Extending XR across Campus: Year 2 of the EDUCAUSE/HP Campus of the Future Project
Executive Summary

In 2018, EDUCAUSE and HP began a partnership to study extended reality (XR) in higher education. The HP Campus of the Future is an initiative to promote the institutional adoption of cutting-edge technologies for research and for teaching and learning. EDUCAUSE supports institutions in their efforts to promote student success and identify those technologies that can best support that success.

This report is the result of a collaboration between HP and EDUCAUSE. In 2018, EDUCAUSE published the *Learning in Three Dimensions* report, which explored the then-current state of the art in the use of XR technologies in higher education. In 2019, EDUCAUSE published the *XR for Teaching and Learning* report, which expanded on the findings of that original report by asking the research question: What factors influence the effectiveness of XR technologies for achieving various learning goals? Before XR (or any technology) can be used to achieve anything, however, it has to be implemented in some way on campus. This report expands further on the findings of both of these previous reports by asking the research question: What factors influence institutional deployment of XR technology?

This study found that institutional deployment of XR is heavily influenced by how the technology comes to campus and by staffing and institutional leadership. When XR comes to campus “under the radar,” so to speak, through faculty members’ teaching and research, it takes time to grow in use on campus; but when it is driven by campus leadership, deployment happens much faster. Deployment of XR requires staff with considerable skill in providing IT support but also with a strong focus on the IT user; and staff must be sufficiently risk-taking to promote its use across disciplines. This approach to campus technology and services derives from the organizational values fostered by institutional leadership.
Key Findings

- **The adoption of XR on campus is influenced by how XR comes to campus.** If XR is adopted first by faculty for their own teaching and research, outside of any institutional support, XR use on campus tends to take considerable time to grow. If XR is promoted by institutional leadership, especially when accompanied by resources, scaling up institutional deployment becomes more efficient.

- **The adoption of XR on campus is also influenced by the organizational structure of the institution.** For XR technology to be deployed on campus, there must be a campus unit or cross-unit collaboration with responsibility for managing it and staffing to support it.

- **Software licensing and hardware management are significant issues for the deployment of XR on campus.** Most XR software is licensed under a single-user consumer license, while institutions of higher education require enterprise or educational licenses. Managing XR hardware, meanwhile, requires processes for supporting it, such as scheduling systems and simply cleaning it after use.

- **Staffing and institutional leadership are even more important for the deployment of XR on campus.** Staff supporting XR technology must be versatile, able to provide everything from introductory how-to workshops to advanced technical support and Unity development, and from IT help to content-specific disciplinary guidance. Supporting XR requires innovation and a commitment to user service on the part of the campus unit responsible for managing it. These professional competencies must be accompanied by parallel organizational values deliberately fostered by institutional leadership.

- **Deployments of XR on campus fall into one of three models: the special initiative, service integration, and grassroots.** Special initiatives are managed by a campus unit or through cross-unit collaboration, which serves to promote and expand use of XR on campus over time as the campus unit gains experience. Alternatively, XR can be integrated into existing services offered by one or more campus units, such as makerspaces or the library. If XR first comes to campus outside of any institutional support, it may take some time for a grassroots effort to grow before reaching sufficient critical mass to receive institutional support.
- **A campus XR lab may actually be two distinct spaces: a computer lab and a studio space.** XR development requires high-end computer hardware and specific software, but these may be located anywhere, including in a “traditional” computer lab. An XR studio can be a small space, but it needs to be uncluttered to keep headset-wearing users from colliding with people and computer hardware.

- **Providing access to XR technology is a matter of social equity.** If student success is a priority for an institution of higher education, then the institution needs to actively work to remove structural barriers to student access to technologies and other campus resources by making this technology available to the campus community via a variety of means.
Introduction

Institutions of higher education are hotbeds of innovation, but that heating is uneven. The deployment of new technologies and practices can vary widely among institutions and even among units within the same institution.

Institutions of higher education have a long history of integrating new technologies into teaching and learning and into their organizational practices broadly. In the mid-2000s, mobile devices were the subject of special projects to evaluate their use cases on campus; now, 99% of students come to campus with a smartphone. Around the same time, learning management systems were also the subject of special projects by campus IT units, but now a learning management system (LMS) is deployed at nearly all US institutions. These technologies have set the stage for the digital transformation of the higher education landscape.

XR technology, too, is being integrated into institutions of higher education. EDUCAUSE research has found that the use of XR for teaching and learning is still relatively low: only about 4% of undergraduate students have access to VR headsets, and of those students, a significant majority (approximately 72%) personally own them. Furthermore, sales of XR headsets are increasing, and as happened with mobile devices, the integration of a technology into higher education often lags behind the more widespread diffusion of that technology in society at large. Demand clearly exists in higher education, and on both sides of the classroom: more than half (53%) of students would like their instructors to make greater use of simulations, and almost two-thirds (62%) would like their instructors to use more online content to supplement other course materials. Likewise, instructors agree that they could be more effective if they were better skilled at integrating simulations (61%) and using online content to supplement other course materials (64%). XR technology is, of course, only one type of simulation and supplementary online content, but it is an increasingly important type, as it has the potential to facilitate creative new pedagogic strategies and enable students to gain new kinds of skills and credentials.

But if XR is to be used in institutions of higher education, it is important to be realistic about how to use it effectively. XR holds the potential to be a game changer for higher education, but it must be deployed thoughtfully in order to fulfill this potential.

HP launched the Campus of the Future project to facilitate the adoption and integration of XR into higher education. EDUCAUSE has always been in the business of investigating how institutions of higher education can most productively deploy technology; current research turns this lens on XR.
This report is a result of this collaboration between HP and EDUCAUSE. The 2018 *Learning in Three Dimensions* report was an exploration of XR technologies in higher education. The 2019 *XR for Teaching and Learning* report, expanding on the findings of that original report, identified factors that influence the effectiveness of XR technologies for achieving various learning goals, as well as methods for integrating XR into pedagogy to support those learning goals. This report builds on all of this prior work. The study reported here was a multiple case study, informed by 47 interviews with people at 17 institutions across the United States, about the deployment and use of XR technology at these institutions. (See appendix B for more details on the methodology.) This study identified organizational factors that influence how XR technology is adopted and deployed within institutions of higher education, and it describes service models that have been implemented to support the use of that technology by the campus community.
Project Description

HP first announced its Campus of the Future project at the EDUCAUSE 2017 Annual Conference, describing it as an effort “to meet the growing challenges of higher education” and “to improve student success, mitigate risk, increase accessibility, and enhance teaching, learning, and research.” An important part of the project was, and still is, to introduce immersive computing to institutions of higher education and to conduct research about that technology.

