

# Advancing Career Aspirations in STEM Fields through Co-Design and XR-Enabled Educational Delivery Models

Alex Renner, Eliot Winer, Kimberly Zarecor, Evrim Baran, Ezequiel Aleman, Anasilvia Salazar Morales

Iowa State University

Ames, Iowa

arenner@iastate.edu, ewiner@iastate.edu, zarecor@iastate.edu, ebaran@iastate.edu,  
ealeman@iastate.edu, kareen@iastate.edu

## ABSTRACT

By 2028, the U.S. will have the largest percentage of foreign-born individuals since 1850 with non-Hispanic whites in the 18-29 age group in the minority. These changing demographics require a major shift in education practices that will affect these residents' ability to continue their education, recruit for civilian careers, enlist in the military, and simply navigate in a digital society. These residents have a range of challenges from language barriers to lack of access to the Internet and mobile devices that must be addressed.

Extended Reality (XR) technologies, interwoven with learning theories, offer solutions to these challenges. This paper presents a study of XR-enabled educational delivery models with the community of Storm Lake to enhance students' aspirations for Science, Technology, Engineering, and Mathematics (STEM) careers. Storm Lake is a rural Iowa community with a large low-skilled workforce employed in the agroindustrial sector and a K-12 student population that is 64% English Language Learners and 85% students of color. The research began with co-design activities (formal process actively involving all stakeholders) with teachers, students, and families in the community without technology use. Analyzed study data showed that traditional technology development and deployment practices would not effectively educate or inspire students on their own. For example, providing teachers with XR devices creates a training burden to properly operate, often resulting in unused technology. Co-design activities, with place-based challenges in XR environments, were effective for students to learn STEM-related content. Co-design activities concluded in a three-day summer workshop for 10 high school students. At the workshop, students defined place-based challenge(s) in their community and implemented an XR technological solution in software and hardware. Assessments showed positive results from the students on several measures, including evidence that the workshop contributed to seven of the 10 applying to a university in a STEM major.

## ABOUT THE AUTHORS

**Alex Raymond Renner**, is a PhD candidate in Mechanical Engineering and Human Computer Interaction (HCI). His research focuses on helping novice users of low-cost “desktop” 3D printers fix defects in printed parts, utilizing the visual thermal process simulation application that he developed.

**Eliot Winer, Ph.D.**, is the director of VRAC and professor of Mechanical Engineering, Electrical and Computer Engineering, and Aerospace Engineering at Iowa State University. Dr. Winer has over 20 years of experience working in virtual reality and 3D computer graphics technologies on sponsored projects for the Department of Defense, Air Force Office of Scientific Research, Department of the Army, National Science Foundation, Department of Agriculture, Boeing, John Deere, and the Federal Highway Administration.

**Kimberly E. Zarecor, Ph.D.**, is professor of Architecture at Iowa State University. Trained as an architect and architectural historian, Dr. Zarecor does research about rural Iowa communities looking at strategies to mitigate the negative effects of population loss on quality of life and developing new ways to integrate rural communities into innovation economies. Her work has been funded by the National Science Foundation where she is currently an expert working for the Innovation and Technology Ecosystems team in the Directorate for Technology, Innovation, and Partnerships (TIP/ITE).

**Evrin Baran, Ph.D.**, is an Associate Professor of Educational Technology at Iowa State University, where she leads multiple initiatives, providing a future-forward, interdisciplinary, and innovative approach to educational research. She is internationally recognized for her work in technology and teacher education, digitalization of higher education, and technology-enabled Science, Technology, Engineering, and Mathematics (STEM) education. Her work has been funded by national and international agencies including the National Science Foundation (NSF) and the European Commission.

**Ezequiel Aleman, Ph.D.**, is a Postdoctoral Researcher at Iowa State University. Dr. Aleman has over 15 years of professional experience in Uruguay, the UK and the U.S. His research focuses on participatory design and research using place-based methodologies and game-based learning.

**Ansilvia Salazar Morales**, is a computer science engineer from Guatemala. She holds an MBA and an MS. in Human-Computer Interaction, and she is currently pursuing a Ph.D. in Human-Computer Interaction at Iowa State University. Fulbright-Laspau alumni, her research focuses on finding new technology usages in the classroom.

# **Advancing Career Aspirations in STEM Fields through Co-Design and XR-Enabled Educational Delivery Models**

**Alex Renner, Eliot Winer, Kimberly Zarecor, Evrim Baran, Ezequiel Aleman, Anasilvia Salazar Morales**  
**Iowa State University**

**Ames, Iowa**

**arenner@iastate.edu, ewiner@iastate.edu, zarecor@iastate.edu, ebaran@iastate.edu,  
ealeman@iastate.edu, kareen@iastate.edu**

## **INTRODUCTION**

### **US Census Demographic Projections**

Pursuing youth populations in rural areas could address military enlistment shortages if recruitment practices proactively adapt for changing demographics in the US population (Vespa et al., 2020). By 2028, white youth in the 18-29 age group will be the minority (Frey, 2018). This age group aligns with those eligible to enlist in the U.S. Military, which range from 17-28 for the Marine Corps and 17-39 years old for other branches (USAGov, 2023). However, by 2045 it is projected that non-Hispanic whites will no longer make up the majority of the U.S. population (Vespa et al., 2020). Adapting recruitment practices goes further than just speaking a potential recruit's native language and respecting their culture. In one rural community it may be easy to explain the benefits of enlisting to a potential recruit who has multiple family members with military service. The same recruiter may drive to the closest rural community in the same day and be talking to youth who are second-generation immigrant children. Recruiters will need to effectively communicate the benefits of enlisting and career opportunities to youth in rural communities, regardless of the demographics.

