12th International Conference of the Immersive Learning Research Network
Selected Academic papers for the iLRN Proceedings
DOI: https://doi.org/10.56198/S7USIO9LQ

Empowering Girls to Be Our Colleagues: Learning Experience Design Case of Summer Camp Engaging Design Thinking for Extended Reality

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Abstract. While improving STEM education and participation has been an objective for decades, a shortage of STEM professionals and gaps in career attainment for women and people of color persist. Educators have increasingly experimented with immersive technologies to engage students in STEM, but many interventions have failed to teach transferable skills or capture usability and student experience in ways that inform future work. This paper presents the design and delivery of a summer camp for middle and high school girls, aimed at teaching design thinking and user experience (UX) testing using immersive technology. Our learner-centered approach introduced students to HCI principles such as usability and design thinking, scaffolding activities from brainstorming to testing XR tools and games, and culminating in students presenting early prototypes they designed. The camp was grounded in the LEDSEL (Learning Experience Design for Scaffolded Experiential Learning) framework, which guides experience design through scaffolded, experiential learning that considers environmental and sociocultural contexts. All students voluntarily presented their prototypes publicly, adopted professional UX language such as "ease of use" and "comfort," addressed usability issues, and engaged STEM speakers, while their interest in returning and pursuing STEM roles suggests benefits of this approach. Key design principles emerging from the camp include using XR as a participatory medium for critique and creation, embedding UX evaluation early, scaffolding from immersive experience to reflection and prototyping, leveraging peer mentoring, providing authentic audiences, and layering instructional support to scaffold STEM learning in informal, learner-centered contexts.

Keywords: Extended Reality, Learning Experience Design, STEM Education.

1 Introduction

Challenges in usability, comfort, mental effort, operation, physical interaction, and access exist when implementing immersive technologies in the learning environment [1]. In addition to these challenges, online instruction and technology literacy, can be barriers to success in STEM education and careers for underrepresented students [2]. Research that explores the gap in student success between minority students and their peers in STEM careers [2 – 4] suggests that Black and Latino students are underrepresented in STEM when comparing to their proportion in the total population [5]. Challenges in designing learning experiences increase the educational disparities impacting the attainment of higher education and economic opportunities in minority populations and should be considered when planning learning experiences to affect change. The curriculum described in this paper was created to address the disparities in STEM education and the need for future professionals proficient in STEM skills: design thinking and user experience (UX) testing for immersive technology (Fig. 1). Subsequently, the design case study describes in this paper looked to explore the implications of design decision for an informal XR learning experience be designed to support girls' identity development as designers and collaborators?

Fig. 1. Students engaging with VR, MR, and Science Museum Activities to Learn about HCI and Design Thinking.

2 Literature Review

2.1 Learning Experience Design to Build and Effective HCI Curriculum

Learning experience design (LXD) is characterized by the intentional integration of learner-centered, theoretically grounded, socio-culturally sensitive design informed by user experience design method [6 - 7]. These connections support learners in building meaningful emotional and social connections and even personal narratives around learning experiences [8-9]. Multimedia that is designed to be emotionally appealing and engaging can help learners form meaningful emotional and social connections to promote increased motivation and learning outcomes [10].

Learner-Centered Design. Learner experience design (LXD) is frequently distinguished from traditional instructional design due to the intentional focus on the learner [6]. Learner-centered design, derived from user-centered design in the early 1990s, puts the learner in the center of design choices [11]. Learner-centered design requires the designer to understand the learner's goals, motivations, diverse set of backgrounds, and needs. Applying this human factor engineering approach to learner-centered experiences with technology requires consideration to the context, tasks, tools, and interface(s) to the tools [11-13]. These factors keep LCD focused on the learner's goals, motivations, diverse set of backgrounds, needs, context, tasks, tools, and interface(s).

Context. A key difference between traditional user-centered design and learner-centered design is the variability of the context, as LCD is situated in a learning context [14]. Variations in context depend upon the specific learners and learning environments and expand with each iteration of a learning experience. Examples include the length of time learners have for the learning experience, the venue, the time of day, the learner's comfort with the venue, the learner's motivation, the learner's comfort with the learning tool implemented, the teacher's comfort with the learning tool implemented, the student's overall sense of self-efficacy [8]. LXD can benefit from synthesizing learners' interactions with the learning environment as well as with the learning space [14].

