*Proceedings of the IASS 2024 Symposium*
*Redefining the Art of Structural Design*
August 26-30, 2024, Zurich Switzerland
Philippe Block, Giulia Boller, Catherine DeWolf,
Jacqueline Pauli, Walter Kaufmann (eds.)

# An Immersive Approach to Learning Structures

Shahin VASSIGH*, Biayna BOGOSIAN[a]

*Florida International University
11200 SW 8th St, Miami, FL 33199
svassigh@fiu.edu

[a] Arizona State University

## Abstract

The evolution of simulation technologies, structural analysis programs, and digital fabrication has significantly advanced architectural design, enabling architects to conceptualize intricate and expressive structural forms. However, teaching and learning structural design and analysis remains a significant challenge. Many architecture programs persist in using teaching methodologies that are directly translated from the engineering field with limited adaptation. These approaches center around abstract mathematical models and terminology, prioritizing analysis of individual elements. While valuable in certain aspects, the lack of context and a holistic approach poses a challenge to a comprehensive understanding of structural concepts for architecture students.

Research on virtual learning emphasizes the significance of interactive and immersive technologies in enhancing educational experiences by providing contextualization and explorations. Extended Reality (XR) can provide bases for visualizing structural behavior under various conditions and manipulating elements in high-fidelity simulations in real-time for observation. Furthermore, the integration of Artificial Intelligence (AI) within immersive environments has the potential to transform the content and delivery methods of structural education. AI-informed learning systems offer the possibility to personalize the curriculum to the individual student's needs by creating adaptive pathways, pinpointing areas of struggle, and providing targeted support for overcoming challenges.

This paper presents “Adaptive Learning Technologies for Exploring Resilient Structures” (ALTERS), an ongoing project that integrates AI and XR to create an engaging platform for learning structures. The project builds on the authors' prior research in developing the "Interactive Structures" (IS) software, as well as other novel immersive learning research projects. The paper outlines the conceptual framework guiding the development of IS, its array of features, and its approach to addressing challenges in architectural education. It will then describe the affordances of emerging technologies in education and their potential to transform how we learn. Subsequently, it will provide a detailed description of the ongoing work for the project and the plans for its future development.

**Keywords**: Structures Pedagogy, Immersive Learning, Extended Reality, Artificial Intelligence for Personalized Learning

## 1. Introduction

The evolution of simulation technologies, structural analysis programs, and digital fabrication has significantly advanced architectural design, empowering architects to conceptualize and realize increasingly intricate and expressive structural forms. These technological developments have expanded the range of structural systems and geometries that can be explored and implemented in contemporary architecture.

However, leveraging these advancements to improve teaching and learning of structural design and analysis remains a significant challenge. While these advanced technologies hold great promise for transforming pedagogical approaches to structures, integrating such innovations into the traditional curriculum has been slow and arduous. After decades of debate, the structures curriculum in most architecture programs is predominantly taught in lecture and seminar courses and is seen as secondary or in support of courses for design studios [1]. These courses persist in utilizing teaching methodologies directly translated from the engineering field, with minimal adaptation to the backgrounds of architecture students who generally lack sufficient grounding in physics and mathematics.

In addition, the content and delivery of the structures courses often fail to adequately serve the interests of architecture students with diverse academic backgrounds [2], [3], [4]. Current approaches often build on the foundation of Newtonian mechanics, adhering to a systematic process involving abstraction and reduction at each analysis stage of the analysis. Consequently, the analytical method for understanding structures entails sequentially breaking down a structure into sub-components such as beams, columns connections, etc. These elements are then isolated from their interconnected structural members and converted into a notation system consisting of simplified diagrams and structural symbols and annotations, commonly referred to as a "free body diagram," for mathematical analysis. While creating the free body diagram is essential for defining analytical solutions to structural problems, it disconnects conceptual relations between structural members and the building structure, especially since, in almost all cases, the complete context is never presented before or after the analysis. The lack of reference to the building context remains largely problematic for architecture students, limiting their capacity to understand structural behavior, thus hindering their capacity for innovation.

