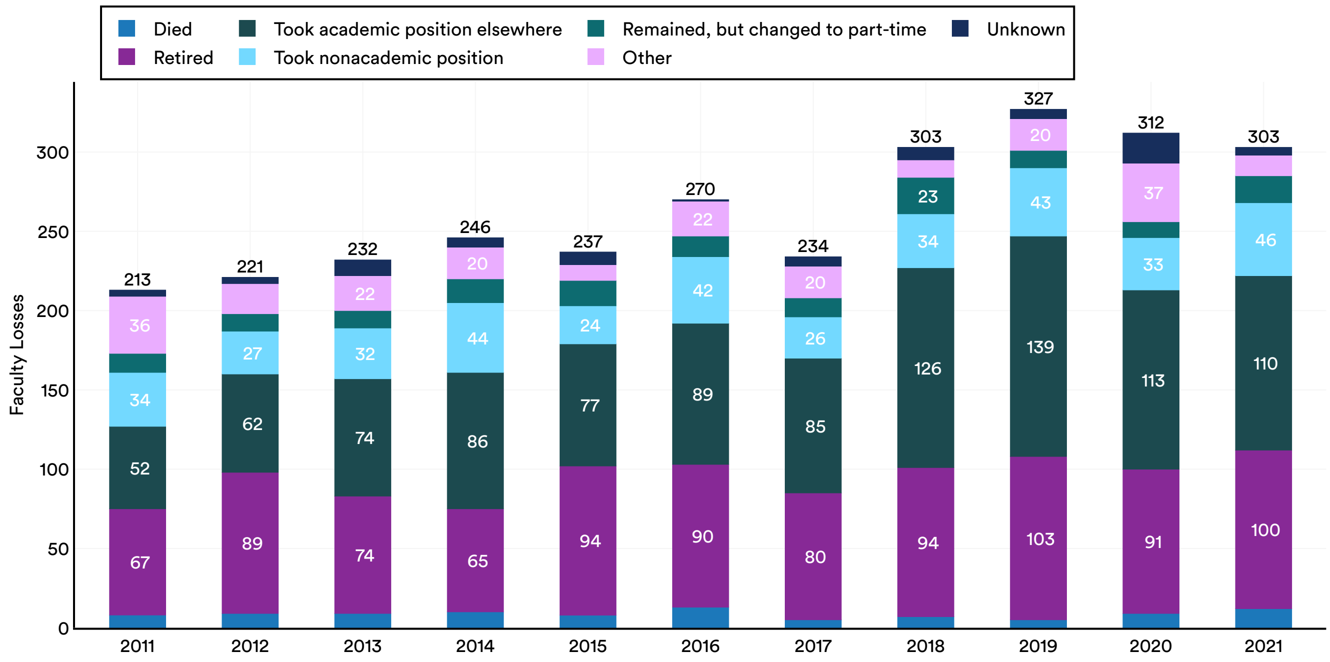

Figure 5.1.18

Narrative Highlight:

Who Funds CS Departments in the U.S.?

The CRA tracks data on the external funding sources of CS departments in the United States. The main funder of American CS departments continues to be the National Science Foundation (NSF), which in 2021 accounted for 34.9% of external funds. However, the share of funding provided by NSF has decreased since 2003 (Figure 5.1.19). In 2021, the next largest sources of funding came from defense agencies such as the Army Research Office, the Office of Naval Research, and the Air Force Research Laboratory (20.3%); industrial sources (12.1%); the Defense Advanced Research Projects Agency (DARPA) (8.8%); and the National Institutes of Health (NIH) (6.8%). The diminishing share of NSF funds over time has been partially offset by increasing funds from industry and NIH.

