Esther Shein

The Impact of AI on Computer Science Education

Understanding why "working hard and struggling is … an important way of learning."

LAST FALL, ERIC KLOPFER decided to conduct an experiment in his undergraduate computer science class at the Massachusetts Institute of Technology (MIT). He divided the class into three groups and gave them a programming task to solve in the Fortran language, which none of them knew.

One group was allowed to use Chat-GPT to solve the problem, the second group was told to use Meta's Code Llama large language model (LLM), and the third group could only use Google. The group that used ChatGPT, predictably, solved the problem quickest, while it took the second group longer to solve it. It took the group using Google even longer, because they had to break the task down into components.

Then, the students were tested on how they solved the problem from memory, and the tables turned. The ChatGPT group "remembered nothing, and they all failed," recalled Klopfer, a professor and director of the Scheller Teacher Education Program and The Education Arcade at MIT.

Meanwhile, half of the Code Llama group passed the test. The group that used Google? Every student passed.

"This is an important educational lesson," said Klopfer. "Working hard and struggling is actually an important way of learning. When you're given an answer, you're not struggling and you're not learning. And when you get more of a complex problem, it's tedious to go back to the beginning of a large language model and troubleshoot it and integrate it."

In contrast, breaking the problem into components allows you to use an LLM to work on small aspects, as opposed to trying to use the model for an entire project, he says. "These skills, of how to break down the problem, are critical to learn."

This example has led Klopfer to confidently conclude that as AI steamrolls its way into every industry, computer science is not doomed. Other computer science experts agree that the more AI is used, the nature of jobs will change so humans must still be taught basic concepts like statistics and knowledge of how systems work.

"You still need the foundation to be effective computer scientists and software engineers," said Beena Ammanath, leader of trustworthy AI and technology trust ethics at Deloitte.

Despite all the hand-wringing

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about AI taking jobs, a recent study by MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) found it might take longer to automate human jobs than previously thought.

Only about 23% of wages linked to vision-related tasks could be cost-effectively replaced by AI, according to the study, indicating that the displacement of jobs due to AI, especially in computer vision, is likely to occur more slowly than initially envisioned.

The findings "suggest that we should expect the effects of AI automation to be smaller than the existing job automation/destruction effects already seen in the economy," the study says. "Whether adding AI automation of these existing effects will substantially increase overall job destruction is unclear." While there is likely to be some job loss, "we also find it likely that a substantial fraction of the AI task automation will happen in areas where traditional automation is occurring," the CSAIL study observed.

How Computer Science Education Will Change to Approach AI

The continued focus on incorporating AI into most job sectors also will change how computer science will be taught, presenting opportunities that are "quite tremendous," according to Risto Miikkulainen, a professor of computer science at the University of Texas at Austin, and associate vice president of evolutionary intelligence at Cognizant AI Labs.

With the advent of tools like Microsoft's Copilot chatbot, for example, some might wonder why they should bother learning to code. Miikkulainen believes students are using Copilot and other chatbots mainly "as a tutor for programming assignments" to make suggested changes.

"All of a sudden, teaching programming becomes much more alive" as a result, Miikkulainen says.

Reid Gordon Simmons, a research professor at the Robotics Institute at Carnegie Mellon University, adds that in the same way compilers translate a programming language's source code into machine code, removing the need for computer science engineers to understand assemblers, "use of AI and ML will make it less and less necessary for them to understand the details of coding."

However, it is still important to teach people how to code, simply because part of becoming a computer scientist is about understanding processes, Simmons said. "My analogy is teaching seven-year-olds arithmetic. By the time you get to middle school, no one does arithmetic by hand; you use calculators."

Even if calculators can do the work for you, you still need to understand the concepts, he said. "Similarly, computer scientists will have to understand the fundamentals of programming in order to be effective in their jobs, but just like using calculators ... they won't have to do a lot of coding."

AI requires the teaching of entirely new disciplines or aspects of computing, such as responsible AI and how to prevent the misuse of AI, Miikkulainen said. "There will be so many people using [AI systems] who don't understand what's under the hood."

New college majors also will crop up in areas including data science, machine learning, user experience, and mobile engineering, as well as in specific branches of AI, such as generative AI, LLMs, and computer vision, said Deloitte's Ammanath.

This will not only prepare students for the jobs of the near-future and make them more marketable, but help keep the U.S. competitive with other countries in the global AI arms race.

At the high school level, AI's impact means "we need to learn a lot rather quickly," said Julie York, an equity fellow with the Computer Science Teachers Association (https://csteachers.org/), and career preparation and technology department chair at South Portland High School in Maine.

"Every new technology has challenged things," York said. "I anticipate we're going to adjust."

York is a big advocate for teaching computational aspects in elementary school.

"Teaching [students] what is a virtual assistant in elementary school is appropriate," said York, adding that her second-grade daughter is learning about digital citizenship and how to be safe online.

"I've always tried to teach my students to critically think and now, to critically think about where the data comes from and what does it look like to get large amounts of data and how can AI be useful as a thought partner, and get feedback from AI to make your projects better," she said.

"One of the doom-and-gloom scenarios is that if AI is doing more, people will do less," says MIT's Klopfer. "I don't see it that way. More people will be using it to make applications, create computational artifacts that are interesting artistically, and express themselves through computing."

The Impact of AI on the Jobs Market

While some tasks may be hard to replace with AI, some studies show the technology already is replacing workers.

A whopping 90% of jobs will be disrupted in some way by generative AI, according to a recent Cognizant study. Whereas in the past, technological advances and automation have mainly impacted manual labor and process-centric knowledge work, the study found that "Generative AI is poised to do the opposite, having a higher disruption on knowledge work."

