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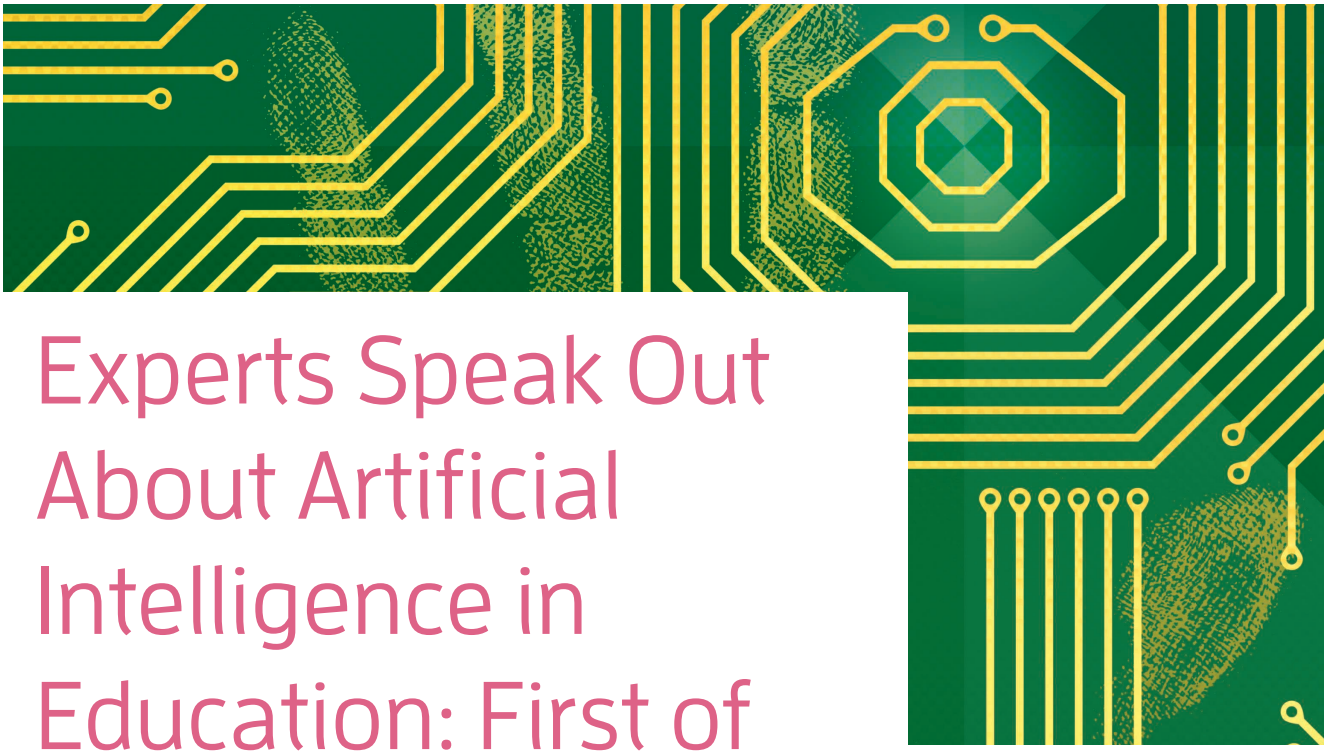

Experts Speak Out About Artificial Intelligence in Education: First of Two Roundtables

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Interactive artificial intelligence empowering education requires that teachers and their students alike be prepared for unpredicted levels of critical and mathematical thinking.

Thanks to the efforts of news and social media, generative artificial intelligence (GAI) has captured the imagination of leaders in almost every segment of society—internationally, in nearly all sectors of business, professional and nonprofessional sports, education, and academia. We, the editors of *Computer*'s "Education" column, have addressed GAI in previous issues of the magazine. The editorial activities related to producing those columns have caused us to consider specific matters requiring additional attention in this column. Accordingly, we invited five experts whose work directly relates to GAI and its effects on education, and, in the format of a virtual panel, we posed specific questions regarding GAI to each. These folks include

- George O. Strawn, director emeritus of the Board on Research Data and Information, National Academy of Sciences
- George K. Thiruvathukal, chair, Department of Computer Science, Loyola University Chicago
- Bernadette Adams, senior policy advisor for AI and emerging technology, U.S. Department of Education, Office of Educational Technology