Sociocultural Aspects. Sociocultural aspects of a learner's identity can impact the way they engage with tools, peers, and instructors. Social learning theory maintains that social interaction and connection are essential to learning [15] and constructivist theory highlights the impacts of social interactions on learning and the construction of knowledge [16]. Literature consistently demonstrates the value of meaningful social connection for learning and self-efficacy [17-19]. Learning experience designers who understand the importance of meaningful social connections to support student learning and comprehension, will construct conditions and opportunities for social learning [9]. In addition, learning experiences can be deepened by encouraging students to share what they learn at home and at school to connect learning experiences to their lived experiences [20].

2.2 Scaffolded Pedagogical Approach

Scaffolded learning experiences support novice learners while guiding them to reflect on what they know, to identify needs and goals, and to provide individualized assistance towards their goals, while offering opportunities for learners to internalize and generalize their learning [20]. Scaffolding can manifest in many ways, including content, interactions, and levels of instructional support staff. Bloom's taxonomy provides "foundational action terms to describe the learning outcomes of users' interaction" [21, p. 134] and can be a helpful guide when integrating scaffolding, as students move from remembering to understanding, applying, analyzing, evaluating, and ultimately creating [22]. Scaffolding can also be guided by social learning theory, in which opportunities are constructed that allow for learners to engage in tribal knowledge sharing and "sense making" individually and as a group [9].

Additionally, scaffolding can be guided by levels of immersion, wherein novice students learn from low fidelity, didactic experiences with the level of behavioral and physical fidelity increasing according to the learner's level of knowledge and experience [23] (as shown in Figure 2). Effective scaffolding can move learners through progressively higher levels of knowing, increasing higher order thinking [22]. While precise details are frequently noted by experts engaged in high fidelity highly interactive immersive experiences. This level of scaffolding relies on the content knowledge, technology knowledge, and pedagogical knowledge of the instructional team [24-25], as the social and technological scaffolding rely on the instructional team members' comfort with the content, tools, and instructional roles.

2.3 Universal Design for Learning (UDL)

To increase effectiveness and inclusivity, LXD should also be informed by universal design for learning (UDL), an approach to learning design that seeks to account for learner differences by providing multiple means of representation, action and expression, and engagement [26]. UDL calls for equitable approaches that serve the needs of all learners, including offering content in multiple modalities. Providing diverse approaches can benefit all students. This extends from

3 Experiential Learning

Experiential learning theory describes learning as a process of learning by doing and adapting one's senses to new knowledge gained from the experiences [27]. Grounded in a synthesis of theories from Piaget, Bruner, Lewin, Dewey and William James [28], experiential learning theory identifies learning experiences as transactions between the learner and the environment [27]. Ideally, LXD will create a "holistic experience" focused on intended outcomes, in which learner's experiential learning leads them to sensing, feeling, thinking, acting, and relating to content [6, p. 87].

Experiential learning across levels of immersion. Immersive mediums are measured and described by many constructs from levels of immersion to degree of presence (i.e., the sense of being "there") to the degree of social presence or connection with others in a virtual space [29], as shown in Figure 2. Experiences on a two-dimensional (2D) flat screen that allow users to engage by moving through the simulation of three dimensions (3D) is frequently referenced as 2.5D, given its advances over 2D but falling short of 3D. 360° video allow users to passively observe a 360° experience that surrounds them but allows little to no ability to impact or engage with the environment, as shown in Figure 2. Augmented reality (AR) allows for the overlay of virtual objects over objects in the physical world, while mixed reality (MR) allows users to engage with virtual objects and physical objects (including using the user's own body as a controller) simultaneously [24]. Highly immersive interactive embodied (HIIE) VR experiences allow users to "inhabit a body" in a virtual space and actively engage with virtual objects through most of their five senses. This enhances the opportunities for learners to experience "learning by doing" in a variety of contexts and in environments that simulate the physical world. Finally, highly immersive interactive (HIIE) MR allows users to engage with virtual objects through their five senses while still engaged with their physical surroundings. This has the potential to allow learners to practice standardized experiences rendered virtually anywhere.

