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Exploring the Developer Challenges of Creating Multi-Platform VR Museum Experiences in a Post-Secondary Design Studio

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Abstract. In this paper, we explore the challenges of creating multi-platform virtual reality museum prototypes within a post-secondary design studio. While most contemporary virtual reality research focuses on head-mounted displays, their accessibility limitations suggest that better guidelines for multi-platform development (creating the same virtual reality application for multiple immersive and non-immersive virtual reality platforms - desktop, mobile, and head-mounted display) can increase virtual reality inclusion, essential for public learning institutions such as museums. However, few studies examine and disseminate the challenges developers face when doing so. Over 12 weeks, 26 post-secondary student developers collaborated with a Canadian science and innovation museum client to create 7 multi-platform virtual reality learning applications. Weekly student developer reflections, prototype presentations, in-class observations, and a final focus group provided qualitative data that were analyzed using reflexive thematic analysis. Initial findings reveal 5 developer challenges and 5 framework developer considerations for creating multi-platform virtual reality experiences within a virtual museum context. This exploratory study highlights the need for further research into developing more inclusive virtual reality experiences for learning.

Keywords: Virtual Reality, Development, Multi-platform VR, WebXR, Virtual Museum.

1 Introduction

Virtual Reality (VR) development has flourished over the last decade, driven by the availability of lower-cost hardware and numerous development tools and frameworks [1, 2]. However, the most common VR platform – the head-mounted display (HMD) – remains inaccessible to many people with mobility challenges [23] and those prone to motion sickness within virtual environments [3, 4]. Additionally, these HMD-related challenges extend to social accessibility issues that may hinder task performance and reduce willingness to use unfamiliar technology in front of others . These challenges are significant when considering VR for general population use-cases – such as publicly funded galleries, libraries, archives, and museums (GLAM) [8]. For example, as public learning institutions, museums are urged to become "accessible to all Canadians by creating a mix of physical and virtual spaces" [9]. Yet, in Canada, it is estimated that 27% of the population above 15 years old (20% of youth between the ages of 15-24) have disabilities that impact their daily activities, such as mobility, mental health, and sensory challenges, such as low vision and hearing loss [10]. In exploring potential solutions, researchers have proposed that more inclusive VR development should focus on supporting multiple VR platforms, such as personal computers (desktops/PCs), mobile devices, and HMDs [5], consistent with earlier VR eras that considered VR to encompass platforms beyond the HMD [11].

Additionally, multi-platform VR appears to be a natural evolution towards realizing mainstream social VR, i.e., the "metaverse" [12]. For example, in 2020, VRChat CEO Graham Gaylor reported that the desktop version accounted for 48% of the platform's users [13]. The continued development of desktop and, more recently, mobile VRChat platforms [14] demonstrates that non-HMD VR platforms are essential to a healthy social VR ecosystem and greater inclusion. This paper is motivated by the limited research on designing and building VR experiences that share equivalent features across multiple VR platforms.

The study described in this paper builds on previous research exploring the development of VR experiences [1, 15, 16], though within the context of developing virtual museum learning experiences [7, 17]. Specifically, we build on Ashatari et al.'s augmented reality (AR) and VR authoring paper [1], which did not specify which VR platforms developers targeted, and on Coelho et al.'s systematic review of VR authoring tools, which considers only HMD "immersive" VR [15].

Additionally, although Scavarelli et al.'s developer/creator interviews [17] and Zubair and Anyameluhor's creator studies [16] addressed multi-platform and VR development, they were limited in scope, suggesting that a more systematic study is warranted. Thus, as VR development is still an emerging field, particularly when focusing on developing VR for multiple immersive and non-immersive platforms, we expand upon these prior works to explore the unique challenges of developing multi-platform VR by end-user developers, who "are opportunistic in terms of coding and do not always have a clear plan for their development needs" [1] within the more concrete context of virtual museum learning experiences.

