BARRIERS AND PATHWAYS TO USE EXTENDED REALITY IN STEM CLASSROOMS: PERSPECTIVES OF KEY STAKEHOLDERS

Wei Wu[1], Yupeng Luo[1], Fadi Castronovo[2], Arlo Liang[1], Frank Gomez[3], Sara Kassis[4], Abraham Wolcott[5]
[1]California State University, Fresno, Fresno, CA, U.S.A.
[2]University of Brighton, Brighton, U.K.
[3]STEM-NET, California State University, CA, U.S.A.
[4]Sonoma State University, Rohnert Park, CA, U.S.A.
[5]San José State University, San Jose, CA, U.S.A.

Abstract

This paper investigates the barriers and pathways to adopting, integrating, and implementing extended reality (XR) in STEM classrooms to support active learning at the California State University from the perspectives of key subject matter experts (SMEs). The research team conducted semi-structured interviews with the SMEs to solicit feedback from the lenses of financial, faculty, and institutional environment at the various phases of the transition to use XR in regular STEM classrooms with large student enrollments rather than exploratory lab-testing scenarios typically seen in research settings. The results unveiled a broad spectrum of barriers subject to the specificity of the discipline, administrative commitment, infrastructure, incentive structure, content development, professional development, and training. The findings suggest that peer support and collective advocacy among STEM faculty, administrators, and industry partners could pave a pathway forward to encourage the use of XR in everyday STEM teaching and learning.

Introduction

There is evidence of increased student engagement and motivation for STEM education when using VR (Truchly et al., 2018), AR (Restivo et al., 2014), and MR (Lafargue, 2018). It has been reported that XR has significant potential to improve students' learning attitude and effectiveness (Tang et al., 2020), transfer students' self-perception (Vézina et al., 2004), and increase their identification with the STEM community (Starr et al., 2019, Peck et al., 2018, Cheryan et al., 2011).

STEM faculty pioneers from the 23 campuses of the California State University (CSU) have successfully implemented XR on different campuses to promote active learning in introductory STEM courses across disciplines by designing immersive, interactive, and multimodal learning experiences. However, many early adopters face significant challenges when exploring XR for classroom use, such as the lack of readily available, affordable, and suitable XR educational resources and the absence of training and technical support to ensure XR fits into existing teaching practices.

The higher education STEM community will benefit from a better understanding of XR's pedagogical impact and guidelines of how individual faculty's success with XR can be replicated across STEM disciplines and under specific institutional contexts. This paper, as part of a National Science Foundation (NSF) funded project, aims to investigate common barriers and suggest pathways to prepare faculty in higher education to transform active learning in STEM with XR based on empirical evidence and insights shared by a group of subject matter experts who play essential roles in advocating XR in STEM education and workforce development.

Background

Adoption of XR in college STEM education

EDUCAUSE published a series of three research reports on XR for teaching and learning in the higher education context and explored the adoption, deployment, learning affordances, challenges, and opportunities, as well as success stories across campuses (Pomerantz, 2018, Pomerantz, 2019, Pomerantz, 2020). In a nutshell, XR has been used to achieve learning goals across domains, including STEM. Effective pedagogical use of XR is mainly witnessed in skill- and competency-based learning, hands-on learning, and learning that involves new forms of interaction, such as simulation (Pomerantz, 2019). Further, researchers find that XR can improve students' academic performance and motivation (Hamilton et al., 2020, Maas and Hughes, 2020).

XR has also enabled new learning environments to facilitate student-centered active learning to support students' retention of information, engagement, skill training, and learning outcomes (Yannier et al., 2020). Additionally, XR empowers interactive experiences that often deliver social and emotional learning opportunities and science lessons so that students can develop soft skills critical to success in both higher education and the workforce (Cook et al., 2020).

Barriers to broader use of XR in STEM

Like many other technological innovations, the diffusion and broad acceptance of XR in STEM classrooms face significant challenges. Despite the overwhelmingly positive reports about XR's educational benefits, most students never experience XR because most faculty are either unfamiliar with it or unable to integrate it into the classroom. The challenges educators face are twofold: 1) the lack of immediately available XR-integrated educational content; and 2) the lack of best practices for expediting learning outcome-driven and pedagogically-sound educational XR development. Understanding XR's pedagogical impacts and assessing student learning are among the most needed research areas (Pomerantz, 2019).