It further found that "jobs involving credit analysis, computer programming, Web development, database administration, and graphic design already have a theoretical maximum exposure score of about 50%. By 2032, as technology advances, some jobs' ex-

ACM Recognizes CS Innovators

ACM recently announced the recipients of four prestigious technical awards in diverse categories, celebrating the hard work and creativity that underpin many of today's most important technologies.

Prateek Mittal of Princeton University was named to receive the 2023 ACM Grace Murray Hopper Award for foundational contributions to safeguarding Internet privacy and security using a cross-layer approach.

Andrew S. Tanenbaum of Vrije Universiteit received the ACM Software System Award for the development of MINIX, which influenced the teaching of Operating Systems principles to multiple generations of students and contributed to the design of widely used operating systems

Guy E. Blelloch of Carnegie Mellon University, Laxman Dhulipala of the University of Maryland, and Julian Shun of the Massachusetts Institute of Technology received the ACM Paris Kanellakis Theory and Practice Award for their contributions to algorithm engineering, including the Ligra, GBBS, and Aspen frameworks.

David Blei of Columbia University was named to receive the ACM–AAAI Allen Newell Award for his significant contributions to machine learning, information retrieval, and statistics.

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posure scores may climb to 80%."

And while an analysis by the International Monetary Fund (IMF) found that 40% of global jobs are already being impacted by AI, that number climbs to 60% of jobs in advanced economies.

"One of the things that sets AI apart is its ability to impact high-skilled jobs," the IMF study noted. "As a result, advanced economies face greater risks from AI—but also more opportunities to leverage its benefits—compared with emerging-markets and developing economies."

The Types of Jobs that Will Be Needed

There is little doubt new jobs will be required in the AI age. Computer scientists' work will morph into designing programs that specify requirements that will be compiled directly into the code, rather than them writing the code itself, Simmons says. AI is "going to lift the way that software engineers approach their jobs to be much more focused on requirements and specifications and validation and verification than the actual coding practices," he said.

AI will not take away jobs, Simmons insisted, but it will change the nature of jobs. "The way I always describe it is every job consists of a number of tasks and those tasks are going to be replaced by AI and automation, but the jobs will not." They will change the need to do certain things manually, just as word processing eliminated the need for manually typing things, he said.

Both Simmons and York said there already is great demand for people who can do prompt engineering, interacting with LLMs to get the information you want. "That's a job that didn't exist two years ago," said Simmons.

Prompt engineering is "the process of structuring text that can be understood by AI; it's a new way of speaking," said York. "We have abbreviated language because of the Internet, like 'lol'. So we're going to learn to speak in prompts."

This makes the human side "more important than ever," York added, because people need to determine where data is coming from and what is missing so they can get accurate informa-

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tion. "The computer can't figure that out," she noted.

Other jobs that will be needed in the future include machine learning engineers, who focus on building, training, and validating models; MLOps (machine learning operations) engineers, who work on testing, deploying, and monitoring models in production; AI testers who can understand the shortcomings of a system's output and fix it, and AI compliance officers who ensure adherence to laws and regulations, said Simmons.

"I firmly believe AI cannot be fully autonomous … there's always going to be humans and machines working together and the machine is augmenting the humans' capabilities," Simmons said. For AI to be successful at augmentation, humans have to determine how systems are designed, the role of the augmenter, how the human's job description changes, and how to create a successful partnership. "Those are questions that need to be asked as new jobs are created," Simmons said.

Looking Ahead

While education already is being reshaped to teach and prepare the next generation for a world where AI is dominant, ultimately no one knows for sure what the impact will be of AI on computer science jobs. What is clear is that education and jobs have always been intertwined and as jobs change due to automation, schools must prepare students to learn to work differently.

In the short term, AI will be disruptive, "and any time you have a major disruption like this, there will be people who will be adversely affected, so there will be some short-term pain while society adjusts," Simmons said.

From an educational perspective, people already are struggling with how to utilize—or not utilize—generative AI, he says. "I think eventually, it's going to be acknowledged that these technologies have to be incorporated into education." Rather than forbidding students from using ChatGPT or Copilot, he said, it is important to figure out how these tools get incorporated into the pedagogy.

That is how CMU is handling the use of ChatGPT. "Here, we're embracing the technology and … we're forcing [students] to use it to teach them something about the technology itself," Simmons said.

One concern York has is that computer science is not a requirement in schools, yet "We all need computers and technology to do most jobs. It is pivotal that you, as a professional, have skills related to computers but … across the country, we do not have standards that say in education, students need to learn A, B, C, about computer science."

If the richest school districts are teaching computer science and programming, all districts need to do likewise, York maintained. "There's a disparity, and it's not just AI," she said. "So we've known the poorest districts will suffer the most and those kids will be further behind by the time they get to college or a career." ▢

Further Reading

Artificial Intelligence and the Future of Teaching and Learning: Insights and Recommendations, U.S. Department of Education, 2023.

AI in Education, Education Next. 2023

The Promises and Perils of Generative AI in Education: TFA's Evolving Perspective, *Teach for America*, August 2023.

AI Won't Replace Humans–But Humans With AI Will Replace Humans Without AI, *Harvard Business Review*, August 2023.

Generative AI and the Future of Work. Deloitte.

Choosing AI's Impact on the Future of Work." *Stanford Social Innovation Review*, October 2023.

Generative AI: How will it affect future jobs and workflows?", McKinsey Global Institute, September 2023.

Esther Shein is a freelance technology and business writer based in the Boston, MA, USA, area.