External Funding Sources (% of Total) of CS Departments in United States, 2003–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

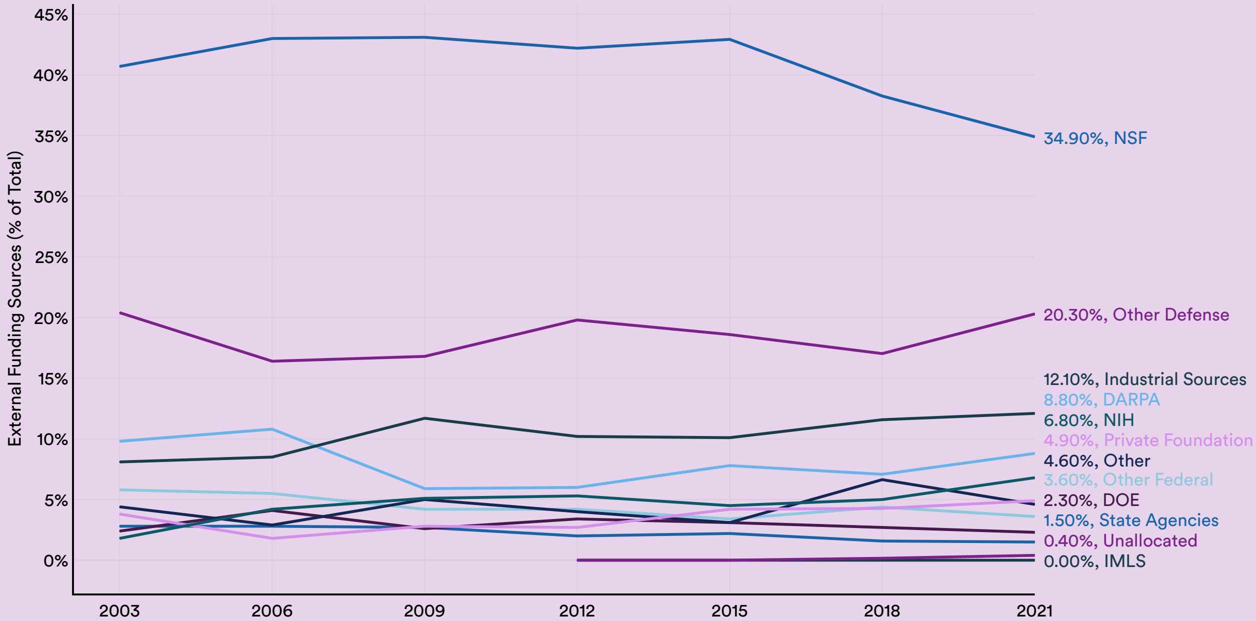

Figure 5.1.19

Narrative Highlight:
Who Funds CS Departments in the U.S.? (cont'd)

Figure 5.1.20 shows the median total expenditures from external sources for computing research in American CS departments. In 2021, the median total expenditure for private universities was $9.7 million compared with $5.7 million for public universities.

Although total median expenditures have increased over the last decade for both private and public CS departments, the gap in expenditure has widened, with private universities beginning to significantly outspend public ones.

Median Total Expenditure From External Sources for Computing Research of U.S. CS Departments, 2011–21
Source: CRA Taulbee Survey, 2022 | Chart: 2023 AI Index Report

