



# CHAPTER 4: AI Education



Artificial Intelligence  
Index Report 2021



## CHAPTER 4: Chapter Preview

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# Overview

As AI has become a more significant driver of economic activity, there has been increased interest from people who want to understand it and gain the necessary qualifications to work in the field. At the same time, rising AI demands from industry are tempting more professors to leave academia for the private sector. This chapter focuses on trends in the skills and training of AI talent through various education platforms and institutions.

What follows is an examination of data from an AI Index survey on the state of AI education in higher education institutions, along with a discussion on computer science (CS) undergraduate graduates and PhD graduates who specialized in AI-related disciplines, based on the annual Computing Research Association (CRA) Taulbee Survey. The final section explores trends in AI education in Europe, drawing on statistics from the Joint Research Centre (JRC) at the European Commission.



## CHAPTER HIGHLIGHTS

- An AI Index survey conducted in 2020 suggests that the world's top universities have increased their investment in AI education over the past four years. The number of courses that teach students the skills necessary to build or deploy a practical AI model on the undergraduate and graduate levels has increased by 102.9% and 41.7%, respectively, in the last four academic years.
- More AI PhD graduates in North America chose to work in industry in the past 10 years, while fewer opted for jobs in academia, according to an annual survey from the Computing Research Association (CRA). The share of new AI PhDs who chose industry jobs increased by 48% in the past decade, from 44.4% in 2010 to 65.7% in 2019. By contrast, the share of new AI PhDs entering academia dropped by 44%, from 42.1% in 2010 to 23.7% in 2019.
- In the last 10 years, AI-related PhDs have gone from 14.2% of the total of CS PhDs granted in the United States, to around 23% as of 2019, according to the CRA survey. At the same time, other previously popular CS PhDs have declined in popularity, including networking, software engineering, and programming languages. Compilers all saw a reduction in PhDs granted relative to 2010, while AI and Robotics/Vision specializations saw a substantial increase.
- After a two-year increase, the number of AI faculty departures from universities to industry jobs in North America dropped from 42 in 2018 to 33 in 2019 (28 of these are tenured faculty and five are untenured). Carnegie Mellon University had the largest number of AI faculty departures between 2004 and 2019 (16), followed by the Georgia Institute of Technology (14) and University of Washington (12).
- The percentage of international students among new AI PhDs in North America continued to rise in 2019, to 64.3%—a 4.3% increase from 2018. Among foreign graduates, 81.8% stayed in the United States and 8.6% have taken jobs outside the United States.
- In the European Union, the vast majority of specialized AI academic offerings are taught at the master's level; robotics and automation is by far the most frequently taught course in the specialized bachelor's and master's programs, while machine learning (ML) dominates in the specialized short courses.

# 4.1 STATE OF AI EDUCATION IN HIGHER EDUCATION INSTITUTIONS

In 2020, AI Index developed a survey that asked computer science departments or schools of computing and informatics at top-ranking universities around the world and in emerging economies about four aspects of their AI education: undergraduate program offerings, graduate program offerings, offerings on AI ethics, and faculty expertise and diversity. The survey was completed by 18 universities from nine countries.<sup>1</sup> Results from the AI Index survey indicate that universities have increased both the number of AI courses they offer that teach students how to build and deploy a practical AI model and the number of AI-focused faculty.

## UNDERGRADUATE AI COURSE OFFERINGS

Course offerings at the undergraduate level were examined by evaluating trends in courses that teach students the skills necessary to build or deploy a practical AI model, intro-level AI and ML courses, and enrollment statistics.

### Undergraduate Courses That Teach AI Skills

The survey results suggest that CS departments have invested heavily in practical AI courses in the past four academic years (AY).<sup>2</sup> The number of

### NUMBER of UNDERGRADUATE COURSES THAT TEACH STUDENTS the SKILLS NECESSARY to BUILD or DEPLOY a PRACTICAL AI MODEL, AY 2016-20

Source: AI Index, 2020 | Chart: 2021 AI Index Report

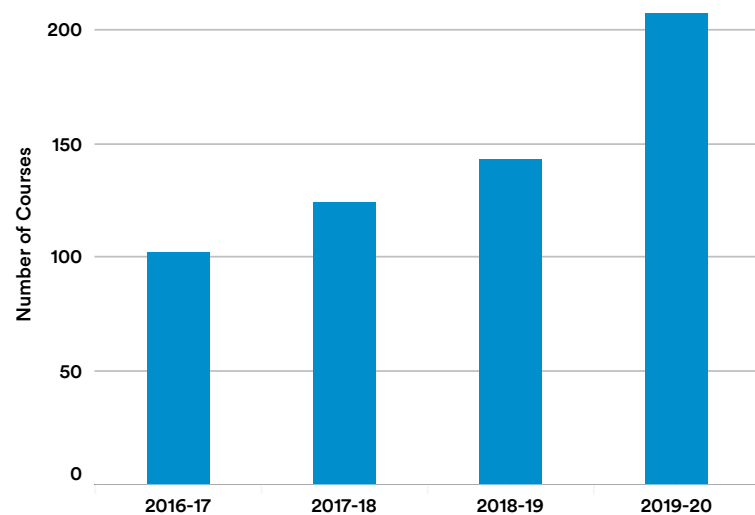


Figure 4.1.1

courses on offer that teach students the skills necessary to build or deploy a practical AI model has increased by 102.9%, from 102 in AY 2016–17 to 207 in AY 2019–20, across 18 universities (Figure 4.1.1).

### Intro-Level AI and ML Courses

The data shows that the number of students who enrolled in or attempted to enroll in an Introduction to Artificial Intelligence course and Introduction to Machine Learning course has jumped by almost 60% in the past four academic years (Figure 4.1.2).<sup>3</sup>

The slight drop in enrollment in the intro-level AI and ML courses in AY 2019–20 is mostly driven by the decrease in the number of course offerings at U.S. universities. Intro-level course enrollment

<sup>1</sup> The survey was distributed to 73 universities online over three waves from November 2020 to January 2021 and completed by 18 universities, a 24.7% response rate. The 18 universities are—Belgium: Katholieke Universiteit Leuven; Canada: McGill University; China: Shanghai Jiao Tong University, Tsinghua University; Germany: Ludwig Maximilian University of Munich, Technical University of Munich; Russia: Higher School of Economics, Moscow Institute of Physics and Technology; Switzerland: École Polytechnique Fédérale de Lausanne; United Kingdom: University of Cambridge; United States: California Institute of Technology, Carnegie Mellon University (Department of Machine Learning), Columbia University, Harvard University, Stanford University, University of Wisconsin–Madison, University of Texas at Austin, Yale University.

<sup>2</sup> See [here](#) for a list of keywords on practical artificial intelligence models provided to the survey respondents. A course is defined as a set of classes that require a minimum of 2.5 class hours (including lecture, lab, TA hours, etc.) per week for at least 10 weeks in total. Multiple courses with the same titles and numbers count as one course.

<sup>3</sup> For universities that have a cap on course registration, the number of students who attempted to enroll in the intro-level AI and ML courses are included.

in the European Union has gradually increased by 165% in the past four academic years, while such enrollment in the United States has seen a clear dip in growth in the last academic year (Figure 4.1.3). Six of the eight U.S. universities surveyed say that the number of (attempted) enrollments for the introductory AI and ML courses has decreased within the last year. Some universities cited students taking leaves during the pandemic as the main cause of the drop; others mentioned structural changes in intro-level AI course offerings—such as creating Intro to Data Science last year—that may have driven students away from traditional intro to AI and ML courses.

