education sciences

MDPI

Article

Exploring the Stratified Nature of Artificial Intelligence Research Funding in United States Educational Systems: A Bibliometric and Network Analysis

Zachary W. Taylor [1,*] and Kayla Stan [2]

[1] School of Education, The University of Southern Mississippi, Hattiesburg, MS 39406, USA
[2] School of Biological, Environmental and Earth Sciences, The University of Southern Mississippi, Hattiesburg, MS 39406, USA; kayla.stan@usm.edu
* Correspondence: z.w.taylor@usm.edu

Abstract: Little is known about the funding organizations and mechanisms behind artificial intelligence (AI) research conducted in United States (U.S.) educational systems (K12 and higher education). This study therefore performs a bibliometric and network analysis of AI research conducted in U.S. educational systems to explore which types of organizations fund peer-reviewed scholarship, which organizations receive this funding, and how these organizations form funded research networks. The results suggest evidence of institutional stratification, with non-U.S. government organizations (such as in China and Europe) funding many AI studies within U.S. educational systems. Moreover, the data suggest stratified funding networks have marginalized Minority-Serving Institutions, consolidating the influence of AI research conducted in U.S. educational systems among few, elite, and predominately White institutions. The implications for research and policy advocacy are also addressed.

Keywords: artificial intelligence; educational research; bibliometrics; network analysis

Citation: Taylor, Z.W.; Stan, K. Exploring the Stratified Nature of Artificial Intelligence Research Funding in United States Educational Systems: A Bibliometric and Network Analysis. *Educ. Sci.* **2024**, *14*, 1248. https://doi.org/10.3390/educsci14111248

Academic Editors: Maiga Chang and Mike Joy

Received: 21 May 2024
Revised: 6 November 2024
Accepted: 11 November 2024
Published: 14 November 2024

1. Introduction

In November 2022, OpenAI launched an early demo of Chat GPT, the organization's flagship artificial intelligence software [1], and soon after, discussions of artificial intelligence were ubiquitous in research settings across many disciplines. However, researchers have both leveraged artificial intelligence as a topic of research and as a method for conducting research for decades, with Dartmouth University's conference on artificial intelligence and Minsky's 1956 report on artificial intelligence emerging in the 1950s [2], formally launching the field [3]. Here, it is important to note that the earliest artificial intelligence research in United States settings was funded by a triumvirate of entities. Minsky's 1956 report was governmental, sponsored by the United States Department of Commerce and published in coordination with the Massachusetts Institute of Technology (MIT). Meanwhile, Dartmouth's groundbreaking 1956 conference on artificial intelligence was sponsored by Dartmouth and Harvard University along with two private entities: International Business Machines Corporation (IBM) and the Bell Telephone Company [3]. These funding partnerships between the government, institutions of higher education, and private industry have defined artificial intelligence research in computer science and engineering fields for decades [2,3].

Yet, relative to other fields, artificial intelligence research conducted in U.S educational systems is in its nascent stage. Educational systems are defined here as those systems within the context of schools and their teaching and learning function rather than software or product development, as is the case in computer science and engineering. In fact, according to Web of Science, the most authoritative database of scientific peer-reviewed scholarship in existence [4–6], the first peer-reviewed journal article on artificial intelligence research conducted in U.S. educational systems was in 2008 [7]. In that study, the authors explored

how an artificially intelligent collaborative learning tool, TagHelper, could help instructors understand how students engage with computer supported collaborative learning activities. Since 2008, thousands of studies on artificial intelligence within the field of U.S. education have been published, with technologies such as Chat GPT catalyzing a "paradigm shift" ([8], p. 3) that may result in an acceleration of artificial intelligence research specifically in U.S. educational systems.

As is the case with any research discipline, the economics of knowledge production often determines who influences the field [9]. This means the funding of research results in the production of research that influences the next cycle of funding and research, which in turn perpetuates this cycle in a vacuum. Recent studies in the field of computer science have validated this cycle, as an analysis of nine years of the National Science Foundation (NSF) found that from 2009 to 2019, the NSF consistently funded a small group of universities who continuously earned artificial intelligence research dollars to produce computer science research, which qualified them to earn future research dollars [10]. Here, researchers have suggested that the NSF, as a funder, has exerted considerable control and influence over the field of artificial intelligence in computer science, delegating considerable influence to a relatively small group of institutions [10].

Because artificial intelligence conducted in U.S. educational systems is in its nascent stage, it is incredibly important to understand who funds artificial intelligence research in U.S. educational systems to identify who may influence the field and determine its direction. In non-educational fields, government entities such as the Department of Commerce and Department of Defense have remained key stakeholders for artificial intelligence research due to their long-standing ties with institutions of higher education such as Carnegie Mellon University and MIT as well as with private industries such as IBM and Google [11]. Today, these stakeholders remain some of the most powerful funders of artificial intelligence research, and thus, its most powerful influencers. As a result, this study leverages Web of Science's first 13 years of artificial intelligence research in U.S. educational systems (2010–2023) to answer two questions related to the funding and power dynamics of this research:

(RQ1) Which organizations fund and receive funding for peer-reviewed scholarship on artificial intelligence research in United States educational systems?
(RQ2) How have funding organizations and recipient organizations formed funded research networks?

2. Literature Review

To date, few studies have addressed which organizations fund artificial intelligence research in U.S. educational systems, with no empirical work analyzing funding of AI research in U.S. educational systems since 1999. However, many government reports and white papers have examined who funds artificial intelligence research, who is funded for this research, and for what purposes.

2.1. The Birth of AI and AI Research Funding

In 1999, the National Research Council (NRC) published a book titled *Funding a Revolution: Government Support for Computing Research*, which detailed the history of how the United States government, private industries, and researchers both inside and outside of academia conducted computing research, including research with artificial intelligence foci and implementation [12]. According to the NRC, early models for the funding of computing research were established in the 1950s by the U.S. government in a response to the ongoing "space race" between the U.S. and the former Soviet Union ([12], p. 12). However, shortly after in the 1960s, following Minsky's first report on artificial intelligence and the Dartmouth AI conference in 1956, many private firms had initiated AI research projects, only to scrap these projects several years later after the firms realized that many AI applications were not scalable and physical manufacturing capacities could not facilitate successful commercialization and profitability [12].

Yet, the origins of broad, non-educational AI research funding began in the 1960s, with the first major industry–institutional collaboration occurring in 1963 between the Advanced Research Projects Agency (later renamed as the Defense Advanced Research Projects Agency or DARPA) and MIT. The project was a $2.2 million grant to fund an AI research group that explored artificial intelligence applications in industrial, military, and defense applications [12]. Later, in the 1970s, DARPA funded three other core AI research centers at Stanford University, Carnegie Mellon University, and Edinburgh University. Together with MIT, these four institutions dominated industry–institutional AI research funding partnerships for decades [12]. Specific to education, Stanford's educational research was conducted primarily by John Brown and Richard Burton, culminating with their Intelligent Computer-Assisted Instruction (ICAI) project, an artificially intelligent tutor designed to assist students with their mathematical and strategic thinking skills [12]. However, beyond Brown and Burton's work on ICAI, little-to-no AI research emerged specifically from educational systems or for educational purposes in the 1970s.