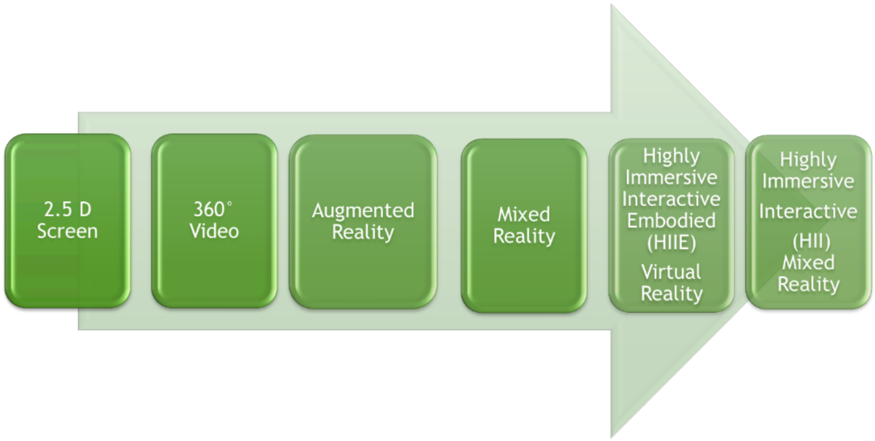

Fig. 2. Levels of Immersion from less to more immersive experiences. Note: Figure in public domain.

Experiential learning with immersive technologies. Immersive technology tools provide students opportunities to engage in “learning by doing” in standardized, reproducible experiences. Virtual reality (VR), mixed reality (MR), and augmented reality educational tools have been established as effective tools to engage students not only with educational content, but also with the context of the learning activities and opportunities for problem-based learning experiences [30-32]. In addition to the cognitive supports provided by these tools, the standardized nature of the immersive experiences supports scaffolding lessons from conceptual content to application and knowledge sharing between students [13]. A recent study identified key affective components of immersive VR for learning as presence, intrinsic motivation, enjoyment, and control and active learning, foregrounding the emotional impacts of VR as key to the potential educational impact [33]. Immersive technologies may impact not only learning value, but also sociocultural and emotional design aspects of LXD. For instance, designers can leverage immersive technologies and experiences designed to engage emotional elements of experiences to enhance a learner’s sense of empathy for others, deepen their connection with the context, or emphasize their connection with the content they are learning [24].

Based on the literature, the researcher developed the learning experience design for scaffolded experiential learning (LEDSEL) design-oriented framework to integrate XR, design thinking, UX testing, scaffolded instruction, and mentoring for informal experiential learning of STEM content, as shown in figure 3. The LEDSEL framework provided the foundation for the design, development, and implementation of a context aware Girls SURGE into STEM design thinking summer camp. This paper explores three research questions grounded in the application of the LEDSEL framework. First (RQ1) we ask how informal XR learning experiences should be designed to support learner’s identity development as designers and collaborators? The second research question (RQ2) derives from the first, asking what design principles emerged that could inform similar experiences. The final question, RQ3 asks, how can an instructional team scaffold STEM learning objectives in learner centered, experiential, informal learning opportunities.

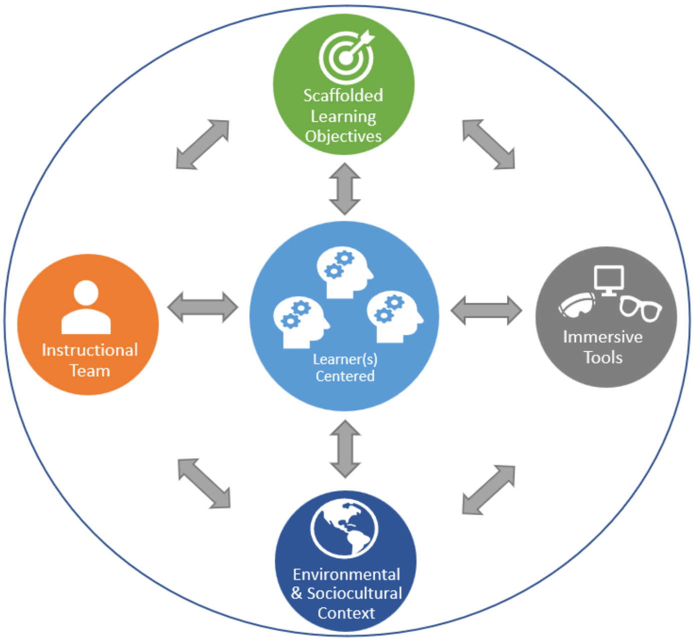

Fig. 3. Learning Experience Design for Scaffolded Experiential Learning (LEDSEL) of STEM Content.