Enabling access and creating pathways for XR to enter STEM classrooms are not only a technological matter but also imperative for equitable STEM educational outcomes. There is little research conducted on how XR may improve *diversity, equity, or inclusion (DEI)* in STEM (Quintero et al., 2019), although it has been acknowledged that *"providing access to XR technology is a matter of social equity*" (Pomerantz, 2020). In the report: "*STEM 2026: A Vision for Innovation in STEM Education*", XR technologies were highlighted to enable flexible and inclusive learning spaces that "*can enhance learners' STEM experiences. Diversifying when and where learning occurs promotes opportunities for culturally relevant pedagogies and activities by facilitating new modes of exploring STEM concepts and developing STEM skills*" (King and Shilling, 2016).

Methodology

This research study used semi-structured interviews (SSIs) to capture the identified barriers to the broader use of XR in STEM classrooms and hope to unveil the root causes of these barriers and potential pathways to overcome them. As both a data collection and research method, the SSI is typically designed to ascertain subjective responses from persons, e.g., subject matter experts, regarding a particular situation or phenomenon they have experienced (McIntosh and Morse, 2015). It employs a relatively detailed interview guide or schedule (Baumbusch, 2010). The SSI is particularly useful when there is sufficient objective knowledge about an experience or phenomenon, but subjective knowledge is lacking. It is conducive for research studies that focus on "why" rather than "how many" or "how much" (McIntosh and Morse, 2015). As XR is being widely explored, "why faculty still find it challenging to integrate XR in the classroom" might be addressed from actual subject matter experts' firsthand experience and insights. The SSI involves a set of open-ended questions that allow for spontaneous and in-depth responses (Ryan et al., 2009). The process of using SSIs as a data collection strategy involves a number of phases, including the development of the interview guide, conducting the interview, and analyzing the interview data (Rubin and Rubin, 2005).

Developing the SSI interview guide

As suggested by best practices, the SSI interview guide or protocol used in this research study was developed based on the analysis of the objective knowledge, i.e., reported literature, which constitutes the framework and foci for the development of the interview question stems. Technology adoption in higher education faced typical patterns of barriers. According to Abrahams (2010), these common barriers could be clustered into *faculty issues*, *resistance to change*, *cost*, *development issues*, *leadership and support*, *and human interaction issues*, to name a few. The research team also acknowledges the applicability of Roger's *Diffusion of Innovation* Theory (Rogers, 2003) and suspects the significance of each cluster of barriers may shift over the course of the diffusion. According to Buchanan et al. (2013), two major factors impacts the adoption of new technology in higher education. These factors are the structural barriers within an institution and the perceived usefulness of the technology.

Based on this previous research efforts, the research team then employed three lenses to examine the barriers and explore pathways to adopt, integrate, and implement XR in higher education STEM classrooms:

- Lens 1: The financial aspect.
- Lens 2: The faculty aspect.
- Lens 3: The institutional environment aspect.

Based on these premises, the research team defined the following three phases of XR technology diffusion in higher education:

- Phase 1: Adoption – identify, evaluate, and purchase XR technology
- Phase 2: Integration – develop, train, design/redesign, and plan XR for intended STEM educational use
- Phase 3: Implementation – deploy, pilot, assess, adjust, and adapt the use of XR in STEM teaching and learning

When intersecting the lens throughout the defined XR diffusion phases, the developed SSI protocol can be represented in Table 1. During the interview, these prompts were not strictly sequenced but only served as potential talking points to encourage the interviewees to offer their opinions and elaborate on specific vital issues encountered. These prompts also helped form the basis of the thematic analysis of the collected interview data.

Conducting the interview

Candidates of the semi-structured interviews were subject matter experts (SMEs) in the CSU and affiliated entities. The SMEs were identified and recruited via referrals based on demonstrated knowledge and experience with implementing and managing XR technologies in their organizations. Once a short list of candidates was curated, an internal screening was made based on the roles they played in XR adoption/integration/implementation, their level of involvement in the day-to-day operation of XR-constructed learning and training environments, as well as their level of involvement in policy-making, strategic planning, and procurement endeavors. Six SMEs, including educators, administrators, and workforce development specialists, were selected for the interviews. All interviews were conducted by the same two research team members via Zoom, and informed consent was obtained from the interviewees for audio-recording the interviews. Each interview lasted about one hour, and it was transcribed and stored in a cloud-based secure repository. A graduate research assistant, who was trained and qualified to conduct research with human subjects, was hired for data processing and thematic analysis.

