CREATING A MORE INCLUSIVE AND ADAPTIVE ROBOTICS TRAINING WITH IMMERSIVE TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE

Author:
BIAYNA BOGOSIAN, ERIC PETERSON, SHAHIN VASSIGH

Affiliation:
ARIZONA STATE UNIVERSITY, USA. UNIVERSITY OF HAWAI'I, USA. FLORIDA INTERNATIONAL UNIVERSITY, USA.

INTRODUCTION

We are confronted with existential challenges characterized by the convergence of global warming, rising social disparities, and economic inequalities exacerbated by automation and artificial intelligence (AI). These intersecting issues define our present moment and shape future possibilities.[1] Given this context, it is imperative to critically reassess established academic disciplines and professions, recognizing their historical foundations in structures of power, inherent biases, and their implications for labor relations and societal equity.[2] Fields such as architecture, engineering, and construction (AEC), which significantly influence our built environment and maintain longstanding associations with issues of discrimination and inequality, demand immediate reevaluation.[3]

As AI and automation increasingly disrupt traditional labor markets, educational frameworks require urgent reimagining. It is crucial not only to equip individuals with technical competencies but also to empower them with critical awareness of AI's implications on social structures, labor dynamics, and ethical considerations. Education should enable diverse communities to actively shape rather than passively experience technological trajectories, fostering their capacity to leverage robotics and automation ethically and sustainably.[4]

In this broader educational reorientation, current robotics training programs require significant transformation. Existing robotics education models often have limitations that hinder scalability, accessibility, and inclusiveness. Primary among these challenges is the high cost of specialized training, restricting access predominantly to well-funded entities and perpetuating economic inequalities.[5] Current robotics training frequently employs resource-intensive methods, such as in-person workshops and reliance on specialized, proprietary equipment. These methods are difficult to scale in response to rising demand for robotics skills.[6] Additionally, traditional pedagogical practices emphasize manufacturer-specific technologies, constraining learners' adaptability across different robotic platforms and limiting the transferability of skills.[7] This lack of interoperability inhibits innovation and reduces workforce agility, precisely when adaptability is increasingly essential in rapidly evolving technological environments.[8]

This paper examines current robotics training practices and explores how recent advances in AI and extended reality (XR) can be leveraged to create more accessible educational content. We investigate both the potential benefits of these technologies—including opportunities for personalized and scalable training—and their ethical risks, particularly algorithmic bias stemming from homogeneous training datasets.[9] We then present two case studies from our work with a coalition of three Minority Serving Institutions (MSIs), including Florida International University (FIU), Arizona State University (ASU), and University of Hawaiʻi at Mānoa (UH Manoa), demonstrating practical approaches that overcome existing limitations in robotics education through AI-powered immersive learning. These projects exemplify strategies that promote greater equity, inclusion, and effectiveness in preparing diverse communities for technological transformation.

CURRENT ROBOTICS TRAINING PRACTICES: LIMITATIONS AND CHALLENGES

The AEC industry is undergoing profound transformation driven by robotic automation and AI integration. These technologies are fundamentally reshaping traditional methodologies in designing, planning, and constructing built environments.[10] Amidst these shifts, practical training has become essential in preparing the workforce to effectively navigate and leverage technological advances.

Access and Resource Constraints

Despite growing demand for roboticists, training programs remain limited in both scale and scope.[11] Industrial robotics training typically occurs in specialized facilities with significant logistical barriers to access. The conventional training model requires students to take time away from work, travel to dedicated training centers, and arrange accommodations during their course of study. To accommodate these constraints, training is often condensed into intensive formats designed for rapid delivery rather than optimal learning.[12] This approach fails to support diverse learning modalities and paces that might better serve a heterogeneous student population. Although effective in some respects, traditional classroom setups for robotics education frequently demand low student-to-teacher ratios and access to specialized equipment, creating bottlenecks that restrict accessibility for the broader workforce.[13]

Proprietary Systems and Limited Transferability

The pedagogical foundation of conventional robotics training presents additional challenges. Learners typically begin with text-based or proprietary manuals focused on specific brands or equipment types. Training sessions generally combine lectures, demonstrations, and supervised practice with training robots. These learning experiences are predominantly oriented toward proprietary systems, interfaces, and software with minimal emphasis on knowledge transferability across platforms.[14] Since robot manufacturers employ different hardware and software configurations with little standardization in control interfaces or programming procedures, proficiency with one system rarely translates directly to others, limiting versatility in increasingly diverse technological environments.[15]

Pedagogical Limitations and Narrow Skill Development

Most training emphasizes equipment commissioning, calibration, and maintenance alongside typical manufacturing operations using proprietary systems. Content is designed to promote mastery of predefined concepts and techniques while discouraging spontaneous decision-making to minimize errors. Knowledge in this model is conceptualized as knowing the singular correct response to predetermined problems, essentially programming students with expected answers rather than developing adaptive problem-solving capacities.[16] There is minimal focus on general knowledge, transferable strategies, or creative approaches for addressing common challenges across different robotic systems, procedures, or environments. Current pedagogical approaches prioritize platform-specific procedural skills at the expense of holistic system thinking and adaptive problem-solving that

would enable contextual flexibility. Technical instruction generally lacks adequate integration of socio-ethical considerations essential for responsible technology development and deployment.[17]
The combined effect of these limitations creates significant barriers to scaling robotics education to meet growing workforce demands while simultaneously restricting access to privileged demographic groups, perpetuating existing inequities in technological fields.[18]