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ROUNDTABLE PANELISTS

Bernadette Adams is a senior policy advisor for AI and emerging technology at the U.S. Department of Education. She leads projects to provide educators with guidance on safely and effectively leveraging AI to support teaching and learning. She also recently served as a technical consultant and subject matter expert on projects to support innovation, entrepreneurship, and science, technology, engineering, and mathematics education across government as a White House leadership fellow. Prior to joining the Department of Education, she worked to advance the use of technology for workforce development at the White House Office of Science and Technology Policy and the National Partnership for Reinventing Government. She holds an M.S. in education from the University of California, Berkeley, and a B.S. in biochemistry from the University of California, San Diego.

Norita Ahmad is a professor of information systems and business analytics at the American University of Sharjah, United Arab Emirates. She is a Member of IEEE.

Arun Majumdar is a cofounder and the CEO of Permion AI. He has 25 years of professional experience in Fortune 500 consulting, defense, and intelligence. As an innovator with McGraw Hill, he developed computer-supported instructional materials for grades K through 12 in support of the No Child Left Behind Act. He won a best product design award in 2000 for MobileDev at Speedware Corporation. He performed graph analytics for a large U.S. national security organization, leading to a U.S. government chief information officer award. He was a best practitioner in architecture for complex systems and a visionary for the Canadian Department of Defense's Netcentric Warfare initiative.

George O. Strawn is the director emeritus of the National Academy of Sciences (NAS) Board on Research Data and Information. Prior to joining the NAS, he was the director of the Federal National Coordination Office for Networking and IT Research and Development at the Office of Science and Technology Policy; National Science Foundation (NSF) chief information officer; executive officer of the NSF Directorate for Computer and Information Science and Engineering (CISE); director of the CISE Division of Advanced Networking Infrastructure and Research; NSF Network program officer; director of the Iowa State University Computation Center; and chair of the Iowa State University Department of Computer Science.

George K. Thiruvathukal is a professor of computer science in and the chair of the Department of Computer Science, Loyola University Chicago, Chicago, IL, USA. His research interests include high-performance computing, programming languages and systems, distributed systems and clouds, and machine learning and computer vision. He received a Ph.D. from the Illinois Institute of Technology. He is also a visiting computer scientist at the Leadership Computing Facility, Argonne National Laboratory.

- Norita Ahmad, professor, American University of Sharjah
- Arun Majumdar, cofounder and chief executive officer (CEO) of Permion AI.

This is the first of two panels, where our participants set the table for the second roundtable discussion in the next monthly "Education" column. They will springboard from this baseline to look ahead to education technology in 10 to 20 years.

COMPUTER: Let's kick off with some introductory statements.

GEORGE O. STRAWN: I will focus on GAI, the latest enhancement of AI, which I would also characterize our newest electronic "symbion" (a near organism living in symbiosis with us). I'll address two slightly different questions. First, I'll suggest how GAI could be a new aid for all education, not just scientific. Then, I'll suggest how GAI could help perform science. I'll start by reviewing some previous educational symbionts and the societal resistance to them.

GEORGE K. THIRUVATHUKAL: Let me preface my discussion by saying that I recently gave an invited talk at the John Vincent Atanasoff (JVA) Symposium on Modern Computing at IEEE Services. To familiarize readers, JVA was one of the key founders of modern electronic computing. His computer was ahead of its time and played a key role in influencing modern computing as we know it. While it was designed for physics computations, it introduced many current concepts (for example, binary longer-term storage) that we readily associate with today's computers. It was pretty remarkable when you consider that it was completed in 1939.

I was delighted to have an invited paper at a symposium named for this

great human being. My talk was about the "reuse" of pretrained models. I know this might sound a bit boring. Still, the current state of machine learning and AI cannot move forward without emphasizing how it is put together (an idea of software engineering, for example, design patterns). Conversely, software engineering cannot advance without understanding how AI solutions are put together. In any event, the relevance of being invited to present our work at the intersection of software engineering and AI was a glimpse into the future, much as Atanasoff must have been thinking when introducing the world to electronic computing. If we don't reimagine the possibilities, we are doomed to a life of stagnancy and irrelevance.

BERNADETTE ADAMS: AI has the potential to revolutionize education by providing personalized learning experiences, automating administrative tasks, and improving student outcomes. However, implementing AI in education must be done thoughtfully and requires careful consideration of potential limitations and ethical concerns.