**NUMBER of STUDENTS WHO ENROLLED or ATTEMPTED to ENROLL in INTRO to AI and INTRO to ML COURSES, AY 2016-20**

Source: AI Index, 2020 | Chart: 2021 AI Index Report

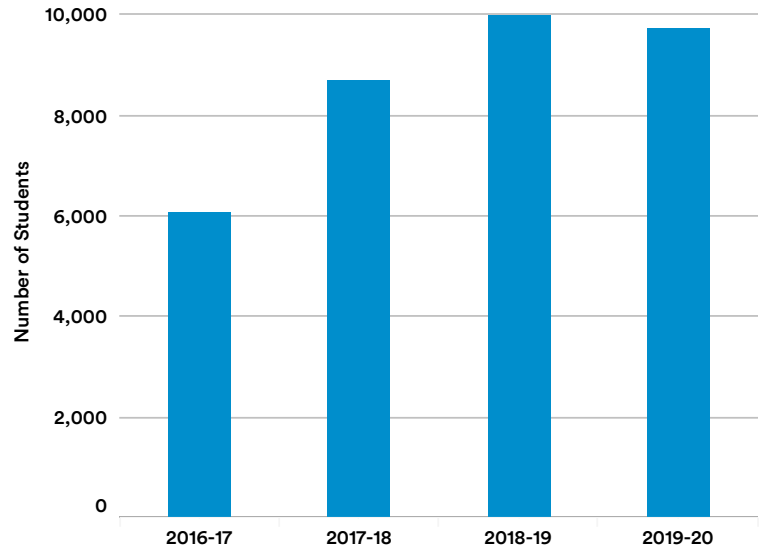


Figure 4.1.2

**PERCENTAGE CHANGE in the NUMBER of STUDENTS WHO ENROLLED or ATTEMPTED to ENROLL in INTRO to AI and INTRO to ML COURSES by GEOGRAPHIC AREA, AY 2016-20**

Source: AI Index, 2020 | Chart: 2021 AI Index Report

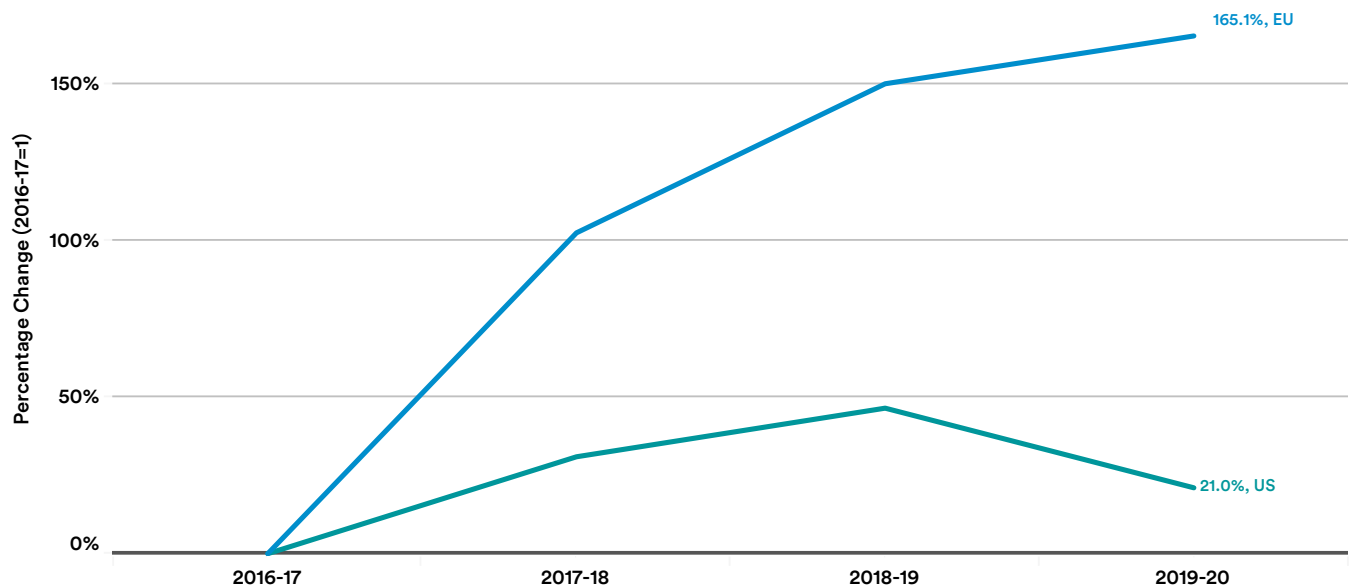


Figure 4.1.3

## GRADUATE AI COURSE OFFERINGS

The survey also looks at course offerings at the graduate or advanced degree level, specifically at graduate courses that teach students the skills necessary to build or deploy a practical AI model.<sup>4</sup>

### Graduate Courses That Focus on AI Skills

Graduate offerings that teach students the skills required to build or deploy a practical AI model increased by 41.7% in the last four academic years, from 151 courses in AY 2016–17 to 214 in AY 2019–20 (Figure 4.1.4).

## FACULTY WHO FOCUS ON AI RESEARCH

As shown in Figure 4.1.5, the number of tenure-track faculty with a primary research focus on AI at the surveyed universities grew significantly over the past four academic years, in keeping with the rising demand for AI classes and degree programs. The number of AI-focused faculty grew by 59.1%, from 105 in AY 2016–17 to 167 in AY 2019–20.

### NUMBER of GRADUATE COURSES THAT TEACH STUDENTS the SKILLS NECESSARY to BUILD or DEPLOY a PRACTICAL AI MODEL, AY 2016-20

Source: AI Index, 2020 | Chart: 2021 AI Index Report

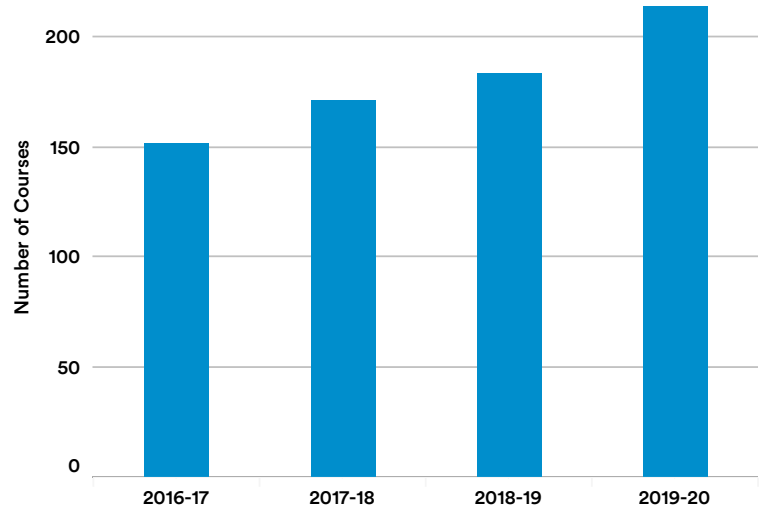


Figure 4.1.4

### NUMBER of TENURE-TRACK FACULTY WHO PRIMARILY FOCUS THEIR RESEARCH on AI, AY 2016-20

Source: AI Index, 2020 | Chart: 2021 AI Index Report

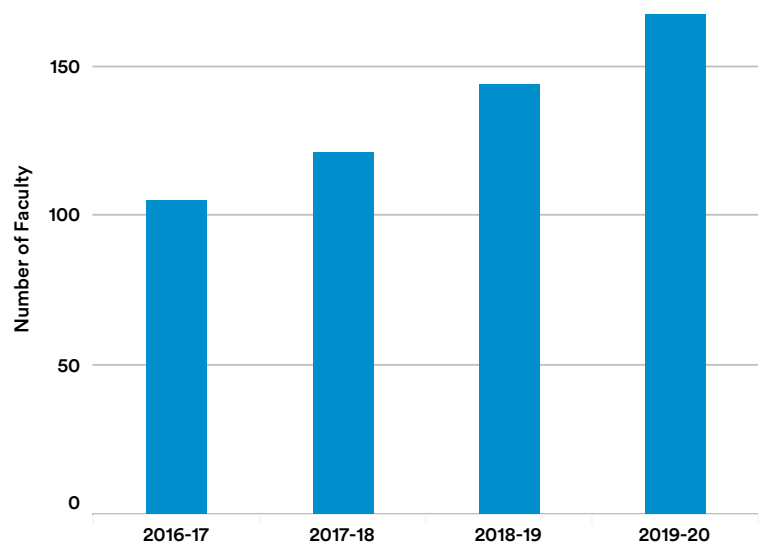


Figure 4.1.5

<sup>4</sup> See [here](#) for a list of keywords on practical artificial intelligence models provided to the survey respondents. A course is defined as a set of classes that require a minimum of 2.5 class hours (including lecture, lab, TA hours, etc.) per week for at least 10 weeks in total. Multiple courses with the same titles and numbers count as one course.