EMERGING TECHNOLOGIES FOR ENHANCED ROBOTICS TRAINING

In recent years, AI and XR have been revolutionizing educational approaches, offering unprecedented opportunities to overcome traditional limitations in robotics training while fundamentally reimagining knowledge transmission and learning experiences. As we embrace these innovations, maintaining critical awareness of both their transformative potential and inherent limitations remains essential for responsible implementation.[19]

AI-Driven Learning: Affordances and Potentials

Understanding the complex mental, psychological, and social processes involved in learning can help educators better serve students with varied needs. This has historically been challenging due to the multidimensional factors that must be accommodated, including diverse backgrounds, differing cognitive capabilities, and the need for immediate, context-sensitive feedback.[20] Emerging advancements in AI and computational technologies offer transformative approaches to addressing these educational challenges.[21] Recent progress in logical reasoning, big data analytics, predictive modeling, and natural language processing enables the development of Intelligent Adaptive Learning Systems that transcend traditional pedagogical methods by offering personalized instruction.[22] This level of personalization offers considerable benefits, particularly in increasing educational efficacy by accommodating individual students' diverse learning paces and trajectories, potentially democratizing access to high-quality education.[23]

AI-Driven Learning: Ethical Considerations and Bias Risks

Despite these promising affordances, integrating AI into educational systems introduces ethical complications. Of paramount concern is the risk of algorithmic bias stemming from training datasets that are skewed or unrepresentative.[24] These biases often arise inadvertently through the natural process of training AI systems on data from homogeneous groups of individuals, leading to narrow or distorted understanding of learning behaviors and needs.[25] To mitigate these risks, educators and researchers must proactively address ethical considerations through thoughtful curation of representative training datasets, continuous monitoring and auditing of algorithmic decision-making, and incorporating explainability and transparency features into AI systems.[26]

Spatial and Immersive Technologies for Education

Spatial and immersive technologies, particularly VR and AR, represent leading frontiers in educational computing.[27] These technologies enable the creation of computer-generated simulations that enhance training experiences, fostering more engaging and enriched learning environments.[28] In robotics training specifically, VR offers safe, risk-free environments where students can engage in simulations before working with actual robotic systems, while AR provides supplementary feedback when students interact with real-world robots, overlaying situational data to deliver real-time guidance.[29] The strategic integration of AR and VR at different training stages offers significant advantages for scalability, allowing for easy updates to training scenarios and facilitating broader distribution of training materials beyond traditional workshops and classrooms.[30]

DIVERSITY AND REPRESENTATION IN ROBOTICS EDUCATION

While the discussion has thus far focused on technological aspects of robotics training, it is crucial to confront broader issues of equity and access. Like other STEM domains, robotics has historically been characterized by a striking lack of diversity. Recent data indicates that women represent merely 16% of individuals in engineering and robotics roles.[31] Similarly, according to the US Bureau of Labor Statistics, women constitute only 10% of the construction industry workforce.[32] These disparities are further reflected in the broader STEM landscape, where National Center for Science and Engineering Statistics data reveals that Hispanics and Blacks comprise only 15% and 9% of the total STEM workforce, respectively.[33]

This narrow representation has multi-layered consequences in robotics education. Curriculum and training materials, predominantly shaped by a restricted demographic, often lack comprehensive perspectives that a more diverse group would contribute. Such environments risk becoming echo chambers that reinforce existing biases and stifle intellectual diversity. As observed across various domains, individuals from different backgrounds offer unique approaches to problem identification, analysis, and resolution.[34] When incorporating AI for personalized training, additional risks emerge regarding the quality and diversity of training data. When these datasets originate from restricted demographics, the resulting AI systems can inadvertently perpetuate biases inherent to those groups.[35] Such biases may have detrimental implications for personalized learning experiences, particularly affecting underrepresented communities.

These limitations extend beyond individual educational programs. Bias becomes systemically ingrained into educational, professional, and research systems, creating a self-reinforcing cycle that limits diversity of thought and innovation.[36] When robotics education lacks diversity, the field's potential for novel applications diminishes, becoming less creative, less competitive, and less economically productive.[37] Addressing these challenges requires intentional efforts to diversify the entire ecosystem of robotics education. Technologies like AI and XR can potentially democratize access, but only if designed with diversity and inclusion as core principles rather than afterthoughts.

IN PURSUIT OF EQUITABLE OUTCOMES

To address training challenges, we present initiatives that originated at Florida International University (FIU) Robotics and Digital Fabrication Lab and have subsequently expanded to form a coalition with Arizona State University (ASU) and University of Hawaii at Manoa (UH at Manoa). These projects represent practical implementations of the theoretical concepts discussed earlier, showcasing how emerging technologies can be leveraged to create more inclusive and adaptive robotics training experiences.

FIU's status as one of the largest public Minority Serving Institutions (MSI) provides an ideal environment for spearheading this research. The RDF Lab, led by a minority woman with backgrounds in architecture, engineering, and computational design, has maintained 75% women representation among its research team, fostering a diverse environment. The Lab's location in a predominantly multilingual city shaped its focus on multicultural accessibility. As faculty from the original RDF Lab team transitioned to positions at ASU's Media and Immersive Experience Center and UH Manoa's School of Architecture, they maintained their research collaborations, creating a natural coalition of MSIs addressing robotics education challenges through their complementary expertise and diverse student populations.