Maintaining effective recruitment practices is important within and across increasingly diverse rural communities. Reports have shown that "rural youth are over-represented among enlistees – about 46% of enlistees came from rural or small town areas while only 40% of the general population lived in these locations" (Kleykamp, 2017). By 2028, the foreign-born share of the US population will reach a "historic high" of 14.9%, which is "higher than any time since 1850" (Vespa et al., 2020). While these statistics highlight increasing diversity over the entire U.S. population, the focus of this research is on youth who are deciding what to do after finishing high school. The Qualified Military Available (QMA) study showed that only 23% of youth ages 17 to 24 were qualified to enlist (Defense, 2020). Improving K-12 Science, Technology, Engineering, and Mathematics (STEM) education would help youth pass the educational requirements to enlist, and help recruiters fill military jobs that require specific skills in STEM fields.

### **Educational Challenges of Rural Youth Populations**

The lack of financial resources in rural communities is not the only challenge to improving STEM education. Rural communities may have fewer businesses willing to donate to local schools. Financial donations could increase the number of teachers, quality of facilities, and quantity of STEM instruction materials. If low-skilled labor is all that is required for large companies in rural communities to make profits, there is no benefit in donating to local schools to help improve STEM education. In rural communities with diverse populations an additional challenge is determining how to effectively provide important school information to students and their families. In some rural communities, school announcements may be provided in both English and Spanish, but there may be more languages and dialects that cannot be translated, because it is too complex to translate in a timely manner. The military's benefits and pay are very competitive in a rural community with low-skilled jobs. Youth in diverse rural communities may be able to have their entire college tuition paid for, leaving them without college debt and with a reliable source of income to help their families and community (Military Advantage, 2023).

In addition to language barriers, residents in rural communities often lack high-quality access to the Internet, which makes communication of school information even more challenging (Zhang et al., 2022). Quickly providing important school information is often dependent on cell phone provider networks in a rural community. Families may not be

able to afford a broadband internet connection at their home even if it is available. The cost is even harder to justify if a family's only computer is a laptop provided by the local school system, and their cell phones can be used as a Wi-Fi hotspot. Even though many parents saw the benefits of remote instruction during the COVID-19 pandemic, they may not understand the benefits of continued learning at home after their children have returned to attending school in-person. Poor quality internet access also affects teachers. Poor internet speed may reduce opportunities to stream a real-time video of their instruction to multiple students, affecting the quality of instruction because students cannot ask questions and interact with each other as they would in the classroom. Educators may not even consider producing instructional materials with engaging features such as animations and interactive programming quizzes due to poor quality internet access. Better internet access would help students find resources online to help them complete their homework. Since teachers must meet some sort of standards (e.g., Iowa Department of Education standards), they cannot lower their expectations for students, forcing them to spend more time on topics in the classroom (Iowa Department of Education, 2023).

Youth from low-income households in rural communities face challenges within the classroom, and additional challenges at home and in their community. After a full day at school, students may need to educate their first-generation immigrant parents about how to complete everyday tasks (e.g., paying bills online). Often the older children in the family have obtained skills to help their parents and younger siblings. These additional responsibilities, that second-generation immigrant children have, make it more challenging to consider going to college, and aspire to a career in a STEM field. High school students often feel guilty for leaving home to go to a college or a university, because the social dynamics in rural communities foster strong family connections. Interestingly, their parents are often unaware of their child's guilt and encourage them to go to a college or university. However, since the children often take care of essential tasks for their family, the parents will have to find alternate ways to complete these duties. Even with this conflict, it is very likely that these parents see the opportunity for their children to extend the STEM skills they learned in their local school at a college or university to obtain the skills that will lead to high skilled jobs. With such strong family connections in rural communities, it is much more likely that these college or university graduates will first look for high skilled jobs in or near their rural community (Sowl et al., 2022). If the high skilled jobs do not exist in their community, they may become entrepreneurs, creating high skilled job opportunities for their friends, families, and for the benefit of their community. Youth who aspire to a career in a STEM field will be ready to fill more than 80% of Department of Defense (DoD) jobs that require STEM skills in the next decade (DoD STEM, 2023).

There are parallels that can be drawn between the conversations that students in rural communities have with their parents about going to college and high school students all over the US who are considering enlisting in the military. The benefits of STEM careers need to be communicated to students and their families in rural communities. STEM workforce development is needed in rural communities, otherwise there will be a problem finding highly skilled workers to maintain food, energy, and water supply systems. Current methods of teaching STEM in a traditional classroom setting inform students of a wide range of topics. STEM education could be improved by highlighting career paths for students interested in a particular STEM field. Using Extended Reality (XR) technology to strategically deliver STEM education to rural communities would engage an untapped workforce including migrants, refugees, and veterans. XR technologies would help fill the "awareness gap" referring to a "lack of understanding" among young people (Ware, 2023). XR technologies could be used to educate potential military recruits about the benefits of a military career in a similar way that XR could educate youth in rural communities about the benefits of a STEM career. XR-based education delivery models would help youth in rural communities and help potential recruits pass the Education the Armed Services Vocational Aptitude Battery (ASVAB) (USAGov, 2023), helping solve "the service's recruiting problem" that Army Secretary Christin Wormuth stated as her "top priority" (Ware, 2023). In addition to tuition assistance and a STEM related career in the military, the military provides welcoming environments on base, ways to stay connected to families, and fulfillment from making an impact in the lives of others (Today's Military, 2023).