In recent years, several technologies have emerged as transformative forces in education, opening new avenues for teaching and learning. Extended Reality (XR), which is an umbrella term encompassing Virtual Reality (VR) and Augmented Reality (AR), along with advancements in computer graphics, simulation algorithms, and spatial computing hardware, have significantly enhanced learning environments [5] and [6]. Additionally, the newfound ability of immersive environments and head-mounted devices to capture data from learners' interactions with the content is significant. When this data is processed and analyzed with AI, it provides insights into the learner’s performance, enabling meaningful intervention by adjusting the curriculum, creating adaptive pathways, identifying areas of difficulty, and offering tailored support to overcome challenges [7]. This paper presents “Adaptive Learning Technologies for Exploring Resilient Structures” (ALTERS), an ongoing project that integrates AI and XR to create an engaging platform for learning structures. The project builds on the authors' prior research in developing the "Interactive Structures" (IS) software (see Figure 1), as well as other novel immersive learning research projects. The paper outlines the conceptual framework guiding the development of IS, its array of features, and its approach to addressing challenges in architectural education. It will then describe the affordances of emerging technologies in education and their potential to transform how we learn. Subsequently, it will provide a detailed description of the ongoing work for the design and development of ALTERS and the plans for its future implementation.

## 2. Interactive Structures: Visualization Structural Behavior

ALTERS builds on the foundation of the Interactive Structures (IS) software completed in 2004 (ISBN: 978-0470262696). Developed with funding from the U.S. Department of Education, IS was designed as a teaching tool that harnessed state-of-the-art audiovisual media technologies to offer an alternative approach to teaching structures. Featuring over 2000 simulations, interactive diagrams, videos, hypertext, and audio narration, the project aimed to assist students in visualizing structural behaviors.

The conceptual underpinning for developing the IS software was rooted in research findings that indicate interactive visualizations can substantially improve students' understanding of abstract engineering concepts [8]. These visualizations eliminate the limitations of two-dimensional abstract representations, providing a mechanism to contextualize the diagrammatic approach within building structure. In addition, they enable learners to get visual access to processes that may be impossible to observe in the real world (See Figures 2-3).

The IS software divided the study of structures into three modules: Basic Concepts, which explores general mechanics principles including statics and strength of materials; Structural Systems, describing the behaviors of