This section presents findings from the annual [Taulbee Survey](#) from the Computing Research Association (CRA). The annual CRA survey documents trends in student enrollment, degree production, employment of graduates, and faculty salaries in academic units in the United States and Canada that grant doctoral degrees in computer science (CS), computer engineering (CE), or information (I). Academic units include departments of computer science and computer engineering or, in some cases, colleges or schools of information or computing.

## 4.2 AI AND CS DEGREE GRADUATES IN NORTH AMERICA

### CS UNDERGRADUATE GRADUATES IN NORTH AMERICA

Most AI-related courses in North America are a part of the CS course offerings at the undergraduate level. The number of new CS undergraduate graduates at doctoral institutions in North America has grown steadily in the last 10 years (Figure 4.2.1). More than 28,000 undergraduates completed CS degrees in 2019, around three times higher than the number in 2010.

### NEW CS PHDS IN THE UNITED STATES

The section examines the trend of CS PhD graduates in the United States with a focus on those with AI-related specialties.<sup>5</sup> The CRA survey includes 20 specialties in total, two of which are directly related to the field of AI, including “artificial intelligence/machine learning” and “robotics/vision.”

NUMBER of NEW CS UNDERGRADUATE GRADUATES at DOCTORAL INSTITUTIONS in NORTH AMERICA, 2010-19

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

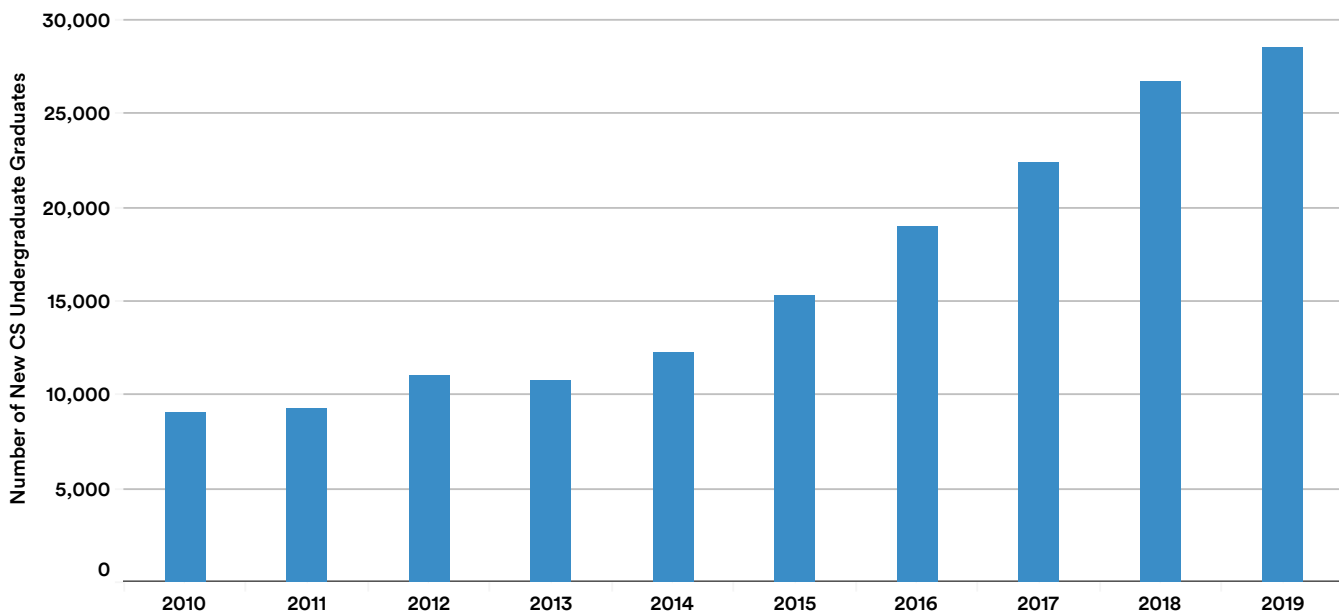


Figure 4.2.1

<sup>5</sup> New CS PhDs in this section include PhD graduates from academic units (departments, colleges, or schools within universities) of computer science in the United States.



## NEW CS PHDS BY SPECIALTY

Among all computer science PhD graduates in 2019, those who specialized in artificial intelligence/machine learning (22.8%), theory and algorithms (8.0%), and robotics/vision (7.3%) top the list (Figure 4.2.2). The AI/ML specialty has been the most popular in the past decade, and the number of AI/ML graduates in 2019 is higher than the number of the next five specialties combined. Moreover, robotics/vision jumped from the eighth most popular specialization in 2018 to the third in 2019.

Over the past 10 years, AI/ML and robotics/vision are the CS PhD specializations that exhibit the most significant growth, relative to 18 other specializations (Figure 4.2.3). The percentage of AI/ML-specialized CS PhD graduates among all new CS PhDs in 2020 is 8.6 percentage points (pp) larger than in 2010, followed by robotics/vision-specialized doctorates at 2.4 pp. By contrast, the share of CS PhDs specializing in networks (-4.8 pp), software engineering (-3.6 pp), and programming languages/compilers (-3.0 pp) experienced negative growth in 2020.

### NEW CS PHDS (% of TOTAL) in the UNITED STATES by SPECIALITY, 2019

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

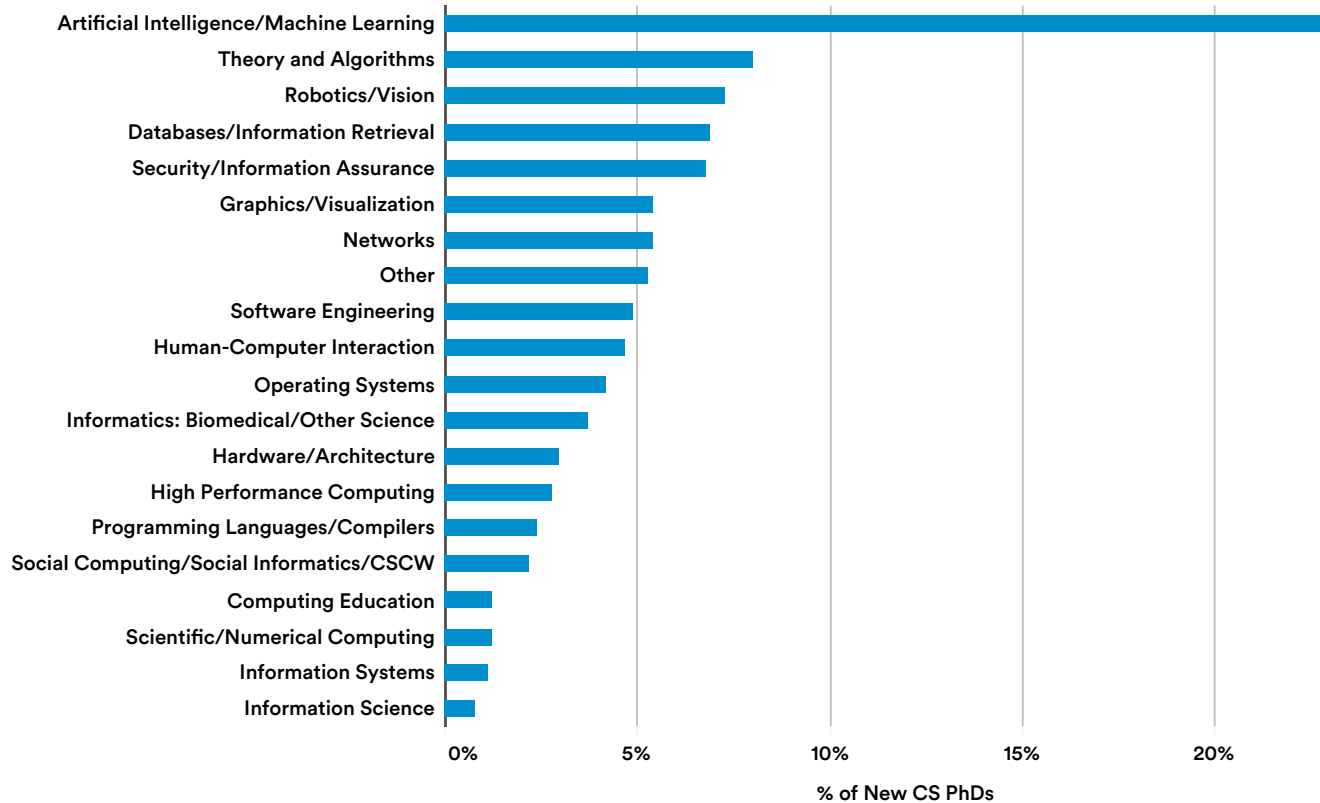


Figure 4.2.2



PERCENTAGE POINT CHANGE in NEW CS PHDS in the UNITED STATES from 2010 to 2019 by SPECIALTY