Table 1. The SSI interview protocol developed for this research study

Lens & Prompts	Phases of XR technology diffusion in higher education		
	Phase 1: Adoption	Phase 2: Integration	Phase 3: Implementation
Lens 1: Financial	Cost of procurement	Cost of prototyping and learning content development	Cost of deployment
	Cost of installation and hosting	Cost of space remodeling and upgrade	Cost of storage and maintenance
Lens 2: Faculty	Lack of technological knowledge	Training related	Learning delivery (designed vs. achieved)
	Lack of motivation for change	Learning content development (cost, time, complexity)	Assessment (measure success)
	Lack of time for obtaining funds, administrative permission, and other resources	Course and instructional design: learning theory, pedagogy choices	Student buy-in
			Accessibility
Lens 3: Institutional Environment	Lack of incentive (financial, release time, recognition)	Lack of systemic knowledge in educational technology integration	Lack of real-time technical support
	Lack of procedure on IT policy (security, privacy, etc.)	Lack of appropriate lab/classroom spaces	Lack of teaching support (student TAs + RAs)
	Lack of technical support	Lack of technical support in content development and troubleshooting	Lack of incentive to persist with initial failure

Participants Information

Between February and June 2022, the research team interviewed six SMEs, including three STEM instructors, one campus academic technology innovation officer, one university system technology innovation grant officer, and one county-level administrator on STEM workforce development. All SMEs (n=6) shared their exposure to XR in academic teaching and learning settings (primarily 2-year and 4-year college education, with some discussion of K-12 education as well).

Analyzing the interview data

Interview transcripts were extracted from the recordings, and thematic analysis was performed to identify patterns, representative quotes, and frequency. Thematic analysis is a method used for "identifying, analyzing, and reporting patterns (themes) within the data" (Braun and Clarke, 2006). In this research, thematic analysis is used as a 'contextualist' method, which acknowledges the ways individuals make meaning of their experience, and, in turn, the ways the broader social context impinges on those meanings while retaining focus on the material and other limits of 'reality.'

Results & Findings

The themes identified in the interviews are tabulated following the pre-established structure of the interview guide. They include the frequency (number of times) the theme was present in all interviews, plus a representative quote for context.

Themes on financial barriers

Table 2 presents the themes identified from the financial aspects of barriers. Cost of procurement, storage, and maintenance are among the most frequently quoted challenges. Even though, from the long-term perspective, the cost of technology is expected to decrease, it is still a top priority in decision-making, especially for institutions that lack resources.

Table 2. Themes associated with financial barriers

Theme	Quote	Total *n*
Cost of procurement	When I am looking at this as an adoption is how quickly the technology is changing and the cost associated with the equipment.	3
Cost of storage and maintenance	So that's something so important to consider as one begins to design and implement a program today that is looking to have an impact is to be sure that all the sustainability and resource questions are addressed upfront. How are we going to maintain 2000 headsets?	3
Cost of deployment	I think another barrier that you've noted is cost. There's the infrastructure cost of having the spaces, the bandwidth, the tools and so on	2
Cost of space and remodeling	I needed to develop a system that required a substantial graphics card and a dedicated space with sensors and unique camera systems.	1

Themes on faculty/teaching-related barriers

As the change agents, faculty plays critical roles in shaping the XR-integrated STEM classroom experiences for students. Table 3 summarizes obstacles identified to relate to faculty and teaching. One of the top challenges faced by faculty is to “fit” XR in their current practices in an organic way. This refers to course instructional design that is grounded in learning theory and the choices of appropriate pedagogy (n=6). The heavy workload (n=4), lack of interest (n=4), or technical knowledge (n=4) to implement the new technology collectively contribute to the resistance to change (n=5) among faculty. The pandemic forced everyone to teach online, while the familiarity with online teaching did not necessarily translate into voluntary willingness to teach online but instead might have created fatigue among faculty with technology or new changes driven by technology. Training or professional development (n=2) dedicated to XR was also rare. For faculty who were enthusiastic, most of the time, they were on their own with little to no support or dedicated resources that they could leverage to sustain such efforts (n=2).