The researchers have developed projects integrating AI-powered spatial and immersive technologies to create personalized robotics training environments that accommodate diverse learning needs. These initiatives specifically focus on overcoming traditional barriers to robotics education while ensuring that the developed systems themselves don't perpetuate existing biases or inequities. Below we present three key projects that illustrate this approach.

Robotics Academy

In 2019, researchers at FIU initialized an NSF-funded project to plan a comprehensive robotics training program. Through expert interviews and focus groups, they assessed industry-specific training needs, emphasizing both in-person and virtual delivery methods for industrial and small robotics knowledge dissemination.

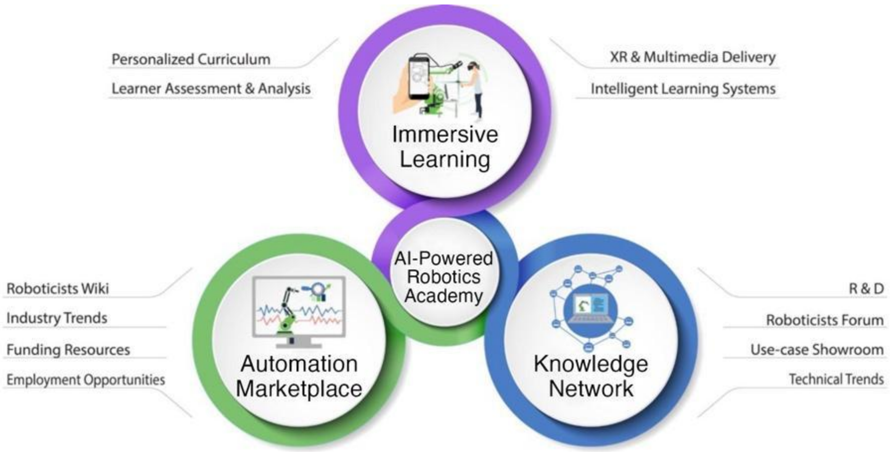

Figure 1. Diagram describing the overall structure of the Robotics Academy.

The Robotics Academy was conceptualized as a cloud-based resource benefiting the AEC workforce, with goals of expanding training access, building a community of AEC roboticists, and connecting employers with skilled professionals. The framework included three components: 1) Immersive Learning with AI-powered curriculum delivered through AR/VR; 2) Open Knowledge Network facilitating information exchange; and 3) Automation Marketplace connecting entrepreneurs, employers, and employees – as illustrated in Figure 1. Following this planning phase, the team developed a VR prototype for the Immersive Learning component. User testing confirmed VR's suitability for introductory and safety topics.[38] The environment, designed for HTC Vive Eye Pro using Unity, simulated an industrial robotics facility with dedicated work cells. Participants navigated at their own pace, interacting with robots, safety videos, and demonstrations on robotic anatomy and terminology – as illustrated in Figure 2.

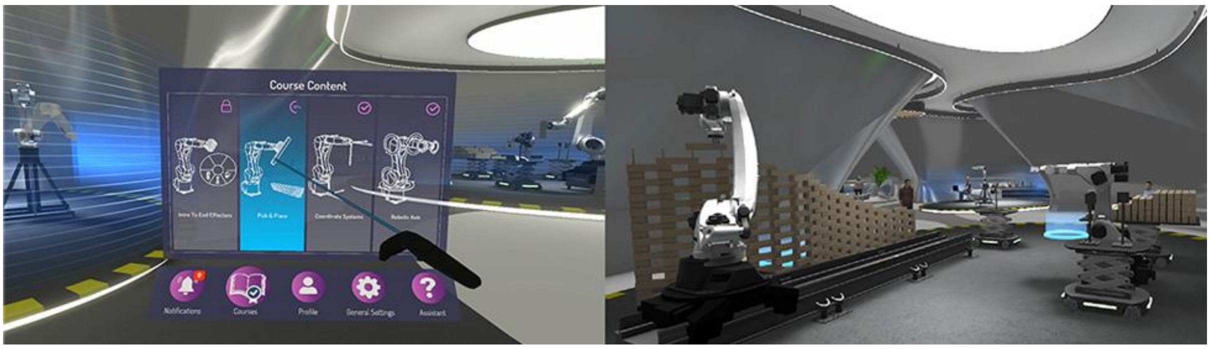

Figure 2. Left: Scene from the VR prototype environment demonstrating the lesson selection user interface. Right: Simulation in the Pick and Place lesson.

VR Curriculum: Intelligent Immersive Environment for Learning Robotics

Building upon the Robotics Academy framework and VR prototype, this NSF-funded project through the Research on Innovative Technologies for Enhanced Learning (RITEL) program creates an adaptive learning environment for industrial robotic arms. The system employs Machine Learning (ML) and Natural Language Processing (NLP) algorithms to personalize the immersive VR curriculum based on individual learning patterns and needs. This technology provides an engaging virtual environment where students can master robotic arm technologies through customized instruction paths.[39,40]

The curriculum includes six core modules, covering foundational topics like workplace safety and robotic anatomy, as well as advanced subjects such as calibrating and programming industrial robotic arms. These modules take the form of a learning game, boosting engagement and offering performance-based scoring.[41] To achieve personalization, the adaptive learning system collects various metrics from VR interactions, including time spent, attempts, verbal responses, and quiz results. It also considers student profiles, like backgrounds and skills, to tailor the training experience. This combined data informs an adaptive learning path aligned with individual needs, preferences and progress – as illustrated in Figure 3.