Beyond DARPA funding, two other organizations became major funders of AI research by industry and institutions of higher education: the National Science Foundation (NSF) and the Office of Naval Research (ONR). These two government organizations funded tens of millions of dollars of broad, non-educational AI research throughout the 1980s and 1990s, with private businesses such as the AT&T Corporation and the IBM Corporation funding major AI research projects and working groups in the 1980s and 1990s, culminating with speech recognition and automated image identification being brought to the commercial market in 1997 after two decades of research funded by DARPA and others [12]. In this relatively short 40-year span, U.S. institutions of higher education brought the field of artificial intelligence into the realm of industry in the 1950s, with government organizations first providing the main source of AI research funding to both institutions of higher education and industry partners in the 1960s and 1970s. However, it is important to note that the bulk of funded AI research was conducted in the computer science field, rather than in education, and little research emerged that offered AI use cases in U.S. educational systems beyond applications for speech recognition [13].

However, these industry partners accelerated their AI research funding in the 1980s and 1990s, given advancements in manufacturing technology to successfully bring AI applications into commercialization rather than into educational settings. By the late 1990s and the origin of the Dot Com Boom, the symbiotic triumvirate of government–industry–institution facilitated hundreds of millions of dollars of AI research funding, generating billions of dollars in commercial projects, government defense initiatives, and university research centers [12]. However, this period generated little AI research conducted in educational systems, instead focusing on government defense initiatives and the commercialization of AI products [12].

2.2. AI Research Funding During the Dot Com Boom

Since the late 1990s and the Dot Com (Internet) Boom, AI research funding has been dominated by government–industry partnerships, given advances in computing power and increases in industrial capacity to bring AI applications to the consumer marketplace [12]. Famously, IBM funded Carnegie Mellon University to help create a Chess-playing AI-powered computer named Deep Blue that defeated reigning Chess world champion Gary Kasparov in 1997, marking one of the greatest achievements of AI at the time [14]. However, in the late 1990s and early 2000s, institutions of higher education largely worked in the background during government–industry contracts meant to support the commercialization of AI across a variety of fields. Perhaps the greatest sole achievement of an institution of higher education during the Dot Com Boom was MIT and Professor Cynthia Breazeal's creation of Kismet in 2001, an artificially intelligent robot, financially supported by the MIT Artificial Intelligence Laboratory through DARPA funding [15]. However, major technology companies such as IBM, AT&T, and Silicon Graphics successfully commercialized technologies under federal contracts, sharing AI innovations with the federal government

while industries profited commercially on these innovations [16]. In fact, from 1976 through 1997, the top 20 organizations procuring AI-related patents issued by the U.S. Patent and Trademark Office were all private industries, led by IBM and Hitachi, with no institutions of higher education in the top 50 [12]. This perhaps may be why AI integration in educational systems has lagged behind other fields, as little educational research from 1970 through 2000 was funded to demonstrate or scale AI applications in U.S. educational systems.

In the early to mid 2000s, AI research funding and development slowed, with DARPA's funding of speech-recognition technology at Carnegie Mellon University and MIT representing one of the largest university investments in AI-related research and development. During the 2000s, natural language processing (NLP) and computer vision (computers enabled to derive information from visual input) advanced through Canadian government funded research by Professor Yoshua Bengio at the Université de Montréal. Bengio and his AI research team developed the first neural language model in 2001, giving way to industry development of similar models that Apple now leverages in their Siri software [17]. Later in 2003, Bengio and colleagues Geoffrey Hinton (University of Toronto) and Yann LeCun (University of New York) leveraged funding from the Canadian Institute for Advanced Research to advance natural language processing and neural networks, leading to Google purchasing Hinton's neural networks startup in 2013 and ushering in the modern AI boom [18].

2.3. Funding the Modern AI Boom, 2010–Present

Recently, AI industry experts have dubbed 2021 as a "breakthrough" year for AI ([19], p. 1), partially owing to OpenAI's publishing of DALL-E and COVID-19 detection related AI birthed by researchers at Facebook [19]. However, the origins of the modern AI boom can be owed to Google and Microsoft's development of large-scale and cloud storage technologies from the mid 2000s to the modern day, allowing AI technology to leverage increasingly larger and more complex datasets [14,17]. Amid these developments, AI funding has become increasingly consolidated between government–industry partnerships, with most government AI research funding (87%) provided by the U.S. Department of Defense to private industry, followed by the U.S. Department of Health and Human Services (17%) [16]. These advancements have been led by companies such as Microsoft, Google, Meta, and IBM who have funded hundreds of millions of dollars of AI research conducted by internal experts unaffiliated with government or academia [11]. In fact, by 2022, the majority of AI PhD holders have joined private industry rather than academia [11], diverting more talent and research funding away from institutions of higher education and toward the private industry.

Only recently has the NSF re-committed to funding AI research specifically at institutions of higher education, as in 2020, the NSF began funding their Expanding AI Innovation through Capacity Building and Partnerships (ExpandAI) program [20]. This program "seeks to advance artificial intelligence innovation by strengthening and broadening participation in AI research and education at Minority-Serving Institutions (MSIs) while fostering the development of a diverse, well-trained national AI workforce" ([20], p. 6). Of the 36 AI research awards from the program since 2020, all have included an institution of higher education as a PI or Co-PI [20]. Yet, this fund has been set at $16.3 million annually [20], which pales in comparison to the hundreds of millions of AI research funded by other U.S. government agencies and private industry. For comparison, the National Institutes of Health (NIH) recently announced a four-year AI research funding program that totals over $130 million "to accelerate the widespread use of artificial intelligence by the biomedical and behavioral research communities" ([21], p. 2).

2.4. Educational Organizations Marginalized by AI Research Funding

Ultimately, little AI research has emerged from these grants, contracts, and various innovations in AI technology for educational systems. Moreover, because government and industry continue to involve themselves in university research, many funded AI research

projects are not published, especially studies focused on AI in educational systems or for educational applications [11]. Without disseminating results publicly, it may be difficult for educators to leverage AI research to improve their educational organizations. Exemplifying this lack of funded AI research in educational systems, the U.S. Government Accountability Office (GAO) released a report in December 2023 that detailed the results of federally funded AI research, and which governmental department reported the highest number of AI use cases. The GAO found that the National Aeronautics and Space Administration (NASA) led all federal agencies with 390 AI use cases, followed by the Department of Commerce (285 use cases), and the Department of Energy (117 use cases). In last place, the Department of Education reported only a single use case stemming from President Biden's $1.8 billion investment in government AI use cases in 2023 [22].