Table 3. Themes associated with faculty/teaching-related barriers

Theme	Quote	Total *n*
Course and instructional design: learning theory, pedagogy choices	How to insert this into my curriculum? What’s the pedagogy and what content can I use? How that would make sense and would fit with what I’m doing. And there just hasn’t been a lot of really well-done content design in a high-quality pedagogical way.	6
Lack of motivation for change	I don’t know about your campus but even today, as we had two years of online teaching experience, our campus still holds a strong position that faculty needs to come back and teach in person. I just feel like the whole educational system is very resistant to new technology, just in general.	5
Workload	I need the teaching load to be reduce then I would have more time on VR. It is not so much about money because if I hire student assistants, then it is mostly my time.	4
Lack of interests	Today, the issue is to find teachers who are enthusiastic and excited about what they could do in a classroom.	4
Lack of technical knowledge	When we first started transitioning to online, there were some professors, for example, did not know how to write on an iPad or to project, so you need to be able know how to do that.	4
Lack of multi-role personnel	I think that it really showed the shortcoming, then how people were having to wear a lot of different hats. Maybe this is an important thing for us to have on campus.	2
Lack of time for obtaining funds, permission, and other resources	There may be 10% of the faculty who tried really did something worthwhile. People that were so enthusiastic still had their day jobs to do if you might say, and so it really became a situation where there just was not enough resource available to sustain that over time.	2
Accessibility	A big implementation concern for me has to do with how we make this as accessible for students with different disabilities as possible. That is a huge barrier, and I do not have a good idea of how to improve.	2
Training related	I do not know if there is training provided to faculty.	2
Assessment	We do collect information on the impact of some of the data that you mentioned, for example, the number of students and the number of faculty/staff, etc. We do not measure it longitudinally over time.	1

Themes on institutional barriers

As much research literature alluded, institutionalizing technology innovation would occur when appropriate infrastructure, resources, policy, and culture were in place (Ely, 2014, Vargo et al., 2015). Large-scale classroom integration of XR requires dedicated physical spaces suitable for the learning activities and interactions enabled by XR (n=3). Given the significance of dedicating faculty to their essential role in teaching, in-classroom support by research assistants (RAs) or teaching assistants (TAs) are often overlooked but highly desirable for smooth and successful XR implementation (n=3).

Organizational or systemic knowledge in educational technology integration could greatly expedite the trial-and-error process and eventually foster the replication of success across campus (n=3). In addition, dedicated procedures on IT policies (n=2) and centralized technical (n=2) and instructional design support (n=2) were also among the highly desired characteristics to cultivate an institutional environment that nourishes and fosters the viability of XR.

Table 4. Themes associated with institutional barriers

Theme	Quote	Total *n*

Lack of appropriate lab/classroom spaces	The problem is that we have no storage at the back of my classroom, and all storage space has already been accounted for.	3
Lack of teaching support (student TAs + RAs)	My plan is just to develop a vector world and have my students do this, so the resource I need is that I wish to have a TA.	3
Lack of systemic knowledge in educational technology integration	we had a 200-megabyte limit on our email until last year. Because they did not like the idea of putting email into the cloud. So, they were dedicated to holding emails onto their hard drives at the District Office. This was the type of mindset that we had to deal with.	3
Lack of procedure on IT policy (security, privacy, etc.)	I think the big red flag that everyone is worried about is a privacy concern, and there was a lot of hope that we could avoid this privacy concern by logging in via Facebook using a commercial license like they used Quest for business.	2
Lack of technical support in content development and troubleshooting	In a dream world, I would have a developer, I would be able to lay out exactly what I am looking for, and they could create a skeleton of it for me and make some quick modifications, and then boom, I will be able to go	1
Lack of real-time technical support	I know that it is going to take forever for them to create a new image, so I try to avoid using our IT because they are just not responsive.	1