One key recommendation for implementing AI in education is to ensure that it aligns with a collective vision for high-quality learning that includes equity. AI systems and tools must be designed to support learners' diverse needs and promote equal access to educational opportunities. This requires a focus on data privacy and security and the need for human oversight and intervention to ensure that AI models are not perpetuating biases or reinforcing inequalities.

NORITA AHMAD: I believe that effectively harnessing AI in all levels of education demands a multifaceted skill set from educators. As AI becomes more integrated into the educational landscape, educators must acquire certain prerequisites to navigate this transformation successfully.

However, having technical proficiency alone is not enough. Educators should also have a strong foundation in pedagogy, including knowledge of learning theories, curriculum design, instructional strategies, and assessment methods. We should know how AI complements, rather than replaces, these pedagogical approaches and instructional strategies. The synergy between AI and pedagogy is where transformative educational experiences can fully materialize.

ARUN MAJUMDAR: As part of an AI tool-developing organization, and as an AI user myself with a mixed educational background from Sub-Saharan Africa and culminating in North America, I bring a multiethnic view to the question, Can AI be harnessed to offer personalized attention during the lifelong educational experience, and if so, how?

***COMPUTER*:** Are there any matters related to GAI in education that nag at you and perhaps keep you awake at night?

AHMAD: First and foremost, we must acknowledge that AI is not a magic wand but a tool with immense potential. To effectively utilize AI in all stages of education, we must possess a firm grasp of AI fundamentals. For example, we should know about machine learning algorithms, neural networks, and data analysis techniques. In addition, as educators, we also need to be comfortable using technology tools, platforms, and software. This includes familiarity with learning management systems, educational apps, and tools that incorporate AI functionalities. By having this familiarity, we will understand AI's capabilities and limitations, helping us make informed decisions about its application.

THIRUVATHUKAL: Regarding teaching, I have a mix of good and bad news to report regarding software engineering and AI. Both the software engineering and AI communities have a lot to learn from each another to advance the state of the art.

I've been spending a lot of time with GAI and thinking about its implications. While promising, we must be mindful that the current state of GAI needs a great deal of work before its results can be trusted across a diverse range of domains. Nevertheless, my use of prompt engineering suggests that we can eliminate the drudgery associated with the current Internet. Many solutions that previously eluded us are now readily available, especially regarding background investigation and coding, especially in obscure languages. For example, I often have to work with spreadsheets, but I really have much motivation to learn how to write macros. Large language models (LLMs) allow me to get great starting solutions that I can customize as needed (reaffirming the importance of humans).

MAJUMDAR: I believe every human being is a unique, singular, sparkling individual. At the very least, each is a diamond in the rough. But conventional education in schools and institutions follows a one-size-fits-all model of courses, "standardized" tests, and rubrics. Could we undertake any long journey in one-size shoes that are ill fitted? Education, like shoes, must be fitted to the individual.

Michael Faraday endowed the world with an understanding of electricity. He had no formal schooling. He was self-taught at the bookshop where he worked. Likewise, Thomas Edison transformed lives with his inventions, and he had no formal education. The norms then could not have predicted nor aided such brilliant minds. Is this also true today?

STRAWN: In his *Dialogues*, Plato wrote that written language gives a person the appearance of wisdom with none of the substance since memorization was the height of wisdom in preliterate cultures. Four-function calculators were initially forbidden from use in math exams since doing arithmetic was one

of the pillars of a basic education. Google use was initially banned as a source for paper writing assignments since going to the physical library was the time-honored method.

COMPUTER: Do you think the current state of the art of GAI is ready for prime time?

MAJUMDAR: Unfortunately, the current GAI systems are not trustworthy, are disconnected from formal educational rubrics, and do not understand anything about human or learner behavior. In contrast, a large body of proven expertise does exist in education systems, within teachers and institutions. Thus, our challenges include integrating this formal knowledge, such as the codification of mathematics, embodiment of educational rubrics, and, importantly, the psychological understanding of human behavior to imbue GAI with ethics, morals, and principles of good teaching.

> First and foremost, we must acknowledge that AI is not a magic wand but a tool with immense potential.

ADAMS: One of the most critical concerns in implementing AI in education is its potential to reinforce existing biases and inequalities.

