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Challenges Facing the Adoption of VR for Language Education: Evaluating Dual-Frame System Design as a Possible Solution

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***Abstract*—This paper aims to review the challenges to wider adoption of VR technologies for language education at the university level, focusing on teaching English as a foreign language (TEFL). The first portion classifies these challenges, as outlined in the current literature, into seven main themes: "Lack of TEFL-Specific Content," "Difficulty to Integrate Learning and Evaluation," "Supporting Various Learning Approaches," "Uncertainty Over Learning Outcomes," "Costs and Development Difficulty," "VR Sickness and Other Physical Issues," and "Space and Setup." In addition to this classification, it considers curriculum-related challenges that are underrepresented in current VR research, such as supporting translanguaging and content and language integrated learning (CLIL). Secondly, a novel design method, Dual-Frame System Design, is introduced, which separates VR-based experiences and TEFL learning content into separate "frames" that can be swapped in and out for different learning needs. Finally, three VR systems created with dual-frame system design are evaluated in terms of their structures, functions, and user experiences for how well they address these challenges. Lessons learned from this evaluation may be useful for the future design of VR systems.**

***Index Terms*—Virtual reality, educational technology, teaching English as a foreign language (TEFL)**

I. INTRODUCTION

The past six years may be considered an era of growing interest in consumer VR, set off with the release of the consumer-oriented Oculus Rift and HTC Vive headsets in 2016. Instructors and researchers in teaching English as a foreign language (TEFL) have begun to integrate this rapidly changing technology, but they face a slate of challenges related to its widespread adoption. While these challenges have been evaluated at length in a number of fields, particularly engineering and medicine, the difficulties related to using VR for TEFL has been understudied.

This paper, through a literature review, first seeks to present a comprehensive set of challenges facing the general adoption of VR for TEFL use. It then introduces a new systematic method for implementing VR, Dual-Frame System Design, and evaluates if this method can meet the above challenges. To do so, three past Dual-Frame systems are assessed, focusing on each system's structure, functions, and user experience (including immersion, satisfaction, and learning outcomes).

II. A REVIEW OF CHALLENGES

Through an analysis of multiple databases (EBSCO, Scopus, and Google Scholar), this paper examined a total of 38 papers dealing with challenges to VR adoption in the classroom, with 16 papers specific to language learning. Emphasis was made on choosing systematic reviews and other aggregated studies that followed key search terms (virtual reality, TEFL, teaching English as a foreign language, language learning, education, challenges, problems, systematic review). Abstracts were reviewed to ensure that the focus of the research was high-immersion VR using head-mounted displays rather than non-HMD phone- or PC-based VR.

Finally, each article was manually searched for explicitly outlined challenges towards the adoption of VR in education and specially coded if TEFL or language learning was mentioned. As a result, seven main themes were found and are explained below.

A. Lack of TEFL-Specific Content

On the lack of current TEFL offerings, through an analysis of over 5,000 VR apps on major platforms, Radianti *et al.* [1] found around 120 specifically focused on education. Out of those 120, only 10 were based on language learning, and many were designed for one-time use or as supplementary activities to topics presented in class. In 2020, five applications were found related to TEFL in the Steam platform, three in Facebook's Oculus Store, and none in the PlayStation VR store [2]. JISC (The Joint Information Systems Committee) [3] mentioned a lack of "appropriate" software in its wide-reaching survey of domestic higher education institutions' use of VR in the UK. As a result of this lack of specialized software, many studies of language learning involved the use of non-TEFL COTS (commercial off-the-shelf) software [4–9]. Another study looked at 17 smartphone-based VR applications for language learning and found that very few provided novel learning scenarios (or novel teaching and learning approaches) that facilitate language acquisition [10].