Moreover, nationwide investments in public U.S. education systems in recent years has remained flat or decreased due to inflationary costs related to human resources and the expenses of operating physical schools [16,22]. Over time, as federal support for public K-12 education has waned, private K-12 education systems have emerged that are funded through student tuition and fees [23]. Typically, the funding structure of U.S. public K-12 education is derived from local, state, and federal sources, with federal contributions accounting for only 10% of the overall operating budgets of K-12 schools [23]. However, this national (federal) funding is largely relegated to federal grant programs to support protected populations of students, such as low-income students and students with disabilities, with no funding allocated to individual K-12 schools for educational research and development [23]. K-12 schools in the U.S. also do not typically raise funds for educational technology research and development, such as artificial intelligence initiatives, as public K-12 schools often must raise additional funds to fill teacher positions and maintain basic operations [23]. As a result, private K-12 education systems may be more adept at procuring private funds for artificial intelligence initiatives as these schools have fewer federal policies to follow and can operate more freely [22,23], yet research has not yet addressed how public versus private K-12 education systems in the United States apply for artificial intelligence research and development funding.

Similarly, the U.S. higher education system is also a dual public–private model, with public institutions receiving taxpayer support that varies from state-to-state, with public institutions also enjoying non-profit organizational status to save on tax costs [23]. Compared to their K-12 counterparts, U.S. higher education also only receives 13% of its funding from federal sources, relying on state funding and student tuition and fees for the majority of its budget [23]. However, many private institutions have emerged that do not receive public benefits other than non-profit organizational status and thus drive revenue to cover expenses through charging higher tuition and fee rates to students than public institutions charge, which is passed through student loans that are federally disbursed for the vast majority of students [23]. Yet despite these funding complexities and heavy reliance on student tuition and fees through student loans, the funding of the research enterprise in U.S. higher education remains split between federal sources at roughly 53% and a combination of institutional funds raised through private organizations and non-profits at roughly 47% [23,24]. Here, both public and private U.S. institutions of higher education can vie for a large percentage of federal funds allocated for technology research and development, and the earliest institutional investors in artificial intelligence were Dartmouth, MIT, and Stanford [2,3]. However, little is known about how public and private higher education systems vie for artificial intelligence research funding. No studies have explored the funding organizations and mechanisms behind artificial intelligence (AI) research conducted in U.S. higher education systems.

Globally, similar to U.S. contexts, little is known about artificial intelligence research funding within higher education systems. Although the U.S. operates within a capitalist education system that relies less on federal funds and more on student tuition and fees through student loans [23], other large and developed countries such as Germany, China, and France operate public higher education systems that rely primarily on federal govern-

ment sources, with public higher education systems in these countries receiving over 60% of their operational budgets from federal or local governmental sources [23,24]. In these countries, public higher education is typically fully subsidized for students, especially those studying at universities, whereas the private higher education systems are much smaller compared to the U.S. and similarly rely on student tuition to sustain their operations [23,24]. However, in recent years, countries such as Japan, South Korea, and India have experienced a rapid growth in their private higher education systems, relying on private philanthropy and student tuition and fees to maintain their operations [23,24], largely owed to declining governmental appropriations to higher education, mirroring developments in the United States [22–24]. However, studies have not explored how this rapid growth in private higher education has impacted how institutions seek research funding for artificial intelligence, specifically artificial intelligence research within educational, non-commercialized systems.

As a result, little is known about which organizations fund peer-reviewed scholarship on artificial intelligence research conducted in United States educational systems, which organizations receive funding, and how these organizations form funded AI research networks. In the computer science field, researchers analyzed over 104 million published documents from 2000–2020 with an AI focus, finding that funded AI research has disproportionately focused on non-educational topics and use cases [23]. Moreover, two government organizations were found to have dominated non-private AI research funding over the past two decades—the NSF and the NIH—with these organizations prioritizing medical applications of AI with a focus on robotics [23]. This may be problematic, as Stanford University's recent report on the state of AI research found that over 80% of all AI research has been published by institutions of higher education, but the collaboration of this research has been between institutions of higher education and nonprofit organizations, with the research failing to focus on applications of AI in U.S. educational systems [11].

Without understanding funders and recipients, it is difficult to discern the economics of the knowledge production structure of AI research in educational systems [9], which may lead to issues of inequitable consolidation of AI funding, academic integrity, or information gatekeeping that may further marginalize the field of education from AI proliferation and advancements that other fields have enjoyed for decades [3,7]. This study fills a considerable gap in the literature, necessary for educators to advocate for AI research funding so that education may benefit from AI as so many other fields have.

3. Materials and Methods

This section will detail how the research team collected and analyzed bibliometric data for this study, as well as replication instructions. The data that support the findings of this study are available from the authors upon reasonable request.

3.1. Data Collection

To collect data, the researchers leveraged Web of Science (WOS) to explore AI research within educational systems. Although there are many databases for academic scholarship, WOS was chosen because of its robust scope and rigor of selection of peer-reviewed journal articles (PRJAs), supported by prior studies as one of the strongest databases of peer-reviewed scholarship available [4–6]. To narrow publication results, the research team targeted WOS' peer-reviewed educational research journal articles with the Boolean terms "education" AND "artificial intelligence" OR "AI" OR "machine learning" OR "deep learning" OR "neural networks". These results were manually cleaned for at least one of those terms being used within the title, keywords, or abstract and were categorized within the field of education according to WOS. Results were further manually cleaned by removing articles with a focus on similar terms, such as "deepening learning" and not "deep learning" or methodological AI essays and position statements that did not gather any empirical data or report on any results. This cleaning procedure resulted in an initial corpora of 373 peer-reviewed studies of AI conducted in U.S. educational systems.

3.2. Data Analysis

To analyze the corpora results, the research team leveraged R (using the tidyverse and reshape2 packages) to isolate PRJAs by author affiliation and funding source. First, R was used to analyze PRJAs by author affiliation, ensuring that all PRJAs in the sample included at least one author from a U.S.-based institution of higher education. Then, R was used to analyze PRJA funders, as WOS categorizes and sorts PRJAs based on metadata, including funding source(s). This resulted in a total of 166 AI-focused peer-reviewed educational research journal articles with at least one author from a U.S. institution of higher education that were funded between 2010 and 2023 according to WOS. A visualization of this identification and screening of research can be found in the PRISMA diagram in Figure 1.

