# Exploring the Future of Engineering Education: Perspectives from a Workshop on Artificial Intelligence and the Future of STEM and Societies

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## Abstract

The objective of this NSF funded workshop was to explore ways that artificial intelligence (AI) is transforming the jobs landscape and in turn, the knowledge portfolio and skills that educators should be imparting on their students prior to graduation. To best address these issues, engineering researchers, policy advocates, and industry leaders were convened to discuss the future of STEM and societies in the age of AI. From an engineering education domain, workshop participants were made aware of fundamental breakthroughs in AI that have resulted in their wide-scale adoption in society, and how these breakthroughs may impact the types of jobs that engineers of the future will do. Pre- and post-survey data were acquired from the participants in order to quantify the differences, if any, in terminology such as AI, and STEM. Beyond semantic differences in terminology, data pertaining to the solutions proposed by different groups were also collected. I.e., from an academic point of view, what changes are needed in industry and government, in order to facilitate the changing nature of education? From a government perspective, what should be the national funding priorities in order to ensure that the U.S. remains highly competitive on the global landscape and leverages the power of AI to innovate and retrain its workforce? From an industry perspective, how should degree programs evolve to meet the needs of the "real world"? Findings from this workshop can serve as a guide to researchers and decision makers in academia, government and industry on how AI will transform both STEM education and the workforce.


## Introduction

Given today's advanced technologies and the integration of evidence-based instructional approaches, an educational transformation is underway. These changes are also fueled by the recognition of the myriad of challenges facing education and in particular, issues in science, technology, engineering and math (STEM) [1]. What and how we teach will directly impact our nation's success, bringing into question the task-centric approach that is prevalent in higher education pedagogy [2]. Instead, teachers and students need access to current, readily accessible information and competencies that prepare them for the knowledge age. Workers need to learn and adapt their knowledge and skills during the lifespan of their careers, as tools and job expectations evolve. We must accept that knowledge acquisition and task readiness can no longer be the instructional focus. Educational goals and standards, such as the National Generation Science Standards (NGSS) [3] and the resource, 21st Century Skills: Learning for Life in Our Times [4] shifts educational emphasis to the development of skills and competencies for solving critical problems for the society as well as more general learning ones such as metacognition, critical thinking and collaboration.

Not only there are valid reasons to redesign curriculum and enhance instructional approaches, but we also have artificial intelligence (AI) that is considered by many to be the fuel accelerating change [5]. According to a recent Brooking's Report, many people are not familiar with AI, despite it being "a wide-ranging tool that enables people to rethink how we integrate information, analyze data, and use the resulting insights to improve decision-making and problem-solving skills."[6] The disconnect between AI and its potential impact in transforming STEM education and the STEM workforce, served as key motivators for organizing the workshop.

## Workshop Overview

The AI+STEM workshop was held on the Carnegie Mellon University campus on December 2nd and 3rd, 2019. The objective of the two-day AI+STEM workshop was to bring together experts and non-experts in the fields of AI and STEM education to discuss ways that industry, academia, and government could work better together to i) explore how the field of STEM education could potentially benefit from AI advancements, ii) propose education and knowledge acquisition strategies for the 21st century job landscape that will require lifelong learning and possibly cause entire shifts in expertise (potentially as a result of the very same AI technologies that could enhance STEM education) and iii) engage with policy and decision makers in order to ensure that ethical guidelines are in place that may mitigate adversarial exploits of AI algorithms and prevent AI algorithms themselves from being used to exploit vulnerable human populations.

America's Strategy for advancing STEM Education sets the goal that "all Americans will have a lifelong access to high-quality STEM education and the United States will be the global leader in STEM literacy, innovation, and employment." [7] While the cost of tuition has increased threefold in private institutions, and fourfold in public institutions (compared to 1974 levels [8]), the average median household income has remained stagnant [8,9]. Furthermore, the time needed to attain a higher education degree typically exceeds 52 months, well beyond the projected 48 months for which students aim [10]. Given the increase in both the cost and duration needed to earn a degree, society is faced with the challenge of achieving lifelong learning that is both scalable and cost effective. The emergence of AI and publicly available STEM content has the potential to address both the access to STEM knowledge and the availability of high-quality STEM content.