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

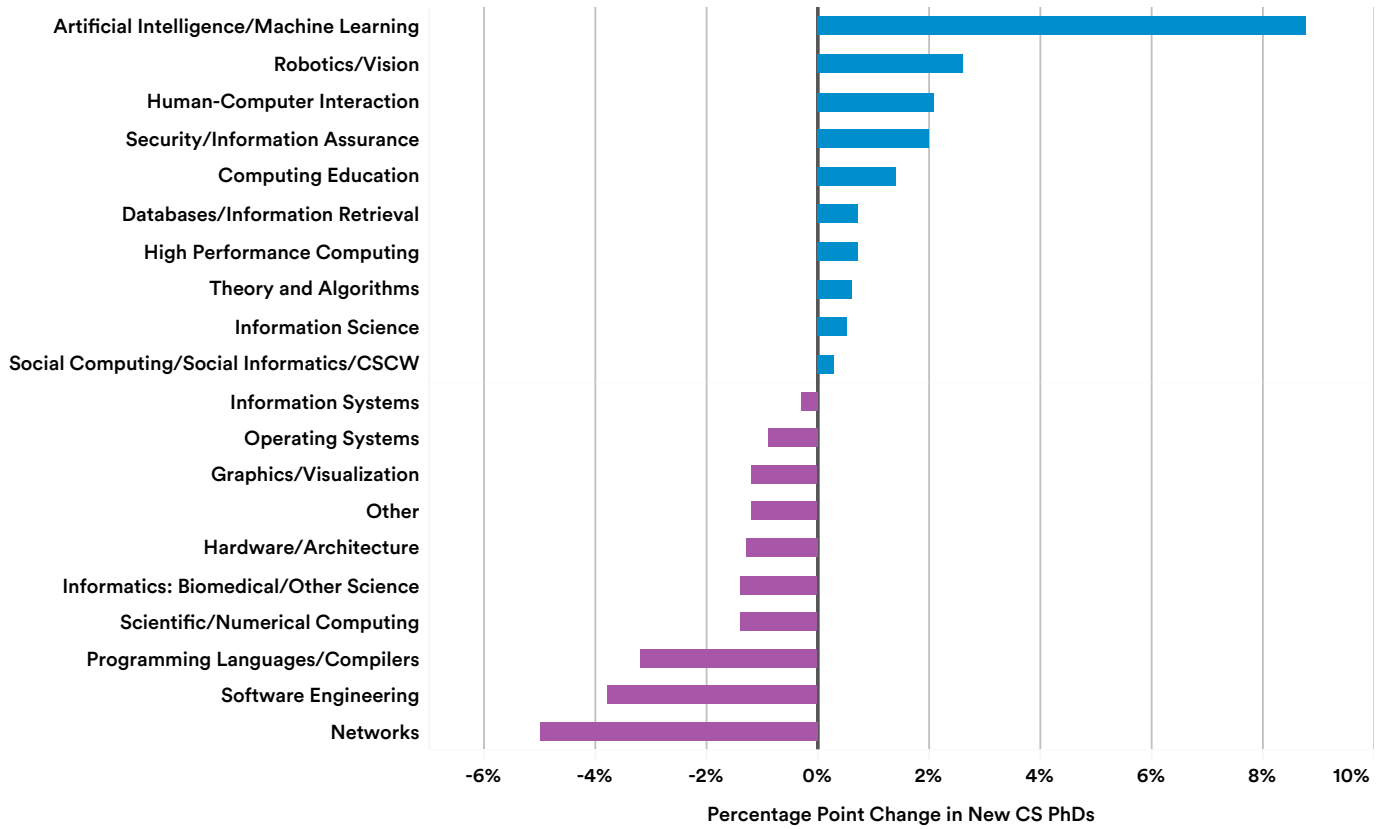


Figure 4.2.3

## NEW CS PHDS WITH AI/ML AND ROBOTICS/VISION SPECIALTIES

Figure 4.2.4a and Figure 4.2.4b take a closer look at the number of recent AI PhDs specializing in AI/ML or robotics/vision in the United States. Between 2010 and 2019, the number of AI/ML-focused graduates grew by 77%, while the percentage of these new PhDs among all CS PhD graduates increased by 61%. The number of both AI/ML and robotics/vision PhD graduates reached an all-time high in 2019.

### NEW CS PHDS with AI/ML and ROBOTICS/VISION SPECIALTY in the UNITED STATES, 2010-19

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

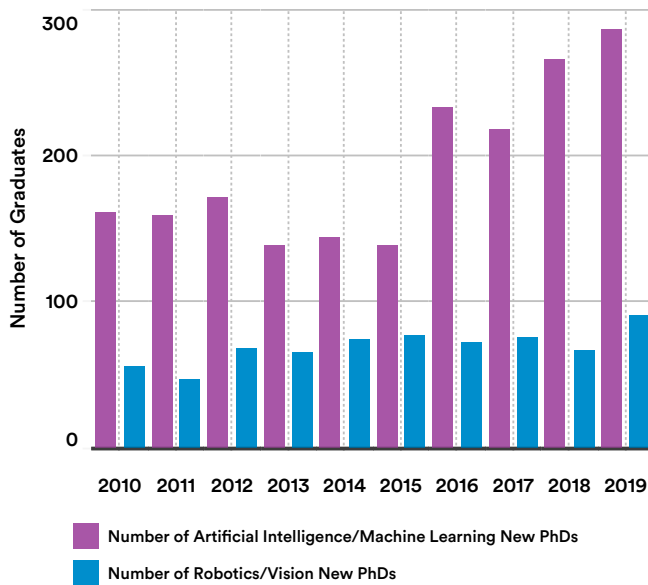


Figure 4.2.4a

### NEW CS PHDS (% of TOTAL) with AI/ML and ROBOTICS/VISION SPECIALTY in the UNITED STATES, 2010-19

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

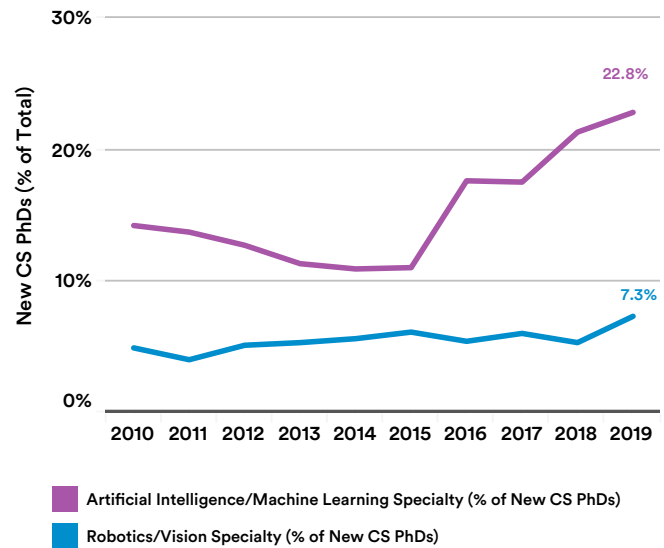


Figure 4.2.4b

## NEW AI PHDS EMPLOYMENT IN NORTH AMERICA

Where do new AI PhD graduates choose to work? This section captures the employment trends of new AI PhDs in academia and industry across North America.<sup>6</sup>

### Industry vs. Academia

In the past 10 years, the number of new AI PhD graduates in North America who chose industry jobs continues to grow, as its share increased by 48%, from 44.4% in 2010 to 65.7% in 2019 (Figure 4.2.5a and Figure 4.2.5b). By contrast, the share of new AI PhDs entering academia dropped by 44%, from 42.1% in 2010 to 23.7% in 2019. As is clear from Figure 4.2.5b, these changes are largely a reflection of the fact that the number of PhD graduates entering academia has remained roughly level through the decade, while the large increase in PhD output is primarily being absorbed by the industry.