4 Objectives and Activities

The goal of the curriculum was to introduce design thinking and user testing principles and apply them by analyzing and evaluating existing AR and VR experiences throughout the camp. In addition to evaluating existing tools, the students rapid prototype new design ideas. The goal of the camps was to have immediate impacts on the design thinking and user testing skills and sense of self-efficacy of girls involved. This is meant to model a sustainable process to impact the students engaged in the program. Further, this was done to empower the young people engaged to be able to understand and share skills related to design thinking and UX testing for immersive technologies with teachers and peers at their own schools. To our knowledge, few outreach programs integrate XR creation, iterative UX testing, and peer mentoring within a single, cohesive design-based learning framework.

Experiential learning of high demand skill sets such as design thinking has been shown to increase student preparation for academic and professional pursuit of STEM. Next, the increase in awareness of STEM careers can help these young women pursue STEM careers and become peer role models. Likewise, the process to teaching the young women to mentor younger students will have a long-term impact, by which we anticipate the mentoring model will help improve attitudes about STEM and intent to pursue a STEM career.

4.1 Objective 1. Introduce Students to Design Thinking, UX Design, and Testing

User experience design is a field of study concerned with understanding and improving the user's experience with technologies [7]. User experience (UX) research focuses on human interface with technology [34]. UX testing is a growing STEM career field that employs researchers and designers familiar with design and user research methodologies [35]. UX professionals investigate user experiences with product usability and efficacy. The concept of UX design integrates well with the design thinking principles of empathizing, defining problems, ideating on the possible solutions, prototyping, and testing. UX principles and design thinking work well to provide an iterative set of internal checks for efficacy of design and testing.

4.2 Objective 2. Increase Self-Efficacy with Immersive Tools and Empower Prosocial Behaviors

A primary objective of the LXD of the Girls SURGE Into STEM Summer camp was the increase in student self-efficacy around technology and thinking of themselves as designers. It was also important to the team that the students thought of prosocial approaches to applying technologies. VR was therefore seen as a potentially appropriate solution, because strategic applications of virtual reality experiences have been demonstrated to encourage prosocial behaviors [36].

The learning experience design described in this paper was learner-centered and driven by social constructivism and experiential learning theory, shaped by universal design for learning (UDL) with a scaffolded pedagogical approach. Brief lectures were followed by experiential learning opportunities, such as short science labs in which students could apply what they learned in lecture. Every design decision made while constructing the learning experiences considered how the interplay between the learners, context, instructional team, and technologies would advance learners toward the stated learning objectives.

4.3 Objective 3. Introduce Students to Immersive Technologies

The design of learning experiences requires knowledge of the learning objectives as well as the technologies to be integrated [25]. Effective integration of technology relies on the intersection of content knowledge, technology knowledge, and pedagogical knowledge. Technologies for the learning experience for the Girls SURGE into STEM camp were chosen based on the expertise and experience of the project staff. Apps that were selected could be accessed for free and provided a range of experiences from 2.5 D experiences to 360° video to highly immersive interactive experiences. This was important to expose the learners to the ranging levels of immersion so they could understand the different affordances of each tool and apply that to their evaluation and future designs.

5 Learning Activities Overview

This summer experience was designed to empower young women with design thinking principles that they could apply through analysis of existing virtual reality (VR) and augmented reality (AR) tools. The camp culminated in an opportunity for the learners to prototype their own design of a technology to solve a problem their student identifies. The learning experience design of this summer experiences depended on the collaboration of an instructional team with a range of education and experience working to integrate immersive technologies to achieve learner centered learning objectives within a novel and engaging context.

5.1 Learning Activity 1- Engage Students with Design Thinking

The instruction begins with an introduction to the components of design thinking (1. empathize, 2. define problems, 3. ideate on possible solutions, 4. prototype and 5. testing) begins with a lecture in which the students learn the definitions and are provided with examples of each step of the design thinking process. The lecture is followed with a brainstorming session in which the students are asked to identify a target audience for an intervention and encouraged to choose some group similar to themselves or a group to which they can relate. After identifying a user class for the intervention, the girls are given three to five minutes to empathize and think about the main points this user class may experience (empathize). Next, the students are asked to vote on the problems they are most interested in addressing and narrow down to one problem for the exercise. Upon identifying the problem, the students work as a class to define the problem, describe it comprehensively, including the context. Finally, the students work as a class to ideate on possible solutions to the identified problem and start drafting sketches of the proposed solutions. The facilitator leads the students to discuss the potential for failure of the proposed solutions and the approaches that the team might use to test the solution.