The diversity of viewpoints on how to best leverage the capabilities of AI to achieve lifelong learning, and combine AI and STEM education, served as a key theme throughout the workshop. The workshop format included a mix of keynote speaker sessions to provide the high-level perspectives from a policy and industry perspective. In addition to opening keynote speeches on each day of the workshop, participants engaged in a series of panel sessions focused on unique, yet complementary STEM+AI topics. Panel sessions were organized based on specific themes, with the themes on day one focusing on AI's role in STEM and workforce development and day two, focusing on ethics, biases and security issues pertaining to AI and its potential use in STEM. Finally, participants themselves had the opportunity to contribute to the advancements of AI+STEM topics though a series of breakout sessions that each focused on a unique, yet complementary AI+STEM topics. There was a total of six breakout sessions including: 1. The 21st Century "Classroom," 2. Data Ownership in the Age of AI 3. Broadening Access to STEM through AI, 4. Ethics of AI in STEM and Society, 5. AI for Advancing Personalized Learning, 6. The Future of Work and Lifelong Learning.

While the workshop covered a wide range of topics concentrated on AI+STEM, the focus of this paper is to explore the differences in perceptions of AI and STEM across a wide range of disciplines and expertise. Knowledge gained from this study will help elucidate the challenges and opportunities that exist in the AI+STEM domains.

## Evaluation of the Workshop

This workshop explored ways that AI is transforming the jobs landscape and in turn, the knowledge portfolio and skills that educators need to impart on their students prior to graduation. While there were measurable outcomes for this workshop (e.g. create a sustainable network of workshop attendees to serve as advisors for future national AI initiatives), the workshop evaluation also collected data on the participants' backgrounds, perspectives, and suggestions via pre- and post-workshop surveys and comments made from small group discussions during the workshop.

Collecting participant responses to surveys requires the recognition that survey instruments be relatively brief and timely. An outside evaluator attended the workshop and during the opening session of the workshop, shared with participants the link to the online pre-survey and encouraged them to use the allocated approximately ten minutes to complete their responses. At the end of the workshop, participants were also given time to complete the post-survey. Additional email reminders were distributed following the workshop to allow for responses from those who hadn't been able to attend the entire two days. There were 14 questions on the presurvey (seven were demographics) and 14 questions on the post-survey (no demographics because the participants were asked on the pre-survey for a unique identifier to link their pre- and post-responses).

This paper shares the evaluation findings that highlight some interesting insights that can potentially provide guidance in shaping the future of AI+STEM education in the U.S. and our society's strategy moving forward in terms of relevance and sustainability in the 21st century.

## Participants

There were 146 participants with a diverse set of expertise and perspectives who attended the workshop. A total of 38 organizations participated in the event, of which 10 were from academia (one of which was a minority serving institution), 11 from industry, 10 non-profit/nongovernment organization, and 7 federal/government. Of those who participated, 71 individuals responded to the NSF workshop survey administered at the start of the workshop (pre) and at the end of the workshop (post). The composition of workshop participants is listed in Table 1 below.

*Table 1: Composition of Workshop Participants*

| Parameter | *n* | % |
|---|---|---|
| Gender | | |
| Male | 50 | 71.4 |
| Female | 19 | 27.1 |
| Other | 1 | 1.4 |
| Job setting | | |
| Government | 6 | 8.6 |
| Higher education | 47 | 67.1 |
| Industry | 12 | 17.1 |
| Other | 5 | 7.1 |
| Job role | | |
| Policy maker | 6 | 8.6 |
| Faculty | 22 | 31.4 |
| Researcher | 7 | 10.0 |
| Student | 15 | 21.4 |
| Other | 20 | 28.6 |
| Ethnicity | | |
| Caucasian | 15 | 21.4 |
| African-American | 8 | 11.4 |
| Asian | 21 | 30.0 |
| Other/Unknown | 3 | 4.3 |
| Prefer not to say | 3 | 4.3 |