B. Difficulty to Integrate Learning and Evaluation

Integrating learning and evaluation in one experience has proven difficult for a variety of reasons. First and foremost is that a traditional desktop or pen-and-paper environment is often superior for text output compared to VR, and while VR environments can have virtual keyboards or speech-to-text functions, the speed and ease of output can be lacking. While it is possible to don and doff one's VR headset to transition between environments, such transitions may take a

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disproportionate amount of time and effort. Knibbe *et al*. [11] found that transitions out of virtual reality could be disorienting, and Gottsacker *et al*. [12] stated that interruptions can cause a break in presence (BIP) that can drop performance in virtual activities.

This means that evaluation in a VR TEFL learning experience is often done after the entire VR experience is completed and in a different environment, rather than interspersed within the VR experience itself.

C. Supporting Various Learning Approaches

The rate of VR implementation in Japan appears to be low but rising, with 26.6% of universities having done so according to an October 2022 Asahi survey [13]. Often, institutions, departments, and individual instructors have specific requirements, the most common nowadays perhaps distance learning, as both the number of universities offering distance learning programs and the proportion of students in such programs have increased rapidly.

The seven challenges mentioned here are further magnified when courses are taught in a distance learning paradigm [14]. The lack of face-to-face instruction makes it difficult to give students directions on how to set up and use the VR systems, and troubleshooting any problems that arise is similarly restricted. In such cases, certain "ilities" of the system, such as reliability, maintainability, compatibility, accessibility, and manageability, become even more paramount.

Kondratiuk *et al*. [15] mentioned two programs specific to language learning (*Mondly VR and VirtualSpeech)* and three general education programs *(Immersive VR Education, AltspaceVR and ClassVR*) that were compatible with distance learning, though their efficacy was not clear.

Childs *et al*. [16] mentioned four sub-challenges related to distance learning, "the lack of social interaction, reduced student engagement and focus, reduced comprehension and information retention, and the lack of flexible and customizable instructor resources."

Kascak *et al*. [17] also outlined such challenges to distance learning but focused on general education, while Coyne *et al*. [18] mentioned difficulties with comfort, the ease of use of the technology, and issues with an integrated learning activity.

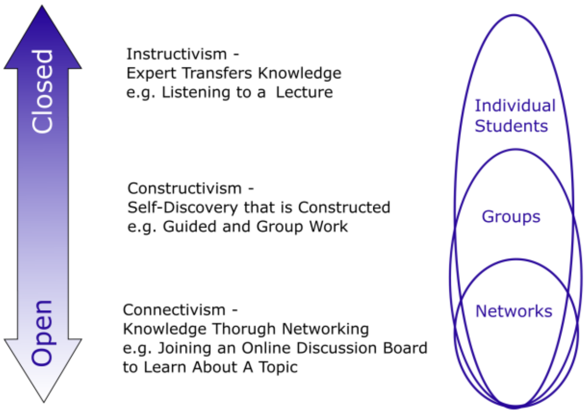

Fig. 1. Instructivism, constructivism, and connectivism.

This ties in deeply with three major teaching styles, instructivism, constructivism, and connectivism (Fig. 1), where VR contents may be more difficult to customize the more open the teaching approach is.

D. Uncertainty over Learning Outcomes

While VR was shown, particularly in the sciences [19–21], to provide greater learning outcomes for task-based routines compared to non-VR methods, there were exceptions as well [22]. In addition, there was little groundwork testing TEFL specifically [23]. While TEFL learning outcomes were observed in a number of studies, whether those outcomes surpass those gained through traditional means is still up for debate. JISC [3] found "a lack of evidence for impact" can "lead to a lack of buy-in and investment from senior leadership".

In addition, many studies focused on only short-term or one-off experiments, leaving few examples testing learning outcomes over a longer term, such as a semester-long university course. This has been noted in discussions about the "novelty effect," where student interest and perceived immersion were attributed in part to the excitement of something new, but longer-term studies were mainly outside of TEFL [24].

Parmaxi [25], in a systematic review, found that VR can provide positive learning outcomes in some cases but had challenges in its pedagogical grounding.