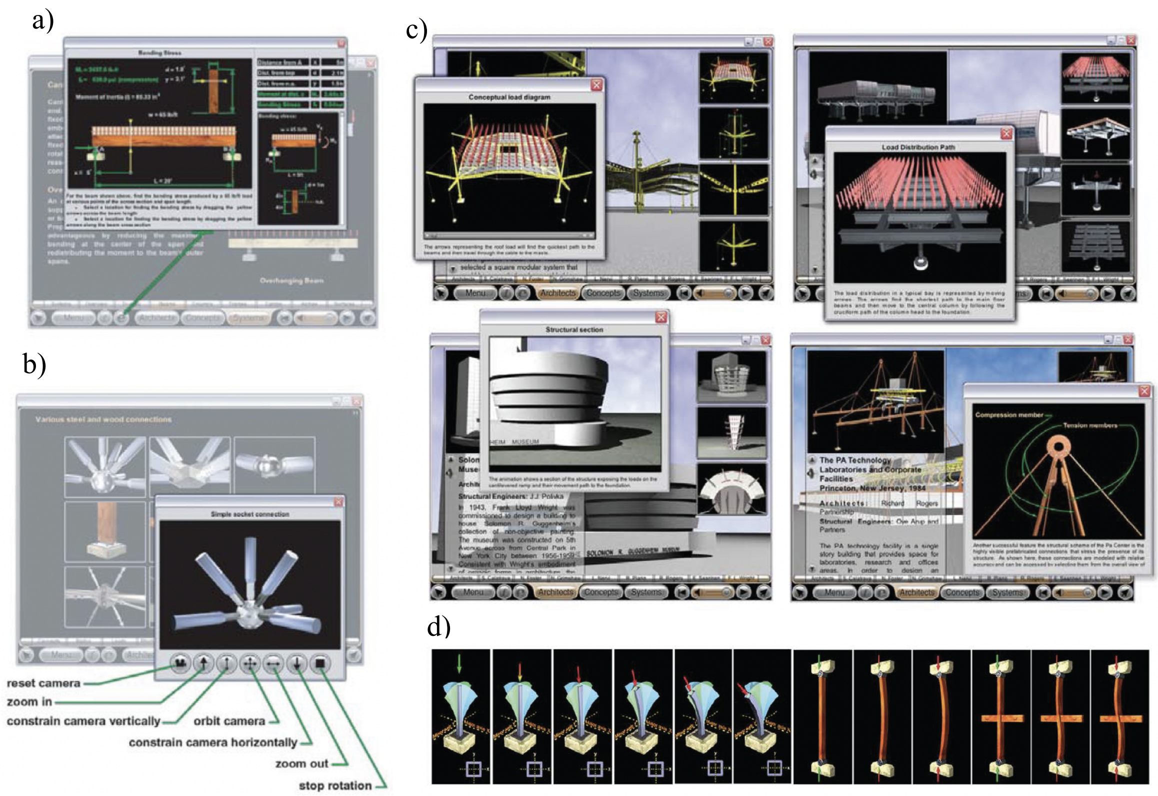


Figure 1: a) Stills from IS interactive exercise with adjustable load; b) Truss connection model; c) Load paths and construction details of four case studies; d) Animation illustrating column buckling and bracing application.

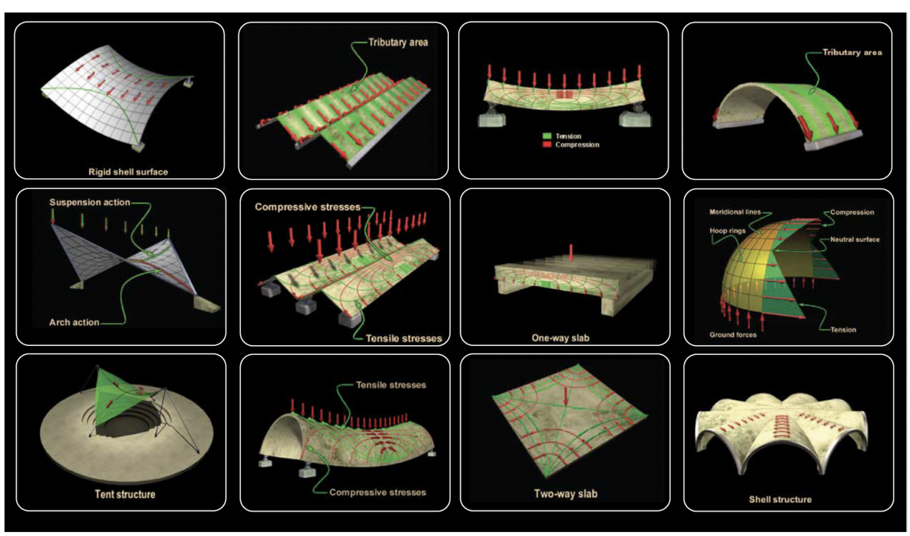


Figure 2. Stills from IS animations show various structural members under loading, some superimposed with stress lines, some showing load paths, and some showing the deflection mechanism.

various subsystems, including trusses, cables, arches, beams, columns, and surfaces, and the architects showcasing significant works of prominent architecture using 3D models and interactive animations.

The project was tested and evaluated simultaneously in multiple structured classes at two US institutions, with positive results showing significant improvement in student performance [9]. Since 2004, the project has been available on DVD through John Wiley and Sons publishers. In 2005, the IS software received the American Institute of Architects (AIA) award for Best University Research. Subsequently, in 2008, the second volume of IS was released.