**Findings**

Although those who attended this invited workshop generally had some knowledge of AI, a presurvey question was included in order to gather participants' definitions of AI in their own words. This question was included to gauge if participants' understanding of AI terminology reflected any convergent or divergent perspectives of AI. According to Merriam Webster's dictionary, AI is defined as:

**1**: a branch of computer science dealing with the simulation of intelligent behavior in computers

**2**: the capability of a machine to imitate intelligent human behavior

Of the 60 responses to the question, "Define AI, in your own words" two participants mentioned the idea that defining AI can be perplexing. One participant wrote, "AI is not a single thing – there are many capabilities that we can try to get a machine to possess. I guess the sum of all that is AI" while another wrote, "AI is a general umbrella term without a consistent definition." All but 10 of the definitions included a technical reference such as computers or machine learning. Examples of the non-technical perspective include the following: "capability to learn new ideas/principles," "approaches to making everything we interact with intelligent," and "AI can do the tedious jobs that people don't want to do." While the sample sizes representing the responses by job role are small, it is interesting to note that the five policy maker responses and the five researcher responses did include a technical reference. While many of the answers included possible benefits of AI such as "being able to perform in smart ways," "make sense of the world's complexity," and "to problem solve, adapt and engage in areas which would normally require human interaction," none of the definitions stated any possible threats presented by AI. In fact, several participants made strong statements such as "AI projects human needs or intent through computational reduction to serve human needs" and that AI is, "an automated method to speed and improve decisions and outcomes to advance benefits to society." These positive statements were surprising since the second day of the workshop was dedicated to AI ethics, security and privacy. One possible explanation could be the optimism shared by workshop participants pertaining to AI and its potential to have positive impact in STEM and society.

Participants' AI definitions did reflect that although they didn't have a common definition of AI, they recognized the role of computers and machines in expanding human knowledge and capabilities. None of the participants parsed AI into computer science, however. Perhaps their various disciplines and job roles represent more than computer sciences and as such, they see AI as an inter-disciplinary field. This possibility is a significant finding for several reasons: i) it expands on the AI definition provided by Merriam Webster's dictionary as being "a branch of computer science," and ii) it highlights the diversity of opinions on the topic, which may help to inform the types of collaborations that are sought out in the future by federal funding agencies (i.e., those that extend beyond computer science and include a diverse set of disciplines).

In addition to participants' initial perspectives on a definition of AI, there was also discussion of STEM education and its meaning. Although there appeared to be consensus on what STEM means, there was a need to be explicit that STEM education applies to all instructional levels and that STEM is also used to describe particular segments of the workforce (e.g., reference to the U.S. STEM workforce [11]). On the pre-survey, participants were asked, "What concerns, if any, do you have with regards to the current state of AI in our schools and workplaces?" Their responses revealed many of the issues addressed during the workshop and even though the participants were able to provide definitions of AI that revealed some understanding of it, many expressed concerns similar to this one stating, "people are not well enough versed in it." When it comes to AI in our schools, one wrote, "AI seems to be misunderstood by school leaders who

tend to view it as AR/VR/MR or machine learning for learning analytics." Another participant commented, "More and more people are using AI without understanding its limitations and negative repercussions in research and training." Many of their comments speak to the need to address peoples' perceptions and understanding of AI in order for us to effectively use in our schools and workforce.

Although a lack understanding about AI was noted, there weren't concerns expressed to slow down and get better versed on AI. Instead there were numerous responses that expressed a sense of urgency such as "we are behind" and "By not funding AI and other STEM in our schools, it is putting our youth at a disadvantage in their future career paths." The lack of progress in our schools was partially attributed to the school systems with comments such as this one, "Our public schools are not working as rapidly to integrate AI within the classrooms." One faculty simply stated, "Not enough is being done, and not quick enough." Another saw the lack of AI in our schools as "an economic issue" and stressed that "in communities where funding is scarce, those schools are really behind." Only one participant addressed lack of progress in both education and industry by stating that "AI in our schools and workplaces is lower than it should be." Furthermore, when AI is in use in schools, there are questions about its effectiveness. A policy maker expressed concern that there is "Inadequate coverage in curriculum and inadequate training of teachers." A faculty member wrote, "We have a hard-enough time to teach fundamentals in our disciplines. I am concerned we may not have enough time to incorporate AI appropriately." How to integrate AI into school settings and the curriculum is a concern. One faculty stated that it is "haphazard at the high school level, while overly focused on machine learning in our universities." Another offered more specifics by sharing "there is not enough focus on problem formation and epistemology." Student preparedness for AI is an ongoing dilemma and is due to issues such as the "lack of sufficient mathematical education (foundation) to understand AI algorithms." For faculty, there is some concern about "attempts to entirely replace human teachers, rather than letting (human and machine) do what they do best."