HP approached EDUCAUSE in early 2017, prior to the EDUCAUSE 2017 Annual Conference, about conducting this evaluation, and the following parameters were established: HP would provide the hardware, and EDUCAUSE would provide the methodological expertise to conduct an evaluation research project investigating the potential uses of 3D technologies in higher education learning and research. HP, keenly aware of the risk of sponsorship bias (or even of the perception of bias), gave EDUCAUSE maximum latitude in carrying out this project. While most of the project’s technology and technical support for participating institutions was HP-branded, EDUCAUSE distributed this technology to participating institutions and was their primary point of contact. More important, EDUCAUSE developed the methodology for this evaluation and conducted all data collection and analysis independently.

Background

Phase 1 of the project spanned the 2017–18 academic year and culminated in the Learning in Three Dimensions report. Phase 2 of the project spanned an 18-month period from late 2018 to early 2020 and culminated in the XR for Teaching and Learning report in 2019 and this report.

The research question answered in the XR for Teaching and Learning report was:

- What factors influence the effectiveness of XR technologies for achieving various learning goals?

In brief, the answer is fidelity, novelty, ease of use, time-on-task, and a spirit of experimentation. The XR for Teaching and Learning report also identified some challenges to and requirements for integrating XR into teaching. These were the starting points for the current study.
This Project

Before XR can be used to achieve any learning goals—before any technology can be used to achieve anything—it has to be adopted for use. But no technology adoption is perfectly smooth; there are always challenges and organizational factors that influence the process. The research question for this project was:

- What factors influence institutional deployment of XR technology?

This study fills out the picture of XR use in higher education. Much of the published research on XR for education consists of studies of single courses or projects in which XR technology was deployed, or meta-analyses that look across these studies. The XR for Teaching and Learning report looked at the use of XR tools and technologies by instructors and students within the context of courses and curricula. But most of this prior work focused on the uses of XR for instruction. That is the primary use case for many technologies in higher education, and XR is no exception. But that is not the whole picture. For XR to be used for teaching and learning, it must first exist on campus and, second, have some measure of institutional support. This report focuses on this aspect of XR adoption on campus: How are XR tools and technologies provided to users on campus, what institutional resources are devoted to it, and how is XR technology being systematically integrated into the operations of institutions of higher education. At the same time, part of the purpose of this report is to inform institutions of higher education that have not yet deployed XR technology how they might go about doing so productively. This report, therefore, relies heavily on examples of XR deployment at institutions that participated in this study. Your mileage may vary, as they say, but hopefully all readers will be able to find something in these examples that may apply within their institutional context.

As with any rapidly changing technology and marketplace, XR terminology is highly fluid. See appendix A for a discussion of this terminology.
**Diffusion of Innovations on Campus**

Everett Rogers’s book *Diffusion of Innovations*\(^\text{12}\) is one of the best-known works of sociology of all time. The reader is probably familiar with the S-curve model of diffusion, which maps out the saturation of an innovative object or practice in society or in a group over time, as well as the five categories of adopters (innovators, early adopters, early majority, late majority, and laggards). Diffusion theory also identifies the characteristics that make each adopter category more or less likely to adopt an innovation and strategies to help persuade potential adopters to adopt an innovation. This study relied heavily on *Diffusion of Innovations* for the frameworks used here to discuss adoption of XR by institutions of higher education.\(^\text{13}\)

**Adoption of XR**

Adoption of an innovation is a multistage process: adopters must first learn about the existence of an innovation, then collect information about it, then make the decision to adopt it (or not). These stages are, of course, in the past for the institutions participating in this study: they all obviously decided to adopt XR technology.

After the decision to adopt an innovation comes the implementation—and this is where things often get complicated, particularly in higher education, where institutions contain multitudes: campus units have different scopes, budgets, risk tolerances, and stakeholders. Furthermore, faculty act in some ways like independent operators (though more at some institutions than at others) and may implement an innovation prior to their unit’s doing so; or they may even reject an innovation that their unit has adopted.

Diffusion theory identifies two broad categories of adoption decisions: collective decisions, whereby the community of interest comes to consensus through some means, and authority decisions, whereby the adoption decision is imposed from the top down. Institutions of higher education, of course, possess mechanisms for collective decision-making, such as faculty senates and other such institutional committees. This is not, however, generally how XR technologies were adopted at the institutions participating in this study.

The research question for this project was: What factors influence institutional deployment of XR technology? In other words, what leads to the decision to adopt XR technology on campus? And after the adoption decision, what influences institutional decisions about how XR technology is to be deployed on campus? For institutions participating in this study at least, two overarching factors influenced the adoption of XR.
First, the method by which XR technology comes to campus affects the process of implementation. Technologies frequently come into institutions of higher education under the radar, as it were, through individual innovators and early adopters, outside of any institutional support. While this report is concerned with institutional deployment rather than individual adoption, this is how XR first came to several participating institutions prior to the start of this study: individual faculty members using various XR technologies for their own teaching or research. This method may lead to institutional adoption: Yale University, Syracuse University, Columbia University, and the University of Pennsylvania are notable examples, but it is a slow ramp-up because a critical mass of individual users must generally be reached before the institution even takes notice of the technology in question (as is currently happening at Syracuse University). Implementation nearly always goes faster when the adoption decision is made by institutional leadership (e.g., the board of trustees or the CIO, as at Wake Technical Community College and the Foothill-De Anza Community College District). This is especially true when institutional leadership accompanies the adoption decision with resources, e.g., small project grants, additional staff, and the like.

At other participating institutions, adoption was motivated from above. At these institutions, XR technology was imposed by institutional leadership, such as the institution's board of trustees. Having been instructed to deploy XR technology, institutions then had to figure out how to make it so. Mostly, that implementation fell to the institution's CIO or the equivalent position (vice chancellor for technology, etc.). At the North Carolina School of Science and Math, for example, the XR technology was provided to a specific department (biology) for which instructors had a clear and preexisting use case (to teach genetics and molecular biology). At Wake Tech, the CIO identified a handful of interested faculty and use cases through workshops and brainstorming sessions. In the Foothill-De Anza Community College District, the CIO took both of these approaches.

The other overarching factor that affects the process of implementation is the existence of institutional infrastructure to support technology. This institutional infrastructure is both technological and organizational; for XR technology to be implemented, there must be a place for it on campus. At Florida International University (FIU), for example, XR technology has been implemented on a large scale in the College of Communication, Architecture + The Arts’ Miami Beach Urban Studios (MBUS), a facility that supports 3D printing and scanning, along with other XR technologies. Likewise, at North Carolina State University (NCSU), XR technology is integrated into the library’s well-established technology lending program. Bucks Innovate, at Bucks County Community College, added XR to an existing set of training programs on offer.
These examples demonstrate that some campus unit must take responsibility for XR technology deployment. Hamilton College provides our final example: the XR initiative at Hamilton is managed by Library and Information Technology Services, a single administrative unit that combines the technology expertise of campus IT with the user focus of the library.