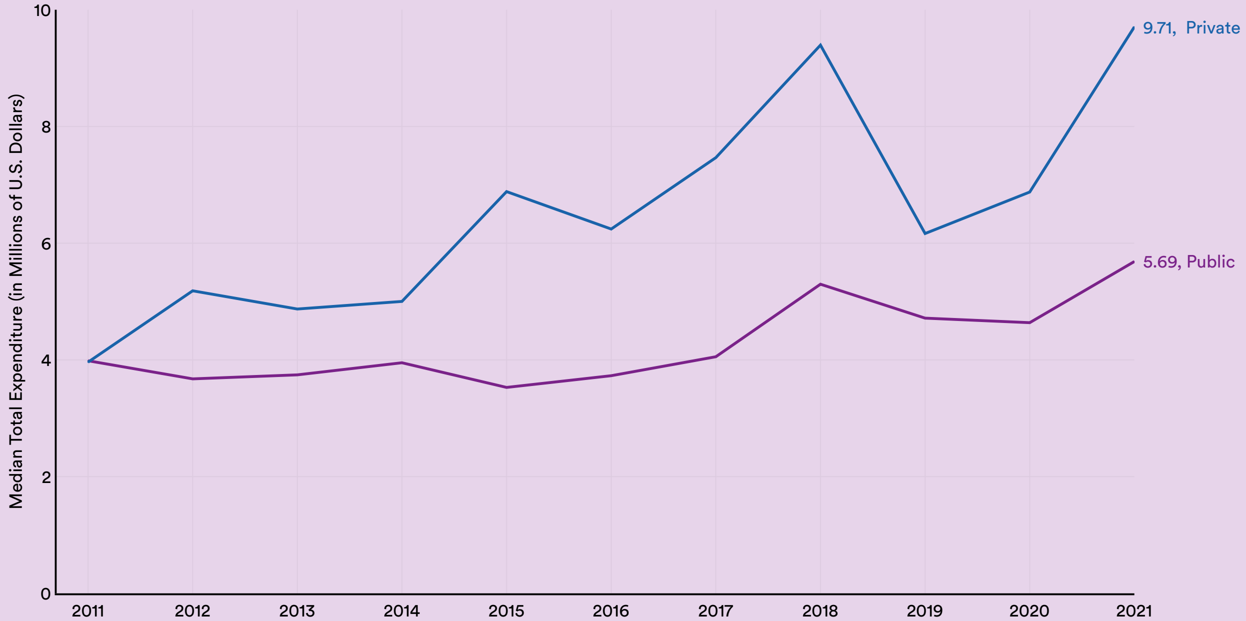

Figure 5.1.20

The following subsection shows trends in K–12 AI education based on K–12 computer science education data in the United States as well as survey data from UNESCO on the state of global K–12 AI education.

5.2 K–12 AI Education

United States

Data on the state of K–12 CS education in the United States comes from Code.org, an education innovation nonprofit dedicated to ensuring that every school includes computer science as part of its core K–12 education. Tracking trends in K–12 CS education can partially serve as a proxy for understanding the state of K–12 AI education in America

State-Level Trends

Figure 5.2.1 highlights the 27 states that in 2022 required that all high schools offer a computer science course.

Figure 5.2.2 highlights the percentage of public high schools in a state that teach computer science. The top three states in terms of rate of computer science teaching are Maryland (98%), South Carolina (93%), and Arkansas (92%).

States Requiring That All High Schools Offer a Computer Science Course, 2022
Source: Code.org, 2022 | Chart: 2023 AI Index Report

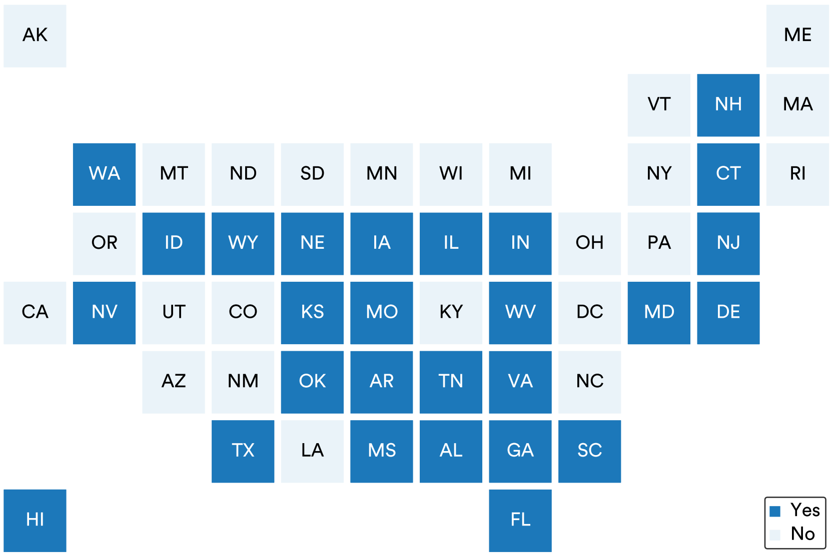

Figure 5.2.1

Public High Schools Teaching Computer Science (% of Total in State), 2022
Source: Code.org, 2022 | Chart: 2023 AI Index Report

