

Virtual Reality-Based Immersive Environments for Second Language Learning

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Abstract: The use of virtual reality (VR) in second language (L2) education has been increasingly transforming L2 instruction in recent years by creating an authentic second language learning environment in a virtual world in which learners are immersed. The design, pedagogical rationale, and classroom-based assessment of a VR-based immersive environment for second language acquisition, focusing on speaking fluency, vocabulary retention, and learners' willingness to communicate, is discussed in this paper. The method employed was a mixed-method quasi-experimental design that involved developing a prototype scene and a six-week classroom pilot with forty-two intermediate-level second language learners. The method used was a quasi-experimental study with a mixed method of prototype scene development and a 6-week classroom pilot in which 42 intermediate-level second language learners were placed into a VR environment while a comparison group was placed in a conventional classroom setting. Pre- and post-test, a structured questionnaire and session interaction logs, as well as short interviews, were used to collect data, which were then analyzed descriptively and thematically with regard to the qualitative data. Results reveal that the learners in the immersive VR environment showed higher gains in oral fluency, vocabulary acquisition, and lower speaking anxiety and willingness to communicate in the target language than the control group. Conversational tasks, structured around scenarios, complete with adaptive dialogue prompts and contextual visual cues, seemed to be the focus of sustaining learner engagement during the pilot period. The study also shows that presence, embodied interaction, and scenario realism are important design aspects in the pedagogical effectiveness of immersive language environments. The issues of cybersickness, hardware availability, and sustainability of immersive content creation are also considered. Based on the results of the study, the paper concludes that well-structured VR-based immersive environments have significant potential in scaling up the teaching and learning of L2S, and that the role of the teacher is still indispensable in the future application of immersive L2 learning technologies in different educational contexts and different learners.

Key Words: virtual reality, second language learning, immersive environments, willingness to communicate, presence, speaking fluency, embodied interaction

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Introduction

In recent years, the necessity for second language (L2) learners to be provided with authentic, meaning-centered, communicative environments, in which the traditional classroom is unable to deliver, because of limited space, speaking time, and ideagrashed dialogue scripts, has gained increasing importance (Parmaxi, 2023). Virtual reality (VR) has offered a solution to this challenge, presenting

learners with a virtual 3D immersive environment that engages them in 2D and 3D, where vocabulary and structures are experienced within an authentic context, not through isolated drills (Legault et al., 2019).

Theoretically, based on constructivist learning theory and cognitive load theory, the use of well-designed immersive environments in the learning process can reduce the cognitive load of extraneous cognitive needs and increase active responses in the learning process by the students in learning target language input, provided that the complexity of the environment and the level of scaffolding learning are well balanced (Song et al., 2023). A number of systematic reviews on high immersion VR language applications (Dhimolea et al., 2022) have found consistently positive results on vocabulary acquisition and motivation, albeit with different conceptualizations and measurements of "immersion" between studies. Additionally, the review of the literature indicates that VR-assisted language learning is likely to enhance short-term vocabulary learning, though the long-term retention of these gains in longer language learning sessions remains in question (Chen et al., 2022).

Long-term research on the use of VR in language learning over a period of 10 years reveals that the use of a VR system in language education has evolved from passive viewing of 360-degree video to more and more interactive immersive environments that facilitate two-way communication (Zheng et al., 2023). Dedicated VR language-learning applications are also reported to have been given parallel reviews, which report that those incorporating conversational tasks produce stronger engagement outcomes than those in which the user is only exposed to a scene (Berns & Reyes-Sanchez, 2021). Generally, findings from various immersive VR classrooms suggest that with pedagogically sound instruction, performance in learning can be better in the immersive classroom than in the real classroom, even in areas other than strictly linguistic domains, further supporting the pedagogical potential of immersive scene design (Liu et al., 2020). In a language-specific context, the use of scenery-based VR environments for dyadic, purposeful communication (e.g., dialogue tasks for tourism purposes) has demonstrated collaborative language use benefits between paired learners (Lin et al., 2023) and measurable language use benefits, including foreign language anxiety, a factor long linked to foreign language production (Kaplan-Rakowski & Gruber, 2023).