Throughout the workshop, speakers and participants questioned how to effectively bring AI into all aspects of our lives. One repeated message was that innovation is a competitive advantage, both in our schools and in our workplaces. In today's world, digital dexterity and lifelong learning are essential skills. One of the industry speakers at the workshop stated, "The world is changing so fast that we have to learn every day." Workshop participants wrestled with how AI will shape the future workforce and how AI is already having an impact. The metaphor of a black box was mentioned several times; no longer can we put our workers into a black box because adaptive skills sets are required. AI doesn't fit into a black box either because systems thinking is needed. The message was clear; we have to look at overall systems that AI will impact. Participants from various disciplines and job roles were able to discuss AI's impact on people, processes, technology and mindset. "To successfully navigate the future workforce, you need to learn empathy, grit and how to work well and network," expressed a workshop participant. While AI was cited for its ability to help us understand uncertainty, there were concerns about its ability to make a partnership between the worker/teacher and the machine.

When it comes to AI in the workplace, workshop participants expressed concerns that AI may cause disruptions that result in people being replaced by machines. Participants were told, however, that it is wise not to make assumptions about who is interested in accelerating or resisting AI. Workers on the floor may actually be interested in automation that takes over the more mundane, repetitive tasks with resistance instead, potentially coming from management. Another speaker prompted thinking about using AI to fundamentally change how we work. Workshop participants, like most of today's workforce, rely on email and were asked to reflect on how it was all that much different from an inter-office memo. At this workshop, there were participants from different work settings and with different job roles interacting and contributing,

but a speaker questioned how often that happens in industry settings. The speaker questioned, "What technologies and AI are used to bring more voices to the table and to use data, such as email trails, to see who the real "leaders" are when it comes to collaborating and contributing?" Sentiments and questions expressed by the speakers were food for thought for participants to ponder and discuss during breakout sessions.

From the pre- and post-conference surveys, participants answered four questions using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) regarding their level of knowledge of AI issues. Specifically, the questions asked participants to agree or disagree with the following statements: I am knowledgeable about AI research issues, I am knowledgeable about AI educational issues, I am knowledgeable about STEM research issues, and I am knowledgeable about STEM educational issues. Only the participants who participated in both pre- and post-surveys were included in the analysis (N = 58). Data analysis (Table 2) showed that participants increased in their knowledge about AI research and educational issues, and STEM research issues (P < .01). There were no significant changes in STEM educational issues.

*Table 2: Pre-Post Results of AI+STEM Questions*

| | Pre | Post | P Value |
|---|---|---|---|
| AI research issues | | | |
| Mean | 3.396 | 3.793 | 0.008 |
| SD | 0.877 | 0.669 | |
| Std. Err. | 0.115 | 0.087 | |
| AI educational issues | | | |
| Mean | 3.140 | 3.526 | 0.001 |
| SD | 0.914 | 0.847 | |
| Std. Err. | 0.121 | 0.112 | |
| STEM research issues | | | |
| Mean | 3.534 | 3.810 | 0.01 |
| SD | 0.921 | 0.907 | |
| Std. Err. | 0.121 | 0.119 | |