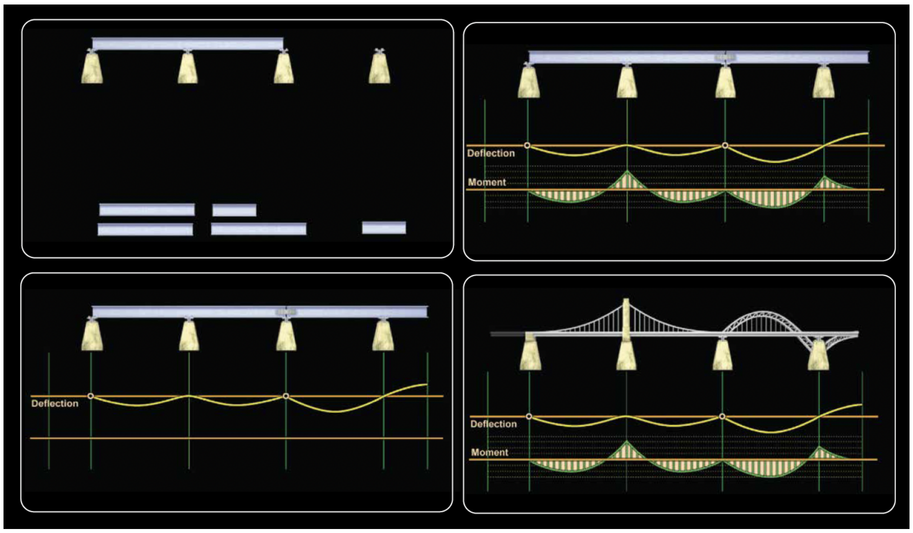


Figure 3. Stills from IS exercise for making a bridge based on the logic of the moment diagram. Learners drag the steel members to create a beam, then construct the deflection mechanism and moment diagram to see which bridge shape offers the most efficient design.

## 3. Convergence of Learning Theories and Technologies

Recent technological advancements coupled with learning theories present a timely and compelling opportunity to rethink IS software. By developing new features and capabilities, the software can offer immersive and accessible experiences, fostering deeper student engagement and enhancing the educational experience. This enhancement aligns with recent paradigms and pedagogical practices that better meet learners' evolving needs.

### 3.1. Immersion & Embodiment for Contextualized Learning

Research highlights the considerable potential of XR technology in transforming educational experiences, demonstrating that these technologies go far beyond mere entertainment. In immersive environments, the heightened sense of presence experienced by learners, along with interactivity, contributes to reducing extraneous cognitive load, leading to better learning outcomes [10]. XR achieves this by offering several affordances that include:

**Embodiment:** In recent decades, the embodied learning theory has become a focal point in designing XR learning environments. This paradigm is based on the principle that cognitive processes are intricately linked with the body's interactions with its surroundings. This suggests that the mind is an integral part of the body's sensorimotor systems, not a separate or abstract entity [11],[12]. Ioannou & Ioannou write that learning is enhanced when we use our bodily senses, perception, imagination, and motor actions while interacting with artifacts and practices, which are essential for our development. They assert that knowledge is grounded on the experience(s) that we collect with our senses, mediated by our body learning [13].

The embodied learning theory has driven the adoption of XR as a key tool for creating immersive experiences that enhance learning through physical interaction, sensory engagement, and the simulation of presence in a virtual space. O'Regan and Noë argue that this illusion enhances perception through embodied actions—leaning, reaching, looking around, or listening attentively—mirroring our interaction with the real world. They contend that when we apply our usual perceptual strategies in an XR setting, the brain's most straightforward and natural assumption is that they are physically situated in that environment, reinforcing the embodied learning experience [14].

**Transcending Reality:** Another significant affordance of XR is its capacity to transcend the constraints of the physical world, enabling learners to manipulate variables and create simulations that are not possible in real life. This aspect of XR allows for exploring scenarios, environments, and conditions that are otherwise inaccessible, dangerous, or nonexistent in the real world [15], [16]. By manipulating variables in these environments, learners can observe the outcomes of experiments or their decisions instantaneously. This dynamic interactivity facilitates a deeper engagement with the material, promoting a more active and experiential learning process.

**Contextualization:** XR's ability to deliver learning context is a critical affordance that has received less attention in research. Fowler argues that XR's immersive nature allows learners to experience the context surrounding theoretical knowledge, bridging the gap between abstract concepts and real-world applications [17]. This aids in understanding complex subjects by situating the learners in a relevant and engaging context [18]. In addition, immersive context can significantly impact how learners grasp concepts. These affordances provide promising avenues for learning structures, offering immersion, virtual component manipulation, and contextual exploration alongside real-time consequence observation.