**Institutional Deployment of XR**

There is a middle ground between individual adoption and having it dictated from on high. Some of the institutions participating in this study began their deployment of XR technology with projects rather than individual courses. At MIT, for example, the Collaborative Learning Environments in Virtual Reality (CLEVR) project is a research effort within the Scheller Teacher Education Program aiming to develop VR simulations for classroom use. For another example, the Morgan State University, School of Community Health and Policy, Nursing Program is seeking research grant funding for a curriculum development project that uses XR technology. Importantly, at both of these institutions, XR technology is being deployed as the centerpiece of an applied research project. In both cases, XR is framed as something that can potentially benefit teaching and learning, and the projects that have deployed it are exploring how to use the technology most effectively as an educational methodology. Further, both of these institutions are deploying these projects at the level of specific academic units; in neither case has this deployment been taken up by other academic units or by a campus-level unit such as central IT or a center for teaching and learning. Perhaps in time the MIT Scheller Teacher Education Program and the MSU Nursing Program will integrate XR technology into their curricula at large, but at present this technology is still framed as applied research.

Another institution at which XR is being deployed at an intermediate scale—that is, within a campus unit—is Bucks County Community College. Bucks Innovate offers corporate training programs on a variety of topics. One of the newer offerings from Bucks Innovate is an XR technology showcase and hands-on demo event for CEOs and other corporate leaders, addressing the question of how organizations can benefit from XR. Because the unit is relatively new at Bucks, it is not yet clear how the deployment of XR by Bucks Innovate will impact the rest of the institution. But, as at MIT and Morgan State, XR is being deployed at Bucks to explore the potential benefits of the technology for teaching and learning.

All of the institutions of higher education that participated in this study have obviously deployed XR technology in some way or would not have been a part of this study. The campus unit with primary responsibility for this deployment varies across participating institutions. The important point here, however,
is that at most participating institutions, a single campus unit had primary responsibility for implementing some set of XR technologies for some set of users. This campus unit may be a degree-granting unit such as the Newhouse School of Public Communications at Syracuse University or the Nursing Program at Morgan State University. What was more common among the participants in this study, however, was that the campus unit was not a degree-granting unit: a library, as in the Foothill-De Anza Community College District; a makerspace, such as the Miami Beach Urban Studios at Florida International University; a research center, such as The Education Arcade within the MIT Scheller Teacher Education Program; or an interdisciplinary initiative, such as the Emerging Technologies Consortium at Columbia University. Furthermore, the set of XR technologies were implemented for some set of users, for some set of use cases. Mostly, these use cases were for teaching, as in the Morgan State University Nursing Program, though some were a combination of both teaching and research, as in the MIT CLEVR project. The important thing in the context of this study is that a decision to deploy some set of XR technologies had already been made by one or more campus leaders with some degree of budgetary control within a unit at the institution, and that the deployment and management of these technologies had been undertaken by a campus unit.
Models of XR Deployment on Campus

Whether XR technology first came to campus under the radar or thanks to campus leadership, and whether that adoption was for an individual early adopter or a project, at some point the decision was made at most of the institutions in this study to promote the diffusion of XR technology more broadly. It is important to note, however, that no participating institution has yet tried to promote the diffusion of XR across the entire campus. Even at FIU and Hamilton College, institutions where XR technology is available to the entire campus community, the technology is not being pushed out. Users may come to the MBUS at FIU or the Hamilton libraries and use XR technology, but it is at the users’ initiative rather than a case of MBUS or library staff actively promoting the technology. To make more students aware of the technology, however, MBUS staff members request class time from interested faculty members so that they can present demonstrations. At Wake Tech Community College and the Foothill-De Anza Community College District, where the CIOs actively sought out faculty interested in using XR, these CIOs are not trying to recruit all faculty to use XR. In the early stages of introducing any new technology to campus, it is always a few early adopters who provide proofs of concept for using the technology on campus.

However XR technology first came to campus, and at whatever scale, it takes time for XR technology to be meaningfully deployed. This is due to several factors: overcoming the inevitable technical difficulties of setting up any new technology, the equally inevitable learning curve for new technology, and identifying how to integrate a new technology into teaching in a pedagogically meaningful way. Institutions at which XR technology is new, or that have not yet implemented XR technology but wish to do so, will not have had time to clear all of these hurdles. Therefore, an important question is: What information and resources do institutions that are new to XR technology need to scale up or facilitate the deployment of XR on campus?

The very short answer is case studies. It is time-consuming and expensive to do anything from scratch. Fortunately, no institution of higher education needs to figure out how to deploy XR technology from scratch because other institutions have already been down that road. This section provides some illustrative case studies—examples of deployment of XR technology—from institutions that have already begun that journey and draws out lessons learned and guidance for institutions that are at earlier stages of deployment.
The Special Initiative

Yale University and HP partnered to explore applications of XR technology on campus even before the launch of the Campus of the Future project. Yale is therefore a useful example of one model of campus XR deployment because its deployment preceded that of all other institutions participating in this study—and of most other institutions of higher education in the United States.

Yale deployed XR technology using a time-honored methodology in higher education for deploying new technologies on campuses: the “special initiative.” Initiatives have been used with great success to introduce all manner of technologies to institutions of higher education, from electronic transcripts to iPods and iPads to the LMS to digital credentials. Readers who have ever been employed by an institution of higher education have at some point probably participated in or at least borne witness to a campus technology initiative. Special initiatives are essentially pilot programs; they have the advantage of promoting adoption of a technology but in a controlled fashion, limiting its diffusion as the responsible campus unit gains experience with the requirements of its deployment and support.

The Blended Reality Applied Research Project at Yale focused on projects and their uses of XR technology. Early in the 2016–17 academic year, a faculty steering committee solicited proposals from across campus “to test hypotheses and investigate the possibilities and limits of hardware and software.” While the researchers on these projects spanned campus units, the Blended Reality Applied Research Project itself was staffed by employees in Yale University Information Technology Services and in the Center for Collaborative Arts and Media, a campus studio for exploration of the intersection of the humanities and computer science, under the Yale School of Art. The Yale Blended Reality Project is now in its fourth year, with three annual reports.

The Campus of the Future XR Research Project at Hamilton College in some ways resembles the Yale Blended Reality Applied Research Project. The Digital Pedagogy Fellowships at Hamilton are two-year small grants to faculty to develop projects integrating XR into courses. Depending on the nature of the project, faculty fellows may work with instructional designers, librarians, or others from the Hamilton Library & IT Services (LITS) unit. While oversight of the Yale Blended Reality Project spanned multiple campus units, oversight of the XR Research Project at Hamilton was entirely by the LITS unit. Hamilton is much smaller than Yale (Yale has approximately 13,000 students and 5,000 full-time faculty; Hamilton has approximately 2,000 and 200, respectively), so naturally the organizational structure of these institutions differs. As a smaller institution, however, Hamilton had less need to filter projects and has therefore taken a more open approach, supporting under the LITS umbrella a very wide range of projects that use XR technology. Additionally, the service model of the LITS unit...
at Hamilton College is relatively “high touch,” possibly an advantage of being a smaller institution. To offer similarly high-touch service around XR at Yale required a wide collaboration to draw in expertise from multiple units.