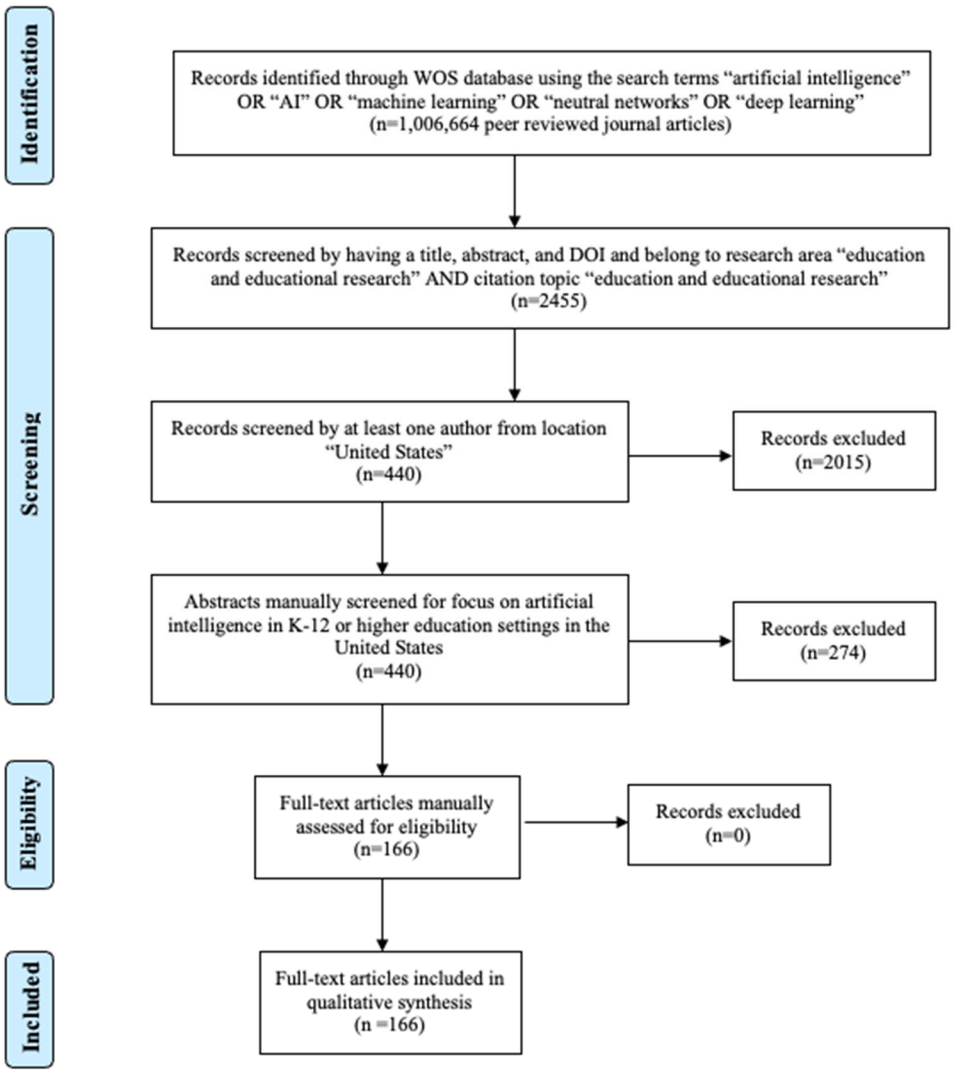

Figure 1. PRISMA flow diagram for systematic review of artificial intelligence articles focused on U.S. educational systems on Web of Science (n = 166).

To analyze funding sources, the research team employed R to categorize main institutions and remove all foreign institutions, removing duplicates from the same institution. Then, funders were cleaned down to the primary funding body (i.e., removing a directorate from NSF listings) to form broader categories of funding bodies. We then conducted a fuzzy match and manually cleaned for consistency (i.e., NSF or N.S.F. records became National Science Foundation). Then, once broader categories of funding bodies emerged, the research team manually researched specific classes of funders, including those from

governmental organizations (subbranches specifically military, such as Office of Naval Research, the Army Research Office, etc.), universities, foundations, professional organizations, private companies, and one unknown entity ("SHEILA"). This analysis can be found in Figure 2a. To calculate funding statistics per manuscript, the research team performed descriptive statistical analysis by manuscript, comparing the number of funders per PRJA (see Figure 2b). Then, descriptive statistics were calculated by top funders, taking each unique PRJA identifier (digital object identifier or DOI) and calculating the yearly number of PRJAs per funder from 2010 through 2023 (see Figure 2).

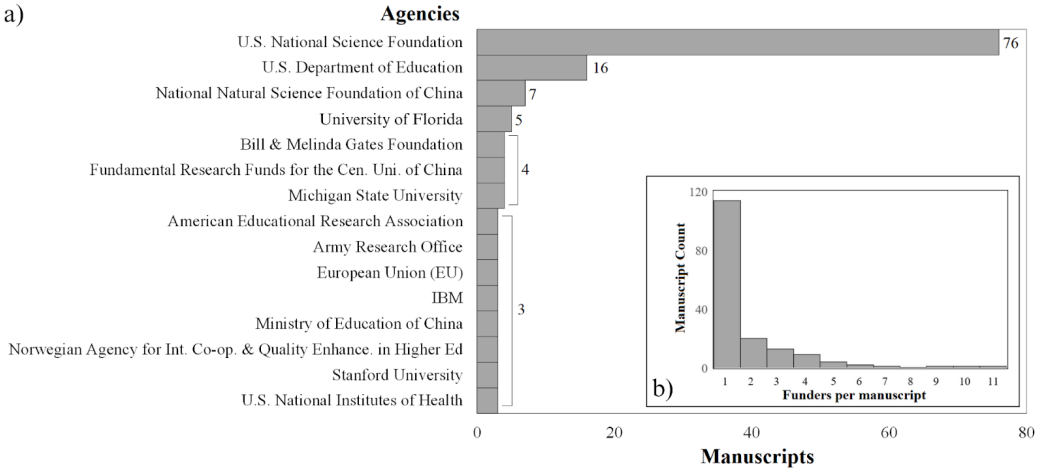

Figure 2. (**a**) Top funders of AI research in U.S. educational systems (2010–2023), (**b**) Number of manuscripts per funder of AI research in U.S. educational systems (2010-2023).

To calculate funding statistics, the research team performed descriptive statistical analysis by institutions of higher education, primarily comparing the number of PRJAs versus funded PRJAs (see Table 1). By funder, the same analysis was performed by total number of funders by institution, meaning a single publication from a single institution with multiple funders was calculated by the number of funders divided by the number of funded manuscripts, resulting in the total average of funders by institution (see Table 2) and overall funded manuscripts by funder (see Figure 3). Finally, a network analysis was conducted based on the co-occurrences of funders and institutions by unique PRJA DOI, with the size of dot (see Figure 4) representing the number of unique PRJAs funded by the organization. The magnitude of the connection is the aggregate number of PRJAs funded to each institution (all institutions get all funders if multiple funders per PRJA). For university funding, universities as funders were manually re-coded to allow institutions to be both funders and institutions. Then, for simplicity and readability, the research team visualized only the top 15 funders according to WOS publications in AI educational research from 2010 through 2023.

Table 1. Top ten institutions of higher education publishing funded AI research in U.S. educational systems.

University	Manuscripts	Percent of Manuscripts Funded
Stanford University	16	50
University of Florida	16	38
University of Illinois	16	38
Michigan State University	15	47
Carnegie Mellon University	14	50

Table 1. *Cont.*

University	Manuscripts	Percent of Manuscripts Funded
Arizona State University	13	38
University of Memphis	13	46
Indiana University	11	9
University of Georgia	10	70
Georgia State University	9	11
Texas Tech University	9	22

Table 2. Top ten institutions of higher education by funding diversity and average funders per peer-reviewed journal article (PRJA).