Integrating AI with XR provides synergistic advantages, enabling customization of the learning experience. In the XR immersive setup, it is possible to monitor students' interactions and record key performance indicators. The collected data can be processed and analyzed with AI to predict how well a student will perform on a given task. AI's predictive capacity can illuminate the decision-making process on the learner's standing, leading to alternative learning paths, targeted advice, and timely feedback grounded in data-driven insights [19]. This proposition underscores the potential of integrating AI and XR in developing educational experiences that are not only interactive and engaging but also adaptive to individual learning trajectories.

### 3.2 Adaptive Intelligent Learning Systems (AILS)

Adaptive Intelligent Learning Systems (AILS) are frameworks that aim to optimize the learning process for each learner. They build on domain knowledge, instructional information, and learner data to analyze and assess learning patterns. AILS's capacity for prediction and decision-making regarding the learner's progress enables customized content delivery, alternative learning paths, targeted advice, and timely feedback, all based on data-driven insights [19], [20]. According to Adam, implementing AILS in educational settings is leading to significant improvements in student engagement, comprehension, and retention rates [21].

Developing AILS typically involves integrating models, including a Domain Model containing the learning content, a Learner Model containing the learner's profile and performance data, and an Instructional Model, serving as the basis for making decisions regarding content delivery, including what, when, and how adaptation should occur [22]. Once these data-driven models are trained and merged, they enable the provision of targeted learner feedback such as relevant explanations, hints, examples, demonstrations, and additional or alternative tasks tailored to each learner. AILS has predominantly been implemented in e-learning contexts, where data regarding student interactions are collected from websites [23], [24]. However, integrating AILS within XR environments could expand data derived from learners' movements, eye gaze, and haptic interactions. This enhancement will allow a more comprehensive understanding of student engagement and learning behaviors in an immersive setting.

## 4. ALTERS Design and Development

The ALTERS platform aims to create an immersive and personalized learning environment. It will consist of a project website to access the VR content and a hardcopy textbook with a mobile AR application. Together, these applications will provide architectural learners with alternative ways of engaging with structural education.

### 4.1 Methodology

The development of the ALTERS platform utilizes methodologies and insights derived from two previous projects supported by the U.S. National Science Foundation (NSF): 1) Intelligent Immersive Environments for Learning Robotics [25], [26], [27] and 2) Augmented Learning for Environmental Robotics Technologies [28],[29]. Although these projects targeted learning robotics for AEC fields, their core objective is based on developing AILS in XR powered by Machine Learning (ML) and Natural Language Processing (NLP). This focus has enabled the authors to refine a methodology that is now guiding the development of the ALTERS project. The method of developing the project is organized into the three overlapping phases described below.

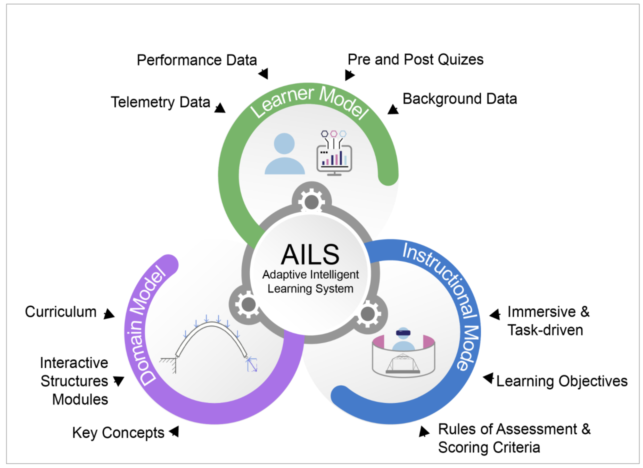


Figure 4: Diagram of AILS components for ALTERS.

**Phase 1: Creating the XR Environments:** This phase, currently underway, focuses on creating a solid foundation for delivering comprehensive XR environments that cater to diverse learning preferences and foster immersive educational experiences in both VR and AR experiences. Leveraging Unity as the primary development environment, the process begins by converting existing IS assets from 3ds Max to FBX format to ensure compatibility and preserve details like textures and animations. These assets undergo optimization within Unity to balance visual fidelity and rendering efficiency, ensuring smooth functionality within XR environments. Further refinement involves decomposing models into fundamental components, such as shapes and structural elements, facilitating precise control and interaction. To enhance efficiency, features like tags and prefabs are utilized in Unity development. Rigid body physics properties are then applied to enable realistic interactions, including mass, gravity, and friction, enhancing the overall XR experience.