E. Costs and Development Difficulty

Similar to studies on learning outcomes, there were clear cost estimates for VR systems in medicine and other areas of the hard sciences [26, 27]. With entry-level headsets such as the Meta Quest 2 starting at around $500 USD (60,000 JPY), and cutting-edge mixed-reality headsets like the Quest Pro coming in at around four times that, outfitting an entire university classroom may require a large outlay just for hardware, rivaling that of a computer lab. PC-connected headsets usually require a high-spec, VR-ready PC, with a cost of around 150,000 yen or more each. In addition, the development cost of VR experiences may be high if using third party developers, as the skills to create VR scenarios are relatively uncommon.

JISC [3] mentioned a "lack of … affordable software" in its survey of UK universities, but, fortunately, platforms to create VR experiences like Unity and Unreal Engine have been lowering the barriers to game design, and both are free for academic use.

Compared to other equipment used for CALL (computer-assisted language learning), such as PCs and tablets, the lifespan of standalone VR headsets might be considered shorter. Many current headsets have built in lithium-ion batteries, which on average can last 2–5 years before heavy degradation. While no studies were found on headset-specific battery lifespan statistics, there were many anecdotal reports of batteries failing under two years. PC-connected headsets might not have that restriction, though some controllers do have batteries that are not replaceable by end users.

Finally, ultra-low-cost smartphone-based VR systems had a period of popularity in the 2010s, but many companies phased out their smartphone-based goggles (Google Dream, Samsung Gear VR, etc.).

F. VR Sickness and Other Physical Issues

VR sickness can arguably be considered the greatest obstacle to allowing inclusive participation in VR-based lessons. Saredakis *et al*., in a systematic review, found an average dropout rate due to VR sickness of 15.6% among 46 experiments (that mentioned dropout rates) [28], and MacArthur *et al*. [29] and Howard and Van Zandt [30] mentioned the importance of other considerations like gender and age for VR sickness in study design. Finally, a systematic study by Caserman *et al*. [31] found that VR sickness rates were higher for earlier, experimental VR headsets compared to current-generation headsets.

Chandra *et al*. [32] mentioned that low latency, high framerates, avoiding rapid movements, low FOV (field of view), ventilated environments, and low exposure durations may help, while Shi *et al*. [33] added blurring DOF (depth of field) and rest frames.

There was also an issue of properly sanitizing headsets. Compared to laptops and tablets, which are usually a small number of flat, nonporous surfaces, VR headsets often had many nooks and crannies, as well as porous foam and cloth, and were placed in very close proximity to the eyes, nose, and mouth, all vectors for disease transmission. Studies of biological contamination of VR headsets and related equipment only began, to the best of this paper's knowledge, in 2020, where antibiotic-resistant staphylococcus aureus was found to grow after regular use [34]. Evaluating methods of disinfection began in earnest in 2022 [35] and found that while nonporous plastic could be easily disinfected, porous materials were more difficult to deal with. Disinfection practices also varied widely, and it was recommended to create a set of best practices [36].

To that end, students currently conducting speaking exercises in TEFL VR scenarios may have to wear masks in addition to receiving disinfected headsets. However, the industry is moving towards the integration of face and mouth tracking, already available on consumer headsets like the Meta Quest Pro, which may make mask-wearing difficult.

G. Space and Setup

Hardware setup times were a major issue with the first generation of VR headsets. SteamVR headsets like the Vive and Oculus headsets like the Rift required multiple IR sensors for outside-in tracking and a connection to a VR-capable PC. The current generation of headsets mainly uses inside-out tracking, which decreases the number of discrete parts to three in most cases (headset and two controllers), and it was found that standalone headsets eventually became more popular and provided lower setup times [37]. However, charging and transporting such headsets from class to class was difficult, and setup times for bringing VR into a traditional classroom could be high [38]. For more complex experiences, the long amount of time required for students to acclimate to VR and complete various tutorials may make short class sessions impractical. It was found that such onboarding issues can detrimentally impact the user experience [39].