Familiarity with XR tools and technologies was not required for a project to be approved for the Yale or the Hamilton initiatives or to be supported by the PennImmersive initiative at the University of Pennsylvania; vision and imagination, however, were required. And this is a critical feature of these initiatives—the decision to prioritize exploration over expertise. Indeed, both Yale and Penn use similar language; Yale refers to their initiative as “an applied research program to explore the area of blended reality,” and Penn describes it as a “public research project to explore the potential” of XR technologies. This framing of the special initiative as research and exploration is important for gaining acceptance for a new technology on campus. Research is close to the hearts of many faculty members in higher education (and of many administrators as well, some of whom used to be faculty), and institutional research is a critical part of decision-making at most institutions of higher education. Research is therefore a useful frame for pitching any innovation to the campus community. Despite being hotbeds of innovation, however, institutions of higher education are often slow to change, as are many large organizations. Framing XR technology as exploratory, therefore, provides time for it to build and gain acceptance and use cases on campus, as well as time for the responsible campus unit to gain experience with supporting the technology.

Part of gaining experience with supporting XR technology is identifying the specific requirements of specific projects. Another part of gaining this experience is identifying the kinds of use cases that might emerge from the campus community. The PennImmersive research project prioritized this approach. As Yale and Hamilton did with their initiatives, PennImmersive provided support for XR projects on campus. Unlike those initiatives, however, PennImmersive’s major focus was a series of open house events on campus (figure 1) to provide an opportunity for members of the campus community, especially those who may not have used it before, to use various XR technologies. These events were well attended—indeed better attended than even the Penn Libraries staff anticipated—and led to an outpouring of questions about what XR technology workshops would be offered in the future, along with requests for specific examples of XR use for teaching and learning. The PennImmersive open house events were highly planned, reminiscent of the exhibitor floor at a conference, with schedules of presentations and demos. Not all institutions hosted such formal events as part of their special initiatives. But technology showcases, whether formal or informal, conference-like or pop-up events on the quad, enable members of the campus community to use a new technology and to start imagining future uses for that technology.
Service Integration

The previous section pointed out that libraries figure largely in campus technology initiatives. The initiatives at Hamilton College and the University of Pennsylvania were overseen by groups within those institutions’ libraries, and even though the project at Yale University was overseen by Information Technology Services, some of the space dedicated to the project was within the main campus library. Libraries often oversee campus technology initiatives for at least two reasons: first, libraries historically have been early adopters of technology on campus; second, since the mid-1980s many academic libraries and campus IT units have merged, a phenomenon that the community has been following since long before EDUCAUSE even came into existence with the merger of Educom and CAUSE. Some of the institutions that participated in this study have combined their libraries and IT units, so it was natural at those institutions for a campus technology initiative to be based in the library.

Academic libraries are not just the site of technology initiatives, however. Libraries also are often the provider of technology services offered to the campus community. North Carolina State University has an extensive technology lending program whereby any member of the campus community can check out a wide range of technologies from the library: digital cameras and 360° video
equipment, microphones, handheld microscopes, laptops and tablets, video game controllers, even Raspberry Pi and Arduino kits. The NCSU Libraries also lend a range of XR technologies, including several models of VR headsets and handheld controllers, Magic Leap headsets, and eye-tracking hardware. In addition, the NCSU Library offers workshops, including “Getting Started with AR” and an orientation session for its VR studio. Specialty technology consultation, whereby a tech advisor provides one-on-one help to students and faculty, is also available.

Libraries are not the only campus units that provide innovative technology services. MBUS, located within the College of Communication, Architecture + The Arts at Florida International University, refers to itself as a “collider” for people and ideas in arts, design, technology, and the sciences.” It is a 16,000-square-foot makerspace-like facility containing a wide range of equipment, from computers and software to 3D printers and scanners to laser cutters. MBUS and all of the equipment within is accessible to all members of the FIU campus community, as well as to residents of surrounding Miami-Dade County. MBUS staff provide support for all equipment and offer scheduled workshops on a variety of topics, both in MBUS and at sites within the university and across the county. In short, MBUS provides technology that is introduced widely but is to be used locally—that is, within the (admittedly large) MBUS space itself, where the interdisciplinary experience is prioritized.

On the other hand, Bucks Innovate, a unit of Bucks County Community College, does not use technology locally but instead takes it on the road. Bucks Innovate offers corporate training programs on a variety of topics and recently ran an event titled Bridging the Generation Gap in the Workplace, which included a technology showcase that enabled participants to test XR technologies. This event was geared toward “C-suite” organizational leaders to enable those who might not have previously used XR technology to experience it and to explore how it might be used in their organizational context—for example, recruiting and retaining new employees (particularly young employees) as well as determining what training will be necessary within their organization. Importantly, Bucks Innovate was already an established unit at Bucks County Community College prior to this event, with the capacity to offer training programs using various technologies. While Bridging the Generation Gap was a one-time event, its success means that similar events are likely to be offered. It is therefore likely that XR will become integrated into the suite of services offered by Bucks Innovate.

Bucks has integrated XR into its services in other ways as well, perhaps the most public being an interactive campus tour using 360° video. Syracuse University has done the same, as have many other institutions.23 Like the Bucks Innovate technology showcase, these virtual campus tours are designed for recruitment, which is the purpose of any campus tour. Institutions providing virtual campus tours, like the other use cases discussed in this section, have integrated XR into existing services provided by well-established campus units.
Grassroots

The special initiative model requires that one or more campus units take ownership of XR deployment on campus. The service integration model requires that one or more campus units provide services around XR technologies. But what if no campus unit is ready to take this on?

The cases of Syracuse University and Columbia University provide excellent examples of this situation. At both universities, some faculty members were using XR in their teaching and research projects even before those institutions joined the Campus of the Future project. At Syracuse, XR use spanned a diverse range of academic units: the S.I. Newhouse School of Public Communications, the School of Architecture, and the College of Visual and Performing Arts. At Columbia, XR use on campus was concentrated mostly in the lab of one computer science professor with a long career of research and development in augmented reality.

At Syracuse, a few faculty members with an interest in XR started meeting informally in the 2017–18 academic year, calling themselves the “VR and Beers” group. Their purpose was (and remains) to discuss ideas for using XR technology in the classroom and as a research front, and to support each other in their efforts. The VR and Beers group has grown over time, from a handful of individuals to 25 or 30 people as of this writing. The group has also increased the scope of its efforts. Several members have submitted grant applications for XR-related projects, and the group has held a few events to showcase XR technology on campus, including pop-up events on the campus quad and at community events off campus. A recent XR showcase event was held specifically for campus leadership, including deans and members of the Office of the CIO.