2 Aims and Scope of this Work

Over 12 weeks, students in a third-year post-secondary design studio were tasked with developing an accessible, multi-platform VR prototype experience for a museum client – Ingenium's Digital Innovation Lab [18] – as an exploration into how to create more accessible immersive virtual learning environments. Ingenium's mandate is to collaborate with partners to explore innovative ways to improve all Canadians' access to its museum's collections and experiences [19], with accessibility a federally mandated requirement [20]. Museums are exploring VR to attract and engage visitors, particularly younger audiences, while promoting experiential learning mandates [21] to structure learning through interconnected personal, sociocultural, and physical contexts [5, 21]. However, with over 8 million people in Canada living with one or more disabilities [1], museums must consider how to develop inclusive museum technologies, particularly as rapidly evolving technologies such as VR continue to develop.

In this study, 26 student developers self-organized into 7 teams, each comprising 4 to 5 members, to develop VR museum prototypes. Researchers collected longitudinal data on student developers with little experience in web programming and none in VR development [1]. The WebXR-based development tools A-Frame [22] and Circles [17] were chosen as teaching and platform tools because they have been used in prior multi-platform VR development studies and are designed to support more accessible multi-platform VR [7, 16, 17]. Data were collected from each participant's weekly reflections, observations of presentations (alpha, beta, and final), an end-of-project focus group, and informal participant-observer notes made throughout 16 4-hour work periods over 12 weeks. Our primary research question (RQ) is:

- What challenges do student end-user developers face when creating multi-platform VR experiences for virtual museums?

The contributions of this paper are:

1. Exploring how student end-user developers create multi-platform VR virtual museum experiences.
2. Identifying five challenges in multi-platform VR development.
3. Defining five considerations for multi-platform VR framework developers to address these challenges.

3 Related Work

Multi-platform support for VR learning experiences is essential as it enables more inclusive participation in VR learning activities. Through a universal design for learning (UDL) approach [5], VR platform selection allows users to choose the platform that best suits their preferences and abilities, or to prefer a specific VR platform depending on the task [7]. Although contemporary VR research and development primarily focus on HMDs, many other VR platforms, such as mobile and desktop devices, are also studied [11]. However, unlike the ubiquitous web-based "responsive-design" principles used for 2D content [23], few studies consider developing equivalent VR experiences across multiple VR platforms, e.g., supporting content and interactions across HMD, mobile, and desktop VR platforms, beyond exploratory works describing early systems [17, 24]. These examples range from the new WebXR API's objectives to work across a variety of immersive and non-immersive VR platforms [25] in an attempt to "democratize interactive, immersive experiences" [26] to HMD-focused experiences modified to work on desktop or mobile platforms on social VR platforms such as VRChat [27] and Rec Room [28] to make their respective social VR experiences more accessible.

There are also "cross-reality" or transitional interfaces, which involve using multiple platforms to complete a task, each suited to various sub-tasks [29]. For example, Wentzel et al. [30] describe "Switchspace" as a design space for switching between desktop and HMD VR, and found that "peeking" interactions made a cross-reality workflow faster, more comfortable, and less cognitively demanding than switching between HMD and desktop VR[30]. However, few studies have compared desktop, mobile, and HMD VR simultaneously beyond prior work, suggesting that WebXR search and selection performance aligns with previous studies [31] and that users may prefer desktop and HMD VR over mobile devices due to a smaller Field of View [32]. Formative studies suggest that social context and task type may affect VR platform preference [7]. The increasing diversity of VR hardware, platforms, and users has driven the need for multi-platform development frameworks that enable developers to create equivalent VR experiences across platforms [17, 24]. These frameworks also include adaptable input systems to ensure a consistent user experience across platforms [24].

