The National Academies of
SCIENCES • ENGINEERING • MEDICINE

With sponsorship from the National Science Foundation, the National Academies of Sciences, Engineering, and Medicine is convening a public symposium to explore ambitions for the future of undergraduate STEM education and identify steps for achieving them.

Prior to the symposium, the National Academies held an idea competition to engage stakeholders with diverse perspectives. Entrants submitted a statement or video addressing some aspect of the symposium's focus: *What should undergraduate STEM education look like in 2040 and beyond to meet the needs of students, science, and society? What should we do now to prepare?*

Entries were evaluated based on their potential to contribute to and advance discussion at the symposium. Entries were also judged on originality and future orientation. Below is one of the winning submissions.

"Campus^{XR} : Where Real and Virtual Education Blends"

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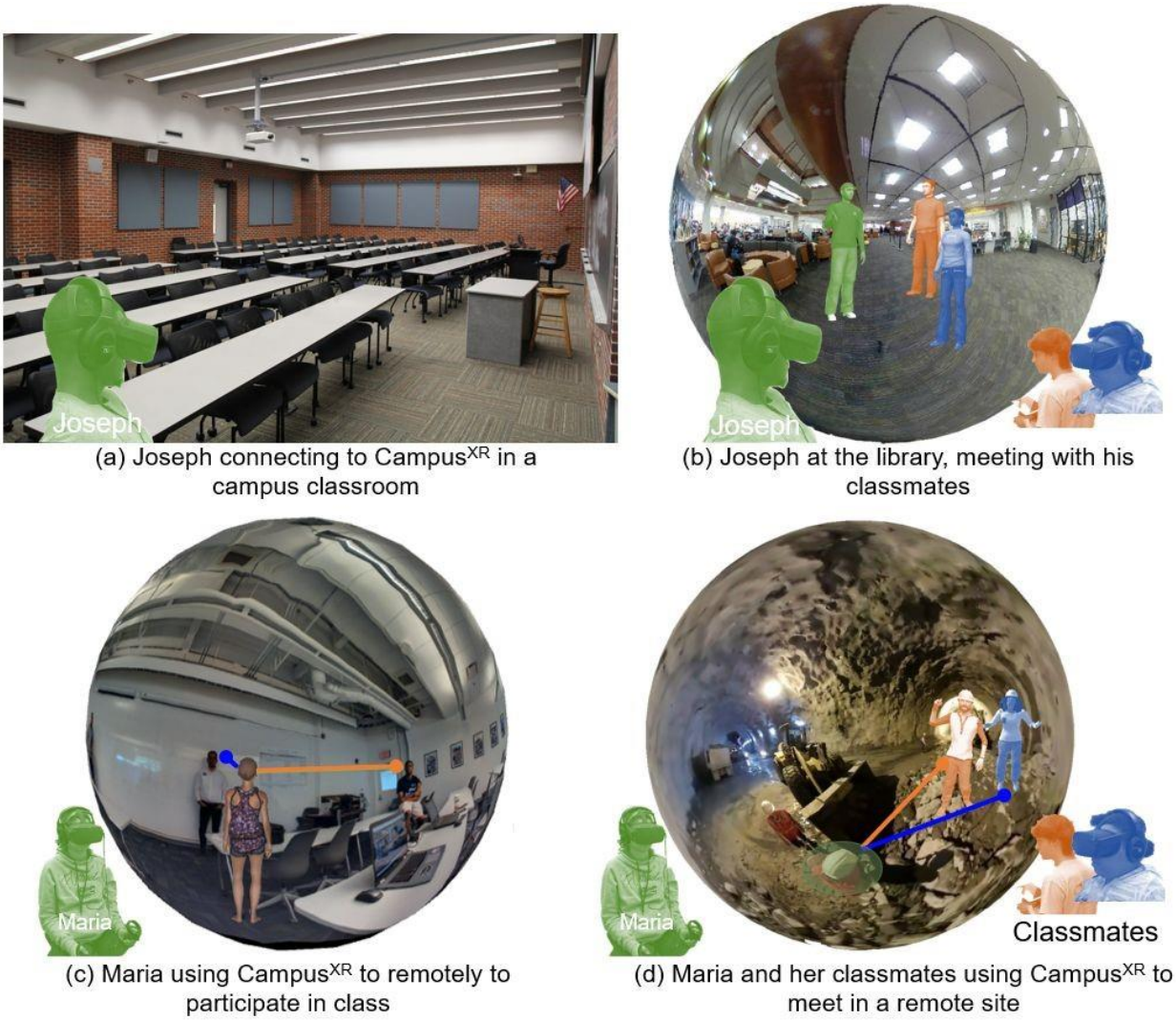
In 2040, Campus^{XR} will deliver a blended learning environment for undergraduate STEM education that seamlessly couples real and virtual environments. Campus^{XR} blurs the line between the real and the virtual worlds by developing novel virtual spaces that are intimately connected to augmented real spaces. Actions in the virtual world, such as drawing on a whiteboard, will be reflected in the real world and vice-versa. Our presence within Campus^{XR} (in person or virtually) will form a continuum between our virtual and physical embodiment, impacting how we interact, communicate, and collaborate on real and virtual worlds. Campus^{XR} aims to be technology agnostic, adapting, and leveraging new emerging technological means that students, instructors, and institutions might use now and in the future (e.g., holographic projections, live omnidirectional images).