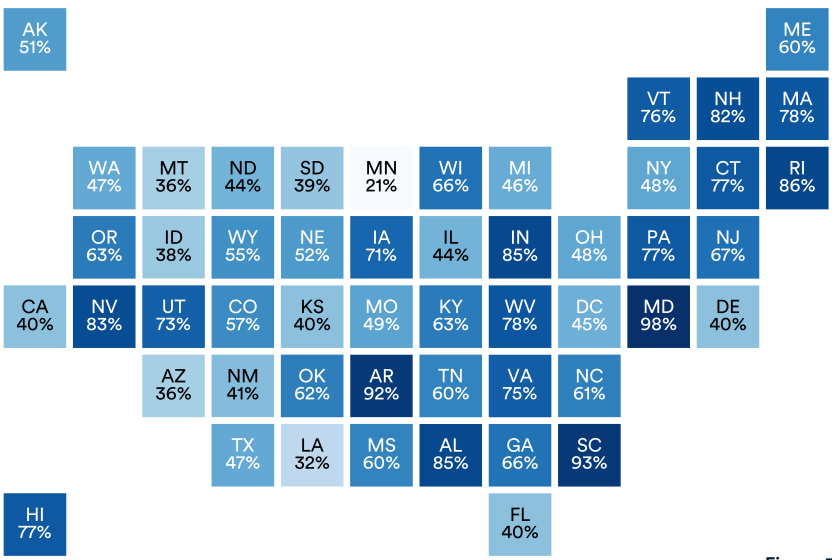

Figure 5.2.2

AP Computer Science

Another barometer for tracking the state of K–12 CS education in the United States is analyzing trends in the total number of AP computer science exams taken.[2]

Year over year the total number of AP computer science exams continued to increase. In 2021, the most recent year for which there is data, there were a total of 181,040 AP computer science exams taken, roughly the same number as the previous year, after several years of significant increases. This leveling could be the result of the pandemic. Since 2007, the number of AP computer science exams has increased over ninefold.

Number of AP Computer Science Exams Taken, 2007–21
Source: Code.org, 2022 | Chart: 2023 AI Index Report

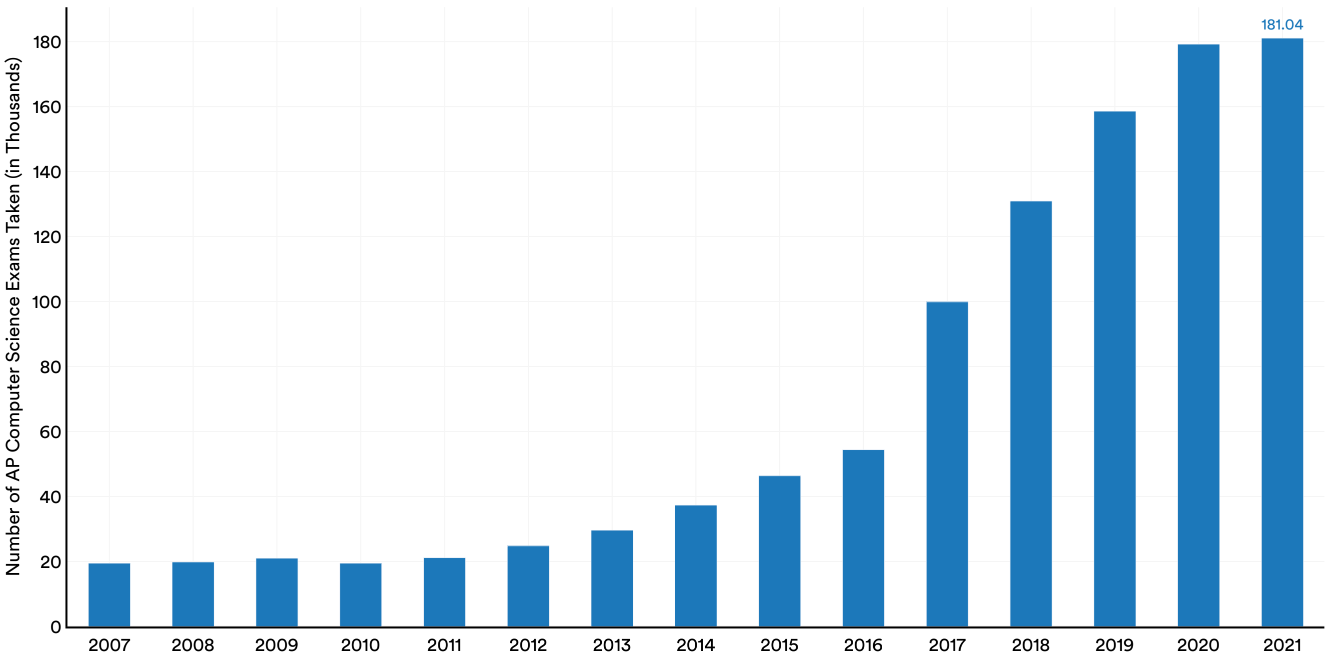

Figure 5.2.3

2 There are two types of AP CS exams: Computer Science A and Computer Science Principles. Data on computer science exams taken includes both exams. AP CS Principles was initially offered in 2017.