Several frameworks have emerged to support multi-platform VR development. Unity3D and Unreal Engine are the most prominent, offering extensive multi-platform capabilities. Additionally, tools such as Nvidia's Omniverse help increase the interoperability of development applications [33]. However, building for multiple platforms simultaneously includes compiling unique applications and potentially using platform-specific code for each platform, and most papers describing VR authoring tools using these engines do not appear to discuss VR beyond the HMD [1, 15, 33, 34]

Another significant multi-platform VR development platform is the WebXR API [25], which enables the development of VR content accessible via supported web browsers, allowing for multi-platform access with minimal platform-specific code. WebXR research can also simplify the distribution of VR experiments [26, 35, 36], as frameworks such as A-Frame [22], a web-based VR development tool built on the WebXR API, enable researchers to create VR applications accessible remotely across various VR platforms. However, beyond formative studies of WebXR VR frameworks, which suggest that browser performance, content creation, learning, and documentation are lacking [7, 16], few studies thoroughly analyze the challenges developers face when creating multi-platform VR.

4 Methodology

In this section, the study design, data collection, and data analyses, along with critical ethical concerns, are described. This work was approved by the research ethics board of the institution where this study was conducted (Algonquin College, protocol #2024-Jan-Scavarelli).

4.1 Study Design

Participants were tasked to create a multi-platform VR experience for a museum (Fig. 1). The museum client wanted an accessible and inclusive experience where visitors from around the country could engage digitally inside one of their buildings to showcase the building and its artifacts in an educational context using "VR escape room" as a design prompt. They also requested that the VR experiences be related to the museums they manage, utilizing the museums' provided 3D-scanned artifacts and text and image artifact database. The client participated in a class introduction and provided feedback throughout the development process after the alpha, beta, and final presentations.

Fig. 1. Three of the seven multi-platform VR prototypes were developed for a museum client in a design studio class. Left: an escape room puzzle using planets and clocks. Middle: a mini-game that requires creating a virtual television stage to match an image. Right: solving a number puzzle using a cathode ray tube (CRT) television.

Available for in-class testing and overnight lending were 2 Meta Quest 3 HMDs and 2 Meta Quest 1 HMDs; two groups used their personal Meta Quest 2 devices. Researcher 2 (R2) acted as a neutral "participant-observer" and collected all consent and pre-study questionnaires, semi-structured observational and focus group audio recordings, and all text-based student milestones.

4.1.1 Participants and Recruitment

We recruited 26 of the 29 students enrolled in a 3rd-year design studio in a design and technology post-secondary program, using convenience sampling because the sample was drawn from a single course. This design studio was chosen as it introduces students to immersive technologies, including VR web application development and networking, and it involves working with a museum client to build multi-platform VR experiences. This classroom setup enables repeated measures over a single semester in a more intimate setting, yielding deeper insights into the individual and group dynamics of developing multi-platform museum VR experiences.

In the design studio's first class, the study was introduced, and students were given the option to voluntarily consent to participate. The three students who did not consent were excluded from the study's analysis. From a pre-study questionnaire, participants are very/extremely comfortable using digital technologies (92%), use digital technologies at least 30 hours a week (84%), are "extremely uncomfortable/not comfortable" developing them (93%), and 19 participants use HMD VR 0 hours a week (73%), with the other 7 (27%) using HMD VR 1-3 hours a week.

4.2 Software

Student participants created their VR experiences using the Circles XR learning framework, which leverages the widely adopted A-Frame foundation and its open-source, inclusive design focus across multiple VR platforms [37]. A-Frame was chosen due to the large developer community and prior research using it [38]. Mozilla Hubs and Frame were also considered; however, Mozilla recently discontinued development of Hubs [39], and Frame [40] is closed-source. Like Mozilla Hubs, Circles also requires Node.js and Node Package Manager (NPM) to support standard web application development processes. Participants were expected to collaborate using GitHub for source control and project management tools, such as GitHub Projects or Trello. They used the Visual Studio Code integrated development environment (IDE) to develop their VR experiences and manage the required JavaScript software packages.

4.3 Data Collection

This study is exploratory and interpretive; thus, our data rely on textual and audio-transcribed materials collected by R2 from student participants to more naturally capture how participants design and develop their multi-platform VR experiences for the museum client. SurveyMonkey, an online form service, collected consent and pre-study questionnaires. During the two-month data collection period from the first project milestone to the final project submission, R2 observed participants and engaged with them to elicit information on challenges, successes, and developer workflows. This data, along with the 10 weekly student milestones from each participant, R2 observations of the major milestone presentations (alpha, beta, and final), and a concluding semi-structured focus group with R2 after the final submission, was transcribed, de-identified, and placed into a folder of text files to be coded by R1 and R2 after final grades were submitted.