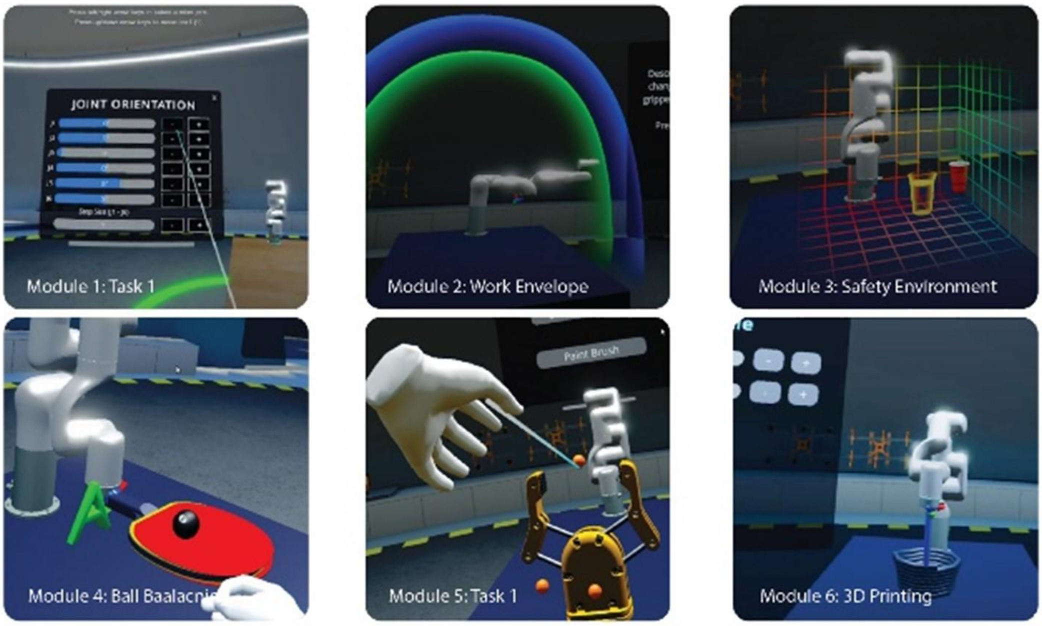

Figure 3. Capture from the six VR modules.

This project addresses a crucial research gap by integrating learning systems with immersive virtual environments to create an adaptive learning experience. While previous research has explored these domains separately, merging these elements to construct a robust personalized learning system represents a novel endeavor. Testing this AI-powered approach within a VR curriculum demonstrates an advanced application of adaptive learning. Furthermore, the curriculum's development by a diverse team and its extensive testing with underrepresented participants safeguard against inherent biases and provide a rich dataset for refining the adaptive learning system.[42]

AR Curriculum: Augmented Learning for Environmental Robotics Technologies

This project, funded by the NSF's Improving Undergraduate STEM Education program, focuses on delivering personalized immersive curriculum focused on learning about environmental robotics technologies. This project, is an educational tool targeting small robotics, emphasizing environmental data collection, analysis, and visualization. The project delivers a specialized curriculum using AR for an immersive learning experience that enhances understanding of environmental data and real-world robotics applications.[43]

Using the project's adaptive learning system, students engage in guided learning activities while wearing an AR headset to work with various "parts kits." In some cases, these kits are physical components that must be assembled in a specific sequence of operations. In other instances, they are snippets of code or blocks of data that can be plugged into one another in various ways to perform actions or to display information. The interactive nature of handling physical components and viewing data with on-demand informational overlays allows learners to explore how the components and data modules can be assembled to create a robot for collecting and viewing data from the environment – as illustrated in Figure 4.

The curriculum comprises three interconnected modules: 1) An introductory module with personalized online lessons introducing environmental robotics concepts, components, and programming; 2) An applied learning module delivered in-person using AR headsets to guide assembly of sensing kits for applications including site condition monitoring, outdoor air and water quality sensing, building comfort and energy monitoring; 3) An exploratory data analysis module, also delivered using AR, covering techniques like understanding datasets, identifying relationships, collaborative visualization, and moving from exploration to action across five subcategories of data cleaning, collaboration, relationships, understanding, and application. This multifaceted curriculum ensures students gain theoretical knowledge, practical skills, and data literacy.

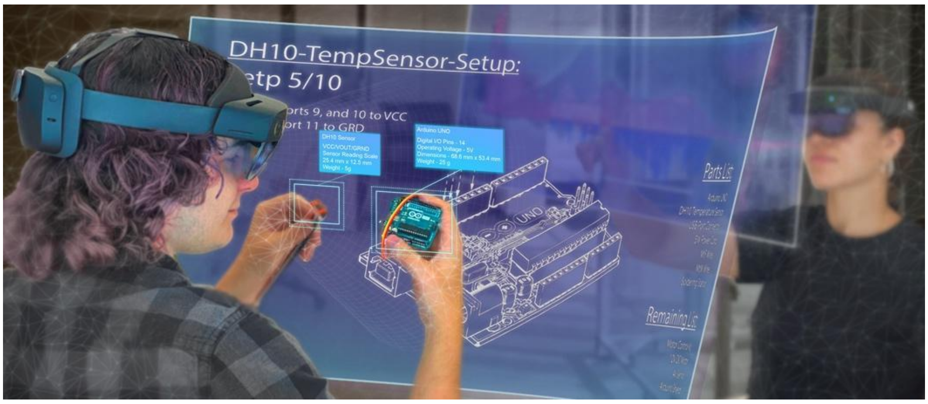

Figure 4. AEC student using the ALERT's AR app to navigate an applied learning module on outdoor air pollution monitoring, assembling a temperature sensing kit with an Arduino microcontroller and a humidity sensor.