### **XR-enabled STEM Educational Delivery Models**

The research presented in this paper focused on developing the content for STEM educational delivery models that were enabled by XR technologies. Traditional STEM curricula designed for instruction within a classroom setting effectively introduces fundamental topics to students. Bridging the XR Technology-to-Practice Gap puts the burden on teachers to show that these technologies lead to improvements in learning outcomes (Cherner, 2023; Fegely, 2023). Educational content needs to take advantage of XR technologies by immersing a student in a 3D virtual environment

(VE) while applying layers of instructional materials. XR-enabled educational models would progress at the student's pace, in a similar way that a player progresses through different levels in a game. New learning theories designed to utilize XR technologies have the potential to overcome the challenges of education practice by enabling students to learn on their own with educators setting goals for students to reach. A study showed that self-guided online training "can increase desirable learning behaviors and improve STEM performance with minimal cost to learners or instructors" (Bernacki, 2020). In rural communities with very diverse demographics, online resources could be used with XR technologies to translate STEM curriculum to multiple languages. While Virtual Reality (VR) viewers for smartphones are a low-cost way to deliver STEM content, the burden is on the teacher to find content related to their curriculum (e.g., a 360-degree video of biology in the ocean) (Google LLC, 2023). Schools could also purchase an educational package with viewers, low-cost smartphones, and pre-installed content like Google Expeditions (Google, 2023). However, if the pre-installed content is no longer supported, then the teachers have to find ways to repurpose the VR viewers and smartphones.

Expertise designing and evaluating XR applications for academic and industrial use does not ensure that the appropriate XR hardware can be identified for use with existing STEM curriculum. (Hoover et al., 2020; Miller et al., 2020; Bhattacharya & Winer, 2018). As educational delivery models are piloted, qualitative metrics that show a positive impact on STEM learning outcomes need to be investigated (Baran et al., 2019; 2016). In addition to creating STEM educational curriculum, modules that help educators learn how to use XR devices are essential for acceptance of this new form of instruction. Co-design processes can help identify teachers' aspirations and students' needs for STEM education content that could be used in an XR-enabled education delivery model. XR environments can utilize place-based education because it integrates local community and environmental resources into the educational process through hands-on, real-world experiences with the active engagement of local citizens and community organizations (Sobel, 2004).

## **BACKGROUND**

### **Community Engagement**

To identify content for XR-enabled STEM educational delivery models, it was essential to identify a community with stakeholders who would actively share their needs and aspirations in a co-design process with an interdisciplinary team of XR, design, and education experts. The community of Storm Lake, Iowa was chosen as a partner for this research. While many rural communities in Iowa are shrinking and aging, Storm Lake's population has risen from 10,600 in 2010 to 11,269 in 2020, and growth is especially robust in the K-12 population (Lynch, 2021). Two large meatpacking plants are by far the largest employers in the community, providing low-skilled jobs to a large number of first-generation immigrants. According to data from the district, the student population in the Storm Lake School District (CSD) consists of 64% English Learner (EL) students and 86.4% Non-Caucasian students (Storm Lake Community School District, 2022). Research shows that in rural communities Quality of Life (QoL) can improve with an emphasis on increasing social capital, especially by building trusting relationships between parts of a community that may not traditionally have had strong connections, what sociologists call bridging social capital (Peters, 2018; Zarecor, 2021). In the case of Storm Lake, the large population of diverse EL students are linked to the agroindustrial workforce, even though the overall population in the community and the staff in the school system are much less diverse. The ISU team and the local collaborators from Iowa 4-H Youth Development program, the Storm Lake CSD, and local community organizations were intentional about connecting with students and families from the migrant and refugee population. The research team wanted to avoid some of the problems that have been documented in other diverse communities in which researchers from outside of the community arrive with a "savior mentality" and do not engage in long-term collaborations, which can negatively affect the results of work with educators (Riley, 2021).

### **Co-design Processes**

One of the methods that has been shown to help with community engagement to identify appropriate content for XR-enabled education models is the co-design process. Co-design goes beyond empathic design approaches (Cardoso & Clarkson, 2012) and involves stakeholders in the act of creation (Steen, 2013). This process relies on recognizing, defining, and distinguishing between symptoms of problems and their underlying causes. Co-design methods borrow

from traditional social science approaches, but regard stakeholders as participant collaborators, rather than as research subjects.

### XR Content Generation Expertise and Educational Delivery Considerations

The wide variety of ways to bridge the “XR Technology-to-Practice Gap” can be overwhelming (Chemer, 2023; Fegely, 2023). Teachers in rural communities may not have access to professional development programs that provide training on how to use XR technology (Mystakidis, 2021). Even with an interdisciplinary team with expertise in XR and education from ISU, teachers in Storm Lake expressed concerns about how to integrate XR into their curriculum. Teachers highlighted the challenge of learning how to use XR devices and then teaching their students how to use them. There is a lack of research on developing education delivery models that can be adapted to a variety of XR systems. The ISU team had experience related to content delivery and had been working together as an interdisciplinary unit, which were critical advantages for moving forward with co-design activities. XR methods that worked with social science dimensions may not have objective measures of their impact on STEM learning outcomes (Baran et al., 2019; 2016). Co-design activities during workshops with students and teachers appear to be most effective when they leverage the stakeholder’s needs and aspirations to create place-based curricula.

## METHODOLOGY

### Overview

Storm Lake was chosen to pilot XR-enabled STEM education models due to its diverse and growing K-12 student population, rural location, and large low-skilled workforce. In a community that speaks over 30 different languages, XR-enabled solutions provide an opportunity to reduce language barriers with experiential learning. Table 1 provides a breakdown of the Storm Lake populations by race. While white alone is still the majority race for the overall population, the next largest ethnicity is Hispanic or Latino at 39.1%. Table 2 highlights three population characteristics that were part of the reason for choosing Storm Lake. The Storm Lake Community School District K-12 demographics listed in Table 2 highlight the diverse youth population, with 86.4% Non-Caucasian students. From 2017-2021 there were 238 veterans in the community that had 11,269 residents in 2020. Table 2 also shows that this rural community has a large first-generation immigrant population. An important note for Table 1 is that some individuals report more than one race and are then shown in more than one category, so the total is greater than 100%.