Themes on preliminary pathways

Despite the obstacles identified, some pathways led to successful XR integration shared by the SMEs. Outstanding leadership (n=6) was frequently mentioned as the key factor contributing to successful initiatives (Table 5). The involvement of student interns and technicians (n=5) in co-developing XR content and experiences with faculty was another frequently quoted success factor (Table 7). Forming a community of practice (n=4) to provide training and assimilate efforts by faculty across campus was a highly effective model to sustain faculty persistence and replicate success (Table 6). Additionally, leveraging seed grants (n=3) to start with small and focused intervention helped several SMEs navigate through the initial stage and allowed them to make a case to convince upper management to invest in more extensive and longer-term projects (Table 5). Dedicated spaces (n=3) on campus to showcase success and advocate broader buy-in and adoption can help alleviate some faculty and students' resistance to technology such as XR (Table 7). Last but not least, faculty was recommended to consider scaffolding when designing STEM learning experiences with XR (n=3). Starting small and focusing on one subject at a time was recommended to eliminate barriers to use and engagement (Table 6).

Table 5. Pathways to overcome financial barriers

Theme	Quote	Total *n*
Outstanding Leadership	I would have to say that our President has been very, very generous. Our Vice President made the case to the President, and our effort was then supported by the President's fund.	6
Seed Grants	"I wrote three grants in 2018, and it was like a big year, even these were small grants. Some of the grants were campus-wide, and some were CSU-wide." "Grant on promoting digital literacy through curriculum changes, learning communities, etc."	3

Table 6. Pathways to overcome faculty/teaching-related barriers

Theme	Quote	Total *n*
Faculty training via a community of practice	Give assigned/buyout time and ask faculty fellows (currently, there are 12) to be involved in the lab while offering technical assistance to help them build what they would like to create.	4
Scaffolded learning design	"Try to start with 1-2-wk long learning modules before full-semester integration, which can be overwhelming." "Scaffolding experience to eliminate barriers of use and engagement."	3
Collaboration with others	"I also got support from two other faculty members (the instructor of the course who let me run the experiment in his class for one week, and another faculty helped me write the grant)."	2

Table 7. Pathways to overcome institutional barriers

Theme	Quote	Total *n*
Interns and technicians	Have student interns help teachers (especially early adopters) in class so teachers can stay focused on teaching rather than technology.	5
Dedicated personnel	Well-staffed programs have a higher chance of success. It does take a dedicated person in	4

	the library/school to sustain the support.	
Dedicated spaces	Dedicated space on campus fosters presence for faculty and students. Faculty involved in the lab can check out equipment and student assistants.	3

Conclusions

This research study aims to identify barriers higher education faculty face in broadening the use of XR in STEM classrooms. Despite the overwhelmingly reported educational benefits of XR, many faculty and students have not gained access to this promising technology yet due to financial, faculty, and institutional obstacles across its adoption, integration, and implementation. This study employed SSIs to uncover valuable insights and firsthand information contextualized in empirical practices by SMEs with diverse backgrounds and institutional knowledge. Thematic analysis was performed to better understand these barriers, with preliminary pathways highlighted to foster further investigation that could help alleviate such barriers and promote the development of a community of practice to accelerate the diffusion of XR in the higher education STEM community.

Acknowledgments

The research team would like to thank all subject matter experts for participating in this research and sharing their insights on XR adoption, integration, and implementation in STEM education. This research is funded by NSF Awards #2126723, #2126711, and #2126716.

References

Abrahams, D. A. 2010. Technology adoption in higher education: a framework for identifying and prioritising issues and barriers to adoption of instructional technology. *Journal of Applied Research in Higher Education,* 2**,** 34-49.

Baumbusch, J. 2010. Semi-structured interviewing in practice-close research. *J Spec Pediatr Nurs,* 15**,** 255-8.

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology,* 3**,** 77-101.

Buchanan, T., Sainter, P., & Saunders, G. (2013). Factors affecting faculty use of learning technologies: implications for models of technology adoption. Journal of Computing in Higher Education, 25(1), 1-11.

Cheryan, S., Meltzoff, A. N. & Kim, S. 2011. Classrooms matter: The design of virtual classrooms influences gender disparities in computer science classes. *Computers & Education,* 57**,** 1825-1835.

Cook, A. V., Anderson, S., Griffiths, M., Kusumoto, L. & Harr, C. 2020. A new approach to soft skill development. *Deloitte Insights* [Online]. Available: https://www2.deloitte.com/us/en/insights/topics/emerging-technologies/immersive-technologies-soft-skill-training.html.