THIRUVATHUKAL: A mistaken conclusion by many—including mainstream media—is that an incorrect response from an LLM is a failure. I see it somewhat differently. The fact that LLMs and AI make mistakes has the possibly unintended consequence of making AI more human. What makes us fun, as humans, are our flaws—and our ability to correct them. In a preprint I wrote with Jamie Davis and Yung-Hsiang Lu, at Purdue, we demonstrated that ChatGPT makes mistakes (as we do) but is often, but not always, able to correct them. Because the generative pretrained transformer is not open (contrary to the implication of coming from a company, OpenAI, with *open* in the name), we do not know precisely what is automated versus having human intervention/supervision. What we do know, however, is that the technology is ever changing and evolving.

COMPUTER: What are your thoughts on the importance of explainable AI as it pertains to education?

ADAMS: An important consideration is the need for AI systems and tools to be inspectable and explainable. Educators must be able to understand how AI models are making recommendations and decisions and to have the ability to override these suggestions when necessary. This requires a focus on transparency and accountability and the need for ongoing evaluation and improvement of AI systems and tools.

AHMAD: Another area of consideration is data literacy. Education powered by AI relies heavily on data collection and interpretation. Understanding how to ethically collect, preprocess, and interpret educational data is pivotal in delivering personalized and effective learning experiences. The growing potential for AI calls for the urgency of addressing the ethical implications to avoid unforeseen and potentially harmful outcomes. No AI integration can succeed without ethical considerations at its core. We must comprehend the ethical dimensions, including data privacy, algorithmic bias, and the potential to exacerbate inequalities. Responsible AI deployment demands a commitment to equitable access and outcomes for all learners.

COMPUTER: Do you see a continuing or changing role for instructors as AI becomes increasingly integrated into teaching and learning?

AHMAD: We should embrace the concept of adaptive learning systems, where AI-powered tools adjust content and the pace based on individual student needs. An understanding of personalized instruction and differentiated learning is fundamental. It can help enhance the learning experience, provide students with access to vast amounts of information, and improve the efficiency of grading and feedback. Continuous learning is not an option but a necessity. Therefore, we need to stay updated on the latest advancements and best practices, ensuring that our approaches in education remain current and effective.

Lastly and most importantly, an adaptable mindset is key. We must be ready to embrace change and innovation as the educational landscape evolves. An openness to experimentation and iteration is what truly propels AI integration forward. While AI offers numerous benefits, educators must remember that human connection remains paramount. Developing emotional intelligence, empathy, and the ability to foster a supportive learning environment is essential to effective teaching. As such, we should engage in reflective practice, continually evaluating the impact of AI on student learning—considering what works, what needs adjustment, and how AI can be optimized to enhance educational outcomes.

ADAMS: Educators must also remain in charge and have the most important relationships with students when AI is implemented in education. While AI can automate many administrative tasks and provide personalized learning experiences, it cannot replace the human connection and empathy essential for effective teaching and learning. To address this limitation, it is important to ensure that AI is used to support and enhance the work of human teachers and administrators rather than to replace them. AI systems also have trouble with context, which humans readily grasp and consider.

Therefore, it is essential to evaluate AI systems and tools using a rigorous and transparent process involving multiple stakeholders, including teachers, students, parents, and administrators. The people most affected by the use of AI in education must also be part of the development of the AI model, system, or tool, even if this slows the pace of adoption, as this will help to ensure that AI systems and tools are effective, reliable, and aligned with educational goals.

COMPUTER: As frequently noted, bias is an issue in the current state of GAI datasets. What should be done to eliminate misinformation and bias?

ADAMS: AI models are only as good as the data they are trained on, and if these data are biased or incomplete, the AI model will reflect these biases. This can lead to unfair treatment of certain groups of students and can perpetuate existing inequalities in education. One example is using AI-powered writing assessment tools, such as automated essay scoring. These tools can give students immediate feedback on their writing, allowing them to improve their skills and receive personalized support. However, educators must ensure that tools such as these are trained on diverse and representative data, and they must regularly evaluate and improve these models to minimize potential bias. In one well-publicized example, the essays of English learners are unfairly singled out for cheating by AI models, a case of biased false positives.

COMPUTER: Is personalization a reasonable objective when bringing AI to education?