**Table 1. Storm Lake Iowa Demographics: Race and Hispanic Origin (US Census Bureau, 2022)**

|                                                               |       |
|---------------------------------------------------------------|-------|
| White alone, percent                                          | 58.3% |
| Black or African American alone, percent (a)                  | 4.2%  |
| American Indian and Alaska Native alone, percent (a)          | 0.3%  |
| Asian alone, percent (a)                                      | 15.3% |
| Native Hawaiian and Other Pacific Islander alone, percent (a) | 3.1%  |
| Two or More Races, percent                                    | 9.2%  |
| Hispanic or Latino, percent (b)                               | 39.1% |
| White alone, not Hispanic or Latino, percent                  | 35.7% |

(a) Includes persons reporting only one race

(b) Hispanics may be of any race, so also are included in applicable race categories

**Table 2. Storm Lake Iowa Demographics: Population Characteristics**

|                                          |       |
|------------------------------------------|-------|
| K-12, Hispanic (a)                       | 54.1% |
| K-12, White (a)                          | 13.6% |
| K-12, Black (a)                          | 5.5%  |
| K-12, Asian (a)                          | 15.5% |
| K-12, Pacific Islander (a)               | 9.2%  |
| K-12, Native American (a)                | 0.2%  |
| K-12, 2+ Races (a)                       | 1.8%  |
| K-12, Total Non-Caucasian (a)            | 86.4% |
| Veterans, 2017-2021(b)                   | 238   |
| Foreign-born persons, percent, 2017-2021 | 31.4% |

(a) (Storm Lake Community School District, 2022)

(b) (US Census Bureau, 2022)

The hypothesis for this research, which was funded by the National Science Foundation (NSF), was that XR-enabled inclusive and place-based STEM educational delivery models would increase interest in STEM careers and entrepreneurship among rural K-12 students and adults. The goal of the project was to pilot new XR-enabled STEM educational delivery models. To achieve this goal, stakeholders' needs and aspirations needed to be identified using co-design processes with assessments of the XR-enabled STEM educational delivery models.

The first step in the project was to meet teachers at the elementary, middle, and high school in Storm Lake. The primary objective was to listen to the members of the community. The agenda included times that were dedicated to ISU team members sitting down to listen to teachers and staff while taking notes about the challenges they faced in the classroom and efforts to engage the families in the community. During the first visit, three members of the 4-H youth group that were in high school accompanied the ISU team and met with teachers from English, Science, Math, and a STEM specialist. The ISU team brought an Augmented Reality (AR) device using simple 2D tracking and two STEM related applications downloaded to two Oculus Quest 2 VR headsets (Oculus, 2023). The authors had extensive experience providing demos with these devices to audiences that had never used VR or AR equipment. However, within the first hour it was clear that simply integrating XR into the teacher's curriculum may not be possible for several reasons including the time and resources needed to: 1) acquire XR equipment; 2) acquire software; 3) train teachers to use the systems; and 4) integrate lesson content into virtual environments. Demonstration of AR and VR devices with teachers is shown in Figure 1a, and a VR demonstration with one of the students from the 4-H youth group is shown in Figure 1b. Throughout the visit, the authors and other members of the research team discussed a variety of ways to expose students to XR tech.



(a)

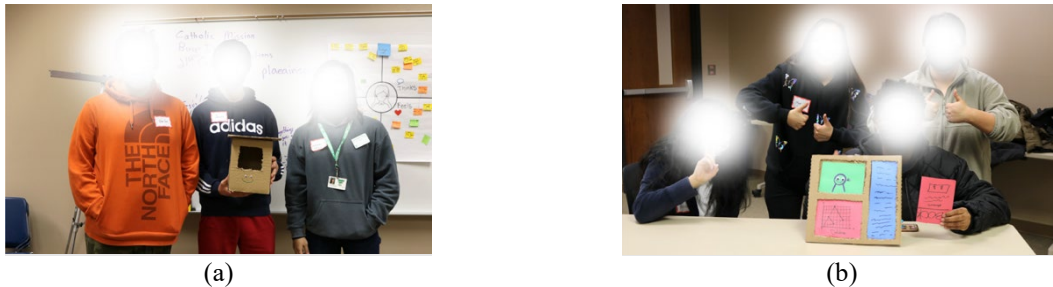


(b)

**Figure 1: Demonstration of AR on an iPad and VR with an Oculus Quest 2 with Storm Lake (a) Teachers and (b) Student**

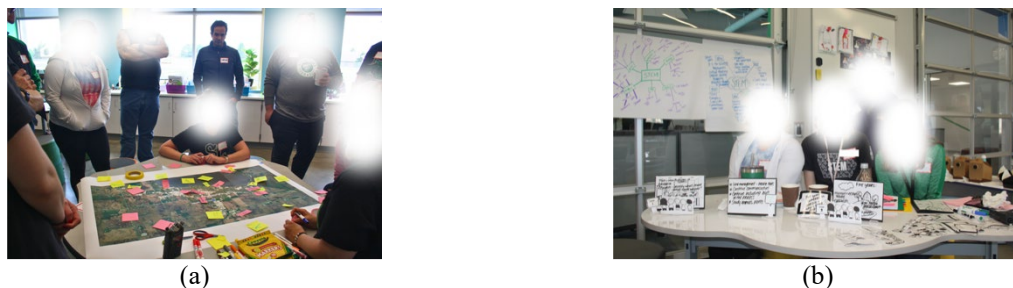
## Coordination Visits

Following the first visit, two coordination visits forged relationships with students and teachers in the Storm Lake CSD. The first coordination visit was held with members of Iowa 4-H, specifically a student group referred to as the “Teen Influencers.” These students were identified by the Iowa 4-H Stakeholder and Partnership Development Program Coordinator and Youth Outreach Educator for Iowa 4-H in Buena Vista County. The ISU team intentionally did not bring any XR devices to focus on content for the education delivery models. Graduate students on the research team from the ISU School of Education performed co-design activities that focused on identifying challenges that the students faced. The students performed activities, including making mind maps, to help communicate their feelings and connect them to challenges they were facing pursuing educational opportunities beyond high school. Seven students were able to attend the entire activity and the two groups shown in Figure 2 converged on a common theme of a ‘digital assistant.’ Cardboard and colored paper were used to help the students convey their mental models of a digital assistant device. The two groups created different prototypes as shown in Figure 2a and Figure 2b. However, they both showed a need for a digital tool to help them find resources that would help them go to college or a university.