The remaining challenge is software setup times. PC-based systems in a traditional computer lab allow the instructor to show his or her screen on a projector or other display, and it is relatively simple for an instructor or assistants to directly provide guidance and troubleshooting using a student's PC (for example, using the mouse over someone's shoulder).

III. UNDERSTUDIED CHALLENGES

Through the course of evaluating three VR systems conceived through Dual-Frame System Design, which will be explained in the next section, two understudied challenges appeared.

The first is that new approaches to TEFL include "translanguaging." While there are multiple definitions for the term [40], this paper treats it as one of the most inclusive definitions, simply using multiple languages in the classroom. Off-the-shelf VR systems are usually tied to a single language, both for input and display, which can limit the ability to translanguage. In Japan, for instance, some university TEFL courses are conducted partially or mostly in Japanese with English-language content scattered throughout. While listening, reading, and speaking are all easily supported in most VR engines, such as Unity or A-Frame, language input is often restricted by the OS to one language at a time. A smartphone or PC, for example, allows for toggling from one language to another relatively easily.

Similar to this is CLIL (content-integrated language learning), which has also been gathering steam in some university TEFL programs. CLIL involves English language learners studying subjects, such as economics, education, and politics, in English. It mixes TEFL-specific teaching methods with content outside of the TEFL field. It can be difficult to integrate TEFL activities into a non-TEFL VR space without needing to transition in and out of a separate TEFL environment.

IV. A POSSIBLE SOLUTION

This research presents a novel system design method, Dual-Frame System Design, which was conceived to allow classroom management and content creation with a lower barrier to teacher entry. Using structure and function mapping in the system design process, there are two separate frames that provide two separate feature sets. The first is a simple-to-edit frame for the teacher to manipulate and the second a more complex VR frame for an educational architect to create and manage.

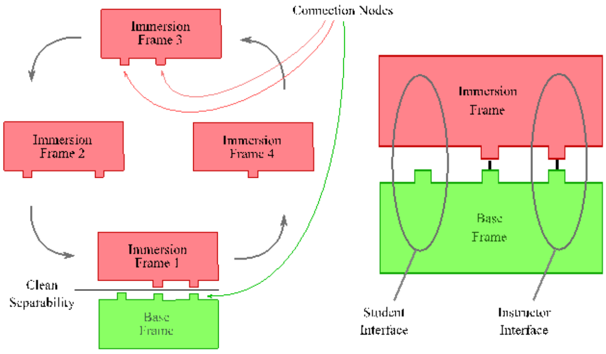

Fig. 2. Dual-frame system design.

As seen in Fig. 2 above, the first frame is called the "Base Frame," shown in green. The contents are editable by an ordinary teacher with a modicum of computer skill, and support of the underlying technologies has and should continue to remain relatively stable. Based on legacy platforms and text-based editing, it is designed with user-friendliness in mind and does not require specialized programming or VR content creation skills. Example platforms include Google Classroom and WordPress. The second frame uses VR technologies and is called the "immersion frame," shown in red. The contents are not easily editable, and the platforms and technologies are relatively unstable, with services changing or disappearing. Thus, many software and hardware updates may be necessary, and an educational architect may be needed to create or edit these contents. However, this frame provides the high-immersion content useful for TEFL learning situations requiring spatial awareness and procedural knowledge. As Fig. 2 shows, different immersion frames can be swapped in and out, such as in cases where a single immersion frame's content is no longer supported. The "connection nodes" are how the frames communicate and control one another, serving as a bridge between the base frame and immersion frame. These nodes can be QR codes, audio controls, webpage links, picture-in-picture videos, or other methods. There may be multiple connection nodes, they can be used by the student, instructor, or both, and they may also be changed depending on the immersion frames being used.

It should be noted that previous works about Experiment A and Experiment B did not evaluate Dual-Frame System Design, leading to the novelty of this new work.

V. METHODS

Three VR systems were created using the Dual-Frame System Design Method and then evaluated on whether they could address the challenges described above.