Traditionally, undergraduate STEM face-to-face instruction introduces challenges for instructors and institutions to effectively deliver learning to students. Campus physical spaces for advanced learning can only accommodate a limited number of students. This campus spatial challenge, coupled with large class sizes, hinders the ability of faculty to adopt innovative teaching approaches that benefit STEM disciplines. Moreover, faculty-student interactions and academic support are not always easily accessible for all on-campus students, depending on their living situation, their non-campus social concerns, connections within their community, or employment demands. The implementation of other authentic STEM experiences that require out-of-the-classroom activities (e.g., field trips, internships, co-ops) pose additional setbacks to provide students

a complete learning experience. These challenges broaden when using remote delivery methods. Online tools are often intimidating, confusing, or simply frustrating for students.

These tools lack part of the informal social interactions and face-to-face contact of the traditional classroom, introducing feelings of isolation and lack of engagement between students and instructors. Due to the lack of direct exposure between students, instructors, and staff, student's disengagement warning signs may not be easily identified, further hindering student learning. In response to these education challenges and the requirements of STEM to adapt to new learning pathways, Campus^{XR} proposes a blended learning environment where remote and face-to-face deliveries are closer than ever before. The blurred real-to-virtual spectrum within Campus^{XR} will enable a highly flexible setting for students from multiple backgrounds, institutions, or phases in life to experience higher education. Within Campus^{XR} , students will be able to attend classes, interact with peers and instructors, experience campus life, and continue their education anytime and anywhere. The continuum of experiences afforded by Campus^{XR} will be particularly beneficial for STEM programs as increasing interaction, communication, and collaboration within and across educational institutions is required. Furthermore, Campus^{XR} presents opportunities for STEM students to get authentic STEM experiences beyond what is possible in traditional classrooms (e.g., impossible-to-reach scenarios and inaccessible workplace environments). The following examples illustrate the use of Campus^{XR} in the year 2040.

On-Campus Computer Science Student - Joseph's Story: Joseph is in his second semester of the Computer Science program at his university. In his Programming Fundamentals class, a group project requires him to meet his peers to brainstorm solutions for a data abstraction problem. He usually meets his classmates in a library room, using the whiteboards and computer projectors. However, today he had a meeting with one of his professors across campus and would not make it to his group meeting on time. Joseph is not worried because he knows that there is a Campus^{XR} room in the building where he is (Fig. 1-a). Using Campus^{XR} , Joseph has the flexibility to meet his group remotely in a seamless fashion. Since the library is part of the Campus^{XR} ecosystem, Joseph can interact with the members of his group in the library in a natural way (Fig. 1-b).



(a) Joseph connecting to Campus^{XR} in a campus classroom

(b) Joseph at the library, meeting with his classmates

(c) Maria using Campus^{XR} to remotely to participate in class

(d) Maria and her classmates using Campus^{XR} to meet in a remote site

Figure 1. Campus^{XR} for STEM Students

Remote Civil Engineering Student - Maria's Story: Maria is currently on a semester-long internship during her senior year at her university's Civil Engineering program. She has to take several classes while working in a geotechnical design firm that is three states away from her campus. Using Campus^{XR} , Maria can attend her Soil Mechanics class that requires classroom instruction and teamwork assignments. When Maria has class (Fig. 2-c), a hologram represents her at the classroom sessions. Using this embodied representation, she can interact, communicate, and collaborate in real-time with her peers and instructor. Moreover, Maria can also leverage Campus^{XR} tools during her work. She can virtually meet her classmates to discuss the class project at the place she works at (Fig. 1-d). She remotely shows her team at the university the site she is helping design. Using the contextual site and the team interactions delivered through Campus^{XR} , Maria and her team can provide examples of rock reinforcement for their Soil Mechanics project.

Campus^{XR} is grounded on existing concepts and technologies that need to be further developed and implemented. These technologies involve advancements in the areas of Internet of Things, ubiquitous computing, virtual reality, among many others. Perhaps more challenging is developing strategies and technologies that computationally mediate remote human presence in the physical environment. This can involve advancements in areas such as tangible interfaces, augmented reality, and holographic representations. Therefore, our vision implies that a multidisciplinary approach involving efforts from several academic areas of expertise would be pursued.

Campus^{XR} presents opportunities to transform undergraduate STEM education, democratizing university campus experiences for students around the world. Campus^{XR} creates a flexible method for student and faculty interactions across real and virtual social spaces, enhancing STEM communication and collaboration. In 2040, Campus^{XR} will assist STEM programs to expand their capabilities within and across multiple disciplines and institutions beyond their physical space limitations. Ultimately, Campus^{XR} will enable higher quality education for any student in any location by removing existing challenges of face-to-face and remote instruction.