5.2 Learning Activity 2 – Introduce Students to User Experience and Testing

Students are introduced to user-centered design and usability on the first day of the camp after the introduction to design thinking activities. This begins with an explanation of user experience as defined by a user's perception as satisfying, entertaining, helpful, motivating, aesthetically pleasing, accessible, supportive of creativity, comfortable, and emotionally fulfilling (when appropriate) [37-38] as shown in Figure 4. After providing examples of UX success and failure, the facilitator relates this construct to the design thinking activities conducted with the class. This is done by asking specific questions of how the design would address the concerns of user experience. Students can also engage with this lesson by sharing user experience problems or successes they have had with technologies that they use regularly.

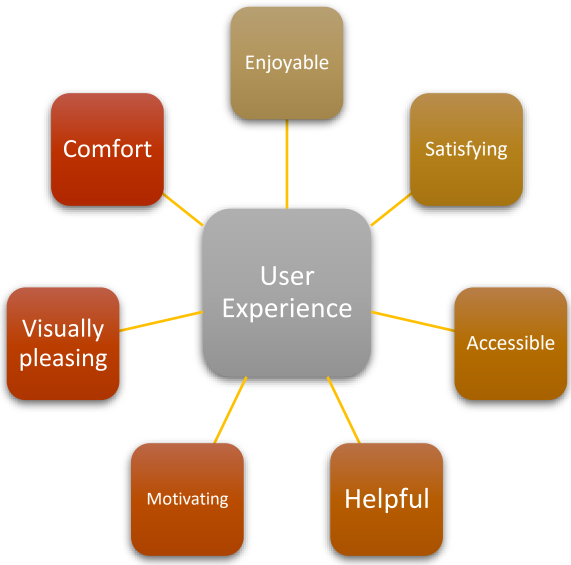

Fig. 4: Basic Elements of User Experience.

In addition to basic principles of user experience, the design also integrates a standard usability scale for the students to evaluate the technologies used. Students are introduced to the system usability scale (SUS) because it is a straightforward, short instrument that has been validated and is used in many user experience studies in industry and academia [39]. Students learn about and are asked to articulate the key factors of the SUS, learnability and usability.

5.3 Learning Activity 3 - Engaging Students with Immersive Technologies

On the first day of the summer camp, the students are introduced to the concept of immersive technologies as described above and pictured in Figure 2. After they learn about design thinking, user experience, and usability testing they are introduced to an array of immersive experiences across levels of immersion and interactivity. During play time after lunch and at the end of each day, students have access to a range of virtual experiences from Beat Sabre (a virtual reality music and motion game) to TiltBrush (a virtual reality 3D art experience). During the UX testing periods students are all asked to engage with the same experience for user testing and focus group practice. The apps used in the camp are the free apps: The Anne Frank Experience, ImmerseMe, Greenland Melting, Mission ISS, and SnapLens. The Anne Franke experience is a virtual experience that allows users to engage with the history of Anne Franke and virtually tour her home. ImmerseMe is a language learning virtual experience that allows learners to practice speaking and listening to another language while being immersed in an authentic location for the target language. Greenland Melting is a 360-video experience created by Frontline that allows users to follow a narrator around Greenland while learning about climate change. Mission ISS is an immersive experience in which learners can move around in a weightless environment while learning about space and the international space station. SnapLens is an application that allows users to create Snapchat filters that they can use on a personal basis or share on Snapchat.

5.4 Learning Activity 4 – Application of UX Principles to Immersive Technologies

After learning about design thinking, UX principles, and immersive technologies, students are empowered to begin user testing of the tools, given the UX principles. Senior students lead the UX testing as junior researchers. Focus groups at the end of experiences allow all students to discuss the usability and efficacy of different tools. They are also encouraged to explore the potential for using the technology in their own formal educational context.

6 The Team

The team design for these learning experiences was also guided by the value of scaffolding. Members of the team range from undergraduate students to professional mentors and graduate students. All of these members have experience in outreach programming for underserved populations, and some even belong to the target population.