EMPLOYMENT of NEW AI PHDS to ACADEMIA or INDUSTRY in NORTH AMERICA, 2010-19

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

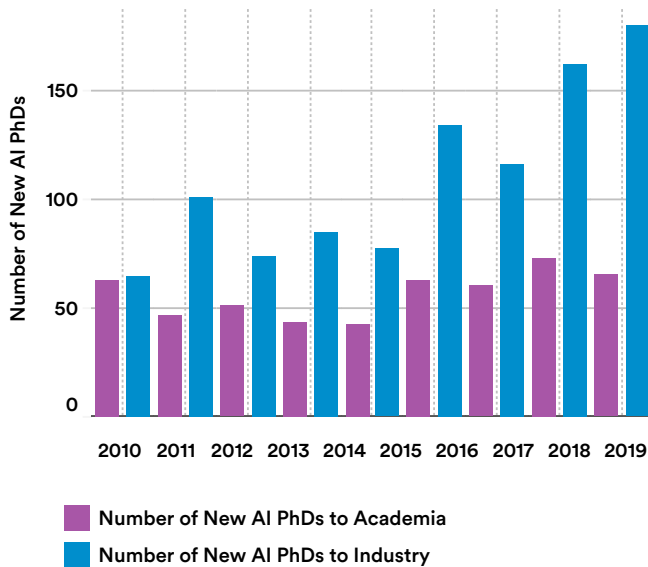


Figure 4.2.5a

EMPLOYMENT of NEW AI PHDS (% of TOTAL) to ACADEMIA or INDUSTRY in NORTH AMERICA, 2010-19

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

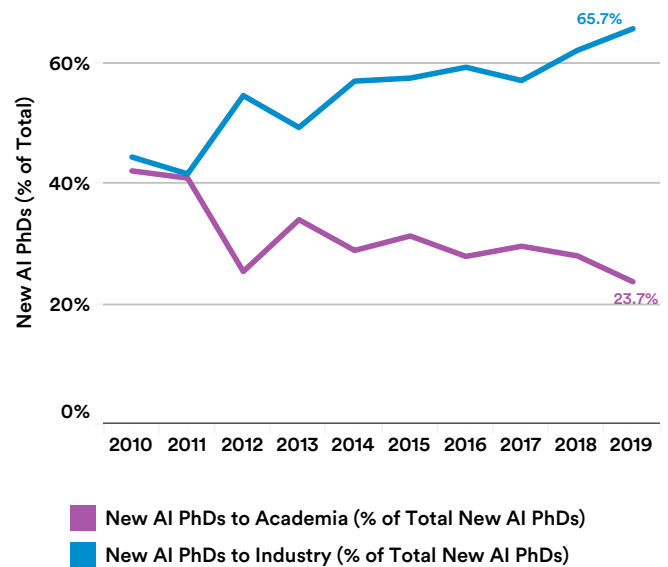


Figure 4.2.5b

<sup>6</sup> New AI PhDs in this section include PhD graduates who specialize in artificial intelligence from academic units (departments, colleges, or schools within universities) of computer science, computer engineering, and information in the United States and Canada.

### NEW INTERNATIONAL AI PHDS (% of TOTAL NEW AI PHDS) in NORTH AMERICA, 2010-19

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

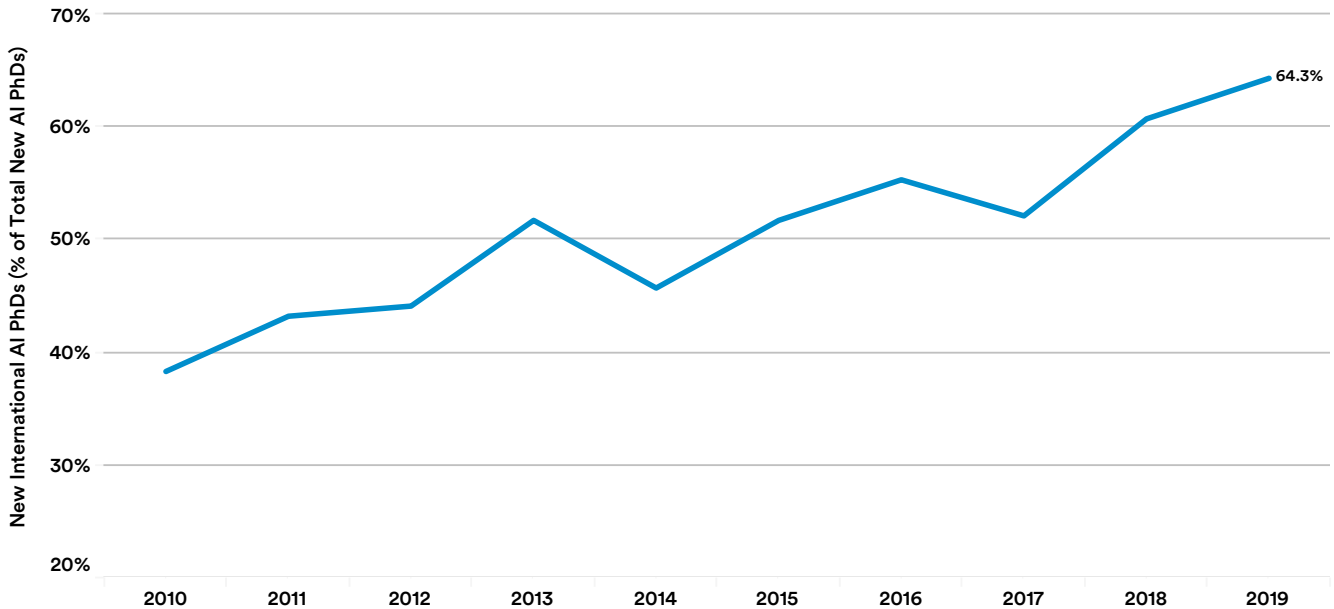


Figure 4.2.6

### NEW INTERNATIONAL AI PHDS

The percentage of international students among new AI PhD graduates in North America continued to rise in 2019, to 64.3%—a 4.3 percentage point increase from 2018 (Figure 4.2.6). For comparison, of all PhDs with a known specialty area, 63.4% of computer engineering, 59.6% of computer science, and 29.5% of information recipients are international students in 2019.

Moreover, among foreign AI PhD graduates in 2019 in the United States specifically, 81.8% stayed in the United States for employment and 8.6% have taken jobs outside the United States (Figure 4.2.7). In comparison, among all international student graduates with known specialties, 77.9% have stayed in the United States while 10.4% were employed elsewhere.

### INTERNATIONAL NEW AI PHDS (% of TOTAL) in the UNITED STATES by LOCATION OF EMPLOYMENT, 2019

Source: CRA Taulbee Survey, 2020 | Chart: 2021 AI Index Report

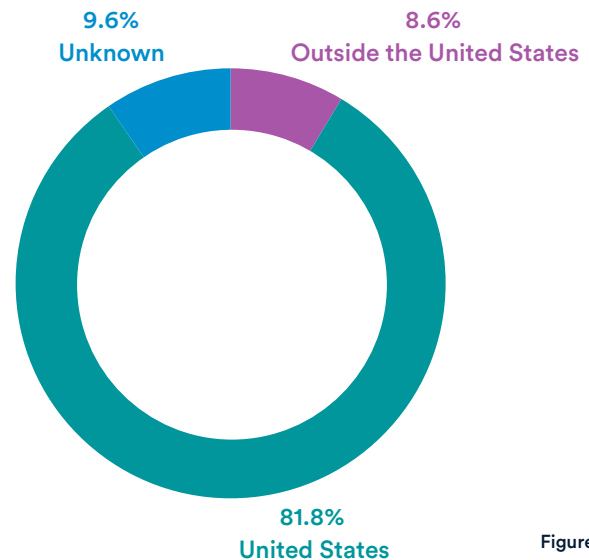


Figure 4.2.7

This section presents research from the Joint Research Center at the European Commission that assessed the academic offerings of advanced digital skills in 27 European Union member states as well as six other countries: the United Kingdom, Norway, Switzerland, Canada, the United States, and Australia. This was the second such study,<sup>7</sup> and the 2020 version addressed four technological domains: artificial intelligence (AI), high performance computing (HPC), cybersecurity (CS), and data science (DS), applying text-mining and machine-learning techniques to extract content related to study programs addressing the specific domains. See the reports “Academic Offer of Advanced Digital Skills in 2019–20. International Comparison” and “Estimation of Supply and Demand of Tertiary Education Places in Advanced Digital Profiles in the EU,” for more detail.