In this project, data collection for personalized learning employs various metrics. First, student profile data captures background info and skill levels, setting the initial context for a personalized curriculum. Second, real-time performance in quick quizzes signals comprehension and engagement, enabling instant content adjustments. Third, eye gaze data is biometrics, revealing focus and cognitive load. This nuanced data informs engagement and support needs, enhancing dynamic, responsive learning. These sources contribute to a personalized educational experience for optimized learning outcomes. Like the other projects, this project also leverages technology to foster inclusivity and the needs of diverse learners. Embracing AR and adaptive learning mechanisms allow for the creation of a learning environment that transcends traditional barriers, accommodating many learning styles and backgrounds.

FUTURE PROSPECTS AND CONCLUSION

The need for diversity and accessibility in robotics training is a concern that demands attention. Historically, robotics education has been constrained by limited resources and specific requirements, limiting its accessibility to a broader range of students. These constraints perpetuate inequality, particularly in minority serving institutions.

Emerging technologies, when implemented ethically and informed by learning science, offer transformative potential to address these issues. Our examination of ongoing projects that originated at Florida International University's Robotics and Digital Fabrication Lab and expanded to Arizona State University and University of Hawaii at Manoa demonstrates how these technologies can democratize robotics education in AEC. These works-in-progress continue to evolve as researchers gather data and respond to emerging challenges.

The case studies illustrate how AI-powered adaptive learning systems when integrated with immersive technologies respond to diverse learning styles, representing both technological advancement and social equity. These initiatives accommodate varied student populations with different educational backgrounds, effectively leveling the educational playing field. These three MSI universities provide ideal environments for developing these systems due to their diverse student populations. Preliminary insights enhance pedagogical approaches and offer frameworks for addressing inclusion challenges throughout the AEC industry.

As this research evolves, AI and XR technologies with inclusive design principles show significant promise for transforming robotics education. By addressing both technological and social barriers, these approaches create accessible pathways for underrepresented groups, driving innovation and producing responsive, ethical technological solutions for our collective future.

AKNOWLEDGMENTS

The case studies presented in this paper were made possible through the support of the National Science Foundation (NSF) under multiple funding programs. This research has been funded through the following NSF awards: 1) the Convergence Accelerator Program (Award No. 2026509), which aims to accelerate research solutions for societal challenges; 2) the Research on Emerging Technologies for Teaching and Learning (RETTL) program (Award No. 2202610), which explores the impact of intelligent and immersive environments on robotics education; and 3) the Improving Undergraduate STEM Education (IUSE) program (Award No. 2315647), which supports innovative approaches to STEM learning, including augmented learning for environmental robotics technologies. The findings, conclusions, recommendations, and opinions expressed in this paper are solely those of the authors and do not necessarily reflect the views of the National Science Foundation.