**Figure 2: “Digital assistant” Prototypes Created by Iowa 4-H Teen Influencers from (a) Group 1, and (b) Group 2.**

A co-design workshop with Storm Lake CSD teachers from pre-K through high school followed. The invited teachers taught a STEM topic or managed facilities equipment associated with STEM. ISU team members used maps of Storm Lake printed ahead of time on large sheets of paper to collect feedback from the teachers shown in Figure 3a. The reason for using the map of Storm Lake was to identify places in the community that could be associated with STEM. The team selected place-based activities since they have been shown to have a greater influence on rural communities with migrant populations (Sobel, 2004). The workshop also focused on identifying the needs and aspirations for STEM education in the community. Teachers identified current needs and outlined ideas for increasing STEM education over many years. While performing these activities, teachers’ explanations of what STEM meant to them were recorded. At the end of the workshop, teachers created prototypes to communicate the strategies they identified to reinform STEM pathways in rural communities shown in Figure 3b.



**Figure 3: STEM Education Workshop with Storm Lake Teachers (a) Identifying Locations on a Map of Storm Lake to Explore STEM Activities, and (b) Prototypes to Communicate the Teachers Aspirations for STEM Education**

## Youth STEM Workshop

The Storm Lake students met and became more comfortable with the ISU team during the engagement activities in the community, which made it easier to get participants for a workshop on campus. The Youth STEM Workshop was held at ISU from June 13<sup>th</sup> to June 15<sup>th</sup>, 2022, with four activities over the three-day period with 10 student participants.

On the first day, the first session focused on “Framing STEM Education” where students used and learned a series of methods to help them deconstruct their perceptions, as well as expectations, about their presence as STEM learners and their future as STEM professionals. The Framing STEM Education session used place-based education methods to help students identify problems in their community. The next morning students spent four hours in a “Design for Life” session where they created 3D models in Sketchup (Sketchup, 2023) of a location in Storm Lake that had a personal connection for them and a STEM-related problem that they identified. In the afternoon of the second day, the students spent four hours participating in a “XR Model for Navigation” session developing an XR prototype scene using Unity that allowed them to explore the 3D models they designed. After this activity, a Microsoft Windows executable was built using Unity (Unity, 2023). On the last day, the students participated in a “Micro Control and NavIO” activity where they built a miniature game controller using an Arduino. Once the miniature game control circuit was built, they tested its functionality by using the joystick to navigate and buttons to perform functions in the application they created during the XR Model for Navigation session. While students learned STEM related skills in all four Youth STEM Workshop activities, the following sections focus on specific aspects of the XR Model for Navigation session to explain how they contributed to the results presented in this research.

### Introduction to XR Development

The students were split into four groups during the XR Model for Navigation session, and they worked together in those groups the entire time. At the beginning of the session, the students were given an overview of the expectations and expected outcomes from the activity. The authors emphasized to the students that the activity was designed to replicate a typical academic research project. Due to the four hour time constraint, the students would start with a template XR environment, but the tasks they would perform in the activity were nearly identical to those performed by undergraduate and graduate students. To further emphasize this fact, two graduate students and two undergraduates assisted and collaborated with the high school students. Important features of the Unity interface shown in Figure 4 were explained to the students (e.g., when the Play button is pressed, the content and functionality created the Scene view would be displayed in the Game view). Less than ten minutes of instruction about the Unity interface was given to the students to reflect how graduate and undergraduate researchers receive some formal instruction. The students were told that they would be learning how to use the Unity application while creating their application. After the students were familiar with the user interface they were shown how to import their 3D models, created during the Design for Life 3D modeling session, into their Unity application.

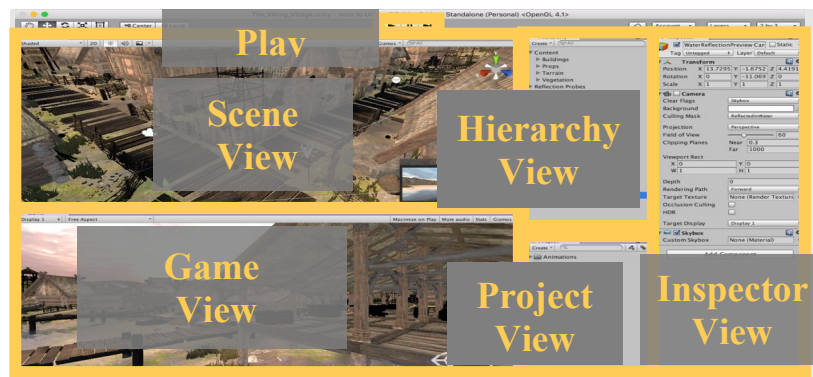


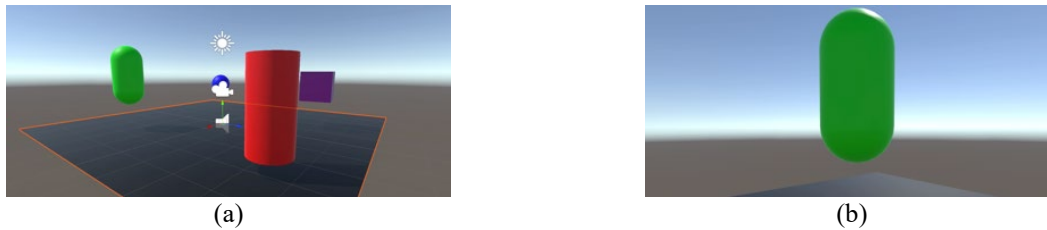
Figure 4: Unity User Interface Instruction