Up to that point, most of the uses of XR on campus had been under the radar, individual projects by individual early adopters, outside of any institutional support. The XR showcase for campus leadership provided a dramatic demonstration of what is possible with XR at Syracuse. These proofs of concept enabled the VR and Beers group to articulate to campus leadership their vision for continuing work with XR on campus and to ask for resources to continue this work.

More or less at the same time that the VR and Beers group was formed at Syracuse, the Emerging Technologies Consortium was formed at Columbia. The ETC focus differs from the efforts at Syracuse in two important ways: first, it has a broader scope, encompassing all emerging technologies, including XR as well as artificial intelligence, machine learning, and robotics; second, the ETC was a more formalized project from the start (no beer apparently having been involved) and enjoyed support from the Office of the CIO from its inception, in the form of funding and a director. Even so, the VR and Beers group and the ETC have
followed similar life-cycle arcs, starting with only a few interested faculty members and expanding their communities of interest several-fold over a mere two to three academic years. Also like VR and Beers, the ETC has hosted several events on campus to showcase XR technology to the campus community, but by having some institutional funding, some of these events were able to include speakers from notable technology companies for keynotes and panel discussions.

As of this writing, the VR and Beers group has been made “official”: the Office of the CIO has given the okay to building a centralized support mechanism under the campus IT unit for XR technology, with the promise of further resources in the future. In other words, there is now a nascent special initiative around XR at Syracuse. Instead of this initiative originating in a campus unit, like the examples in the previous section, it built up from an interdisciplinary grassroots effort until it achieved critical mass and then was able to garner campus resources.

“When the train is already in motion, it’s harder to say stop.”

—Jason Webb, Instructional Analyst, Syracuse University
Building an XR Lab

The Miami Beach Urban Studios (MBUS) at Florida International University is available to all members of the FIU campus community and has more printers available than any other FIU location, making it popular with students. But it is in Miami Beach, approximately 16 miles from the main FIU campus located in the western part of Miami-Dade County. Although intended to broaden the FIU student experience—in the words of John Stuart, associate dean for cultural and community engagement and executive director of MBUS, “akin to offering a techno-cultural-scientific study abroad within the vast city”—this is still a significant distance for busy students, particularly in a city with the kind of traffic that Miami is known for. To scale up XR teaching capacity beyond MBUS, FIU is establishing a VR lab on the main campus, focused on introducing the technology to students in the university’s First-Year Experience courses.

Many logistical issues present themselves in developing such a facility: identifying an appropriate space, identifying hardware and software configurations for such a space, staffing the space with support staff knowledgeable in the technology, outreach to the campus community, etc. This section will briefly address each of these issues but with the caveat that this is a moving target: XR hardware and software are undergoing rapid development, and XR labs are still relatively new, so nothing like best practices has yet emerged.

Physical Space and Hardware

XR technology actually requires not one space but two. The first type of space is a more or less traditional computer lab. People working on XR development with their computers can be located anywhere—in a lab, in the developer’s office, in the campus coffee shop, on the sofa at home. But this section will stick to a discussion of lab spaces.

The difference between a “traditional” computer lab and one with support for XR is based not on the space but on the computers. Any computer used for XR development must be high-end: a powerful CPU and graphics card, a great deal of RAM, and a high-resolution screen are the bare minimum requirements. Computers designed for gaming often come configured with such a feature set. Such high-end computers tend to be fairly expensive, so the initial setup and ongoing maintenance costs for XR hardware are likely to be greater than for “ordinary” campus computer lab equipment. Between the moments when these words were written and when you read them, the specifications for XR-capable computers are likely to change, so we apologize for not providing recommendations that are more specific.
The second type of space that XR technology requires is a studio. This is not a traditional studio space like those many institutions have created for video production, containing large and expensive pieces of equipment: video camera, teleprompter, lighting rigs, etc. Rather, an XR studio needs to be little more than an empty space, and not very large; a small classroom or even an average-sized office would make a reasonably sized XR studio. Figure 2 shows an XR studio space at Hamilton College that is simply an otherwise empty corner of a larger office suite. Figure 3 shows XR studio space at NCSU consisting of an office cubicle inside a library. It may be desirable for an XR studio to be an interior room to allow lighting levels to be controlled; curtains hung on the walls can reduce echoing, as in a traditional studio. As these figures show, however, that is clearly not a requirement.  

Figure 2. Students using the Research & Design Studio’s VR Zone at Hamilton College  
*Image courtesy of Benjamin Salzman*
An XR studio must be a space in which a user can don a VR headset and move around freely while in a simulation, without fear of bumping into other people or expensive hardware or tripping over cords on the floor. Many current VR and AR headsets are tethered to a computer, so a long cable is necessary to give the user maximum freedom of movement; such freedom is critical in an XR studio because a user wearing a headset is blind to the physical world. We have heard stories about users wearing VR headsets getting tangled up in cords and pulling computers off tables to their doom or accidentally punching a monitor. However, solutions to such problems can be surprisingly low-tech: retractable dog leashes have been used to good effect to get cables out of the way. Alternatively, an extra-long cable can be attached to the ceiling in the center of the space, so that when a user dons a headset the cable is overhead instead of sideways.

Given the minimalism of the XR studio space, the cost to the institution for setting it up is fairly low, though finding space can itself be one of the most intractable problems in institutions of higher education, where space is often at a premium.
An XR studio space also requires a computer, though this may be tucked in a corner. The computer need not be stationary; it can be a laptop on a cart. A powerful laptop, such as one configured for gaming—or better still, a backpack computer (figure 4)—might be ideal for an XR studio. Such a rig, mobile by definition, may actually be more desirable for some use cases than a dedicated XR studio on campus. A mobile XR rig allows the technology to be deployed anywhere, not just in the studio but also in a classroom, on the quad, off campus, etc. A mobile XR rig may also be packaged as a kit and standardized, which makes it easier to deploy in classrooms, especially for multiple simultaneous users.27

Figure 4. The HP VR backpack
Image courtesy of HP Inc.

Equity

One last point before leaving the subject of building an XR lab. For an institution of higher education to provide access to XR hardware and software—whether in a lab space or through other means—is a matter of social equity.

EDUCAUSE research has found that only about 4% of students have access to VR or AR headsets, but of those, approximately 72% personally own them.28 These numbers are likely to increase as XR becomes more widely used in education.
and in society at large. That said, however, 95% of students own a smartphone, and 91% own a laptop. These are very large percentages, nearly saturation.\textsuperscript{29} But these are the workhorse technologies for student success; let us consider those students who do \textit{not} own these critical technologies. According to one recent study, 48% of community college students and 41% of students at four-year institutions were food insecure.\textsuperscript{30} Another study found that 12% and 9%, respectively, were homeless.\textsuperscript{31} Food insecurity and homelessness obviously aren’t the only reasons for not personally owning a smartphone, a laptop, or a VR headset. But institutions of higher education have done a good job of providing access to many technologies on campus through computer labs, and building an XR lab continues this work of pursuing equity. If student success is a priority for an institution of higher education,\textsuperscript{32} then it needs to actively work to remove structural barriers to students’ access to technologies and other campus resources.