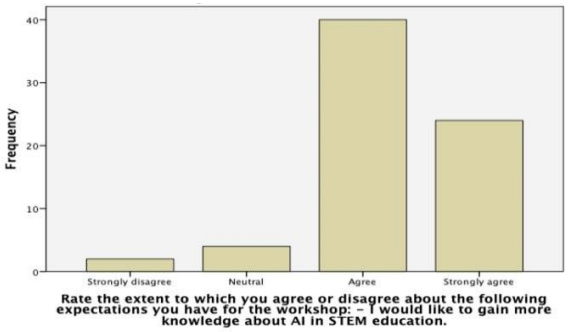


*Figure 1: Survey results about AI+STEM education*

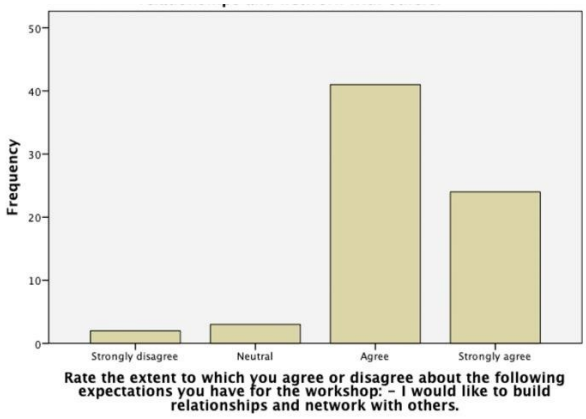


*Figure 2: Survey results about networking*

The survey responses from Figures 1 and 2 are both encouraging and surprising. While many of the participants who attended the AI+STEM workshop had some expertise or knowledge in the field, many felt as though participating in the AI+STEM workshop would enable them to gain

more knowledge about AI in STEM education and expand their professional network with others. These findings are informative and highlight the thinking of the participants, prior to participating in the workshop. The majority of the survey respondents in Figure 2 cited networking with others as a critical component of why they attended the workshop. This finding highlights the interest of diverse stakeholders to engage with experts and non-experts across different disciplines and backgrounds. From a national funding strategy perspective, federal funding agencies could view these findings as an indication of the desire expressed by individuals from government, industry, and academia, to foster more collaborative funding opportunities focused on AI+STEM.

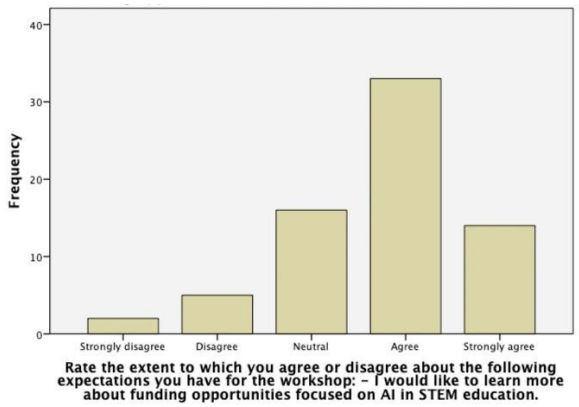


*Figure 3: Responses pertaining to funding*

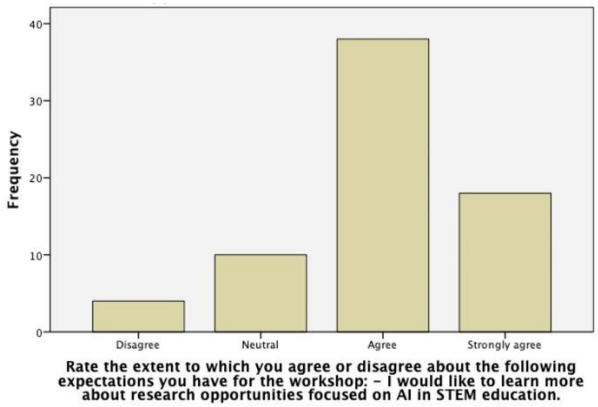


*Figure 4: Responses pertaining to research*

Figure 3 indicates that a majority of participants were interested in learning more about funding and research opportunities in the AI+STEM space. Compared to Figures 1 and 2, there were less participants who responded with "Agree" and "Strongly Agree" responses. These findings could be a result of the presence of participants from several funding agencies including representatives from the National Science Foundation (NSF), National Institutes of Health (NIH), Office of Naval Research (ONR), and the National Aeronautics and Space Administration (NASA). Figure 4 indicates that diverse stakeholders are interested in learning more about research opportunities pertaining to AI+STEM, hereby highlighting the fact that individuals beyond academia, are interested in not only utilizing AI as a tool to advance STEM, but also in the research dimension that results in the development of AI.