University	Funders	Average Funders Per PRJA
University of Illinois	23	3.8
Stanford University	19	2.4
Michigan State University	13	1.9
University of Memphis	11	1.8
University of Florida	11	1.8
Carnegie Mellon University	11	1.6
Arizona State University	11	2.2
University of Georgia	9	1.3
University of Colorado	7	4
Harvard University	7	1.8

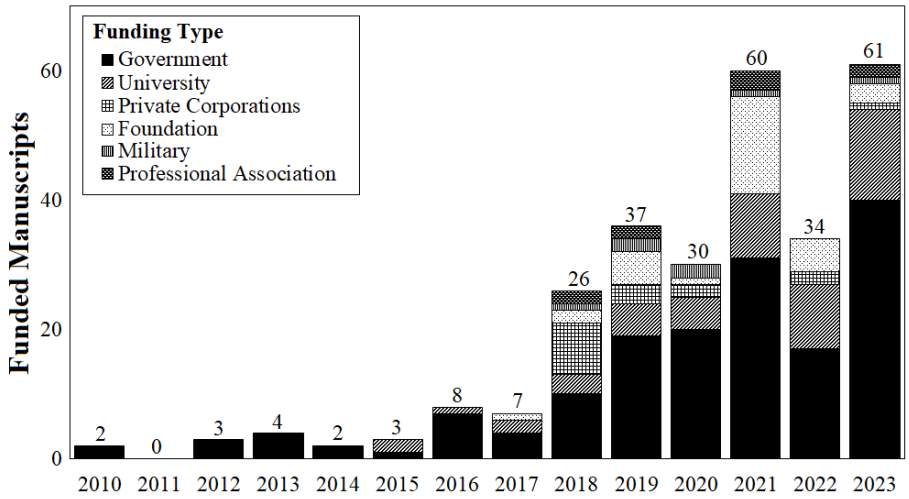

Figure 3. Historical overview of funded manuscripts by funder (2010–2023). Note: Chinese funding began in 2017 (the NNSF, the FRF, and the MEC).

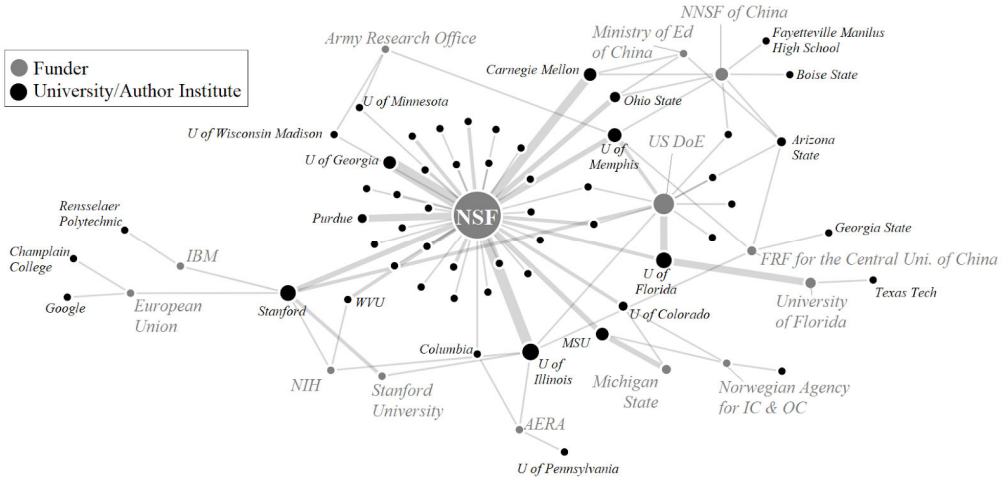

Figure 4. Network analysis of funders and recipients of artificial intelligence research in U.S. educational systems.

3.3. Limitations

This study is primarily limited by time and the PRJA database, namely Web of Science. As artificial intelligence as a field of research is entering another boom period [17,19], it is likely that peer-reviewed work will continue to accelerate in educational systems as it has in nearly all other fields [11]. As a result, future studies could replicate this work in five or ten years from now to further analyze trends in AI funding for research in educational systems both in the United States and in other countries. Moreover, this study leverages WOS, which is one of if not the most robust database for scientific peer-reviewed scholarship in the world [4–6,23]. However, especially given the proliferation of scientific research in the 20th and 21st centuries in the United States, WOS may not have contained every peer-reviewed journal article at the time of this study's data collection and analysis. Moreover, the authors' institution did not have a subscription to Scopus, limiting this review. As a result, future research could expand the scope of data collection by engaging with other databases or including other forms of research—such as white papers and organizational reports—to better understand who funds AI research and who receives this funding, including institutions of higher education.

4. Results

4.1. Top Funders and Funders per PRJA

Answering this study's first research question, Figure 2a,b below displays the top funders of AI research conducted in U.S. educational systems from 2010–2023. Given the data in Figure 2a, the U.S. National Science Foundation (NSF) has been easily the most prominent source of funding for AI research conducted in U.S. educational systems, credited for 76 PRJAs focused on AI in educational research, followed by the U.S. Department of Education, credited with 16 PRJAs focused on AI in U.S. educational systems.

However, somewhat surprisingly, the National Natural Science Foundation of China was credited with 7 PRJAs focused on AI in U.S. educational systems, more than any institution of higher education, including the University of Florida (5 PRJAs), Michigan State University (4 PRJAs), and Stanford University (3 PRJAs). In fact, the leading educational research association in the United States, the American Educational Research Association (AERA), was only credited with funding three PRJAs focused on AI in U.S. educational systems from 2010–2023. Given the data in Figure 2a, government organizations—mainly from China but also the European Union and a national Norwegian technology agency—have funded AI research in U.S. educational systems.

Additionally, although Stanford University's recent AI report suggested that institutions of higher education frequently collaborate with nonprofit organizations to produce AI-focused research [11], the same is not true in AI research in U.S. educational systems

specifically. The only nonprofit organizations in the top 15 funders were the Bill & Melinda Gates Foundation with four PRJAs and the aforementioned AERA. Similarly, only 1 private industry was in the top 15 organizations funding AI research in U.S. educational systems from 2010 through 2023: IBM. Here, many reports have suggested that AI research has been predominantly funded by government organizations and private industry [16,17], with academic partnerships emerging with nonprofit organizations for AI-funded projects [11]. However, our data suggest AI research in U.S. educational systems from 2010–2023 has been funded primarily by government entities, including several non-U.S. countries.

Regarding funders per PRJA, the data in Figure 2b suggest that most PRJAs are supported by funding from one organization. However, many PRJAs credit multiple funding sources, with several PRJAs crediting 10 or more funding organizations. Here, and supporting prior literature, data in Figure 2b suggest that most AI research in U.S. educational systems is funded by a single organization, similar to many non-educational research partnerships such as Carnegie Mellon's long-standing partnership with IBM, and MIT's many funded AI research endeavors with the NSF [12].