The first, Experiment A [41], was a single-user activity that repurposed an existing VR experience, using non-TEFL off-the-shelf applications for TEFL purposes and focusing on a game ("Experience Colorblindness") in which participants must select correct fruit by following audio instructions. While selecting fruit, participants were in an environment of artificial colorblindness. Three main data sources were used for this experiment. The first source was testing data, including an in-game score that counted the number of correct and incorrect fruit choices. In addition, students completed a Google Forms test in the VR environment through the Oculus Rift's picture-in-picture feature. This test prepared students by teaching them the names of various fruit types. The second source was a multiple-choice Likert scale survey on the user experience and perceived effects on English learning. The third source was a set of semi-structured interviews based on seed questions related to likes and dislikes, as well as areas for improvement. Ten students at a vocational college in Tokyo and six Japanese adult learners of English participated, and experiments were conducted in an ordinary classroom or office room. The interventions were conducted in individual sessions over a multi-week period, in which the instructor and student shared a room for each session.

The second, Experiment B [42], created a collaborative VR classroom where students used avatars to explore a virtual world while completing active learning TEFL assignments. There were two data sources, the first being an evaluation of learning outcomes using pre- and post-testing. These tests measured understanding of English concepts, grammar, vocabulary, and other materials covered in the VR lesson. The second source was a set of Likert scale student surveys focusing on usability, learning experiences, interest in VR, and other topics. Eight students, adult learners of English in Japan, completed an individual learning session and survey with the instructor.

The third, Experiment C [43], attempted livestreaming a 180-degree 3D VR video of a TEFL lesson, with multiple students watching over the internet in an example of distance learning. To participate in the class, students used audio-based controls in lieu of a virtual keyboard. Three main data sources were used, with the first evaluating learning outcomes through pre- and post-testing, with each test focusing on a learning concept from the lesson. Next, a Likert scale survey on system usability and self-assessed learning outcomes was given, including questions on excitement and engagement. Finally, semi-structured interviews were given, using probing and follow-up questions. These included asking about interaction with teachers, the usefulness of instructions, and impacts on interest in learning English. Two university students completed testing over five sessions at a laboratory in Tokyo, with the instructor in a separate area to avoid audio interference.

For the remainder of this paper, these three experiments will be referred to by "Experiment A," "Experiment B", and "Experiment C" for clarity. In addition, insights were drawn from the author's dissertation, "Repurposing Virtual Realities Through Dual-Frame System Design" [44].

Finally, the three systems were evaluated in terms of their structures and functions to see if they addressed the seven challenges.

VI. RESULTS FROM DUAL-FRAME SYSTEM DESIGN

A. Lack of TEFL-Specific Content

For Experiment A, repurposing an existing non-TEFL game ("Experience: Colorblindness") through Dual-Frame system design allowed for English learners to study vocabulary and pronunciation. In this scenario, students attempted to sort and classify fruit without being able to see the full spectrum of color. The immersion frame in this case was the "Experience Colorblindness" VR application and the base frame was a web portal optimized for VR that ran as a picture-in-picture supplement. This web portal contained learning materials and testing modules to convert "Experience Colorblindness" into a TEFL experience.

For Experiment B, The VRChat platform, an online avatar-based virtual world, had no existing TEFL content. Using the VRChat SDK for Unity, a customized TEFL scenario was created. In addition, a customized web portal similar to that found in Experiment A provided the ability to use TEFL learning materials.

Experiment C tested VR180 livestreaming, a type of one-way communication. However, it was difficult to use in active learning use cases, especially in a distance learning paradigm. Using the base frame of audio controls and a virtual chatboard, the VR180 livestreaming service, acting as the Immersion Frame, was repurposed for TEFL

B. Difficulty to Integrate Learning and Evaluation

For both Experiment A and Experiment B, evaluation and learning materials were contained in the picture-in-picture web portal. Transition times between the base and immersion frame were quite low. For Experiment A, it was near-instant when moving one's eyes to just view the contents. The transition time for manipulating the base frame was mostly under five seconds, and under one second to return to manipulating the immersion frame.