NOTES

[1] Wongi Kim. "The Effects of Climate Change on Income Inequality: Evidence from APEC Member Economies." *KIEP Research Paper, Apec Study Series* (2021): 21-02.
[2] Anton Korinek and Joseph E. Stiglitz. *Artificial intelligence, globalization, and strategies for economic development*. No. w28453. National Bureau of Economic Research, 2021.
[3] Mohamed El Zomor, Piyush Pradhananga, Gabriella Santi, and Shahin Vassigh. "Preparing the future workforce of architecture, engineering, and construction for robotic automation processes." In *2020 ASEE Virtual Annual Conference Content Access*. 2020.
[4] Rajeev Alur, Richard Baraniuk, Rastislav Bodik, Ann Drobnis, Sumit Gulwani, Bjoern Hartmann, Yasmin Kafai et al. "Computer-aided personalized education." *arXiv preprint arXiv:2007.03704* (2020).
[5] Amanda Bergson-Shilcock. "Funding Resilience: How Public Policies Can Support Businesses in Upskilling Workers for a Changing Economy." *National Skills Coalition* (2020).
[6] Neil Vaughan, Bodgan Gabrys, and Venketesh N. Dubey. "An overview of self-adaptive technologies within virtual reality training." *Computer Science Review* 22 (2016): 65-87.
[7] Ali Yuce, A. Mohammed Abubakar, and Mustafa Ilkan. "Intelligent tutoring systems and learning performance: Applying task-technology fit and IS success model." *Online Information Review* 43, no. 4 (2019): 600-616.
[8] Deepak Kem. "Personalised and adaptive learning: Emerging learning platforms in the era of digital and smart learning." *International Journal of Social Science and Human Research* 5, no. 2 (2022): 385-391.
[9] Gissela Moya, and Vincent Le. "Algorithmic Bias Explained: How Automated Decision Making Becomes Automated Discrimination." *Greenlining Institute* (2021).
[10] Stylianos Mystakidi. "Metaverse." *Encyclopedia* 2, no. 1 (2022): 486-497.
[11] Olaf Zawacki-Richter, Victoria I. Marín, Melissa Bond, and Franziska Gouverneur. "Systematic Review of Research on Artificial Intelligence Applications in Higher Education – Where Are the Educators?" *International Journal of Educational Technology in Higher Education* 16, no. 1 (2019): 1-27.
[12] Ryan S. Baker. "Challenges for the future of educational data mining: The Baker learning analytics prizes." *Journal of educational data mining* 11, no. 1 (2019): 1-17.
[13] Elaheh Mousavinasab, Nahid Zarifsanaiey, S. Rosanna Niakan, Mohammadreza Koshkaki, Roxana Ghaffari, Mehdi Ranjbar, and Parisa Sohrabi. "Intelligent Tutoring Systems: A Systematic Review of Characteristics, Applications, and Evaluation Methods." *Interactive Learning Environments* 29, no. 1 (2021): 142-163.
[14] Kenneth Holstein, Bruce M. McLaren, and Vincent Aleven. "Co-designing a real-time classroom orchestration tool to support teacher–AI complementarity." *Journal of Learning Analytics* 6, no. 2 (2019): 27-52.
[15] Gregory S. Nelson. "Bias in artificial intelligence." *North Carolina Medical Journal* 80, no. 4 (2019): 220-222.
[16] Timnit Gebru. "Oxford handbook on AI ethics book chapter on race and gender." *arXiv preprint arXiv:1908.06165* (2019).
[17] Dillon Roselli, Jeanna Matthews, and Nisha Talagala. "Managing bias in AI." In *Companion Proceedings of the 2019 World Wide Web Conference*, pp. 539-544. 2019.
[18] Kamen Kamenov. "Immersive experience—The 4th wave in tech: Learning the ropes." *Accenture* (2017).
[19] Sergey Martirosov and Pavel Kopecek. "Virtual reality and its influence on training and education-literature review." *Annals of DAAAM & Proceedings* 28 (2017).
[20] Ernesto Antonini, Jacopo Gaspari, and Cristina Visconti. "Collaborative learning experiences in a changing environment: Innovative educational approaches in architecture." *Sustainability* 13, no. 16 (2021): 8895.
[21] Vincent Michael Memmesheimer and Achim Ebert. "Scalable extended reality: A future research agenda." *Big Data and Cognitive Computing* 6, no. 1 (2022): 12:1-12:17.
[22] Bob Wessling. "Celebrating the first-international women in robotics day." *The Robot Report* (2023).
[23] Charlie Gallagher. "Spotlight on Statistics, The Construction Industry: Characteristics of the Employed." *US Bureau of Labor Statistics* (2022).
[24] National Science Foundation. "Women, Minorities, and Persons with Disabilities in Science and Engineering." *National Center for Science and Engineering Statistics* (2023).
[25] Laura E. Gomez and Patrick Bernet. "Diversity improves performance and outcomes." *Journal of the National Medical Association* 111, no. 4 (2019): 383-392.
[26] Ninareh Mehrabi, Fred Morstatter, Nripsuta Saxena, Kristina Lerman, and Aram Galstyan. "A survey on bias and fairness in machine learning." *ACM Computing Surveys* 54, no. 6 (2021): 1-35.
[27] Thomas Dee and Seth Gershenson. "Unconscious Bias in the Classroom: Evidence and Opportunities." *Stanford Center for Education Policy Analysis* (2017).
[28] Bas Hofstra, Vivek V. Kulkarni, Sebastian Munoz-Najar Galvez, Bryan He, Dan Jurafsky, and Daniel A. McFarland. "The diversity–innovation paradox in science." *Proceedings of the National Academy of Sciences* 117, no. 17 (2020): 9284-9291.