4.2. Funded Manuscripts by Funder

The data in Figure 3 display a historical overview of funded manuscripts (PRJAs) from 2010 through 2023. These longitudinal data suggest AI research conducted in U.S. educational systems has been consistently funded by government entities, with a marked increase in investment and research productivity occurring in 2018.

To explore this change, the research team identified when certain organizations began funding AI research in U.S. educational systems, finding that China began funding this research in 2017, resulting in a large increase in funded PRJAs in 2018. The primary Chinese organizations that began funding research in 2018 were the National Natural Science Foundation (NNSF), the Fundamental Research Funds for the Central University of China (FRF), and the Ministry of Education of China (MEC). As a result, AI research conducted in U.S. educational systems reached a peak in 2023 with 61 funded PRJAs, up from 2 in 2010 and 0 in 2011. Although it is difficult to establish a causal relationship, it should be noted that many scholars consider the modern AI boom to have started around 2010 [14,17,19]. Yet, the data in this study suggest AI research in U.S. educational systems may have lagged behind other fields, or Chinese entities catalyzed the rise in this research in 2017.

4.3. Funded AI Research in U.S. Educational Systems by Institution

Table 1 below displays the top 11 institutions of higher education publishing PRJAs of AI research conducted in U.S. educational systems alongside the percentage of their PRJAs that were funded. Results suggest Stanford University and Carnegie Mellon University's historical ties to DARPA funding and private industry may have carried into educational research systems, as these two institutions were responsible for 30 of the 166 PRJAs published between 2010 and 2023. However, institutions such as the University of Florida and the University of Illinois (16 PRJAs) matched Stanford's output, suggesting that there is some degree of fragmentation in AI research output based in U.S. educational systems.

Moreover, the University of Georgia (UGA) led all institutions of higher education with 70% of their PRJAs being funded. Although there is no central database or historical record of AI-related research centers in institutions of higher education, UGA established their Artificial Intelligence Center in 1995, which became their Institute for Artificial Intelligence in 2008 (University of Georgia, 2023). Perhaps establishing an AI research center before the modern AI boom helped UGA's institute procure AI research funding; however, empirical work has focused on the history and development of AI research centers at institutions of higher education and how these institutes procure AI research funding—this may be an area for future research.

The data in Table 2 display the number of AI research funders per PRJA from 2010 through 2023. The data in Table 2 suggest the University of Illinois (UI) could be considered the most collaborative or the most fiscally diverse institution for AI research in U.S. educa-

tional systems. UI led all institutions of higher education with an average of 3.8 unique funders per PRJA, followed by Stanford at 2.4 funders per PRJA. Although there is no prior empirical work that explores how diverse, diffuse AI research partnerships may help produce AI research in U.S. educational systems, this represents an area of future research.

4.4. Network Analysis of Organizations and Funded AI Research

Figure 4 displays a network analysis of funders and recipients of AI research in U.S. educational systems from 2010 through 2023. Central to the network is the NSF, connected directly to many institutions of higher education, with the strongest connections to being to UI, UGA, Stanford, and Carnegie Mellon. The U.S. Department of Education, although a much weaker funder, also had strong network connections to the University of Florida and the University of Memphis.

On the periphery of the network were international government organizations, as the NNSF of China funded AI research conducted in U.S. educational systems at several schools, including a high school in New York State (Fayetteville–Manilus), Boise State University, and Carnegie Mellon. Other Chinese government entities have network connections with Georgia State University, UM, and Ohio State University. Other international government organizations included the European Union funding AI research for Stanford and Champlain College, and the Norwegian entity funding Michigan State University and the University of Colorado. The only three organizations who were both a funder and recipient of funding were Stanford University, Michigan State University, and the University of Florida, who funded AI research conducted in U.S. educational systems at Texas Tech University, the University of Illinois, and the University of Colorado.

The organizations with the strongest networks were the NSF followed by the U.S. Department of Education. Regarding institutions of higher education, Stanford University, the University of Florida, the University of Illinois, the University of Memphis, and Carnegie Mellon University had the strongest networks, which translated to many of these institutions producing the most PRJAs. Inversely, there were two institutions with direct connections to the NSF (the University of Wisconsin–Madison, the University of Minnesota–Twin Cities) but were also connected to the U.S. Army Research Office, which may suggest that AI funding in military education systems may not yield as many PRJAs or that these institutions are not allowed to publish their results and instead must keep research results internal.

Finally, the only private industry within the network was IBM, who funded AI research conducted in U.S. educational systems at Stanford University and the Rensselaer Polytechnic Institute. Here, Stanford's connections with IBM are decades old and well known [11], but the Rensselaer Polytechnic Institute may be considered an outlier, considering the history of AI funding of institutions of higher education. As a result, institutions of higher education seeking industry funding may look to Rensselaer's strategy regarding how the institution was able to break into a group of institutions that have remained fairly stratified over the past 30 years of AI research funding in general (e.g., Stanford University, Carnegie Mellon University, the University of Illinois, and the University of Georgia).

5. Discussion

As the first study of funded AI research conducted in U.S. educational systems, this study makes several contributions to the literature pertinent to which organizations fund this type of research, how research productive these organizations are, and which organizations are connected through their funded AI research. As a result, implications for many stakeholders emerge.

First, compared to the fields of computer science, engineering, linguistics, finance, business, and others, AI research within the field of education has lagged and is lagging behind many fields and industries. For instance, Rahkovsky et al. estimated that researchers in non-educational fields have produced over 104 million articles related to artificial intelligence since 1956, predicting an extreme growth period between 2020 and 2023 [23].

However, the data in this study suggest AI research in U.S. educational systems only spiked in 2018 after Chinese governmental organizations began funding the research (see Figure 3). Moreover, the NSF, the NIH, and the U.S. Department of Defense have been critical funders of AI research in recent decades [12,16,17], in addition to private industries such as IBM [12]. However, these entities either have not funded AI research in U.S. educational systems at the same level as other fields or AI research in U.S. educational systems has not been published in peer-reviewed journals at the same level as other fields. In either case, it is problematic that so few AI-focused educational articles have been published in the field of education since 2010 (only 373 PRJAs) with even fewer crediting a funding source (only 166 PRJAs). One evidentiary instance can be traced to how the U.S. Department of Education only produced one AI use case in 2023 after receiving part of a $1.8B federal grant from President Biden [22], while other federal departments produced hundreds of use cases. In short, this study suggests the bulk of funded AI research has not been conducted within U.S. educational systems, evidenced by the dearth of PRJAs within this scope since 2010.