Student Mentors. The high school peer mentors not only receive additional exposure to the content and presentations, but they are also given a stipend upon completion of their week of mentoring. Undergraduate and graduate students who serve as mentors are actively engaged with training for each of the immersive experiences before supporting the students. The undergraduate and graduate student mentors are required to complete human subjects training and acquire human subjects research certification. In addition to affinity with the learners due to age and other demographics, the student mentors may have a better understanding of the parts of the learning process that novices may struggle with. At the end of the first camp, camp organizers recruit high school students to support the delivery of the content for the middle school workshop. This is part of our intentional LXD in order to help young women shift their perspective of what scientists look like and be empowered to share and create STEM content for educating and empowering others.

Professional Mentors. Every week, the students survey the virtual and augmented reality STEM content, apply design thinking experiences, conduct user testing on AR & VR educational tools, and prototype their own STEM educational tools. Each of the invited STEM professionals provide 20-30 minute presentations about their field and answered questions. Each week, the students are visited by speakers from the natural sciences, local engineers, and scientists from our partners at Apple, Facebook, NASA, and various universities. During the exploration of STEM education apps, girls are also introduced to leading professionals in STEM careers.

The diverse faculty and student leadership, varying in age, degree earned, and mastery of immersive technology, paired with the peer mentoring and guest lecturers, contribute to the increase of student involvement with diverse women as scientists. The process of analyzing the AR/VR STEM tools will not only teach the students about the career field and process of user experience testing, but it also exposes them to content from 40 science apps. Students all develop a prototype of an idea they create or iterate upon. Finally, modeling mentoring and giving students opportunities to mentor peers in the workshop increases their ability to be mentors.

7 Methods

This mixed methods research study aimed to provide insights into underrepresented middle and high school students (ages 11-17), mentor, and teacher engagement with and perceptions of immersive media tools for learning and student engagement. The camp was hosted at a large local science museum, the Fort Worth Museum of Science and History. Participants were recruited through email promotions sent to guidance counselors and the university website, and through museum promotions, including emails and social media, during the spring semester. During the one-week camp, students had two hours per day of guided instruction between use of technology and mentor presentations, as well as one hour of VR free play in headsets with appropriate VR games and learning tools. The camp ended with students sharing their design plans in presentation to their peers, family, and friends.

7.1 Participants & Recruitment

Recruitment was done through the Fort Worth Young Women's Leadership academy and local middle and high schools, restricting participation to students aged 11-18. Students were registered for the summer camp online and both parents and students completed the informed consent and assent forms and multimedia release forms after the student and or the parent read the consent forms. Selection criteria for the camp was meant to include evaluation of the student application essay and need. Similarly, the camp was meant to empower young women interested in STEM, but young men were not excluded from the camp. Given the novelty of the camp, all participants who applied were invited to participate. The camp recruited eleven young women in the North Texas area to introduce them to augmented and virtual reality STEM content and introduce them to STEM careers.

7.2 Data Collection

When students registered for the camp, the research team collected basic demographic information and on the first day of camp students and parents completed the informed consent/assent for minors forms and photo release forms. Participants and parents were informed that they did not have to consent/assent in order to attend the free summer camp. For tacit assessment, a basic pre-posttest asked students to list as many STEM careers as they can in a two-minute period. Students were introduced to AR & VR technologies and instructed on design thinking and user testing approaches as described in the camp design section above. Following the immersive technology activities, students were asked to evaluate their experiences and apply what they learned to their own design of AR and VR tools. Throughout the one-week camp, eleven girls were mentored by peers, older students, and leading professionals in STEM careers who volunteered to share their experiences.

7.3 Context

The one-week summer camp was hosted at a local science and history museum, an environment rich with opportunities for learning that the students found positive and enjoyable. The summer camp was designed with week 1 focused on upper-level (9th – 12th) grade students. Week 2 focused on lower-level (6th – 8th) grade students with students from week one acting as mentors. The setting of the museum added to the depth of learning through opportunities for emotional engagement and engagement with the environment, as shown in Figure 5. The context also allowed for safe, simultaneous use of multiple technologies, as well as for students to have regular support with concepts or technologies. This was all balanced with regular activities in the science classroom that ranged from brainstorming and prototyping to short lectures, as shown in Figure 5.

Fig 5. After design thinking brainstorming, learners explore museum, try mixed reality and listen to guest speakers.