Institutions of higher education must provide access to XR and other technology not only for those students who do not own it but also for those who are remote from campus. This is particularly an issue for community colleges and other institutions with a high percentage of commuter students. Many institutions of higher education provide enterprise-licensed software, such as statistical analysis packages and video production tools, to the campus community. As discussed later in this report, however, many vendors do not offer an enterprise license for XR software, so this may not be possible currently, though it is something that institutions of higher education should demand from technology vendors of all stripes.

Many institutions also provide cloud-based applications, such as email and the learning management system (LMS), to the campus community. Cloud-based XR is still in its infancy, though there is some speculation that 5G networks might enable it.\textsuperscript{33} Once cloud-based XR becomes feasible, it might be the mechanism by which institutions of higher education will be able to provide access to XR for students who are remote from campus. Combining cloud-based XR with the use of inexpensive consumer XR hardware, such as Google Cardboard and a smartphone (which most students already own), or with a technology lending program such as that offered by the NCSU Libraries, would enable an institution to develop simulations of traditional lab spaces, such as chemistry or biology labs, for students remote from campus.

“Is there a student equity impact? This technology can’t be available only in specific spaces and at specific times. It has to be liberated from being time and place bound as much as possible.”

—Joseph Moreau, vice chancellor of technology and CTO, Foothill-De Anza Community College District
Factors that Influence Institutional Deployment of XR

One of the most significant challenges in deploying XR at an institution of higher education, according to David Woodbury, department head of Learning Spaces & Services for the NCSU Libraries, is deploying “consumer technology in an enterprise environment.” At present, most of the XR technology being used in higher education is designed for the consumer market, with the implicit assumption of a single purchaser and a single end user—an assumption that clearly does not match the situation at institutions of higher education. And because of this assumption, many vendors do not offer an enterprise license or an educational license. So when an institution gets to the point of installing and wanting to license XR development software on multiple computers, there may be no good way to do this short of multiple transactions. This is inefficient and expensive and, as anyone who has ever dealt with software licensing knows, tends to result in a proliferation of installs of the free or trial version rather than a licensed version. This situation is bad for both the vendor and the user. At many institutions of higher education, the IT unit maintains a repository of software, under enterprise licenses, that can be installed by members of the campus community. Vendors in the XR space seeking to gain a foothold in the education marketplace would do well to offer enterprise licenses for educational institutions.

The consumer marketplace assumption of a single end user also has implications for managing XR technology. Some issues here are quite simple: in a lab or hardware lending situation, headsets and handheld controllers should be cleaned after each use, just as one wipes down equipment in the gym after a workout. Ensuring the cleanliness of XR hardware, not to mention the cost of antibacterial wipes, must fall to some unit on campus. Other issues here are more complex. The scheduling system in a lab must enable users to book time with XR hardware. If XR technology is being lent out through the library or other campus unit, the circulation system must contain rules for access permissions, loan times, etc. The NCSU Libraries lends XR hardware as part of its technology lending program. The Libraries will also mail books to users remote from campus on request, through campus mail and even to homes. As of this writing, NCSU Libraries staff are discussing mailing XR and other technology to users, which raises several issues: how to package it, what to do if it is damaged in transit or goes missing, what pieces of technologies can be packaged together to make kits for specific use cases.

The prospect of mailing kits of relatively expensive hardware to users off campus is enough to give many IT staff heart palpitations. To even consider such a thing requires a fairly high risk tolerance by the campus unit responsible for the technology, as well as a deep commitment to providing user-focused services. Which brings us to perhaps the most critical factor that influences institutional

“One of the biggest challenges is managing consumer technology in an enterprise environment.”

—David Woodbury, department head of Learning Spaces & Services, NC State University Libraries
deployment of XR: staffing. For most of the staff who work with XR on campus at institutions participating in this study, XR is just one part of their job. The Blended Reality Applied Research Project at Yale is headed by a combination of faculty members and staff in the campus IT unit. The XR initiative at Hamilton College is led by the Research and Instructional Design (R&ID) team in the Library & Information Technology Services unit. XR technology is supported at NCSU by library staff. XR technology at FIU is supported by the professional and student staff of the Miami Beach Urban Studios facility. The one exception to this absence of staff dedicated solely to XR on campus is the full-time director of the Emerging Technologies Consortium at Columbia University—and even there, the scope of the ETC is all emerging technologies, not just XR. At all of these institutions, XR is only one service offering supported by these campus units. All of the staff supporting XR at these institutions, therefore, need to be both extremely knowledgeable and extremely flexible. IT staff must be able to help users with teaching and learning aspects of the technology, for example, and instructional designers must be able to help with technical problems. This flexibility requires cross-disciplinary teams: examples include initiatives that span academic units, such as those at Yale and Columbia, and academic units that were created to be cross-disciplinary, such as the LITS unit at Hamilton or MBUS at FIU. The service model for the campus unit supporting XR needs to be equally innovative, as with the technology lending program at NCSU, and the creation of a dedicated staff position at Columbia.

This innovativeness and commitment to service do not just happen; these are values that can be fostered by institutional leadership. Organizational culture exerts a significant influence on the deployment of XR on campus, though organizational culture cannot be laid entirely at the feet of institutional leadership. Prior EDUCAUSE research has shown that leadership, and in particular the CIO and the enterprise architect (at those institutions that have one), has considerable influence over strategic direction and the enterprise-wide vision of technology and services. Institutional leaders might be risk-averse, or they might encourage risk-taking. They might keep XR technology under lock and key, available to students only for course-related projects and with their instructor’s permission, or they might encourage its use by providing access through services available to the entire campus community, such as a lab or a makerspace, or a technology lending service. Institutional leaders might slam on the brakes by re-allocating resources away from an existing campus XR initiative, or they might support XR efforts on campus by providing resources. As with so many things in institutions of higher education (and in organizations generally), an institution’s vision of itself as innovative translates directly into the level of support provided to students and faculty for innovative efforts. And ultimately, this vision is largely a reflection of institutional leadership.
Conclusion

XR technology is still making inroads into higher education. The integration of a technology into higher education often lags behind the broader adoption of that technology in society at large. In part this is because requirements for a technology to be useful as an educational technology are different from and more specific than the requirements of the general consumer market. But the consumer market, of course, includes students and faculty and the campus community generally. Only a small percentage of students have access to a VR headset, but of those who do, a majority own it. Furthermore, sales of XR headsets have been increasing for several years. There are also very inexpensive options for headsets that require a smartphone, which nearly all students and faculty own. Use of XR on campus may be relatively rare now, but institutions of higher education must prepare for the not-too-distant future, when it will be ubiquitous.