## 4.3 AI EDUCATION IN THE EUROPEAN UNION AND BEYOND

### AI OFFERINGS IN EU27

The study revealed a total number of 1,032 AI programs across program scopes and program levels in the 27 EU countries (Figure 4.3.1). The overwhelming majority of specialized AI academic offerings in the EU are taught at the master’s level, which leads to a degree that equips

students with strong competencies for the workforce. Germany leads the other member nations in offering the most specialized AI programs, followed by the Netherlands, France, and Sweden. France tops the list in offering the most AI programs at the master’s level.

#### NUMBER of SPECIALIZED AI PROGRAMS in EU27, 2019-20

Source: Joint Research Centre, European Commission, 2020 | Chart: 2021 AI Index Report

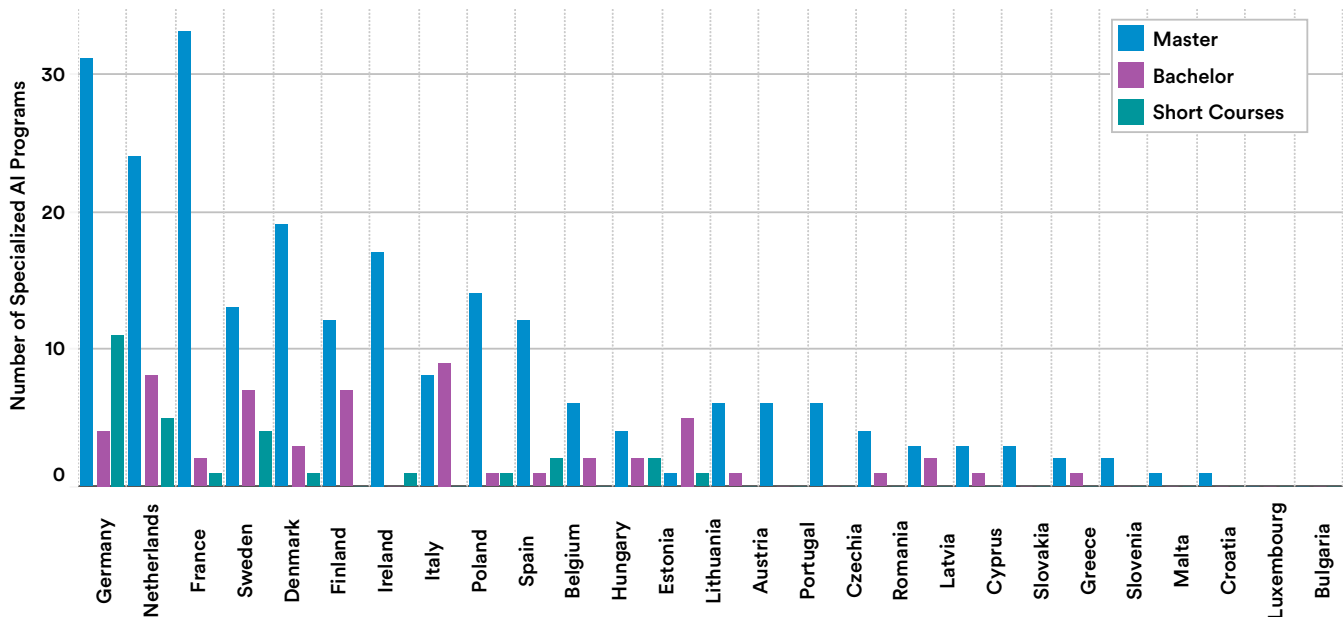


Figure 4.3.1

<sup>7</sup> Note that the 2020 report introduced methodological improvements from the 2019 version; therefore, a strict comparison is not possible. Improvements include the removal of certain keywords and the addition of others to identify the programs. Still, more than 90% of all detected programs in the 2020 edition are triggered by keywords present in the 2019 study.

### By Content Taught in AI-Related Courses

What types of AI technologies are the most popular among the course offerings in three levels of specialized AI programs in the European Union? Data suggests that robotics and automation are by far the most frequently taught courses in the specialized bachelor's and master's programs, while machine learning dominates in the specialized short courses (Figure 4.3.2). As short courses cater to working professionals, the trend shows that machine learning has become one of the key competencies in the professional development and implementation of AI.

It is also important to mention the role of AI ethics and AI applications, as both content areas claim a significant share of the education offerings among the three program levels. AI ethics—including courses on security, safety, accountability, and explainability—accounts for 14% of the curriculum on average, while AI applications—such as courses on big data, the internet of things, and virtual reality—take a similar share on average.

**SPECIALIZED AI PROGRAMS (% of TOTAL) by CONTENT AREA in EU27, 2019-20**

Source: Joint Research Centre, European Commission, 2020 | Chart: 2021 AI Index Report

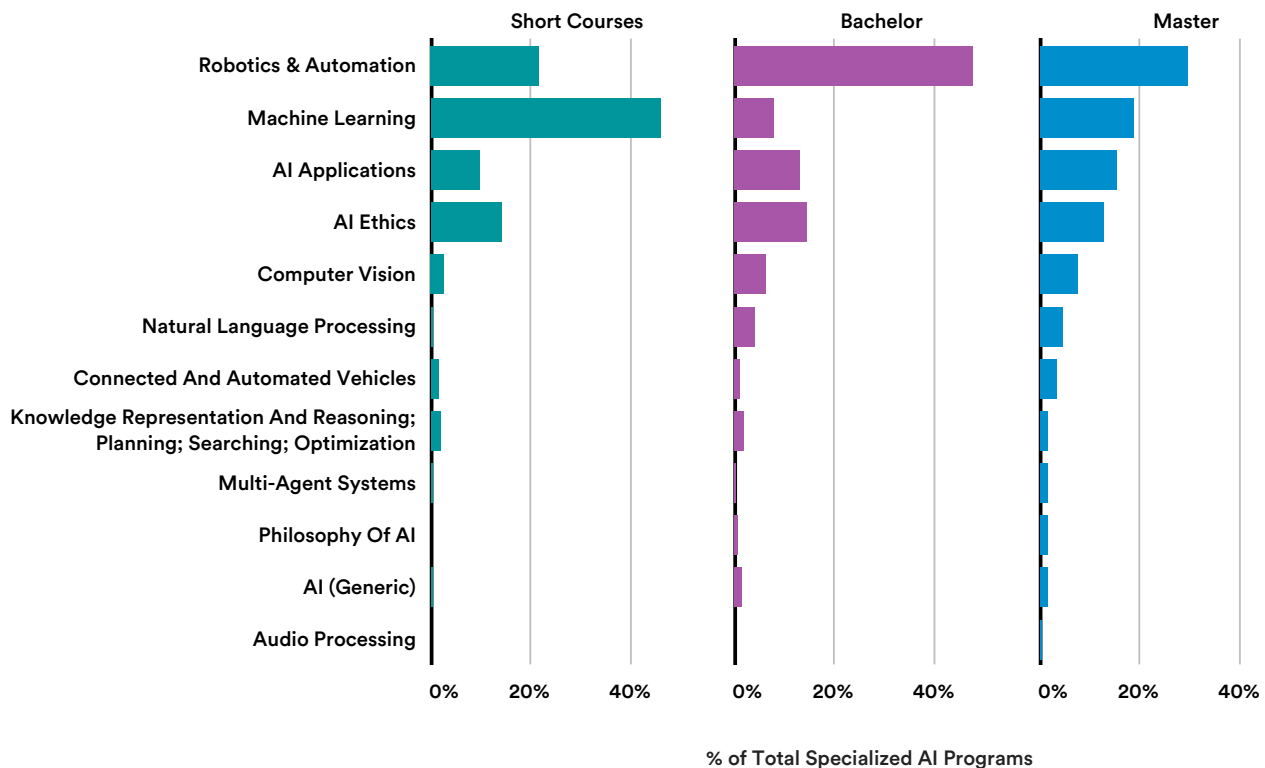


Figure 4.3.2

### INTERNATIONAL COMPARISON

The JRC report compared AI education in the 27 EU member states with other countries in Europe, including Norway, Switzerland, and the United Kingdom, as well as Canada, the United States, and Australia. Figure 4.3.3 shows the total number of 1,680 specialized AI programs in all countries considered in the 2019–20 academic year. The United States appears to have offered more programs specialized in AI than any other geographic area, although EU27 comes in a close second in terms of the number of AI-specialized master’s programs.