The instructor of the design studio, a Circles and A-Frame contributor and author of this paper (R1), was involved in the study. To satisfy ethical requirements, R2 acted as a neutral "participant-observer" and collected all consent forms and pre-study questionnaires, semi-structured observational and focus group audio data, and all student milestones. After data collection, all data were transcribed and de-identified using participant codes. Only after all final grades were submitted could R1 access the anonymized data and begin coding independently and collaboratively. After initial coding, R2 worked with R1 to analyze emerging themes. Due to potential identification challenges, the institution's research ethics board did not permit us to collect age and gender information in our pre-study questionnaire. However, as the course is in the third year and has no mature students, we can assume that all participants are in their early twenties. This program and class have historically had an approximately even gender distribution between men and women.

4.4 Data Analysis

As noted by qualitative researchers, thematic analysis (TA) is a "useful method for working within a participatory research paradigm, with participants as collaborators" [41]. Specifically, what Braun and Clarke reframe as *reflexive* TA in later publications, to separate it from other forms of TA that may require reliability measures [42], is to highlight how "qualitative researchers are always thinking, reflecting, learning and evolving."

We followed the steps suggested by Braun and Clarke [41], with two researchers (R1 and R2) involved in the process. R2 first *familiarized themselves with the data*, conducted an *initial coding pass in Excel, and then identified themes*. After submitting the final grades, R1 independently familiarized themselves with all transcribed and de-identified data, conducted an initial coding pass using qualitative software tools (Taguette and NVivo), and searched for themes. At this point, R1 and R2 reviewed *themes* and collaborated to *define and name themes*.

Table 1. This table summarizes the 5 primary themes that emerged from the study's coding process, as described in Section 4.

5 Multi-platform VR Developer Challenges (DC)		
DC1	*The VR Development Platform Biases Multi-Platform Development*	The platform used for VR development receives priority for development.
DC2	*Expectations Constrain Creativity*	Feedback from peers, clients, and knowledge limitations constrain creativity.
DC3	*3D Software and Optimization Workflows Create High-friction*	3D formats require moving between several 3D software packages.
DC4	*Coding and Development Tools Provide an Unstable Foundation*	VR programming is made difficult by inadequate learning, unstable tools and frameworks, and optimization challenges
DC5	*Experience Design is Visual-First. Accessibility and Sound Low-Priority*	Accessibility and sound are considered after the VR experience has been designed.

5 Results

This section describes five multi-platform VR developer challenges (DC) identified from the thematic analysis described in our methodology section.

Table 2. This table showcases the supported VR platforms for each group project: desktop VR (DVR), mobile VR (MVR), and HMD VR (HVR). The table highlights whether features beyond Circles' specific implementation were entirely (●) or partially implemented (◐).

Which Platform and Whether Social and Accessibility Features Were Implemented in the Final 7 Group Projects				
Group	DVR	MVR	HVR	Accessibility
1	●		●	●
2	●	●		◐
3	●			
4	●	●	●	
5	●	●		●
6	●	●		●
7	●			

(DC.1) The VR Development Platform Biases Multi-Platform Development: Participants entering this course had experience developing for desktop platforms and focused their efforts on those platforms for this project. However, as noted in Table 2, few participants completed development for all VR platforms. Specifically, only 2 of the 7 groups demonstrated HMD VR, and 4 of the 7 groups demonstrated mobile VR (Table 2). Researchers observed that participants found the desktop the easiest and most effective platform for debugging and hosting, and often deferred development and testing of HMD and mobile platforms until the end. Sometimes this led to the inclusion of unsupported mobile and/or HMD VR platforms in the final submission (Table 2).