The research question for this project was: What factors influence institutional deployment of XR technology? This study found that the adoption of XR on campus is strongly influenced by the way XR comes to campus, specifically whether it is adopted first by faculty for their own uses or promoted by institutional leadership. Faculty uses of XR take time to emerge as a community of interest builds on campus. Where there is institutional support, however, XR can be deployed as part of a special initiative or integrated into existing service offerings. Either way, XR deployment requires able staffing and commitment by institutional leadership.

Higher education has a long history of deploying new technologies. This digital transformation is having a profound impact across all kinds of institutions of higher education. XR holds the potential to be a game changer, but it must be closely linked to an institution’s services, practices, and values.
**Recommendations**

Every institution of higher education is unique in its organizational structure and the resources it dedicates to supporting IT, instructional design, and emerging technologies. XR is in some ways like other emerging technologies on campus: sometimes it arrives under the radar through adoption by individual faculty members; sometimes it is driven by institutional leadership, and its diffusion on campus is influenced by the institutional resources provided to support it and the campus units tasked with doing so. On the other hand, XR places some unique demands on institutions of higher education—e.g., supporting the technology requires innovativeness and diverse skills that may require cross-institutional collaborations. This report relies heavily on examples of XR deployment in institutions of higher education to provide models for institutions that have not yet deployed XR technology, and it reveals how they might start to do so most productively. Starting from these examples, this report also takes a higher-altitude view to help institutions of higher education see how these models might fit their local context. Some of the examples and lessons learned discussed in this report will therefore not be applicable to all institutions. Nevertheless, all recommendations are presented here for institutions of higher education that are interested in deploying XR technologies, with the understanding that your mileage may vary.

**For Institutions**

- **Identify or create a group that will take ownership of XR and will support it at the institution.** This can be an existing campus unit, such as Library & IT Services at Hamilton College or the Miami Beach Urban Studios at Florida International University, or it might be a newly forged collaboration across campus units, such as the Emerging Technologies Consortium at Columbia. This group will physically maintain the hardware and update and license the software. Beyond that, the services provided by this group may vary by institution, but they might offer tutorials and workshops, showcases, visits to classes, and events for the community.

- **Create a special initiative to explore the uses of XR on campus.** The special initiative is a time-honored mechanism for introducing new technologies into institutions of higher education, and this framing as exploratory is important for gaining acceptance of a new technology on campus, especially with faculty. A special initiative provides time for ideas and use cases for XR to disseminate to the campus community and for new potential users to emerge. Critically, a special initiative also provides time
for the campus unit supporting XR to gain experience with the technology. As with any special initiative, systematic data collection is critical to enable evaluation of its impact.

- **Promote informal social networks around XR technology.** Such a group creates buy-in with the technology, as members support each other’s uses and brainstorm new ones; thus membership grows over time. The case of Syracuse University illustrates that such an informal group might in time “graduate” to the status of a campus initiative. The VR and Beers group grew over several academic years, gaining members, developing projects, and seeking grant funding; now it has gained support from the Office of the CIO.

- **It is a matter of social equity to provide access to hardware and software as institutional resources.** This applies to XR as well as to any other technology. Providing access to technology through the institution benefits students who do not own it and, just as important, benefits students who are remote from campus. This is particularly an issue for community colleges and other institutions with a high percentage of commuter students. The way technologies are provided depends on the technology itself and on the user community. A lab might be more appropriate for some use cases, while enterprise-licensed software in the cloud or for download might be more appropriate for others.

**For Institutional Leaders and Managers**

- **Institutional leadership is critical to the success of XR deployment.** The support provided by institutional leadership has a profound effect on XR adoption on campus. *Support* here means budget—providing hardware, software, and staff—and permission, so that potential users have the space to innovate with the technology and service models.

- **The level of risk tolerance by institutional leadership is critical to the success of XR deployment.** Providing the resources to support XR technology, and the flexibility to design an appropriate service model for the campus community, will promote its use across campus.

- **A commitment to user service is critical to the success of XR deployment.** Effective use of XR technology requires both technical skills and an understanding of instructional design. Developing capacity across institutional silos will promote the use of XR across campus.

- **Shop the technology around to potential early adopters.** Some faculty are willing—even eager—early adopters; others not so much. Like many new technologies on campus, XR will be used increasingly as successful use cases are developed and word about them spreads.
- **Showcase successful use cases.** Harness the enthusiasm of early adopters by providing them a venue for demonstrating their uses of XR technology. Some people need to see a technology in use before they can imagine how they might employ it for their own use cases.

- **Showcase evidence of impact.** There is a growing body of research on the effectiveness of XR for teaching and learning a variety of subjects and skills. The previous reports from this project, the 2018 *Learning in Three Dimensions* report and the 2019 *XR for Teaching and Learning* report, contain many citations to such studies. Some instructors may need to see data on the efficacy of this technology for learning, along with evidence of its impact, before they would be willing to use it in their own teaching.

- **Provide space for using XR.** Some people need to try a technology themselves before they can imagine how they might use it for their own purposes. Providing access to XR in a computer lab, a makerspace, or another campus unit enables members of the campus community to experiment with the technology.

### For XR Technology Vendors

- **Offer enterprise licenses for educational institutions.** Most of the XR technology being used in higher education is designed for the consumer market, with the implicit assumption of a single purchaser and a single end user. But this is not the situation at institutions of higher education, where the purchaser is the institution and both hardware and software are employed by multiple users.
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Appendix A: A Note on Terminology

As with any rapidly changing technology and marketplace, the terminology around XR technologies is highly fluid. However, four terms crop up often and, to a certain extent, overlap: virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR). Many discussions of these technologies reference the concept, first proposed in the mid-1990s, of a “virtuality continuum” (see figure A1), from entirely real to entirely virtual. On one end of this continuum is the physical world, and on the other end is VR—an entirely simulated environment. In between those two poles is MR, which encompasses AR and augmented virtuality (AV). AR is the physical world augmented with virtual objects, while AV is a simulated environment augmented with physical objects. Even the authors of early papers about the virtuality continuum admit that as graphics rendering technology improves, it will become increasingly difficult to determine whether augmentations—and even the environment being augmented—are physical or virtual. We are not yet at that point in technology development, but we are perhaps not far off. Think about how realistic computer-generated imagery (CGI) in movies can be. Nevertheless, in the virtuality continuum, both AR and AV are points on the spectrum of MR.