The United States appears to have offered more programs specialized in AI than any other geographic area although EU27 comes in a close second in terms of the number of AI-specialized master’s programs.

NUMBER of SPECIALIZED AI PROGRAMS by GEOGRAPHIC AREA and LEVEL, 2019-20

Source: Joint Research Centre, European Commission, 2020 | Chart: 2021 AI Index Report

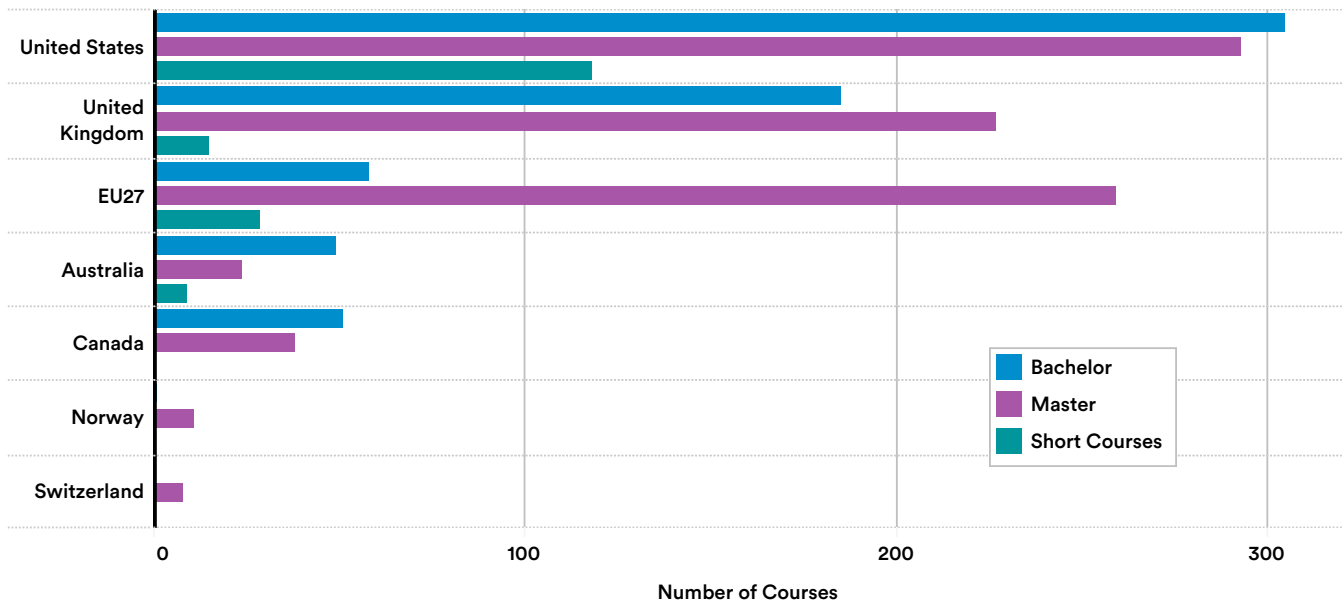


Figure 4.3.3



## AI Brain Drain and Faculty Departure

Michael Gofman and Zhao Jin, researchers from the University of Rochester and Cheung Kong Graduate School of Business, respectively, published a paper titled “Artificial Intelligence, Education, and Entrepreneurship” in 2019 that explores the relationship between domain-specific knowledge of university students and their ability to establish startups and attract funding.<sup>8</sup> For the source of variation in students’ AI-specific knowledge, the co-authors used the departure of AI professors—what they referred to as “an unprecedented brain drain”—from universities to industry between 2004 and

2018. They relied on data hand-collected from LinkedIn as well as authors’ affiliation from the Scopus database of academic publications and conferences to complement the results from the LinkedIn search.

The paper found that AI faculty departures have a negative effect on AI startups founded by students who graduate from universities where those professors used to work, with the researchers pointing to a chilling effect on future AI entrepreneurs in the years following the faculty departures. PhD students are the most affected, compared with undergraduate

### NUMBER of AI FACULTY DEPARTURES in NORTH AMERICA, 2004-19

Source: Gofman and Jin, 2020 | Chart: 2021 AI Index Report

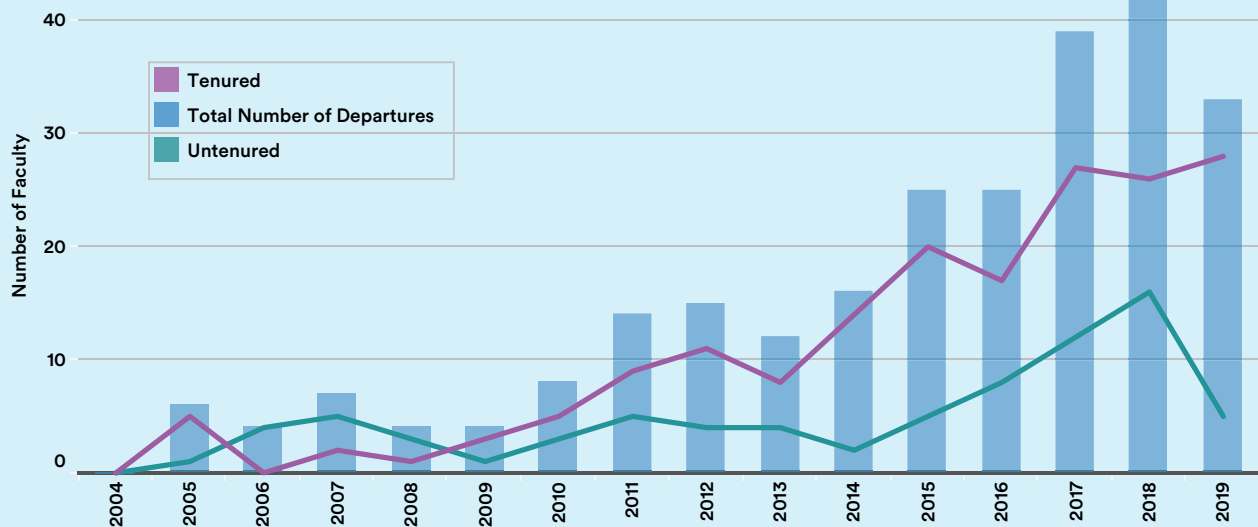


Figure 4.4.1

<sup>8</sup> See [AI Brain Drain Index](#) for more details.

## AI Brain Drain and Faculty Departure (continued)

and master’s students, and the negative impact intensifies when the AI professors who leave are replaced by faculty from lower-ranked schools or untenured AI professors.

With the updated data of 2019 from Gofman and Jin, Figure 4.4.1 shows that after a two-year increase, the total number of AI faculty departures from universities in North America

to industry dropped from 42 in 2018 to 33 in 2019 (28 of these are tenured faculty and 5 are untenured). Between 2004 and 2019, Carnegie Mellon University had the largest number of AI faculty departures in 2019 (16), followed by the Georgia Institute of Technology (14) and University of Washington (12), as shown in Figure 4.4.2.