### XR Device Choice and Setup

After the students imported their 3D models into Unity, they were shown how to view their application on an Oculus Quest 2 that was tethered to their PCs. The ability to view an application in a Head Mounted Display (HMD) without being in a tracked space was one reason for choosing the Oculus platform. The co-design activities highlighted the importance of visualizing place-based problems and for the students to work in small groups before presenting their work. Even with the HMD tethered to a PC, students could pass the HMD to their group members, and other groups could walk a short distance to see each other's work. The ability to deploy the application to an Oculus Quest 2 without the HMD being tethered to a PC was also a key factor in choosing this XR device. The low cost of an Oculus Quest 2 was the final reason for choosing this XR device. The portability of the Oculus Quest 2 makes it easy for recruiters to show potential recruits XR environments that visualize life in the military.

### Template XR Environment Framework

The template environment was designed and implemented for importing a 3D model of a landscape, converting the Sketchup file using Unity. A C# script was provided that allowed the students to navigate their environment using the keyboard up, down, left, and right arrow keys to translate forward, back, left, and right. The same script allowed students to use the PC's mouse to look up, down, left, right within the VE. The XR player is the red cylinder shown in the top of Figure 5a, and an example of what the XR player's view inside the HMD is shown in Figure 5b. The student's 3D models replaced the primitive green capsule shape and other shapes. The red cylinder was made transparent when the students made their applications.



**Figure 5: Template XR Environment Framework (a) Scene and (b) Game View**

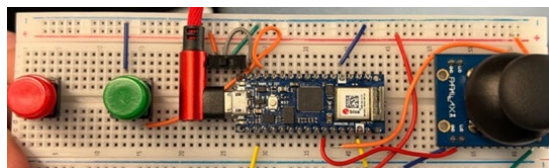
### Problem Framework for Co-Inquiry

Once the students imported their 3D models from the design session into the XR environment, they had a visual aid that made it easier to explain what they designed and the associated place-based problem(s). Students started to explain how the 3D models that they placed in their XR environment related to STEM. The students modeled locations in their rural community that had some problem that they wanted to fix, highlighting the benefits of place-based XR education, as outlined in XR-enabled STEM Educational Delivery Models section of the introduction. Co-inquiry involves teachers working together with students to examine educational practices by exploring student responses to instruction leading to new understandings and changes to curriculum. The students were asked to pause their work so that the problem framework for co-inquiry could be explained.

The students were told that in XR anything is possible, and that they could design solutions to address some of the problems that they identified. Websites to download 3D models were provided to help the students. If students could not find 3D models that represented what they wanted to add to their XR environment, undergraduate students with 3D modeling experience would create models for the students on-the-fly. As students began to find, download, and then import 3D models into their scene, they were asked to explain why they chose each particular model, how it relates to STEM, and how it would fix the problems they identified in their community. The co-inquiry process could also be used with potential recruits to help explain what they would like to do in a military career.

### Play Cast Share

The plan was for the students to formally share their work by playing their games and casting the HMD view to a TV. Instead, more time was given to students so that they could finish their applications and then create a Windows executable for the "Micro Control and NavIO activity that would occur the very next morning. During that activity, the students built the microcontroller with a joystick and buttons shown in Figure 6 and were able to test its functionality with the Unity application.



**Figure 6: Microcontroller Gamepad Used to Navigate XR Applications**

## **Creating Place-based XR-enabled educational models**

During the first session in the “Framing STEM Education” activity at the Youth STEM Workshop, students learned how to define STEM-related issues they identified in Storm Lake Iowa (e.g., bad smells from the meatprocessing facilities near the lake). In the second, the “Design for Life” activity, students used Google Sketchup to 3D model landscapes and buildings that visually represented their place-based STEM related issues. In the third, the “XR Model for Navigation” activity, students successfully imported their models. The XR device and template helped get the activity started, but the co-design process and place-based environment generated new ideas from students about how to improve their community.

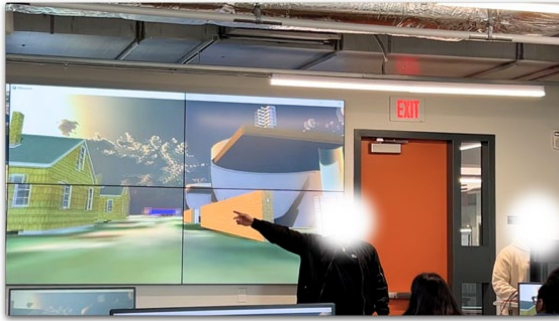
## **RESULTS AND DISCUSSION**

### **Defining Educational Delivery Model Content (Why it needed to be place-based)**

Establishing a personal connection with the students and teachers through multiple engagements and focusing on listening to their ideas and concerns were essential to successfully co-designing the educational content. Demonstration of XR technology should only be used to explain how the devices work. Discussions about how XR technologies could be used with STEM education should be held after defining educational delivery model content. Guided low-tech activities should be used to encourage students and teachers to freely express their thoughts and feelings providing a broader perspective on their needs and aspirations. It is beneficial to go to a rural community like Storm Lake for the workshops with teachers and students to have short, focused activities. Locations in their home community, where students are most likely to feel comfortable, should be identified to improve the probability of success for activities. The location should be convenient for students to arrive and leave as needed, and so that their families could observe activities and provide further insight.

Holding the teacher workshop in the pre-K STEM education classroom brought the community of STEM educators together. The large printed maps of Storm Lake helped teachers to situate themselves within the community and come up with ideas and aspirations for place-based STEM education. Both workshops showed that there was a level of care for the diverse cultures within the community, among fellow students and teachers, and within the community in general. The co-design process successfully made the teachers and students feel like participant collaborators. The problems that students identified in their community and the teachers’ aspirations were a catalyst for developing place-based activities for the Youth STEM Workshop that would define educational delivery model content.