(DC.2) Expectations Constrain Creativity: Participants faced several expectations that constrained the design and development of their projects. Beyond the expected competing visions among group members, who "struggled to come up with an idea everyone was happy with," there was also consternation about the instructor's and the client's accessibility requirements. Participants found these expectations to be a constraint on their creativity and difficult to implement due to a lack of clarity. One participant stated, "I felt it was less of an incentive to actively try to go farther with the project because we had to create something for [museum client] specifically and not a VR project of our choosing." This sentiment is likely found in many undergraduate and professional group projects; however, when accessibility requirements are integral to the success and potential deployment of a general-public-facing project, it is particularly noteworthy. Accessibility as a requirement is an opportunity for creativity, as it requires developers to consider how people navigate virtual space in different ways. However, the participants' perceptions reflect an attitudinal barrier commonly observed in accessibility work: treating this as a chore rather than an opportunity to try something new [43].

(DC.3) 3D Software and Optimization Workflows Create High Friction: Modelling and texturing of 3D models were the primary focus of developmentacrossr most projects. However, students noted many challenges in using 3D software, such as Autodesk Maya and Blender, to optimize models for less powerful mobile hardware. For example, Autodesk Maya does not support the glTF 3D format – the "JPEG of 3D" [44] – that A-Frame and Circles recommend. Thus, most students had to use Blender to export Maya-created FBX models to the glTF format. Additionally, the 3D models the museum client supplied were very high-resolution scans, which pose challenges for VR on lower-powered platforms such as mobile devices. For example, one participant stated: "We have little experience dealing with these types of models in A-Frame, so it took quite a bit of fiddling and some research to get the textures to load in properly." Other students struggled with maintaining the authenticity of the client-provided 3D scans while reworking the models to be more performant - "I struggled a bit with the creation of some models, mainly because I want to make sure they match the reference."

(DC.4) Coding and Development Ecosystems Provide an Unstable Foundation: Programming was discussed less frequently in milestone reflections and researcher observations, suggesting that less time was allocated to programming for each VR experience. Participants found developing with JavaScript, A-Frame, and Circles challenging, making it difficult to achieve the desired result. For example, one participant stated, "The code was sluggish, and some game elements like the artifacts, printer, and keyboard didn't function properly initially." Additionally, participants observed that tools are esoteric and rapidly changing. For example, students struggled with the WebXR API's security settings, which require all development code to be served over HTTPS to access device orientation and position in mobile web browsers. Additionally, participants noted that learning pathways are inadequate because Circles' documentation was less extensive than A-Frame's and was not recognized by AI tools such as ChatGPT, which participants regularly used for debugging. For example, one participant stated, "Being able to ask ChatGPT about something makes a world of difference … because you don't have to dig to spend hours digging through documentation."

(DC.5) Experience Design is Visual First. Accessibility and Sound are Low Priorities for Students: Participants focused heavily on visual design before considering sound and accessibility, despite the client's urging that these aspects be addressed from the outset. Even with client and instructor feedback emphasizing accessibility as a focal point of the experience, only 4 of 7 groups incorporated some form of accessibility (Table 2). Participants lamented client and instructor feedback that suggested more accessibility without clear standards on what it looks like – "Why are we trying so hard to meet their requirements? Accessibility for what?" This highlighted a disconnect in communication. For the client, accessibility with an immersive focus was the priority. However, the importance of this did not get across to the students fully, and the end users, people who may be experiencing disability, were lost in the design. Some participants looked to the web and to accessibility principles for gaming to implement multiple languages, colour contrast settings, and Circles accessibility features such as teleport pads and narration audio. Additionally, researchers observed that sound design was not a priority for all groups except 2 (which included participants who identified as musicians). One participant echoed a common sentiment, noting that audio had taken a lower priority than other visual features: "Audio has continued to progress, but will be delayed."