NUMBER of AI FACULTY DEPARTURES in NORTH AMERICA (with UNIVERSITY AFFILIATION) by UNIVERSITY, 2004-18

Source: Gofman and Jin, 2020 | Chart: 2021 AI Index Report

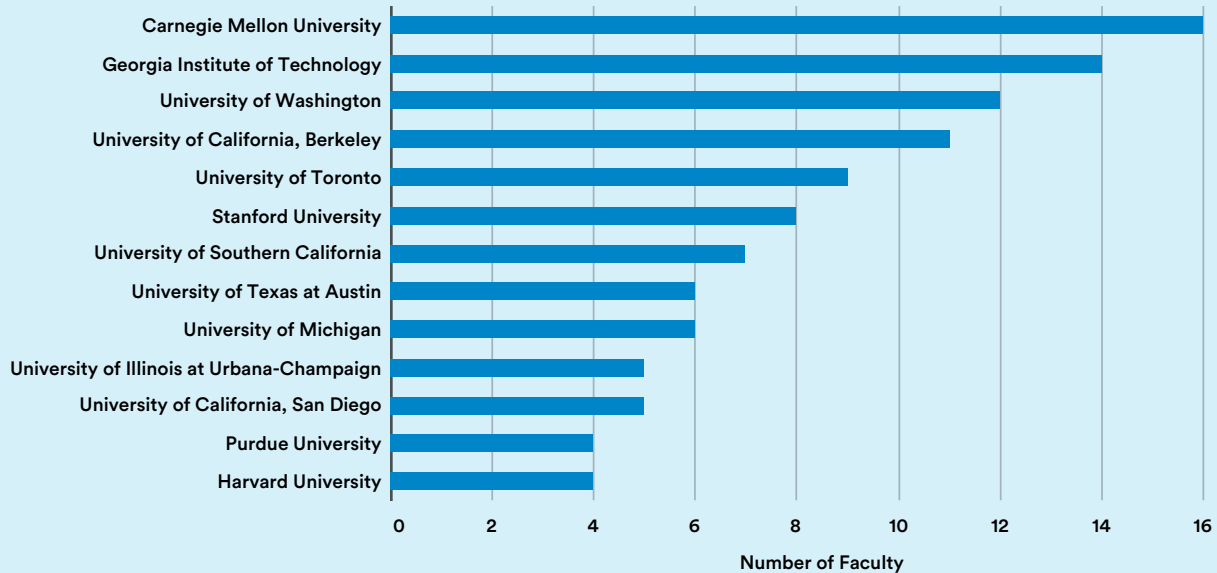


Figure 4.4.2



# APPENDIX

## CRA TAULBEE SURVEY

Prepared by Betsy Bizot (CRA senior research associate) and Stu Zweben (CRA survey chair, professor emeritus at The Ohio State University)

### Source

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](#).

### Methodology

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 does not 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. So the 2019 data points were newly available last spring, and the numbers provided for 2020 will be available in May 2021.

The CRA Taulbee Survey is sent only to doctoral departments of computer science, computer engineering, and information science/systems. Historically, (a) Taulbee covers 1/4 to 1/3 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.

### Nuances

- Of particular interest in PhD job market trends are the metrics on the AI PhD area of specialization. The categorization of specialty areas changed in 2008 and was clarified in 2016. From 2004-2007, AI and robotics were grouped; from 2008-present, AI is separate; 2016 clarified to respondents that AI includes ML.
- Notes about the trends in new tenure-track hires (overall and particularly at AAU schools): In the 2018 Taulbee Survey, for the first time, we asked how many new hires had come from the following sources: new PhD, postdoc, industry, and other academic. Results indicated that 29% of new assistant professors came from another academic institution.
- Some may have been teaching or research faculty rather than tenure-track, but there is probably some movement between institutions, meaning the total number hired overstates the total who are actually new.

## AI INDEX EDUCATION SURVEY

Prepared by Daniel Zhang (Stanford Institute for Human-Centered Artificial Intelligence)

### Methodology

The survey was distributed to 73 universities online over three waves from November 2020 to January 2021 and completed by 18 universities, a 24.7% response rate. The selection of universities is based on the [World University Rankings 2021](#) and [Emerging Economies University Rankings 2020](#) by The Times Higher Education.

The 18 universities are:

- Belgium: Katholieke Universiteit Leuven
- Canada: McGill University
- China: Shanghai Jiao Tong University, Tsinghua University
- Germany: Ludwig Maximilian University of Munich, Technical University of Munich
- Russia: Higher School of Economics, Moscow Institute of Physics and Technology
- Switzerland: École Polytechnique Fédérale de Lausanne
- United Kingdom: University of Cambridge
- United States: California Institute of Technology, Carnegie Mellon University (Department of Machine Learning), Columbia University, Harvard University, Stanford University, University of Wisconsin–Madison, University of Texas at Austin, Yale University

### Key Definitions

- **Major or a study program:** a set of required and elective courses in an area of discipline—such as AI—that leads to a bachelor's degree upon successful completion.
- **Course:** a set of classes that require a minimum of 2.5 class hours (including lecture, lab, TA hours, etc.) per week for at least 10 weeks in total. Multiple courses with the same titles and numbers count as one course.

### • Practical Artificial Intelligence Models - Keywords:

Adaptive learning, AI Application, Anomaly detection, Artificial general intelligence, Artificial intelligence, Audio processing, Automated vehicle, Automatic translation, Autonomous system, Autonomous vehicle, Business intelligence, Chatbot, Computational creativity, Computational linguistics, Computational neuroscience, Computer vision, Control theory, Cyber physical steam, Deep learning, Deep neural network, Expert system, Face recognition, Human-AI interaction, Image processing, Image recognition, Inductive programming, Intelligence software, Intelligent agent, Intelligent control, Intelligent software development, Intelligence system, Knowledge representation and reasoning, Machine learning, Machine translation, Multi-agent system, Narrow artificial intelligence, Natural language generation, Natural language processing, Natural language understanding, Neural network, Pattern recognition, Predictive analysis, Recommender system, Reinforcement learning, Robot system, Robotics, Semantic web, Sentiment analysis, Service robot, Social robot, Sound synthesis, Speaker identification, Speech processing, Speech recognition, Speech synthesis, Strong artificial intelligence, Supervised learning, Support vector machine, Swarm intelligence, Text mining, Transfer learning, Unsupervised learning, Voice recognition, Weak artificial intelligence (Adapted from: [Joint Research Centre, European Commission](#), p.68)

- **AI Ethics - Keywords:** Accountability, Consent, Contestability, Ethics, Equality, Explainability, Fairness, Non-discrimination, Privacy, Reliability, Safety, Security, Transparency, Trustworthy ai, Uncertainty, Well-being (Adapted from: [Joint Research Centre, European Commission](#), p.68)

## EU ACADEMIC OFFERING, JOINT RESEARCH CENTER, EUROPEAN COMMISSION

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### Source

The Joint Research Centre (JRC) is the European Commission's science and knowledge service. The JRC employs scientists to carry out research in order to provide independent scientific advice and support to EU policy. Learn more about JRC [here](#).

### Methodology

By means of text-mining techniques, the study identifies AI-related education programs from the programs' descriptions present in JRC's database. To query the database, a list of domain-specific keywords is obtained through a multistep methodology involving (i) selection of top keywords from AI-specific scientific journals; (ii) extraction of representative terms of the industrial dimension of the technology; (iii) topic modeling; and (iv) validation by experts. In this edition, the list of keywords has been enlarged to better cover certain AI subdomains and to expand to related transversal domains, such as philosophy and ethics in AI. Then the keywords are grouped into categories, which are used to analyze the content areas taught in the identified programs. The content areas used are adapted from the JRC report "[Defining Artificial Intelligence: Towards an Operational Definition and Taxonomy of Artificial Intelligence](#)," conducted in the context of [AI Watch](#).

The education programs are classified into specialized and broad, according to the depth with which they address artificial intelligence. Specialized programs

are those with a strong focus in AI, e.g., "automation and computer vision" or "advanced computer science (computational intelligence)." Broad programs target the addressed domain, but in a more generic way, usually aiming at building wider profiles or making reference to the domain in the framework of a program specialized in a different discipline (e.g., biomedical engineering).

Due to some methodological improvements introduced in this edition, namely the addition of new keywords, a strict comparison is not possible. Still, more than 90% of all detected programs in this edition are triggered by keywords present in the 2019 study.

The original source on which queries are performed is the Studyportals' database, which is made up of over 207,000 programs from 3,700 universities in over 120 countries. Studyportals collects information from institutions' websites, and their database is regularly updated. This source, although offering the widest coverage among all those identified, still suffers from some lack of coverage, mostly because it only tracks English-language programs. This poses a comparability issue between English-native-speaking countries and the rest, but also between countries with differing levels of incorporation of English as a teaching language in higher education. Bachelor's-level studies are expected to be more affected by this fact, where the offer is mostly taught in a native language, unlike master's, which attracts more international audiences and faculties. As a consequence, this study may be showing a partial picture of the level of inclusion of advanced digital skills in bachelor's degree programs.