8 Results

Eleven girls (ages 11-17) participated during the sessions, with high school students learning during the first week and middle school students learning both from instructors and from high school mentors who were paid to attend as mentors during the second week. The basic daily schedule was broken into four learning periods separated by three breaks that included snacks, lunch and fun daily activities ranging from a museum tour to freeplay on VR games. Each day's learning included a mini talk with an introduction to new HCI concepts and skills, hands-on activities, a short talk about an area of STEM delivered by a professional in the field, and time for practicing skills learned that day.

During the VR experiences, students displayed varying levels of emotion with each immersive experience. Of the three VR applications used, Mission ISS brought reports of frustration and cybersickness. Students reported less frustration and an easier user experience with Greenland Melting. Students displayed the highest level of positivity when working with the language learning tool, ImmerseMe, as not only were students engaged, but they also requested to continue after the allotted time. Data and feedback received from participants described areas of improvement in the construction of a reproducible camp for educational and community settings devoted to STEM awareness and education in underrepresented populations.

8.1 Learning Outcomes

The students engaged in this program learned about and experienced a range of immersive technologies, as each student engaged with at least five immersive tools for at least 10 hours total. The students also engaged with different tools for STEM education. Students were taught to critically evaluate the tools and use their evaluations to guide their own design of AR and VR tools to help other young women learn about STEM. The most impressive of the learning outcomes from the experiences was the final presentation of design prototypes. Each student presented their own prototype, framed around the design thinking principles. First, they explained the problem they identified, next they described their solution with a description of the context and the users, and finally they explained how they would know if their solution was effective. Every student was given the option to only show the teacher their prototype, but every student chose to give a presentation to the group and parents who attended the last day.

8.2 UX/Usability Outcomes

By the third day of the camp students were able to lead focus group discussions about the apps they tested using the language of the system usability scale (SUS). Students learned to identify UX issues daily while also guiding them in design thinking activities from empathizing with potential users to storyboarding and presenting ideas. This was evidenced by the fact that students frequently return to camp explaining situations that they had observed of poor usability outside of the learning context. This was also made evident on the last day of camp in the student discussions of their prototypes.

8.3 Rapid Prototyping /Public Speaking Presentation Outcomes

After introducing the concepts, the team used the Socratic approach to demonstrate approaches to rapid prototyping and team provided brief explanations and anecdotes. Ultimately, given the short duration of the camp, the students were guided through paper prototyping, a lower fidelity version of prototyping. Students were mentored by faculty, undergraduate students, graduate students, and peers as they prepared their prototypes. Students were given the option to present their prototypes on the last day, and every student chose to present their prototype to the group and the family guests on the last day. The student's presentations included reports of having learned a great deal and wanting to return to the camp in the future. Likewise, the students were able to answer questions about their designs and audience members indicated a sense of awe about some of the presentations and stated intentions. Each of the students also demonstrated a capacity to be our future colleague by describing which technologies they would want to use in the future using language of UX testers, such as ease of use or comfortable to use.

Another interesting trend emerged in the brainstorming and rapid prototyping, which was the students leaning in to discuss things that they were not comfortable discussing in rooms with boys. In the camp, girls discussed feminine issues, such as their menstrual cycles, as a problem that might be addressed with technology. This aligns with the LIDEL Consideration of sociocultural context.

8.4 Mentoring Experience Outcomes

The group of underrepresented girls was exposed to rich experiences, female STEM guest speakers, and immersive technology that would otherwise not have experiences. The invited professionals and mentors frequently noted that the student experiences were more profound than expected. The outcomes of the experience we designed were students eagerly requesting more time to learn with us after designing creative projects that reflected their application of design thinking and confidence in the presentations of their ideas.

8.5 STEM Career Awareness

Students were given one minute to list as many STEM Careers as they could think of in one minute on the first day of camp. The test was run again on the last day of camp and the numbers of listed careers increased for each student. Similarly, the student comments after the camp indicated an increase in awareness, as some students indicated that they wanted to do the jobs of some of the speakers (entomologist, chemical engineer, material scientist, VR designer, and game designer).

9 Conclusion

Eleven participants (ages 11–17) took part in a one-week informal XR design thinking summer camp informed by the LEDSEL design framework. Participants engaged with multiple immersive technologies, participated in structured UX evaluation and design activities, and collaborated with peers, near-peer mentors, and STEM professionals. Results show that informal XR learning experiences supported learners' emerging identities as designers and collaborators (RQ1) by positioning participants as active evaluators and creators of XR experiences rather than passive users. Learners adopted UX and usability language in discussions, engaged in peer mentoring roles, and voluntarily presented design prototypes to peers and family members, indicating increased confidence and ownership of their work.