The Youth STEM workshop had Institutional Review Board (IRB) approval for data collection to help assess the outcomes of the workshop. An important quantitative measure of the effectiveness of the Youth STEM Workshop was that seven of ten students who attended the workshop later enrolled in a college or university in a STEM major; in some cases these plans were already in place, but the workshop feedback was that their confidence that they could be successful at a postsecondary school increased. With this low number of participants, statistical significance cannot be established, but as a feasibility study, the results are encouraging to explore these activities with larger groups of youth and adults. Some important qualitative results were identified during the XR Model for Navigation activity. Within the first 45 minutes students were viewing 3D models that they created in an XR device. This led to observable increases in the students’ motivation, interest, and excitement during the session, which helped them stay focused through the remainder of the activity. The problem framework for co-inquiry provided an excellent way for the student to communicate the STEM-related issues they identified through visualization. Students often pointed at the screen to ensure that ISU team members understood the problems they identified. This enabled any ISU team member (with or without Unity experience) to find 3D models to add to their Unity application, creating place-based XR-enabled educational models. Navigating through the XR environment helped students decide what to add, and where to place new 3D models. Students were able to successfully navigate in Unity using a keyboard and look around in their scene using a mouse. All four groups shown in Figure 7a-d, connected their microcontroller gamepad to the presentation PC via USB to give live demonstrations of the applications.



(a) Group 1



(b) Group 2



(c) Group 3



(d) Group 4

**Figure 7: Youth STEM Workshop Final Presentations for (a) Group 1, (b) Group 2, (c) Group 3, (d) Group 4**

## CONCLUSION AND FUTURE WORK

The overall goal of the project was to pilot new XR-enabled STEM educational delivery models developed with youth and adults in rural communities. The activities designed for the Youth STEM Workshop provided a major step forward in achieving the project goal. The educational delivery model developed with the students during the Youth STEM Workshop is a template that will be used to develop more XR-enabled STEM delivery models for youth and adults. Co-design workshops with teachers and students were an extremely effective way to identify stakeholder needs and aspirations for new place-based educational curricula in STEM fields. Place-based XR environments facilitated creation of content that was meaningful for the youth. Encouragement from XR activity coordinators to add 3D models to communicate STEM related problems in their community was invaluable in helping students brainstorm ideas for their XR applications. The ability to create place-based virtual content that did not exist in the students' XR environment helped students visualize a better life in their communities and helped them realize that they could facilitate those changes with more STEM education at a college or university. The activity also highlighted multiple opportunities for XR-enabled recruiting practices. Co-designing seemed to help non-native English speakers communicate what they wanted in their XR environment. Co-designing a military career path using XR technologies would help potential recruits see their future from the first day on base to many years later in their careers. The place-based attribute of the template XR environment could increase recruitment by visualizing STEM skills that they would learn in the military. Putting a recruit at a job that requires STEM skills in an XR environment is more powerful than verbal explanations from recruiters.

The template XR environment framework would be an excellent starting point for developing place-based recruitment tools and for people interested in replicating the Youth STEM Workshop. The framework acted as a central hub for a wide range of incoming 3D models. Sketchup was used to create the models, but other 3D modeling programs could be used if they export Unity compatible 3D models. There are tradeoffs between the quantity and quality of XR devices to use when co-designing with youth. Using one XR device for every three students during the workshop seemed to work well for students to visualize and share content with their peers. The quality of XR devices depends on the budget for the activity. Exploring the environment with the custom designed microcontroller gamepad was fun for the students

to build and use, but not necessary for the workshop. A gamepad that is compatible with Unity would control the XR player provided in the XR environment framework. The success of the activity motivates further development of authoring tools for recruiters, teachers, and the general public. Without easy-to-use XR curriculum authoring tools teachers were not co-designing the XR-enabled educational models. Replicating the Youth STEM Workshop activities with teachers in the Storm Lake CSD would provide additional insights into educational delivery models. Tools that have been used in the Storm Lake CSD like CoSpaces (CoSpaces, 2023) and Merge Cube (Merge, 2023) will be included in future activities with students and teachers.

## ACKNOWLEDGEMENTS

This project was funded by the National Science Foundation, award # 2125503. Project title: SCC-PG: Preparing the Next-Generation Rural Workforce Through Inclusive and Place-Based Smart and Connected STEM Educational Delivery Models.