For Experiment B, transition times were also low, as the same system as Experiment A was used. Students found the test-taking system easy to use, with a Likert scale score of 4.25 out of 5 (with 1 being the lowest and 5 being the highest).

For Experiment C, Transition times were higher, though the semi-synchronous system reduced the impact of this. The average lag from recording by the instructor to the student viewing the recording was 46 seconds (variation within 10 seconds). Student submission of text to reception took on average three seconds, so the theoretical minimum lag of two-way communication was 49 seconds. However, practically, students had to speak and use voice commands, which added to the waiting time even further. Thus a system based on commercially-available web streaming platforms may not be reliable or allow for ordinary English spoken communication.

C. Supporting Various Learning Approaches

The web portal allows for customizing the learning experience to meet various needs, but Experiment A in particular successfully tested an asynchronous setup without any live elements within the experience, which points to usefulness for distance learning. Live support was given before and during the experience. Experiment B successfully tested a synchronous system, in which the instructor and students inhabited the same VR world through avatars. Experiment C allowed for two-way communication through a livestreaming 3D setup. In these cases, instructivist and constructivist approaches, as well as connectivist approaches to some extent (depending on the use of the web portal), were possible.

D. Uncertainty over Learning Outcomes

All three experiences found positive learning outcomes but could not directly compare those outcomes with learning methods using more common platforms (desktop-computer, pen and paper, whiteboard, etc.). The variety of both VR and non-VR systems made it difficult to draw generalizable conclusions.

For Experiment A, while the use of the web portal did not increase learning outcomes for advanced students (CEFR B2 or higher), it increased them for beginner-level students (CEFR A2 or lower), and their chances of completing the task of correctly identifying fruit increased from 38% to 71%. On a Likert scale of 1–5, students rated their learning outcomes at 4.5 for advanced and 4.25 for beginners.

For Experiment B, correct answer rates improved from under 40% in a pre-test to over 70% in a post-test. A decrease in students answering "I don't know" to questions occurred from 52% in the pre-test to 15% in the post-test.

For Experiment C, there is a clear transfer of knowledge, as shown through the pre-and post-tests. Correct answer rates improved from under 30% on average to over 60%. Students felt they increased their English knowledge, one feeling a "very positive" and one a "somewhat positive" increase.

Thus, while positive learning outcomes were present for all three systems, whether these learning outcomes will persist in the longer term, as well as whether these outcomes are greater than those found through more traditional learning means, is still uncertain.

E. Costs and Development Difficulty

Dual-Frame system design has the flexibility to adopt lower-cost smartphone-based headsets. However, PC-based HMD costs remain high. In addition, such systems remove the necessity for a comprehensive system developed entirely within VR. Switching immersion frames allows for new content without high costs.

Specialized skills for VR platforms, such as Unity and Unreal, are not required, though they can be useful in some cases. Instructors would not need any VR or programming skills: only the ability to edit web pages, and Google Classroom forms, as well as similar basic skills, are also required.

The cost of system components for Experiment A, in 2019, was measured at approximately 240,000 JPY. In 2022, for a system with equivalent performance, approximately 160,000 JPY would be needed. There were no development costs for the VR game, as it was off-the-shelf and free to play. Creating the web portal contents required approximately five hours of preparation.

For Experiment B, which required a desktop-based system for an instructor and a laptop-based system for a student, the approximate MRSP of the desktop-based instructor system was 160,000 JPY, though a modern equivalent would run around 130,000 JPY. The laptop-based student system was the same as in Experiment A. Thus, the total system cost approximated 400,000 JPY in 2019 and 290,000 JPY in 2022. Around 10–15 hours of development time for the Unity VRChat scenario and 5 hours for creating the web portal were needed.