For VR, the focus is on utilizing HTC Vive Eye Head-Mounted-Displays (HMD), integrating telemetry for data collection, and incorporating assessments for enhanced learning experiences. Meanwhile, AR development initially centers on engaging animations and overlays for contextualized learning using a hardcopy book, with plans for further HMD integration for assessment purposes. Throughout this phase, tasks are broken down systematically to streamline development and ensure seamless integration of assessments and telemetry, providing valuable insights into user interactions and behaviors.

**Phase 2: Developing the AILS:** In the ongoing phase of the project, significant effort is dedicated to developing the AILS (see Figures 4). This encompasses key tasks, including data collection from learners, model creation, and the application of AI algorithms. The process starts with constructing the Domain Model, which involves assessing and refining the existing IS curriculum and content. Key concepts are clearly defined, and metadata indicating difficulty levels and relevance to other topics are organized. Additionally, new interactive tasks and case studies are integrated. Subsequently, the project progresses to developing the Learner Model by gathering student performance data from Unity3D, such as task completion time, attempt frequency, and quiz responses. Intake survey data on students' academic backgrounds is also incorporated to evaluate their proficiency in physics and mathematics. Following this, the Instructional Model is established, outlining learning objectives for each module, decision-making rules for assigning lessons and tasks, and scoring criteria. This framework enables the delivery of affirmative feedback to reinforce correct answers and corrective feedback to address misconceptions or areas of difficulty. The ML workflow relies on Unity Barracuda, a lightweight cross-platform neural networks inference library, which plays a crucial role in this project phase. While the primary focus of AILS implementation is currently within the VR environment, future iterations of the ALTERS platform aim to explore integration with AR Head-Mounted Displays (HMDs). However, it is important to note that current AR HMDs face limitations in computational power and data processing compared to VR systems, which presents challenges in implementing complex AI algorithms and managing large real-time datasets on AR devices.


Figure 5: An architecture student engaging with the VR course content of ALTERS through an immersive case study of Pier Luigi Nervi's Palazzetto dello Sport.

**Phase 3: Testing, Implementation, and Project Delivery:** This crucial phase marks the transition from development to testing, implementation, and eventual delivery of the ALTERS platform, designed to offer immersive and personalized learning experiences for architectural students.

The process begins with rigorous testing of beta versions of the ALTERS platform to identify and rectify any potential issues. Student data is collected during this phase to evaluate platform performance, with feedback mechanisms hardcoded into Unity for iterative refinement (see Figures 5-6). Simultaneously, the Adaptive Intelligent Learning System (AILS) undergoes continuous improvement. AI models are trained using collected data to develop personalized learning pathways, enhancing adaptability to individual student needs. Testing involves both control and experimental groups of students. The control group follows traditional lecture methods, while the experimental group engages with the immersive VR environment provided by ALTERS. Performance metrics from these groups are analyzed to gauge the ALTERS intervention's impact on student learning outcomes.

Upon successful testing and refinement, the ALTERS platform is prepared for full-scale implementation and delivery. Project outcomes are delivered in various formats to cater to diverse learners. Immersive VR content is downloadable from a designated website for use with VR headsets, while a physical textbook format augmented with AR technology provides interactive content for traditional learners, enhancing their educational experience.

Figure 6: Stills from the AR-enabled hardcopy book.

## 5. Conclusion: Transforming Structures Education with AI-driven XR

The ALTERS platform proposes an innovative to the longstanding challenges of teaching structures to architecture students by integrating advancements in AI and XR technologies. This approach transforms the traditional passive lecture format into a dynamic, engaging learning system that actively involves students with the content. The platform's AILS is a key component in enabling personalized learning pathways tailored to each student's needs, pace, and areas of difficulty. By situating structural concepts within realistic, interactive environments, ALTERS removes the abstraction often associated with traditional teaching methods, making it easier for students to understand how theoretical concepts apply in real-world scenarios. Using simulations within the immersive platform provides students with visual access to structural behaviors, revealing the dynamic impacts of various forces on structural elements—phenomena that are difficult or impossible to observe directly in the physical world. These visualizations are crucial for developing a deep understanding of structural integrity and behavior. Additionally, the modular design of the ALTERS platform allows for scalability and future growth, ensuring its long-term relevance and effectiveness as new advancements in AI and XR technologies emerge.