Figure A1. Significant points on the virtuality continuum
Since those early publications on the virtuality continuum, these terms have shifted. The term AV is no longer widely used. The term AR is used to mean the physical world augmented with virtual objects, but those virtual objects are static, mere overlays atop the physical world. Many AR applications have been developed for museums and for specific museum exhibits. The Franklin Institute in Philadelphia, for example, deployed an excellent AR app for the touring Terracotta Warriors exhibit. The term MR (and the emerging term “hybrid reality”) is also used to mean the physical world augmented with virtual objects, but those virtual objects are interactive: the user can affect the state and behavior of these virtual objects, which in turn may also affect the state and behavior of physical objects. A research project at Harvard University, for example, is developing MR overlays for learning electronics whereby the user can see and change the flow of electricity and the magnetic fields around a simple audio speaker.36

The use of these terms in association with commercial products is where things often get confusing. The HTC VIVE, for example, is marketed as a VR headset, but some newer models contain forward-facing cameras (also called “pass-through” cameras) that allow the user to view the physical world in the headset. Some newer models of headsets compatible with Microsoft Windows also contain pass-through cameras and are marketed as mixed reality headsets.

A cardinal rule of educational technology is that the technology used should follow from the educational use. VR, AR, MR, and even AV all have potential pedagogical uses. Part of the purpose of this report is to explore and suggest what those purposes may be. To include the broadest possible range of simulation-based technologies in discussions about their instructional use, therefore, EDUCAUSE has opted to use a broader term: extended reality (XR).37
Appendix B: Methodology

This study used the multiple case study method,\textsuperscript{38} with the phenomenon under study being deployments of XR technology in institutions of higher education. Participating institutions were selected as exemplary cases:\textsuperscript{39} institutions that participated in phase 1 of the Campus of the Future project were selected because of their depth of experience with XR technology and the larger number of use cases on campus; institutions with little or no prior experience with XR were selected specifically to be as different from these phase 1 institutions as possible.

A total of 17 educational institutions in the United States participated in this research project (see appendix C). A total of 47 interviews were conducted with 38 people between January and November 2019. These interviewees spanned a wide range of jobs: instructors at all levels, deans and directors of academic units, librarians, instructional designers and directors of campus centers for teaching and learning, and C-level institutional leadership. These people were identified via snowball sampling, starting with the individual who is HP’s primary institutional contact for the Campus of the Future project.

The primary data collection method for this project was semi-structured interviews. These interviews elicited detailed information about the interviewees’ involvement in using XR technology. The interviews were supplemented by document analysis; project teams at some participating institutions had published reports or created blogs to document the progress of XR-related projects, and these became a data source about use cases on campus. Similarly, news articles in campus publications and the higher education press about participating institutions provided some information about campus use cases. Finally, some interviewees had published articles and books, or referred to publications by their colleagues, about XR in their discipline. These documents were used primarily to inform the creation of interview prompts.
Appendix C: Participating Institutions

A total of 17 educational institutions in the United States participated in this research project:

- Barnard College
- Bryant University
- Bucks County Community College
- Columbia University
- Dartmouth College
- Florida International University
- Foothill-De Anza Community College District
- Hamilton College
- Harvard University
- MIT
- Morgan State University
- The New School
- North Carolina School of Science and Math
- Syracuse University
- University of Pennsylvania
- Wake Technical Community College
- Yale University

The makeup of these participating institutions was as follows:

- Most were four-year doctoral universities with high or very high research activity.
- One was a four-year master’s institution: Bryant University.
- Three were four-year baccalaureate institutions: Barnard College, Hamilton College, and Foothill College (one of the two campuses of the Foothill-De Anza Community College District).
- Three institutions were community colleges: Bucks County Community College and Wake Tech Community College are two-year associate’s colleges. Foothill-De Anza Community College is actually a community college district of two campuses, one a two-year associate’s college and one a four-year baccalaureate college.
- One institution was a historically black college or university (HBCU): Morgan State University.

- One institution was a high school: the North Carolina School of Science and Math (NCSSM), a two-year public residential high school with a focus on STEM disciplines.

These institutions that participated in this study were not representative, nor were they intended to be representative, of the state of higher education in the United States, or globally. These institutions were selected as critical cases; that is, they were chosen specifically for their informativeness about the use of XR in higher education.

Some of the institutions that participated in this study also participated in the year 1 Campus of the Future project, which led to the *Learning in Three Dimensions* report, and some were new in year 2. The *Learning in Three Dimensions* report presented a broad-brushstroke overview of XR technology in higher education. This study delves deeper into the adoption and implementation of XR technology in higher education and consequently casts a wider net of types of institutions. Institutions with much prior XR experience are naturally going to be further down the road of technology deployment than institutions with little or no prior XR experience. The wider the range of experience with XR at participating institutions, however, the more informative these cases could be.
Notes


2. Dana C. Gierdowski, ECAR Study of Undergraduate Students and Information Technology, 2019, research report (Louisville, CO: ECAR, October 2019).


13. In Diffusion of Innovations theory, the term “adoption” refers strictly to the behavior of individuals. An organization, according to diffusion theory, does not “adopt” an innovation; rather, an organization “assimilates” an innovation. The term “adoption” is used throughout this report, however, because it is likely to be the more familiar term, even though the unit of analysis here is the organization, e.g., an institution of higher education or a campus unit within an institution of higher education. See, for example: Alan D. Meyer and James B. Goes, “Organizational Assimilation of Innovations: A Multilevel Contextual Analysis,” The Academy of Management Journal 31, no. 4 (1988): 897–923.


22. NCSU was not a participating institution in the HP Campus of the Future initiative, in that HP did not provide XR hardware to NCSU prior to this study. However, NCSU features in this study because it has a unique service model for providing access to XR technology on campus, a service model that we at ECAR are not aware of at any other institution.


25. The Simtainer, an experimental design for an XR studio, demonstrates just how flexible such a space can be. The Simtainer is little more than an empty intermodal shipping container; the standard size for a small one is 20 × 8 × 8 feet.


29. “Saturation” is a concept from the Diffusion of Innovations framework that indicates the point at which as large a percentage of a population has adopted an innovation as will ever adopt it. This is rarely 100%, as there are always some people who reject a technology for whatever reasons. Televisions and cell phones are two of the most common technologies in the United States, for example, yet “only” 96% of the US population own these technologies.

30. Sara Goldrick-Rab, Christine Baker-Smith, Vanessa Coca, Elizabeth Looker and Tiffani Williams, “College and University Basic Needs Insecurity: A National #RealCollege Survey Report,” The Hope Center for College, Community, and Justice, April 2019.


37. In particular, see the EDUCAUSE XR (Extended Reality) Community Group.


40. This analysis was conducted using variables from the Carnegie Classification of Institutions of Higher Education, 2018 Update Public File.


42. The institutions that participated in this study were not representative—nor were they intended to be—of the state of higher education in the United States or globally. Indeed, it would probably have been impossible to draw a representative sample of institutions for this study. To draw such a sample from a population, you would first have to know what is being represented. The Carnegie Classification of Institutions of Higher Education data files list all degree-granting institutions of higher education in the United States. The most recent Carnegie data file could be used to define the population. However, it would have been impossible to define a sampling frame, as we cannot identify every institution of higher education in the US that has adopted XR technology.