For Experiment C, in the case of students possessing an appropriate smartphone and laptop, the costs were lower relative to the previous systems, at approximately 4,000 yen per student for the headset. For the instructor side, assuming possessing a laptop and projector, the costs were approximately 35,000 yen for the camera. Creating the audio control system took approximately 20 hours of work.

F. VR Sickness and Other Physical Issues

VR contents within Dual-Frame system design have nothing inherent to stop VR sickness, but there can be accommodations for other physical issues within the VR space due to the flexibility of a web-based portal.

However, it can be possible in some cases to replace HMD-based, stereoscopic VR content with non-HMD VR content (that is less likely to cause VR sickeness) while keeping the same base frame. Experiment B showed that using cross-platform systems such as VRChat could theoretically allow for inclusive use of VR, as students who would be unable use the VR version of VRChat for whatever reason may attempt to use the PC version instead, controlled with a traditional mouse or keyboard. While not everyone can use a traditional desktop setup, the proportion is far higher than VR, and various accommodations for inclusivity, both hardware- and software-based, have been tried and tested.

For Experiment A, no students out of the 16 subjects reported VR sickness. However, the pool of students that were given offers to participate in the experiment all had a previous experience with stereoscopic VR. Thus, there may have been a self-selection bias towards students that did not perceive VR sickness in the past.

For Experiment B, three students complained of motion sickness to varying degrees. Some described the sensation as mild, and one said it was troublesome to the point of distraction. Two sessions had to be stopped because of extreme nausea. Compared to Experiment A, the longer times could be a cause of this.

For Experiment C, the two students tested already had experience with VR and had shown no signs of VR sickness or other discomfort within that experience. So, VR sickness may still be an issue for other users.

G. *Space and Setup Times*

Simple systems, such as Experiment A with its small number of users, were quick to set up. Complex systems, especially if they are moved, may take a long time.

Systems requiring calibration, such as speech-to-text, many require a period of optimization only suitable for long-term courses. In addition, even for short experiences, many students still needed basic instructions for VR use, which can take time if conducted formally.

Simplified Dual Frame systems with detailed instructions for use worked on an individual basis, but highly complex systems may need granular management and are better suited for institutional-level setups and maintenance

For Experiment A, learning outcome tests were conducted within the classroom. Out of two test sessions, the setup time for the first test was approximately 15 minutes, and the setup time for the second test was 10 minutes. From a Likert scale of 1 to 5, with 5 being the easiest to use, the beginner group rated the experience as 4.5, and the advanced group as 4.0.

For Experiment B, Setup times were on average over 30 minutes. This was mainly due to having to prepare very different hardware for the student and teacher, including setting up a desktop. Updates occasionally took time, as well.

This time would be lower if both student and teacher system used the same hardware and were laptop-based. Using the same hardware was not adopted for this study as the study would have gone over budget.

For Experiment C, in which semi-structured interviews took place, a code for “delay” included complaints about long setup times and lengthy instructions on how to use the system. Multisession periods of calibration for improving text-to-speech accuracy, and the lag between sending communication and the teacher receiving it, were also points of contention.

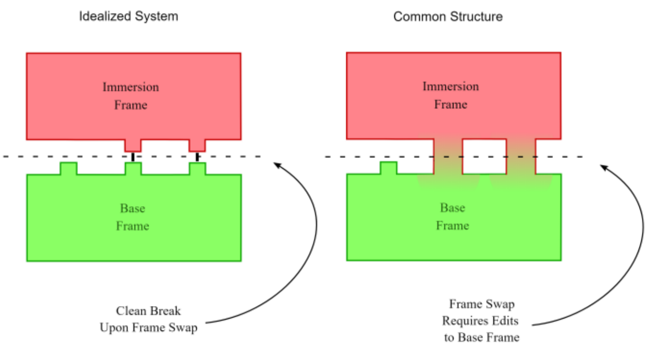

Fig. 3. The Reality of dual-frame connections.