6 Discussion

This study identified five emerging themes for end-user multi-platform VR developers and multi-platform VR framework developers. Some of the themes discussed in the results section echo previous observations on non-multi-platform VR, such as numerous development uncertainties, barriers to testing, and a lack of concrete design guidelines and examples, suggesting that much work remains several years later [1, 15, 33]. However, the focus on multi-platform VR over a more extended study period, within a narrower focus of museums, allowed us more profound insights into these challenges and the identification of new ones, revealing perceived tensions between accessibility and authenticity if accessibility is not considered from the start, nor its importance understood by those developing the product, in addition to subtle tensions between creator (CX) versus user experience (UX) considerations, and support for immersive versus non-immersive development platforms. Although some of these conflicts may seem intuitive, preliminary evidence of their existence in the less-studied field of multi-platform VR development is insightful. This section highlights five multi-platform VR framework developer considerations (FDC) for building more usable multi-platform VR development Frameworks.

(FDC.1) The Need for Clearer VR Accessibility Requirements – *"Another challenge was incorporating more accessibility features, since we were so focused on having a complete and enriching experience first."* Accessibility was a late consideration in the final stages of participants' VR experience development, despite the client's urging otherwise. Accessibility is a legal requirement for Canadian federal institutions and must be considered in digital products to ensure inclusive experiences for all. One of the challenges the industry faces is that technologies are advancing more rapidly than the knowledge of accessibility in these areas. Further research is needed on these emerging mixed-reality products. While the client had hoped the students would take on exploring this challenge, some felt it was in direct conflict with their goals. This indicates a greater need to introduce accessibility early in academic curricula as a prerequisite for these classes, to help students understand the importance of accessibility and inclusion, and to view accessible design as a challenge to improve a product for more people, rather than a hindrance. Part of the challenge was that the VR accessibility requirements were not clearly defined by the client, the instructor, or the framework itself. Even with guidance on universal design principles and the museum client's suggestions regarding web-based accessibility design, the pathways between 2D content interactions and more immersive 3D content and interactions remained unclear to participants. This lack of clarity suggests that rapidly evolving emerging technologies make it difficult for clear accessibility standards to keep up. However, accessible design needs to be considered more broadly across post-secondary education so that students fundamentally understand its importance. VR frameworks, such as A-Frame and Circles, should clearly articulate and embed accessibility design principles in their introductory documentation and APIs.

(FDC.2) Increase Transparency Around Authenticity and Accessibility Conflicts in Immersive Representations – *"Personally, I struggled a bit with the creation of some models mainly because I want to make sure they match the reference, and some of the models do have a lot of detail"*: During the study, many participants noted challenges in building a museum experience for VR, feeling that the assets produced needed to precisely mimic the highly detailed 3D models supplied by the client, despite the fact that this was not a requirement in the brief. There can be a conflict between creating a VR experience that runs on more accessible mobile hardware and the expectations of clients and developers. For example, can the affordances of immersive VR in learning still be applied to non-photorealistic virtual environments? Perhaps [45, 46], but a conversation will be required for those new to VR, such as end-user developers and VR clients. Developers and stakeholders will need to discuss the acceptable ranges for accessibility and authenticity at the beginning of the project, as including both in full may be incompatible. For example, considerations could include whether accuracy disclaimers should be included for artifacts, interactions, environments, and experiences in virtual worlds [47]. Also, if a user can teleport or interact unnaturally with virtual artifacts, does that alter their perception of those artifacts' authenticity?

(FDC.3) Limit VR Platform Bias with Multi-platform Development Tools – *"Currently, they haven't tested their code on a Head-Mounted Display (HMD) as they haven't used one yet."*: Participants found developing for desktop VR to be more natural and familiar, so less testing was done on mobile and HMD platforms. Developing on a desktop is convenient and efficient. Still, it introduces a natural bias toward design and development, with an overemphasis on desktop-focused interactions and experience design; more immersive HMD interactions are considered later. Frameworks such as A-Frame and Circles need to better address how to deploy development builds to mobile and HMD for more inclusive testing, while also considering how interactions developed in non-immersive VR environments can be more effectively "re-target" to more immersive platforms such as HMD VR. Including more immersive software simulators [48] and authoring tools directly within mobile and HMD VR platforms could also help [49].