In 2021, the states which saw the greatest number of AP computer science exams taken were California (31,189), followed by Texas (17,307), Florida (14,864), New York (13,304), and New Jersey (9,391) (Figure 5.2.4).

Figure 5.2.5 looks at the number of AP CS exams taken per capita.[3] The state with the largest per capita amount of AP computer science exams taken in 2021 was Maryland, with 124.1 exams per 100,000 inhabitants. The next states were New Jersey (101.3), Connecticut (89.7), California (79.7), and Massachusetts (78.0).

Number of AP Computer Science Exams Taken, 2021

Source: Code.org, 2022 | Chart: 2023 AI Index Report

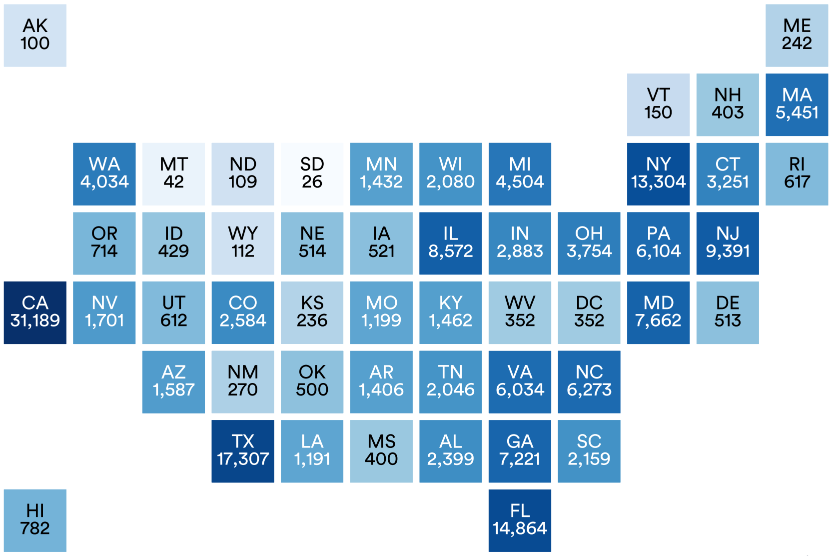

Figure 5.2.4

Number of AP Computer Science Exams Taken per 100,000 Inhabitants, 2021

Source: Code.org, 2022 | Chart: 2023 AI Index Report

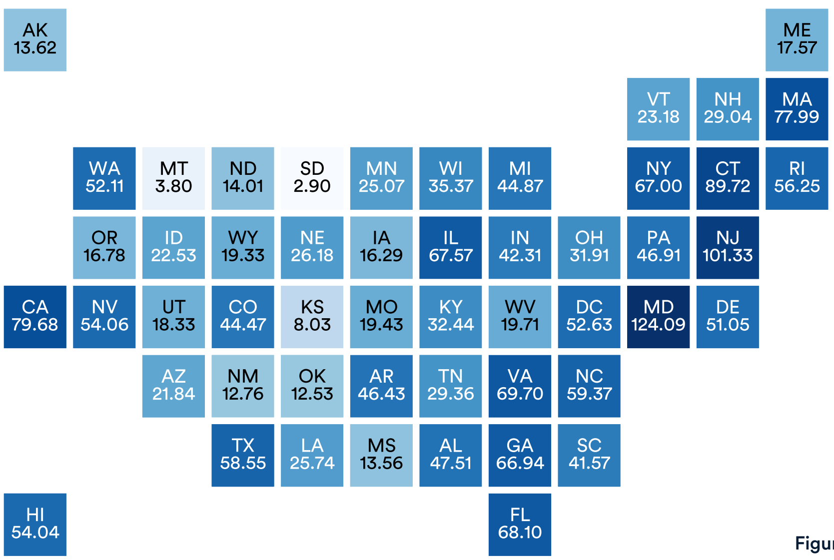

Figure 5.2.5

3 More specifically, Figure 5.2.5 normalizes the number of AP CS exams taken—the total number of exams taken in a particular state in 2021 is divided by the state's population based on the 2021 U.S. Census.