Exploration of the design process and implementation demonstrated that informal science learning in XR (RQ1) supports identity development when learners are treated as designers and collaborators with voice, agency, and audience. Learners were not only engaged with the hands-on opportunity to "play" in VR, they also were engaged throughout the evaluation process, mentor presentations, and design stages. All students voluntarily presenting their prototypes publicly, adopted professional UX language, "ease of use," "comfort," usability issues, and asked questions of the STEM speakers who attended the camp. Likewise, students' expressions of interest in returning to the camp and pursuing STEM-related roles suggests potential benefits to this approach.

From these outcomes, several design principles emerged that may inform similar informal XR learning experiences (RQ2). These include designing XR as a participatory medium for critique and creation, embedding UX evaluation practices early, scaffolding learning from immersive experience to reflection and prototyping, leveraging peer and near-peer mentoring to support collaboration, and providing authentic audiences for learner work. The summer experience also suggests that effective informal XR learning experiences combine immersive technology with social learning, reflection, and public expression. Scaffolding in this camp also demonstrated the effectiveness of having mentors who could build scaffolds and provide support to students socially to get students up to the level of their peers.

Finally, findings indicate that instructional teams can scaffold STEM learning objectives in learner-centered, experiential, informal contexts (RQ3) through progressive exposure to immersive technologies, low-fidelity prototyping, short instructional inputs paired with hands-on activities, Socratic mentoring approaches, and layered instructional support across instructional roles.

9.1 Limitations

This study was limited by the small sample size. Although results may not be generalizable, a small number of attendees provided an ideal environment for testing the curriculum. The small group size also allowed for almost a 1:1 ratio of leaders to students, resulting in more attention to individual student needs and interests. This also demonstrates another limitation, as it is hard to tell if this camp would have run smoothly with only 3-4 facilitators.

The study was also conducted inside an open museum, requiring the team to stay flexible according to the needs and expectations of the museum. While research in a working setting can provide insight into applications of the curriculum, student experiences in the museum may have impacted the students' overall impressions of and responses to the camp. Finally, self-reported surveys such as those used for data collection do not ensure that participants provide complete, honest, or accurate information. Survey respondents may misunderstand questions, rush to complete the survey, rank all items the same, or answer according to what they think the leaders would like to hear.

9.2 Future Work and Contributions to LXD

The potential to empower the learners in this case to feel capable of pursuing well-paying STEM careers is a major outcome of the LXD described in this paper. Further, students who participated went back to their home schools with more skills, increased self-efficacy, and a model of mentorship. This experience, though small, had extensive impacts on the students involved and has the potential to inform future LXD. Future work includes replicating this camp with different groups of students and increasing the number of participants to achieve statistical significance. Future work can also replicate the activities in this experience for different demographics.

Discussion

Interaction is important as it relates to technology adoption, cognitive load, and usability. While each of these perspectives describe elements of interaction, they fail to comprehensively detail how educators should design for both usability and learning with an interface. The objective success of the camp demonstrates the impact of learning experiences designed with the learners at the center, informed by learning objective, context, and available technology. This iterative design will be adapted and evolved every year, as the learners, context, and available technologies change.

These findings extend theory on experiential learning, learner-centered design, and social learning by demonstrating that immersive XR experiences, scaffolded design thinking activities, UX evaluation practices, and peer mentoring can be deliberately combined to support identity formation, engagement, and skill development in informal STEM contexts. Likewise, the application of the LIDEL design framework could be used as the foundation to create similar experiential learning experiences across learner types. The authors encourage use of the framework across domains, contexts, and demographic groups. For example, applying LIDEL to boys' experiences suggests providing safe, single-gender spaces where they can explore topics they might hesitate to discuss in mixed groups, before introducing structured cross-gender collaboration to support perspective-taking.

Acknowledgments

We would like to acknowledge and thank the American Association of University Women (AAUW) for supporting this research through funding and mentorship. We would also like to thank the Fort Worth Museum of Science and History for hosting our summer camp. Special thanks to the student volunteers and mentors from the SURGE XR lab at University of North Texas who supported the research, but did not satisfy the threshold for authorship.

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