Ely, D. P. 2014. Conditions that Facilitate the Implementation of Educational Technology Innovations. *Journal of Research on Computing in Education,* 23**,** 298-305.

Hamilton, D., McKechnie, J., Edgerton, E. & Wilson, C. 2020. Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*.

King, J. B. & Shilling, R. 2016. STEM 2026: A Vision for Innovation in STEM Education. Washington, DC: U.S. Department of Education, Office of Innovation and Improvement.

Lafargue, D. 2018. *The Influence of Mixed Reality Learning Environments in Higher Education STEM Programs: A Study of Student Perceptions of Mixed Reality Self-Efficacy, Engagement, and Motivation Using Augmented and Virtual Reality*, University of Louisiana at Lafayette.

Maas, M. J. & Hughes, J. M. 2020. Virtual, augmented and mixed reality in K–12 education: a review of the literature. *Technology, Pedagogy and Education,* 29**,** 231-249.

McIntosh, M. J. & Morse, J. M. 2015. Situating and Constructing Diversity in Semi-Structured Interviews. *Glob Qual Nurs Res,* 2**,** 2333393615597674.

Peck, T. C., Doan, M., Bourne, K. A. & Good, J. J. 2018. The effect of gender body-swap illusions on working memory and stereotype threat. *IEEE transactions on visualization and computer graphics,* 24**,** 1604-1612.

Pomerantz, J. 2018. Learning in Three Dimensions: Report on the EDUCAUSE/HP Campus of the Future Project. *ECAR research report.* Louisville, CO: EDUCAUSE.

Pomerantz, J. 2019. XR for Teaching and Learning: Year 2 of the EDUCAUSE/HP Campus of the Future Project. *ECAR research report.* Louisville, CO: EDUCAUSE.

Pomerantz, J. 2020. Extending XR across Campus: Year 2 of the EDUCAUSE/HP Campus of the Future Project. *ECAR research report.* Louisville, CO: EDUCAUSE.

Quintero, J., Baldiris, S., Rubira, R., Ceron, J. & Velez, G. 2019. Augmented Reality in Educational Inclusion. A Systematic Review on the Last Decade. *Front Psychol,* 10**,** 1835.

Restivo, T., Chouzal, F., Rodrigues, J., Menezes, P. & Lopes, J. B. Augmented reality to improve STEM motivation. 2014 IEEE Global Engineering Education Conference (EDUCON), 2014. IEEE, 803-806.

Rogers, E. M. 2003. *Diffusion of Innovation,* New York, Free Press.

Rubin, H. & Rubin, I. 2005. *Qualitative Interviewing (2nd ed.): The Art of Hearing Data*.

Ryan, F., Coughlan, M. & Cronin, P. 2009. Interviewing in qualitative research: The one-to-one interview. *International Journal of Therapy and Rehabilitation,* 16**,** 309-314.

Starr, C. R., Anderson, B. R. & Green, K. A. 2019. "I'm a Computer Scientist!": Virtual Reality Experience Influences Stereotype Threat and STEM Motivation Among Undergraduate Women. *Journal of Science Education and Technology,* 28**,** 493-507.

Tang, Y. M., Au, K. M., Lau, H. C. W., Ho, G. T. S. & Wu, C. H. 2020. Evaluating the effectiveness of learning design with mixed reality (MR) in higher education. *Virtual Reality,* 24**,** 797-807.

Truchly, P., Medvecký, M., Podhradský, P. & Vančo, M. Virtual reality applications in stem education. 2018 16th International Conference on Emerging eLearning Technologies and Applications (ICETA), 2018. IEEE, 597-602.

Vargo, S. L., Wieland, H. & Akaka, M. A. 2015. Innovation through institutionalization: A service ecosystems perspective. *Industrial Marketing Management,* 44**,** 63-72.

Vézina, N., IsaBelle, C., Fournier, H., Dufresne, A. & Doucet, J.-J. 3D Virtual Reality: Motivation, sense of belonging and perseverance. EdMedia+ Innovate Learning, 2004. Association for the Advancement of Computing in Education (AACE), 1677-1682.

Yannier, N., Hudson, S. E. & Koedinger, K. R. 2020. Active Learning is About More Than Hands-On: A Mixed-Reality AI System to Support STEM Education. *International Journal of Artificial Intelligence in Education,* 30**,** 74-96.