[29] Michael A. Madaio, Luke Stark, Jennifer Wortman Vaughan, and Hanna Wallach. "Co-designing checklists to understand organizational challenges and opportunities around fairness in AI." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pp. 1-14. 2020.
[30] Jennifer Wang and Sarah Jones. "Gender Diversity in Robotics Education: Current Trends and Future Directions." *International Journal of STEM Education* 8, no. 1 (2022): 1-18.
[31] Gloria Fernandez-Nieto, Javier Castellano, and Rafael Martinez. "Mapping the Construction Industry Workforce: A Demographic Analysis of Skilled Labor Distribution." *Journal of Construction Engineering and Management* 147, no. 5 (2021): 04021035.
[32] Patricia Hamrick. "The STEM Pipeline: Examining Racial and Ethnic Representation." *Science Education Policy Review* 29, no. 3 (2023): 87-102.
[33] Lauren A. Rivera and András Tilcsik. "Scaling Up Diversity: Organizational Implications of Industry Trends." *American Sociological Review* 86, no. 2 (2021): 252-277.
[34] David Johnson and Miguel Garcia. "Algorithmic Bias in Educational Technology: Detection and Mitigation Strategies." *IEEE Transactions on Learning Technologies* 15, no. 2 (2022): 193-209.
[35] Tanya Chakraborty and Sandra Mitchell. "Institutional Frameworks and Unconscious Bias in Technical Education." *Journal of Higher Education Policy and Management* 43, no. 5 (2021): 529-544.
[36] Wendy Liu and Daniel Cortes. "Innovation Outcomes in Diverse Technical Teams: A Meta-Analysis." *Research Policy* 51, no. 4 (2022): 104456.
[37] Wei Chen, James Thomas, and Melissa Wong. "Equitable Design Principles for AI-Powered Educational Systems." *Learning and Instruction* 74 (2022): 101541.
[38] Shahin Vassigh and Biayna Bogosian. "Envisioning an Open Knowledge Network (OKN) for AEC Roboticists." In *43rd Annual Conference of the Association for Computer Aided Design in Architecture: Habits of the Anthropocene: Scarcity and Abundance in a Post-Material Economy, ACADIA 2023*, pp. 71-76. Association for Computer Aided Design in Architecture, 2023.
[39] Shahin Vassigh, Seth Corrigan, Biayna Bogosian, and Eric Peterson. "Adaptive Immersive Learning Environments for Teaching Industrial Robotics." *Emerging Technologies and Future of Work* 117 (2023).
[40] Eric Peterson, Biayna Bogosian, Jorge Tubella, and Shahin Vassigh. "Teaching robotics with virtual reality: Developing curriculum for the 21st century workforce." In *International Conference on Applied Human Factors and Ergonomics*, pp. 12-18. Cham: Springer International Publishing, 2021.
[41] Shahin Vassigh, Biayna Bogosian, and Eric Peterson. "Performance-Driven VR Learning for Robotics." In *The International Conference on Computational Design and Robotic Fabrication*, pp. 356-367. Singapore: Springer Nature Singapore, 2023.
[42] Peterson et al, 2021.
[43] Biayna Bogosian, Shahin Vassigh, and Eric Peterson. "Augmented Learning for Environmental Robotics Technologies (ALERT)." *Emerging Technologies and Future of Work* 117 (2023).

BIBLIOGRAPHY

Alur, Rajeev, Richard Baraniuk, Rastislav Bodik, Ann Drobnis, Sumit Gulwani, Bjoern Hartmann, Yasmin Kafai et al. "Computer-aided personalized education." *arXiv preprint arXiv:2007.03704* (2020).

Antonini, Ernesto, Jacopo Gaspari, and Cristina Visconti. "Collaborative learning experiences in a changing environment: Innovative educational approaches in architecture." *Sustainability* 13, no. 16 (2021): 8895.

Baker, Ryan S. "Challenges for the future of educational data mining: The Baker learning analytics prizes." *Journal of educational data mining* 11, no. 1 (2019): 1-17.

Bergson-Shilcock, Amanda. "Funding Resilience: How Public Policies Can Support Businesses in Upskilling Workers for a Changing Economy." *National Skills Coalition* (2020).

Bogosian, Biayna, Shahin Vassigh, and Eric Peterson. "Augmented Learning for Environmental Robotics Technologies (ALERT)." *Emerging Technologies and Future of Work* 117 (2023).

Chakraborty, Tanya, and Sandra Mitchell. "Institutional Frameworks and Unconscious Bias in Technical Education." *Journal of Higher Education Policy and Management* 43, no. 5 (2021): 529-544.

Chen, Wei, James Thomas, and Melissa Wong. "Equitable Design Principles for AI-Powered Educational Systems." *Learning and Instruction* 74 (2022): 101541.

Dee, Thomas, and Seth Gershenson. "Unconscious Bias in the Classroom: Evidence and Opportunities." *Stanford Center for Education Policy Analysis* (2017).

ElZomor, Mohamed, Piyush Pradhananga, Gabriella Santi, and Shahin Vassigh. "Preparing the future workforce of architecture, engineering, and construction for robotic automation processes." In *2020 ASEE Virtual Annual Conference Content Access*. 2020.

Fernandez-Nieto, Gloria, Javier Castellano, and Rafael Martinez. "Mapping the Construction Industry Workforce: A Demographic Analysis of Skilled Labor Distribution." *Journal of Construction Engineering and Management* 147, no. 5 (2021): 04021035.

Gallagher, Charlie. "Spotlight on Statistics, The Construction Industry: Characteristics of the Employed." *US Bureau of Labor Statistics* (2022).

Gebru, Timnit. "Oxford handbook on AI ethics book chapter on race and gender." *arXiv preprint arXiv:1908.06165* (2019).

Gomez, Laura E., and Patrick Bernet. "Diversity improves performance and outcomes." *Journal of the National Medical Association* 111, no. 4 (2019): 383-392.

Hamrick, Patricia. "The STEM Pipeline: Examining Racial and Ethnic Representation." *Science Education Policy Review* 29, no. 3 (2023): 87-102.

Hofstra, Bas, Vivek V. Kulkarni, Sebastian Munoz-Najar Galvez, Bryan He, Dan Jurafsky, and Daniel A. McFarland. "The diversity–innovation paradox in science." *Proceedings of the National Academy of Sciences* 117, no. 17 (2020): 9284-9291.

Holstein, Kenneth, Bruce M. McLaren, and Vincent Aleven. "Co-designing a real-time classroom orchestration tool to support teacher–AI complementarity." *Journal of Learning Analytics* 6, no. 2 (2019): 27-52.

Johnson, David, and Miguel Garcia. "Algorithmic Bias in Educational Technology: Detection and Mitigation Strategies." *IEEE Transactions on Learning Technologies* 15, no. 2 (2022): 193-209.