Although the workshop participants did not indicate significant changes in their knowledge level of STEM educational issues, there are reasons that could explain this finding. This workshop was not solely focused on specific topics such as the integration of AI into education, but rather looked at STEM and AI educational issues through a broader lens. During the workshop, educational issues were identified and discussed. Next steps and possible solutions will be explored as this work goes forward.

**Action Items and Next Steps**

This workshop served as a foundation to bring together experts and non-experts across a wide range of disciplines. The main action items identified include the need to:

- develop a strategy that would facilitate the organization of an annual workshop similar in size and scope. This annual workshop will help keep current and future participants up to date on the current state of research and policies pertaining to AI and STEM education.
- identify ways to better integrate AI into current and future STEM curricula and ways to ensure that educators are trained to teach the next generation of STEM students about the benefits and challenges of AI in STEM education and society.

- create an online platform that enables the free exchange of ideas and best practices pertaining to AI and STEM education. This would also include non-experts, who may not be technical leaders in AI or STEM education, but whose participation and engagement would help advance the national conversation pertaining to AI and STEM.

Several next steps that are motivated by the action items above include:

- explore national funding opportunities that enable workshop participants to collaborate towards solving one or more of the main action items outlined above. Securing AI STEM funding would enable participants to organize annual workshop events and advance basic and applied research problems pertaining to AI in STEM education.
- keep workshop participants engaged in current events pertaining to AI STEM education through periodic dissemination of upcoming events pertaining to AI STEM such as conferences, hackathons, etc. To facilitate this process, workshop organizers provided participants with an opportunity to opt-in and share their contact information with other workshop participants who are interested in engaging and collaborating.
- disseminate the research data and results through scientific publications and conference presentations. Workshop organizers have prepared several dissemination activities including engagements beyond the scientific community to include policy makers and national and international organizations.

## Conclusion

The two-day workshop on AI and the future of STEM and societies brought together experts from a wide range of disciplines and sectors. The survey results on the definitions of the terms, AI and STEM, indicate that progress needs to made in terms of reaching a consensus on what these terms mean or what should be done to integrate them into practice. Workshop participants see AI usage across several industries, but indicated that its use to transform STEM was still at a nascent stage. Some workshop participants highlighted the need for educators to be trained on AI state-of-the-art before they are able to disseminate that knowledge to learners. The digital landscape is also changing the learner-educator relationship by providing a more diverse source of educational content. While there are benefits to the wider range of educational content, there is also the challenge of standardizing educational content. The positive opinions expressed by workshop participants pertaining to AI and its potential to transform STEM was encouraging and highlighted the optimistic view of the participants. Yet they did recognize that reality that AI brings fears, concerns and disruptions, such as job replacements. Participants found great value in the networking component of the workshop and expressed interest in more funding and collaborative research. These results were promising, especially given the diversity of the workshop participants that included not only experts in AI, but non-experts who were typically simply perceived as consumers of AI technology. The survey results reveal that a majority of participants not only want to be consumers of AI technology, but also part of a research team that leads to the advancements of AI and its potential use in STEM and workforce development.

## Limitations and Future Study

Given the small sample size, conclusion of the study has limited statistical power to justify generalization of the results. In detail, the sub-group of job settings such as government and industry are relatively smaller than other groups. Furthermore, there is a chance that participants' ethnic backgrounds may influence their AI perspectives and involvements. Lastly, participants' AI definitions, interest, and experiences can vary by regions because of their proximity to geographic locations close to AI sectors (e.g. Pittsburgh or Silicon Valley) that have a high

impact on the communities/culture. Therefore, there is a necessity to expand this study with a larger population of participants from various ethnic backgrounds, professions and regions.

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