MAJUMDAR: Where some see "learning disabilities," others see "genius." But this is the undiscovered opportunity that resides in everyone. Norms and standards exist in place of individual tutelage and attention because there are not enough teachers to pair up with all students. Here is a great opportunity for AI to engage in the teachers' and students' educational lives. AI can tailor approaches, assess, adapt the learning process, take feedback from assessments, and provide fresh material at the edge of the known, pushing the learner's cognitive development.

With AI, teachers can steer students, retaining individualization and personalization to accelerate progress. Students and AI can forge smart communities, exchange knowledge, and progress faster. Human teachers suffer from bias, uneven knowledge, and depth of subject. GAI is far more complete, although it often requires some iterative queries to get its logic correct. AI can teach and perform fast enough to engage any "genius"-level learner at any level. A virtuous cycle of humans and AI can roll as quickly as the learner's mind rolls, well beyond what any ordinary human teacher could keep up with. AI can operate tirelessly with the student, always ready for the next steps.

STRAWN: ChatGPT has galvanized the media to focus anew on the promises and perils of AI. Wikipedia defines GAI as "artificial intelligence capable of generating text, images, or other media, using generative models." (This definition is not very helpful but is an example of bad writing, which I'm complaining about). Also, I'm assuming "ChatGPT-16," not today's ChatGPT-4, which still makes plenty of mistakes.

John Atanasoff, who invented the first electronic digital (special purpose) computer, was asked after a talk what he was doing in retirement. He said he was worrying about language because the two most widely used languages, English and Chinese, were so complicated that they doomed many of their speakers to semiliteracy. Since simplified artificial languages like Esperanto are not likely to catch on, more automation assistance with reading and writing existing languages may be an answer. ChatGPT and other language aids might allow poor to average writers into a more democratic cohort of educated persons. For example, see "Experimental Evidence on the Productivity Effects of Generative Artificial Intelligence."[1]

COMPUTER: What role should AI play in science education, especially computer science?

STRAWN: Science is performed by proposing hypotheses and seeking data to support or refute them. Since GAI can not only write articles but also write programs and create works of art, perhaps it can also generate hypotheses for consideration by scientists. And perhaps AI could even help seek data to support or refute them. Such activities would initially be seen as giving scientists the appearance of wisdom with none of the required substance, as Plato has already observed.

THIRUVATHUKAL: I will take a significant risk and posit that the emphasis on prompt engineering may not be the most important question. I think software engineering already addressed this problem, yet the world may not have noticed. We've long talked about the importance of requirements/requirements engineering. My worldview is that formulating requirements is a key component of prompt engineering. After all, if you don't know what you want to do, and cannot express it, you should expect low-fidelity responses from GAI from the get-go. Beyond the initial formulation of requirements, one must have critical thinking skills to know when a response (from GAI) is altogether wrong or needs refinement.

COMPUTER: What are your closing thoughts, and what helps you sleep at night?

MAJUMDAR: AI, combined with principles and policies of operations, can empower self-learning, teaching our citizens and students to create a "smarter" world for a brighter tomorrow. AI becomes a mentor, a repository of all human knowledge, and ultimately a partner to teachers and students in solving the most challenging problems of our times.

The road to achieving this vision requires rethinking education and is a daunting and massive task. But with small steps, huge journeys can begin.

AHMAD: Harnessing AI in education requires a multifaceted approach. It's not just about algorithms and data—it's about blending technology with pedagogy, ethics, collaboration, and a deep commitment to enhancing the learning journey for all students. Our dedication and combined expertise in these domains will shape the future of education, making it more personalized, inclusive, and effective.

ADAMS: To ensure that AI supports high-quality learning that includes equity, it is important to focus on data privacy and security, transparency and accountability, and ongoing evaluation and improvement of AI systems and tools. Policy makers, educators, and other key constituents must work together to develop ethical and legal frameworks that ensure that AI is used responsibly and equitably. By doing so, we can harness the power of AI to create a more equitable and effective education system for all students.

THIRUVATHUKAL: I paint with this broad brush to highlight the importance of critical skills for today's students: how to write and refine requirements. And how can we evaluate the responses? This has a striking parallel to agile methods, where our understanding of the problem space may lead to multiple generations of refinements to the solution.

STRAWN: All these symbionts reduce the time to accomplish newly automatable activities. The great virtue of this is more time for creative activities. As the definition of creative activities changes with new kinds of AI and their further uses in education and science, we might ask, What will be the definition of an educated person in 2100?

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