As the project progresses, future research and development efforts will focus on expanding the range of structural scenarios and simulations, refining AILS algorithms, integrating advanced haptic feedback technologies, conducting longitudinal studies to assess the platform's impact on student learning outcomes, and exploring collaborative learning experiences within the platform. By addressing these areas, the ALTERS platform has the potential to set new benchmarks for teaching methodologies in architecture education and contribute to the growing body of knowledge on the effectiveness of AI and XR in structures education, ultimately paving the way for a more engaging, personalized, and impactful learning experience for architectural students.

### Acknowledgments

This material is based upon work supported by the U.S. National Science Foundation's Research on Emerging Technologies for Teaching and Learning program and under Award No. 2202610: *Collaborative Research: Intelligent Immersive Environments for Learning Robotics*, as well as research on Improving Undergraduate STEM Education program and under Award No. 2315647: *Augmented Learning for Environmental Robotics Training (ALERT).* Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

### References:

[1] S. Shareef and G. Farivarsadri, "An Innovative Framework for Teaching/Learning Technical Courses in Architectural Education," *Sustainability*, vol. 12, no. 22, p. 9514, 2020.

[2] S. Vassigh and S. Herrera, "Interactive Teaching through Simulation Environments," in *Proc. Association for Computer Aided Design in Architecture (ACADIA)*, Dover, DE, 2010, pp. 327-332.

[3] N. Emami and P. Buelow, "Teaching Structures to Architecture Students through Hands-on Activities," in *Proc. Canadian International Conference on Advances in Education, Teaching, and Technology*, 2016, pp. 1-8.

[4] G. Black and S. Duff, "A Model for Teaching Structures, Finite Element Analysis in Architectural Education," *Journal of Architectural Education*, vol. 48, no. 1, p. 39, Sep. 1994.

[5] D. Davis, S. Vassigh, H. Alhaffar, A. Elias, and G. Gallardo, "Learning Building Sciences in Virtual Environments," in *Proc. ASEE Annual Conference & Exposition*, 2018.

[6] P. Wang, P. Wu, J. Wang, H. Chi, and X. Wang, "A Critical Review of the Use of Virtual Reality in Construction Engineering Education and Training," *International Journal of Environmental Research and Public Health*, vol. 15, no. 6, p. 1204, 2018.

[7] EDUCAUSE Review, "Adaptive Learning Systems: Surviving the Storm," [Online]. Available: http://er.educause.edu/articles/2016/10/adaptive-learning-systems-surviving-the-storm

[8] S. Vassigh, "Interactive Learning Structures Environment: An Alternative Pedagogy," in *Proc. EdMedia+ Innovate Learning, Association for the Advancement of Computing in Education*, 2003, pp. 345-348.

[9] S. Vassigh, "A Digital Pedagogy for Learning Structures," *Architectural Design*, vol. 74, no. 1, pp. 112-115, Jan./Feb. 2004.

[10] G. B. Petersen, G. Petkakis, and G. Makransky, "A Study of How Immersion and Interactivity Drive VR Learning," *Computers & Education*, vol. 179, p. 104429, 2022.

[11] M. C. Johnson-Glenberg, H. Bartolomea, and E. Kalina, "Platform is Not Destiny: Embodied Learning Effects Comparing 2D Desktop to 3D Virtual Reality STEM Experiences," *Journal of Computer Assisted Learning*, vol. 37, no. 5, pp. 1263-1284, Oct. 2021.

[12] M. Wilson, "Six Views of Embodied Cognition," *Psychonomic Bulletin and Review*, vol. 9, no. 4, pp. 625-636, 2002.

[13] M. Ioannou and A. Ioannou, "Technology-Enhanced Embodied Learning," *Educational Technology & Society*, vol. 23, no. 3, pp. 81-94, 2020.