(FDC.4) Consider the User Experience (UX) and Creator/Developer Experience (CX) – "*Working with the Circles framework could be challenging at times due to the lack of documentation and some variances in the framework from using a-frame on its own."*: When evaluating the usability of VR experiences, factors such as accessibility, interactions, environment design, and other elements related to the VR user's experience (UX) should be considered. However, to ensure appropriate UX is employed, frameworks such as Circles must facilitate the creation of more accessible and usable VR experiences (CX). In this study, the creator primarily spent their time designing an experience rather than developing a usable VR experience, due to the framework's poor usability. This highlights a flaw in Circles' framework design, as developing usability is a key aspect of creating a successful VR experience. Creators must clearly understand what they can do (framework design) and how to do it (documentation design) to help create a more usable and complete VR UX.

(FDC.5) Include More Diverse Learning Opportunities – *"I would say the greatest challenge this week was trying to narrow down our brainstormed ideas and consolidate it to one coherent one."*: In this study, participants created a multi-platform VR experience, focusing on 3D design and delaying accessibility and social interactions until later in the project. Programming was generally challenging due to incomplete frameworks, rapidly evolving tools, and unfamiliarity with the programming language (JavaScript). Participants requested video tutorials and AI support to better understand the code and receive guidance. This video tutorial request is profound, as the participants were third-year university students and thus in their late twenties to early thirties. Most development documentation is textual, but this is perhaps a vestigial form of how older generations consume knowledge. Additionally, 3D content creation was complex due to interoperability challenges between 3D tools and recommended 3D formats, such as GLTF. Clearer, more diverse documentation and examples could help reduce challenges related to the creation of programming and 3D content. Additionally, challenges in implementing accessibility within the project and attitudinal barriers to participants' inclusion suggest that future classes should better define accessibility as a foundational feature, which could be better supported by earlier classes that also include accessibility and inclusion design practices in the core curriculum, such as the XR Access Initiative [50] and WCAG principles [51].

7 Limitations and Future Work

Some limitations of this study include the context, study design, and demographics. Capturing data from non-classroom contexts could reveal more details about how other end-user developers create multi-platform VR experiences. Additionally, although we collaborated with the author's research ethics board to minimize study bias, the instructor (R2) who conducted the de-identified data analysis may not be able to eliminate all potential sources of bias.

Focusing on student end-user developers was convenient, enabling us to easily capture data over a 12-week period with multiple data points. However, it skews the results in favour of student perspectives. By focusing on group projects, it is challenging to analyze individual creators' work in depth, as students often assume specific roles – for example, one student may be the 3D modeller, and another may focus on programming. Thus, although capturing a younger audience is helpful for future considerations as they progress into professional roles, a more diverse sample beyond post-secondary student demographics and museum contexts would also help generalize the results.

Finally, as accessibility was a significant focus, including the voices of people with disabilities directly in the development process, whether through consultation or user studies, is crucial. In the future, with the above design considerations in mind, implementing these prototypes in live museum contexts is crucial for evaluating usability and fit for museum-goers.

8 Conclusion

There are numerous challenges for VR and VR framework developers in supporting multi-platform VR, which is crucial for creating more inclusive VR experiences. Over 12 weeks, 26 student developers in 7 teams collaborated with a museum client to create multi-platform VR experiences. Weekly reflections, prototype presentations, and a focus group provided qualitative data and were analyzed using reflexive thematic analysis. Five key challenges emerged around VR platform bias, constrained developer expectations, high-friction workflows, unstable development ecosystems, and low-priority sound and accessibility development. The results highlight five key considerations for developing more effective multi-platform VR frameworks, including more research needed in the areas of VR and other mixed realities to be able to provide explicit accessibility requirements to students, mitigating VR platform bias, balancing both user experience and creator experience, enhancing transparency regarding authenticity and accessibility conflicts, and incorporating more diverse learning opportunities. These considerations underscore the need for further research and development of accessible, multi-platform VR frameworks for museum learning contexts and beyond.

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