Next, following Geuna's theory of the economics of knowledge production [11], the data in this study make it clear that several institutions of higher education still monopolize the bulk of AI research funding, including funding for AI research in U.S. educational systems. Institutions such as Stanford University, Carnegie Mellon University, and the University of Georgia have enjoyed decades of AI research funding partnerships with government organizations (e.g., the NSF and the NIH) and private organizations (e.g., IBM and AT&T). Here, prior research has demonstrated a distinct stratification of institutions of higher education that have influenced the field of AI and computer science for decades, including elite institutions such as MIT, Dartmouth, Harvard, and Stanford. This study suggests that within the field of education, the same is true—AI research funding stratification also exists regarding funded AI research in U.S. educational systems. Geuna would argue that because an original subset of stratified institutions of higher education pioneered the field of AI and influenced how AI is researched, developed, and reported on, these same institutions may be disproportionately influencing the subfield of AI within U.S. educational systems [11]. As a result, many institutions of higher education may be left behind during the modern AI boom of the 2010s and 2020s. Perhaps this is why NSF recently announced a round of (modest) funding for AI research at Minority-Serving Institutions, acknowledging how these institutions have not been awarded AI research funding, including decades of NSF funding for AI research directed toward elite, predominantly White institutions of higher education [20].

However, it must be noted that Minority-Serving Institutions may have applied for AI research funding in the past but had not been awarded, and in nearly all cases, grant applications are not made public and are not researchable. In addition, certain institutions with a long tradition and history of conducting AI research, such as Dartmouth or Stanford, may hold institutional expertise in this field and be much better positioned to earn AI research funding. As a result, many elite institutions with ample experience and staffing may be more competitive for AI funding schemes than peers. Yet, the only Minority-Serving Institutions (MSIs) within this study's network analysis were Arizona State University (a Hispanic-Serving Institution or HSI) and Georgia State University (a Predominantly Black Institution or PBI). From here, future research could explore how institutions outside of the academic elite apply for, access, and utilize AI research funding, paying specific attention to whether Minority-Serving Institutions (e.g., HSIs and PBIs) access this funding and whether this funding is focused within educational systems or maintains a focus within computer science, engineering, and linguistics fields. In no uncertain terms, this study suggests that AI research funding has not focused on U.S. educational systems and has not been racially equitable by institution type from 2010 through 2023.

For institutions of higher education seeking AI funding for research in U.S. educational systems, this study's network analysis suggests that it may be difficult to access AI research networks that have been established and strengthened over the course of many decades. One potential strategy to access AI research funding within U.S. educational systems

would be to establish partnerships with more elite institutions. This study's network analysis found that three institutions (Stanford University, Michigan State University, and the University of Florida) funded AI research in U.S. educational systems at three other institutions (Texas Tech University, the University of Illinois, and the University of Colorado). To be clear, each of these institutions are predominantly White institutions [25] and such siloed funding partnerships may be accelerating institutional stratification and exclusion of Minority-Serving Institutions. However, educational leaders at MSIs and other excluded institutions may seek partnerships with institutions who are already established in the field of AI. The data in Table 2 suggest that many institutions of higher education publish PRJAs that credit multiple funders, meaning that many AI research studies within U.S. educational systems are collaborative and potentially interdisciplinary, such as studies crediting a governmental organization and a private industry. As a result, future research could explore the nature of funded AI research partnerships across sector, specifically focusing on whether predominantly White institutions include MSIs or how other funding organizations make intentional efforts to diversify AI research funding in U.S. educational systems, such as NSF's recent round of MSI funding [20].

Although prior research has not specifically focused on AI research funding within U.S. educational systems, prior studies have explored trends in artificial intelligence and have strongly suggested that artificial intelligence has been and will be funded through private organizations operating in business systems with the main goal of product development and capitalization [10,14,16,26]. In this study, the results suggest that very few, powerful U.S. institutions of higher education with close ties to private industries have received the majority of AI research funding. In addition, researchers have asserted that the U.S. did not face stiff competition for technology research in the 1950s and 1960s, but that technology-focused nations such as China has amplified competition for AI research funds toward technology development [14,16,23,26]. However, the U.S. and China have experienced considerable political tension in recent years [22,23], which complicates the financial relationship these nations may enjoy when it comes to AI research funding within U.S. educational systems.

Finally, although there was no guiding hypothesis to understand how organizations fund AI research in U.S. educational systems, Stanford University's recent report on the state of AI research hinted at the influence of non-U.S. entities within the field of AI research [11]. In the report, Maslej et al. found that the U.S. led the world in private investment in AI, but that China has emerged in recent years as the worldwide leader in AI research publications, including PRJAs, conference proceedings, and reports [11]. The report also suggested that China may be investing more heavily in AI outside of the private industry [11], a finding that this study corroborates. The data in this study suggest that China, along with the European Union and the Norwegian Agency for International Cooperation and Quality Enhancement in Higher Education, have emerged as critical funders of AI research in U.S. educational systems. Although the NSF and U.S. Department of Education are the two largest sources of AI funding for research in U.S. educational systems (see Figure 2a), it is problematic that non-U.S. countries are leveraging U.S. educational systems as their own AI research labs.

Perhaps more problematic is the lack of funding for AI research conducted in U.S. educational systems from private industries and nonprofits (see Figure 2a), as private industry has contributed billions of dollars of AI-related research-and-development funds over the past five decades [12,16,26], with far fewer resources dedicated to U.S. education. Although little is known about AI-related research funding in non-U.S. countries, many other countries have substantially expanded their private higher education systems in recent decades, largely relying on a combination of private organizational funds and student tuition to amplify this growth [24,25]. Countries such as India, Japan, and Brazil have experienced massive growth in their private higher education sectors in recent decades, fueled by investments by businesses [24,25], although these investments cannot be tied directly to investments in AI-related research to inform educational systems. Here, there

is ample opportunity to investigate how rapidly-privatizing educational systems in non-U.S. countries have partnered with businesses and other private organizations to fund AI-related research in educational systems.

This funding pattern may perhaps be why so many academics with AI PhDs are leaving higher education and pursuing private industry [11], resulting in a form of brain drain in the field of education at every level [11,22]. In this circumstance, many PhDs may be simply following the money, as the U.S. private educational system, at both the K-12 and higher education levels, has expanded in recent decades, mirroring a global trend in the privatization of education and research funding [24,25]. This criticism may also be extended toward U.S. government organizations, as the NIH and the U.S. Department of Defense have invested hundreds of millions of dollars in AI research and development in non-education fields [16,21], while U.S. education—including K-12 and higher education systems—have received far fewer resources. These funding structures have allowed the fields of computer science, engineering, and linguistics to far outpace the education field in terms of AI research and development [11,16], influencing the field in ways that have marginalized AI research in U.S. educational systems since 2010.