## REFERENCES

- Zhang, H., Guan, Y., Kamal, A., Qiao, D., Zheng, M., Arora, A., Boyraz, O., Cox, B., Daniels, T., Darr, M., Jacobson, D., Khokhar, A., Kim, S., Koltjes, J., Liu, J., Luby, M., Nadolny, L., Peschel, J., Schnable, P., ... Tang, L. (2022). ARA: A Wireless Living Lab Vision for Smart and Connected Rural Communities. *WiNTECH 2021 - Proceedings of the 15th ACM Workshop on Wireless Network Testbeds, Experimental Evaluation and Characterization, Part of ACM MOBICOM 2021*, 9–16. <https://doi.org/10.1145/3477086.3480837>
- Batalova, J., & Feldblum, J. (2020). *Immigrant-Origin Students in* (Issue October). <https://www.migrationpolicy.org/sites/default/files/publications/immigrant-origin-students-postsecondary-ed-final.pdf>
- Ware, D. (2023). *Army secretary says recruiting troubles are 'very serious' and fixing them could stretch into 2024*. <https://www.stripes.com/branches/army/2023-02-23/army-recruiting-soldiers-enlistment-9233311.html>
- Defense, U. D. of. (2020). *2020 Qualified Military Available (QMA) Study*.
- Kleykamp, M. (2017). *When A Simple Statistic Isn't So Simple: The Story of Rural Enlistments*. <https://veteranscholars.com/2017/04/11/when-a-simple-statistic-isnt-so-simple-the-story-of-rural-enlistments/>
- USAGov. (2023). *Requirements to enlist in the U.S. military*. <https://www.usa.gov/military-requirements>
- Vespa, J., Medina, L., & Armstrong, D. M. (2020). *Demographic Turning Points for the United States: Population Projections for 2020 to 2060 Population Estimates and Projections Current Population Reports*. [www.census.gov/programs-surveys/popproj](http://www.census.gov/programs-surveys/popproj)
- Frey, W. (2018). *The US will become 'minority white' in 2045, Census projects*. <https://www.brookings.edu/blog/the-avenue/2018/03/14/the-us-will-become-minority-white-in-2045-census-projects/>
- Lynch, J. Q. (2021). *2020 census shows Iowa urban areas grow, but population decline continues in rural areas*. <https://www.thegazette.com/government-politics/iowa-urban-areas-grow-but-population-decline-continues-in-rural-areas/>
- Steen, M. (2013). Co-design as a process of joint inquiry and imagination. *Design Issues*, 29(2), 16–28. [https://doi.org/10.1162/DESI\\_a\\_00207](https://doi.org/10.1162/DESI_a_00207)
- Cardoso, C., & Clarkson, P. J. (2012). *Simulation in user-centered design: helping designers to*. 23(1), 1–22.
- Riley, K., & Solic, K. (2021). Abolitionist Teacher Education in the Contact Zone: Tensions of Facilitating Teacher Candidate Learning in Activist Educator Spaces. *Equity and Excellence in Education*, 54(2), 152–164. <https://doi.org/10.1080/10665684.2021.1951633>
- Cherner, T., & Fegely, A. (2023). *Bridging the XR Technology-to-Practice Gap: Methods and Strategies for Blending Extended Realities into Classroom Instruction*.
- Fegely, A., & Cherner, T. (2023). *Bridging the XR Technology-to-Practice Gap: Methods and Strategies for Blending Extended Realities into Classroom Instruction Volume II*.
- Mystakidis, S., Fraggaki, M., & Filippousis, G. (2021). Ready teacher one: Virtual and augmented reality online professional development for k-12 school teachers. *Computers*, 10(10), 1–16. <https://doi.org/10.3390/computers10100134>
- US Census Bureau. (2022). *U.S. Census Bureau QuickFacts: Storm Lake city, Iowa*. <https://www.census.gov/quickfacts/stormlakecityiowa>

- Harris, R. S., & Hodges, C. (2018). STEM Education in Rural Schools: Implications of Untapped Potential. *National Youth at Risk Journal*, 3(1), 1–12. <https://doi.org/10.20429/nyarj.2018.030102>
- Sobel, D. (2004). Place-Based education: connecting classrooms and communities closing the achievement gap: the seer rePort. *The NAMTA Journal*, 39(1), 61–78. [www.orionmagazine.org](http://www.orionmagazine.org)
- CoSpaces. (2023). CoSpaces Edu for kid-friendly 3D creation and coding. <https://cospaces.io/edu/>
- Unity. (2023). Unity Real-Time Development Platform | 3D, 2D, VR & AR Engine. <https://unity.com/>
- Oculus. (2023). Meta Quest 2: Immersive All-In-One VR Headset | Meta Store | Meta Store. <https://www.meta.com/quest/products/quest-2/>
- SketchUp. (2023). 3D Design Software | 3D Modeling on the Web | SketchUp. <https://www.sketchup.com/>
- Merge. (2023). Merge Cube | AR/VR Learning & Creation. Retrieved June 4, 2023, from <https://mergeedu.com/cube>
- Iowa Department of Education. (2023). Science Standards. <https://educateiowa.gov/standard/science/science>
- Bernacki, M. L., Vosicka, L., & Utz, J. C. (2020). Supplemental Material for Can a Brief, Digital Skill Training Intervention Help Undergraduates “Learn to Learn” and Improve Their STEM Achievement? *Journal of Educational Psychology*, 112(4), 765–781. <https://doi.org/10.1037/edu0000405.supp>
- DoD STEM. (2023). STEM Careers | DoD STEM. <https://dodstem.us/explore/career/>
- Today’s Military. (2023). Life in the Military — Today’s Military. <https://www.todayismilitary.com/life-in-the-military>
- Google LLC. (2023). Cardboard - Apps on Google Play. [https://play.google.com/store/apps/details?id=com.google.samples.apps.cardboarddemo&hl=en\\_US&gl=US](https://play.google.com/store/apps/details?id=com.google.samples.apps.cardboarddemo&hl=en_US&gl=US)
- Google. (2023). Expeditions & Tour Creator are no longer available - Expeditions Help. <https://support.google.com/edu/expeditions/answer/10892826?hl=en>
- Military Advantage. (2023). Military Benefits at a Glance | Military.com. <https://www.military.com/join-armed-forces/military-benefits-overview.html>
- Sowl, S., Smith, R. A., & Brown, M. G. (2022). Rural College Graduates: Who Comes Home?\*. *Rural Sociology*, 87(1), 303–329. <https://doi.org/10.1111/ruso.12416>
- Zarecor, K. E., Peters, D. J., & Hamideh, S. (2021). Rural Smart Shrinkage and Perceptions of Quality of Life in the American Midwest. In J. Martinez, C. A. Mikkelsen, & R. Phillips (Eds.), *Handbook of Quality of Life and Sustainability* (pp. 395–415). Springer International Publishing. [https://doi.org/10.1007/978-3-030-50540-0\\_20](https://doi.org/10.1007/978-3-030-50540-0_20)
- Storm Lake Community School District. (2022). District Information | Storm Lake Community School District. <https://www.storm-lake.k12.ia.us/page/district-information>