Narrative Highlight:

The State of International K–12 Education

In 2021, UNESCO released one of the most comprehensive reports to date on the international state of government-endorsed AI curricula. To gather information, UNESCO released two surveys: the first to representatives of 193 UNESCO member states and the second to over 10,000 private- and third-sector actors. As part of these surveys, respondents were asked to report on the status of AI curricula for students in K–12 general education.

Figure 5.2.6, taken from the UNESCO report, highlights the governments that have taken steps to implement AI curricula and across which levels of education. For example, Germany is in the process of developing government-endorsed AI curricular standards on the primary, middle, and high-school levels, and the Chinese government has already endorsed and implemented standards across those same three levels.

Government Implementation of AI Curricula by Country, Status, and Education Level
Source: UNESCO, 2022 | Table: 2023 AI Index Report

Country	Status	Primary School	Middle School	High School
Armenia	Endorsed and Implemented		✓	✓
Austria	Endorsed and Implemented			✓
Belgium	Endorsed and Implemented			✓
China	Endorsed and Implemented	✓	✓	✓
India	Endorsed and Implemented		✓	✓
Kuwait	Endorsed and Implemented	✓	✓	
Portugal	Endorsed and Implemented	✓	✓	✓
Qatar	Endorsed and Implemented	✓	✓	✓
Serbia	Endorsed and Implemented		✓	✓
South Korea	Endorsed and Implemented			✓
United Arab Emirates	Endorsed and Implemented	✓	✓	✓
Bulgaria	In Development	✓	✓	✓
Germany	In Development	✓	✓	✓
Jordan	In Development		✓	✓
Saudia Arabia	In Development	✓	✓	✓
Serbia	In Development		✓	✓

Figure 5.2.6[4]

4 According to the UNESCO report, Serbia has already endorsed and implemented certain kinds of K–12 AI curricula, but is also simultaneously in the process of developing others—thus it is listed under both categories.

Narrative Highlight:

The State of International K–12 Education (cont'd)

Figure 5.2.7 identifies the topic areas most emphasized in the K–12 AI curricula profiled in the UNESCO report. The four topics toward which the most time was allocated were algorithms and programming (18%), AI technologies (14%), data literacy (12%), and application of AI to other domains (12%).

Time Allocated (% of Total) in K–12 AI Curricula by Topic, 2022
Source: UNESCO, 2022 | Chart: 2023 AI Index Report