These results show that it may be difficult to separate the Base Frame and Immersion Frame, Systems requiring calibration, such as speech-to-text, may require a period of optimization only suitable for long-term courses. Fig. 3 shows the theoretical problem if Immersion Frames and Base Frames are too functionally intertwined to be easily swapped. In such a case, swapping the Immersion Frame would require changes to the Base Frame, and vice versa.

Table I is an at-a-glance restatement of the above findings. The findings are simplified, through expert opinion, into categories of how well each system meets the 7 challenges. ○ stands for clearly meeting a challenge, △ means it is not clear whether the system meets a challenge, and × means a system clearly does not meet the challenge Each challenge is denoted by its heading letter in the above analysis.

TABLE I: FINDINGS AT A GLANCE

Challenge	Experiment A	Experiment B	Experiment C
A. Lack of TEFL-Specific Content	○	○	○
B. Difficulty to Integrate Learning and Evaluation	○	○	×
C. Supporting Various Learning Approaches	○	○	○
D. Uncertainty over Learning Outcomes	△	△	△
E. Costs and Development Difficulty	△	×	△
F. VR Sickness and Other Physical Issues	△	×	△
G. Space and Setup Times	○	△	×

VII. CONCLUSIONS

VR holds unique challenges for teachers hoping to implement it into their classrooms or in distance learning situations. As shown in the above three experiments, while VR may be best suited for learning specific skills that take advantage of the medium, recent technological developments may also allow for more widespread and longer-term adoption, even if initially for a small subset of students.

Dual-frame systems might remove the necessity for a comprehensive system developed entirely within VR, and switching immersion frames may allow for new content without high costs. In general, specialized skills for VR platforms (such as Unity and Unreal) are not required for instructors, though they can be used by educational technologists. Instructors would only need to edit web pages and classroom activities using off-the-shelf services such as Google Classroom.

However, there are major weaknesses due to the rapid progression of technology. Even core functions found in a base frame, such as picture-in-picture, may come and go due to operating system or program updates.

VR equipment may be trending towards standalone models, at least for comprehensive systems that are developed to be used within a single VR program. With many standalone models, some required features would have to be integrated within a single app accessible through an app store. While this is the smoothest and easiest way from a UX/UI perspective, it requires customization and compatibility with outside systems to be conducted in the VR application development stage. This may be useful for a very large organization willing to make major investments in a platform, such as a university-wide effort to provide VR experiences to hundreds or thousands of students. For making customized scenarios and allowing for LMS integration, audio control, and similarly useful features without possessing specialized VR programming skills, a PC-based system would be more appropriate. The audio control method used for Experiment C and the web portal used in Experiment A and Experiment B (running on Oculus Dash) would be very difficult on standalone systems without dedicated app development.

The reasoning behind this is that PC-based (and smartphone-based systems, though not the focus of this research) are, much like headset foam, relatively "porous," allowing for interconnections to outside systems more easily. The most popular standalone systems are closer to "walled gardens," in which a limited number of curated applications can be used. Perhaps most importantly, multitasking separate applications does not run well on Unity or Unreal, such as web browsing while in a game. Having features available on standard PCs entirely encapsulated within a game engine might be cost-prohibitive and lead to CPU/GPU/RAM bottlenecks for most standalone HMD applications.

When it comes to the field of VR content development, this analysis shows that it is possible to repurpose existing scenarios instead of requiring a large time and/or cost commitment for the development of a specialized application on a platform such as Unity or Unreal. App development, depending on complexity, can reach into the thousands of man-hours and cost tens of thousands of dollars. In contrast, the learning curve for a Web-Portal-based system, as found in some of the experiments, is also relatively shallow. Many teachers have been given training on web-browser-based systems, and many school IT departments are equipped to handle questions at that level.

Expanding on the VR development side, such systems can support the function for teachers without programming experience to still create content customized for their classrooms and learning goals. While this does little to lower hardware costs, it may lower development costs compared to a made-for-VR software suite.

If VR is to be adopted in the longer term and for a wider group of TEFL users, the sort of customization found in Dual-Frame systems can allow for various learning methods to be implemented in VR.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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