[14] J. K. O'Regan and A. Noë, "A Sensorimotor Account of Vision and Visual Consciousness," *Behavioral and Brain Sciences*, vol. 24, no. 5, pp. 939-1031, 2001.

[15] M. M. Bagher, P. Sajjadi, J. O. Wallgrün, P. C. Femina, and A. Klippel, "Move the Object or Move the User: The Role of Interaction Techniques on Embodied Learning in VR," *Frontiers in Virtual Reality*, vol. 2, p. 695312, 2021.

[16] H. Lin et al., "Virtual Geographic Environments (VGEs): A New Generation of Geographic Analysis Tool," *Earth-Science Reviews*, vol. 126, pp. 74-84, 2013.

[17] L. W. Chen, J. P. Tsai, Y. C. Kao, and Y. X. Wu, "Investigating the Learning Performances Between Sequence- and Context-Based Teaching Designs for Virtual Reality (VR)-Based Machine Tool Operation Training," *Computer Applications in Engineering Education*, vol. 27, no. 5, pp. 1043-1063, 2019.

[18] C. Fowler, "Virtual Reality and Learning: Where is the Pedagogy?" *British Journal of Educational Technology*, vol. 46, no. 2, pp. 412-422, 2016.

[19] L. Cen, D. Ruta, and J. Ng, "Big Education: Opportunities for Big Data Analytics," in *Proc. IEEE International Conference on Digital Signal Processing (DSP)*, 2015, pp. 502-506.

[20] E. Herder, S. Sosnovsky, and V. Dimitrova, "Adaptive Intelligent Learning Environments," in *Technology-Enhanced Learning: Research Themes*, E. Duval, M. Sharples, and R. Sutherland, Eds. Cham: Springer, 2017, pp. 109-114.

[21] A. Adam, "Employing Adaptive Learning and Intelligent Tutoring Robots for Virtual Classrooms and Smart Campuses: Reforming Education in the Age of Artificial Intelligence," in *Advanced Computing and Intelligent Technologies: Proc. ICACIT*, Singapore: Springer Nature Singapore, 2022, pp. 395-406.

[22] F. Martin, Y. Chen, R. L. Moore, and C. D. Westine, "A Systematic Review of Adaptive Learning Research Designs, Context, Strategies, and Technologies from 2009 to 2018," *Educational Technology Research and Development*, vol. 68, pp. 1903-1929, 2020.

[23] B. Radenković, M. Despotović, Z. Bogdanović, and D. Barać, "Creating an Adaptive Environment for E-learning Courses," *Journal of Information and Organizational Sciences*, vol. 33, no. 1, pp. 179-189, 2009.

[24] Ö. Özyurt and H. Özyurt, "Learning Style Based Individualized Adaptive E-learning Environments: Content Analysis of the Articles Published from 2005 to 2014," *Computers in Human Behavior*, vol. 52, pp. 349-358, 2015.

[25] S. Vassigh, B. Bogosian, and E. Peterson, "Performance-Driven VR Learning for Robotics," in *Proc. International Conference on Computational Design and Robotic Fabrication*, Singapore: Springer Nature Singapore, 2023, pp. 356-367.

[26] E. Peterson, B. Bogosian, J. Tubella, and S. Vassigh, "Teaching Robotics with Virtual Reality: Developing Curriculum for the 21st Century Workforce," in *Proc. International Conference on Applied Human Factors and Ergonomics*, Springer, 2021, pp. 12-18.

[27] E. Coltey, Y. Tao, T. Wang, S. Vassigh, S. Chen, and M. Shyu, "Generalized Structure for Adaptable Immersive Learning Environments," in *Proc. IEEE 22nd International Conference on Information Reuse and Integration for Data Science*, 2021.

[28] B. Bogosian, S. Vassigh, and E. Peterson, "Augmented Learning for Environmental Robotics Technologies (ALERT)," in *Emerging Technologies and Future of Work*, T. Ahram and W. Karwowski, Eds. AHFE Open Access, 2023, vol. 117. [Online]. Available: http://doi.org/10.54941/ahfe1004407

[29] S. Vassigh, "Harnessing AI for Enhanced Learning: Insights from the Robotics Academy," *Open Access Government*, 2024. [Online]. Available: https://doi.org/10.56367/OAG-041-11175