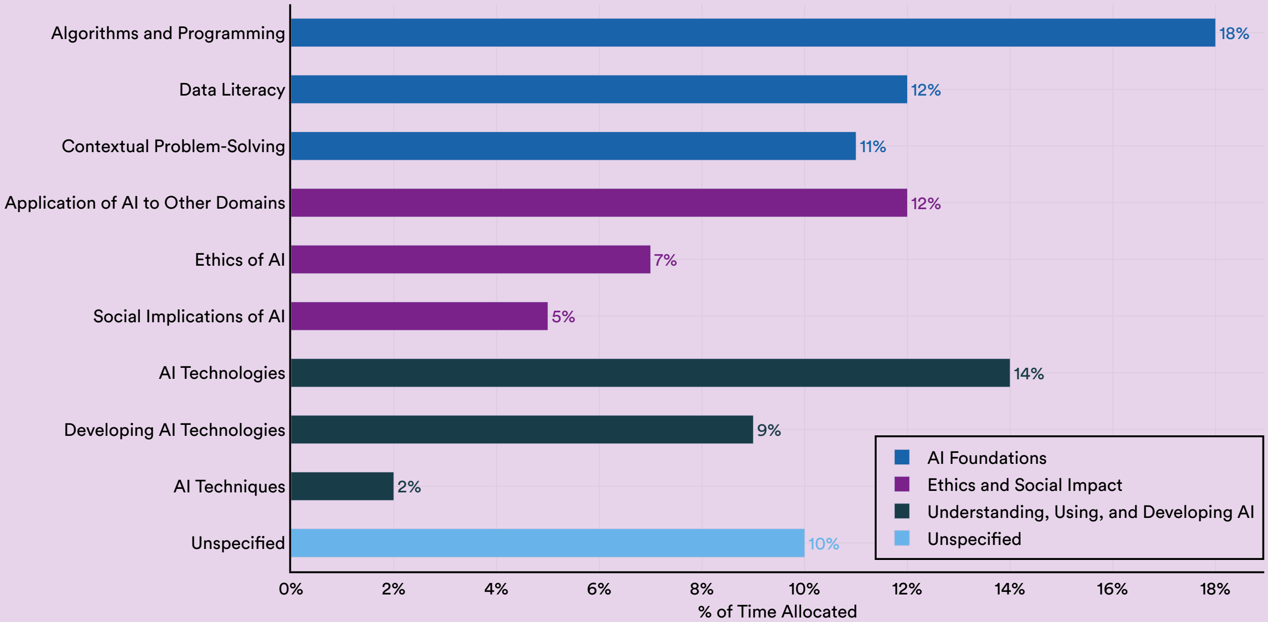

Figure 5.2.7

Narrative Highlight:

The State of International K–12 Education (cont'd)

What might an actual K–12 AI curriculum look like in practice? The UNESCO report includes detailed information about a sample curriculum that was deployed in Austria, the Austrian Data Science and Artificial Intelligence curriculum. As noted in the report:

"The Austrian Data Science and Artificial Intelligence curriculum includes digital basics such as using an operating system to store and print files, design presentations, and use spreadsheets and word-processing software. It also covers design and reflection on types and social issues in digital media, and safe digital media use. Students in high school engage programming languages, algorithms and simulations. They learn the basic principles of data literacy, including collecting data, structuring a spreadsheet, and carrying out analyses and visualizations. They apply criteria to evaluate the credibility and reliability of data sources as well as digital content. Students are expected to know about careers in ICT, including AI, and the social applications of emerging technologies. They create digital media and learn about the cloud and how to connect and network computers. They also gain an understanding of the ethical dilemmas that are associated with the use of such technologies, and become active participants in social discourse on these issues. Finally, students are tasked with using technology to make public statements and understand how this reflects the democratic process."

"They also gain an understanding of the ethical dilemmas that are associated with the use of such technologies, and become active participants in social discourse on these issues."

Appendix

Computing Research Association (CRA Taulbee Survey)

Note: This year's AI Index reused the methodological notes that were submitted by the CRA for previous editions of the AI Index. For more complete delineations of the methodology used by the CRA, please consult the individual CRA surveys that are linked below.

Computing Research Association (CRA) members are 200-plus North American organizations active in computing research: academic departments of computer science and computer engineering; laboratories and centers in industry, government, and academia; and affiliated professional societies (AAAI, ACM, CACS/AIC, IEEE Computer Society, SIAM USENIX). CRA's mission is to enhance innovation by joining with industry, government, and academia to strengthen research and advanced education in computing. Learn more about CRA here.

The CRA Taulbee Survey gathers survey data during the fall of each academic year by reaching out to over 200 PhD-granting departments. Details about the Taulbee Survey can be found here. Taulbee doesn't directly survey the students. The department identifies each new PhD's area of specialization as well as their type of employment. Data is collected from September to January of each academic year for PhDs awarded in the previous academic year. Results are published in May after data collection closes.

The CRA Taulbee Survey is sent only to doctoral departments of computer science, computer engineering, and information science/systems. Historically, (a) Taulbee covers one-quarter to one-third of total BS CS recipients in the United States; (b) the percent of women earning bachelor's degrees is lower in the Taulbee schools than overall; and (c) Taulbee tracks the trends in overall CS production.

The AI Index used data from the following iterations of the CRA survey:

CRA, 2021

CRA, 2020

CRA, 2019

CRA, 2018

CRA, 2017

CRA, 2016

CRA, 2015

CRA, 2014

CRA, 2013

CRA, 2012

CRA, 2011

Code.org

State Level Data

The following link includes a full description of the methodology used by Code.org to collect its data. The staff at Code.org also maintains a database of the state of American K–12 education and, in this policy primer, provides a greater amount of detail on the state of American K–12 education in each state.

AP Computer Science Data

The AP computer science data is provided to Code.org as per an agreement the College Board maintains with Code.org. The AP Computer Science data comes from the college board's national and state summary reports.

The State of International K–12 Education

Data on the state of international K–12 AI education was taken from the following UNESCO report, published in 2021. The methodology is outlined in greater detail on pages 18 to 20 in the report and, for the sake of brevity, is not completely reproduced in the 2023 AI index.