6. Conclusions

Ultimately, this study suggests that AI research in U.S. educational systems lags far behind AI research in other fields, with limited private industry and nonprofit funding for AI research in U.S. educational systems. This finding is a notable difference compared to the overall funding mechanisms of U.S. education in general, as both the K-12 and higher education systems in the United States have experienced a privatization movement in recent decades, with greater numbers of schools at both levels relying on private funding sources and student tuition to maintain operations [23,25]. Yet, this study suggests that private industries are not investing in AI-related research in U.S. educational systems—instead, the AI research dollars may be flowing toward businesses or other academic fields. Yet, of the many institutions of higher education who were early adopters and researchers of AI in non-education fields (e.g., Stanford University, Carnegie Mellon University, and the University of Georgia), the same institutions also dominate AI research funding for U.S. educational systems, producing a stratified field that has potentially marginalized Minority-Serving Institutions. From here, educators and policymakers need to advocate for both greater levels of support for AI research in U.S. educational systems as well as more equitable distribution of AI research funds across different institutions who have not historically had access to these funds. The NSF's recent effort to fund AI research at Minority-Serving Institutions should be applauded [20], but other fields such as computer science, engineering, and linguistics have enjoyed a wealth of AI research funding for far longer and in far higher amounts, stratifying the field of AI and leaving education behind [11,22,26]. To invest in the future means investing in education, and U.S. government organizations, as well as private industries and nonprofits, must prioritize funding AI research in U.S. educational systems, otherwise talent will continue to leave the field, and U.S. education will fall far further behind peers during the modern AI boom and beyond.

Author Contributions: Conceptualization, Z.W.T. and K.S.; methodology, K.S.; software, K.S.; formal analysis, K.S.; investigation, Z.W.T. and K.S.; data curation, K.S.; writing—original draft preparation, Z.W.T.; writing—review and editing, Z.W.T.; visualization, K.S.; project administration, Z.W.T. and K.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is available upon request from the authors.

Acknowledgments: We wish to acknowledge the legacy of Pat Somers.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. OpenAI. ChatGPT. Available online: https://openai.com/blog/chatgpt (accessed on 15 April 2024).
2. Minsky, M. Heuristic Aspects of the Artificial Intelligence Problem. In *Clearinghouse for Federal Scientific and Technical Information*; United Stated Department of Commerce, National Bureau of Standards: Arlington, VA, USA, 1956.
3. Dartmouth University. Artificial Intelligence Coined at Dartmouth. Available online: https://home.dartmouth.edu/about/artificial-intelligence-ai-coined-dartmouth (accessed on 15 April 2024).
4. Liu, W. A matter of time: Publication dates in Web of Science Core Collection. *Scientometrics* **2021**, *126*, 849–857. [CrossRef]
5. Pranckutė, R. Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. *Publications* **2021**, *9*, 12. [CrossRef]
6. Singh, V.K.; Singh, P.; Karmakar, M.; Leta, J.; Mayr, P. The journal coverage of Web of Science, Scopus, and Dimensions: A comparative analysis. *Scientometrics* **2021**, *126*, 5113–5142. [CrossRef]
7. Rosé, C.; Wang, Y.C.; Cui, Y. Analyzing collaborative learning processes automatically: Exploiting the advances of computational linguistics in computer-supported collaborative learning. *Comput. Support. Learn.* **2008**, *3*, 237–271. [CrossRef]
8. Manke, K. AI Lectures at Berkeley to Explore Possibilities, Implications of ChatGPT. Available online: https://data.berkeley.edu/news/ai-lectures-berkeley-explore-possibilities-implications-chatgpt (accessed on 15 April 2024).
9. Geuna, A. *The Economics of Knowledge Production: Funding and the Structure of University Research*; Edward Elgar: Ann Arbor, MI, USA, 1999.
10. Abadi, H.; He, Z.; Pecht, M. Artificial Intelligence-Related Research Funding by the U.S. National Science Foundation and the National Natural Science Foundation of China. *IEEE Access* **2020**, *8*, 183448–183459. [CrossRef]
11. Maslej, N.; Fattorini, L.; Brynjolfsson, E.; Etchemendy, J.; Ligett, K.; Lyons, T.; Perrault, R. The AI Index 2023 Annual Report. Available online: https://aiindex.stanford.edu/wp-content/uploads/2023/04/HAI_AI-Index-Report_2023.pdf (accessed on 15 April 2024).
12. National Research Council (NRC). *Funding a Revolution: Government Support for Computing Research*; National Academies Press: Washington, DC, USA, 1999.
13. Reddy, D.R. Speech recognition by machine: A review. *Proc. IEEE* **1976**, *64*, 501–531. [CrossRef]
14. Anyoha, R. *The History of Artificial Intelligence*; Harvard University: Cambridge, MA, USA, 2017.
15. MIT News. Artificial Intelligence Laboratory. Available online: https://news.mit.edu/2001/troody-0516 (accessed on 15 April 2024).
16. Dawson, G.S.; Desouza, K.C.; Denford, J.S. Understanding Artificial Intelligence Spending by the U.S. Federal Government. Available online: https://www.brookings.edu/articles/understanding-artificial-intelligence-spending-by-the-u-s-federal-government/ (accessed on 15 April 2024).
17. Foote, K. A Brief History of Natural Language Processing. Available online: https://www.dataversity.net/a-brief-history-of-natural-language-processing-nlp/ (accessed on 15 April 2024).
18. Vector Institute. Geoffrey Hinton. Available online: https://vectorinstitute.ai/team/geoffrey-hinton/ (accessed on 15 April 2024).
19. Sharma, S. 2021 Was a Breakthrough Year for AI. Available online: https://venturebeat.com/ai/2021-was-a-breakthrough-year-for-ai (accessed on 15 April 2024).
20. National Science Foundation (NSF). Expanding AI Innovation Through Capacity Building and Partnerships (ExpandAI). Available online: https://new.nsf.gov/funding/opportunities/expanding-ai-innovation-through-capacity-building/nsf23-506/solicitation (accessed on 15 April 2024).
21. National Institutes of Health (NIH). NIH Launches Bridge2AI Program to Expand the Use of Artificial Intelligence in Biomedical and Behavioral Research. Available online: https://www.nih.gov/news-events/news-releases/nih-launches-bridge2ai-program-expand-use-artificial-intelligence-biomedical-behavioral-research (accessed on 15 April 2024).
22. United States Government Accountability Office (GAO). Artificial Intelligence: Agencies Have Begun Implementation But Need to Complete Key Requirements. Available online: https://www.gao.gov/assets/d24105980.pdf (accessed on 15 April 2024).
23. Rice, J.; Monk, D.; Zhang, J. School finance: An overview. *Econ. Educ.* **2020**, 333–344. [CrossRef]
24. Altbach, P.; Reisberg, L.; Rumbley, L. *Trends in Global Higher Education: Tracking an Academic Revolution*; UNESCO Publishing: Boston, MA, USA, 2010.
25. Hazelkorn, E. *Rankings and the Reshaping of Higher Education: The Battle for World-Class Excellence*; Palgrave Macmillan: New York, NY, USA, 2015.
26. Rahkovsky, I.; Toney, A.; Boyack, K.W.; Klavans, R.; Murdick, D.A. AI research funding portfolios and extreme growth. *Front. Res. Metr. Anal.* **2021**, *6*, 630124. [CrossRef] [PubMed]