Kamenov, Kamen. "Immersive experience—The 4th wave in tech: Learning the ropes." *Accenture* (2017).

Kem, Deepak. "Personalised and adaptive learning: Emerging learning platforms in the era of digital and smart learning." *International Journal of Social Science and Human Research* 5, no. 2 (2022): 385-391.

Kim, Wongi. "The Effects of Climate Change on Income Inequality: Evidence from APEC Member Economies." *KIEP Research Paper, Apec Study Series* (2021): 21-02.

Korinek, Anton, and Joseph E. Stiglitz. *Artificial intelligence, globalization, and strategies for economic development*. No. w28453. National Bureau of Economic Research, 2021.

Liu, Wendy, and Daniel Cortes. "Innovation Outcomes in Diverse Technical Teams: A Meta-Analysis." *Research Policy* 51, no. 4 (2022): 104456.

Madaio, Michael A., Luke Stark, Jennifer Wortman Vaughan, and Hanna Wallach. "Co-designing checklists to understand organizational challenges and opportunities around fairness in AI." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pp. 1-14. 2020.

Martirosov, Sergey, and Pavel Kopecek. "Virtual reality and its influence on training and education-literature review." *Annals of DAAAM & Proceedings* 28 (2017).

Mehrabi, Ninareh, Fred Morstatter, Nripsuta Saxena, Kristina Lerman, and Aram Galstyan. "A survey on bias and fairness in machine learning." *ACM Computing Surveys* 54, no. 6 (2021): 1-35.

Memmesheimer, Vincent Michael, and Achim Ebert. "Scalable extended reality: A future research agenda." *Big Data and Cognitive Computing* 6, no. 1 (2022): 12:1-12:17.

Mousavinasab, Elaheh, Nahid Zarifsanaiey, S. Rosanna Niakan, Mohammadreza Koshkaki, Roxana Ghaffari, Mehdi Ranjbar, and Parisa Sohrabi. "Intelligent Tutoring Systems: A Systematic Review of Characteristics, Applications, and Evaluation Methods." *Interactive Learning Environments* 29, no. 1 (2021): 142-163.

Moya, Gissela, and Vincent Le. "Algorithmic Bias Explained: How Automated Decision Making Becomes Automated Discrimination." *Greenlining Institute* (2021).

Mystakidis, Stylianos. "Metaverse." *Encyclopedia* 2, no. 1 (2022): 486-497.

National Science Foundation. "Women, Minorities, and Persons with Disabilities in Science and Engineering." *National Center for Science and Engineering Statistics* (2023).

Nelson, Gregory S. "Bias in artificial intelligence." *North Carolina Medical Journal* 80, no. 4 (2019): 220-222.

Peterson, Eric, Biayna Bogosian, Jorge Tubella, and Shahin Vassigh. "Teaching robotics with virtual reality: Developing curriculum for the 21st century workforce." In *International Conference on Applied Human Factors and Ergonomics*, pp. 12-18. Cham: Springer International Publishing, 2021.

Roselli, Dillon, Jeanna Matthews, and Nisha Talagala. "Managing bias in AI." In *Companion Proceedings of the 2019 World Wide Web Conference*, pp. 539-544. 2019.

Rivera, Lauren A., and András Tilcsik. "Scaling Up Diversity: Organizational Implications of Industry Trends." *American Sociological Review* 86, no. 2 (2021): 252-277.

Vassigh, Shahin, and Biayna Bogosian. "Envisioning an Open Knowledge Network (OKN) for AEC Roboticists." In *43rd Annual Conference of the Association for Computer Aided Design in Architecture: Habits of the Anthropocene: Scarcity and Abundance in a Post-Material Economy, ACADIA 2023*, pp. 71-76. Association for Computer Aided Design in Architecture, 2023.

Vassigh, Shahin, Biayna Bogosian, and Eric Peterson. "Performance-Driven VR Learning for Robotics." In *The International Conference on Computational Design and Robotic Fabrication*, pp. 356-367. Singapore: Springer Nature Singapore, 2023.

Vassigh, Shahin, Seth Corrigan, Biayna Bogosian, and Eric Peterson. "Adaptive Immersive Learning Environments for Teaching Industrial Robotics." *Emerging Technologies and Future of Work* 117 (2023).

Vaughan, Neil, Bodgan Gabrys, and Venketesh N. Dubey. "An overview of self-adaptive technologies within virtual reality training." *Computer Science Review* 22 (2016): 65-87.

Wang, Jennifer, and Sarah Jones. "Gender Diversity in Robotics Education: Current Trends and Future Directions." *International Journal of STEM Education* 8, no. 1 (2022): 1-18.

Wessling, Bob. "Celebrating the first-international women in robotics day." *The Robot Report* (2023).

Yuce, Ali, A. Mohammed Abubakar, and Mustafa Ilkan. "Intelligent tutoring systems and learning performance: Applying task-technology fit and IS success model." *Online Information Review* 43, no. 4 (2019): 600-616.

Zawacki-Richter, Olaf, Victoria I. Marín, Melissa Bond, and Franziska Gouverneur. "Systematic Review of Research on Artificial Intelligence Applications in Higher Education – Where Are the Educators?" *International Journal of Educational Technology in Higher Education* 16, no. 1 (2019): 1-27.