Even with this growing body of evidence, however, empirical research into the effects of the interaction of specific VR design features (e.g., scenario realism, dialogue adaptivity, and immersion intensity) on measurable L2 learning outcomes is still sparse, and only a handful of studies have directly compared VR-immersed learners with comparison groups that received traditional instruction under matched conditions. The present study aims to address this lack by designing and testing an L2 teaching environment built around VR technology.

The present paper has several contributions to VR-assisted second language education. First, it suggests a conceptual architecture for a VR environment for immersive second language learning, where the learner's profile, the dialogue processing in the scenario, and the actuation of the immersive regulation are configured in a modular way to offer personalized and context-appropriate language learning experiences. Second, the study offers empirical evidence from a six-week pilot study in the classroom where learners who used the proposed VR environment were compared to a comparison group in which learners were taught the same material using the conventional approach, with emphasis on important learning outcomes (Oral Fluency, Vocabulary retention, Willingness to communicate). Third, the research proposes critical practical aspects and implementation issues, such as how to prevent cybersickness, how to make the hardware accessible and how to keep the immersive scenario content sustainable, which are important for institutions considering the implementation of VR-based language learning solutions. Last, the study introduces a comprehensive collection of evaluation measures and results which can be used as

a starting point and a benchmark for future comparative studies of VR-supported immersive language learning systems.

The rest of this paper is structured as follows. In Section II, the current study is placed in the broader context of the growing research on VR-mediated language learning. The conceptual framework and architecture of the proposed VR-based immersive environment are introduced in Section III. The study design and the learners who participated in the pilot evaluation are described in Section IV. In Section V, the design of the immersive scenes and the interaction mechanics that are used in the prototype are described. The learning outcomes and learner experience during the pilot is presented in Section VI. A discussion of the findings, based on the objectives of the study, is presented in Section VII. The paper concludes with a Summary (Section VIII) which outlines main findings and research directions.

The Expanding Research Landscape of VR-Mediated Language Learning

In addition to fully immersive VR, AR – game-based approaches which mix mobile and print materials, have shown how problem-based, situated gaming formats can be used to meaningfully support foreign language learning outcomes – thus showing that underpinning pedagogical mechanisms of immersive and semi-immersive learning are situated, task-driven and problem-based approaches to learning (Yu et al., 2022). The design of immersive VR learning environments has also been discussed in systematic literature review studies, all highlighting the importance of the development and application of evaluation frameworks which take into account usability, presence, and alignment with the learning goals (Sato et al., 2019).

Vocabulary acquisition and listening comprehension are consistently targeted more often than all other language learning skills in reviews consolidating AR- and VR-enhanced language learning research, while speaking and pragmatic competence are relatively under-researched skills that have been deemed important for communicative competence (Lee, 2022). The studies on the use of VR in authentic learning also point to the need for a socially and culturally realistic communicative situation to be recreated in a VR scenario for optimal pedagogical value in twenty-first-century language classrooms (Cao et al., 2023). From the late 2000s, bibliometric analyses of the VR and AR technology trends in the field of language education reveal a growth of publications and a variety of target languages and learner groups, reflecting the shift in these studies from the initial stage of proof of concept to the later stage of rigorous and outcome-oriented evaluation (Huang et al., 2021).

The literature on the affordances and challenges of using VR in language skill learning over the last 10 years reveals consistent findings of increased motivation and use of vocabulary in context, but frequent problems of cybersickness, cost, and content development expertise (Utami et al., 2021). Additionally, VR methods that focus on meaningful learning experiences around specific, content-based learning tasks (e.g., geography-themed English vocabulary learning) highlight how meaningful exploration and learning tasks can improve vocabulary learning and maintain students' engagement over time (Qiu et al., 2023). Complementary approaches to embedding immersive VR within wider learning contexts highlight design principles that span subject areas and are clearly relevant to language-based cases, such as clearly structuring a task, providing the right scaffolding, or managing cognitive load (Bahari, 2022).

Previous research on the use of AR in language learning for gaming purposes showed significant improvements in motivation among English learners who reported were not very motivated when learning English in the classroom (Li et al., 2022). In recent years, interventions that focus on verbal communication skills in second language acquisition (SLA) have produced improvements in areas of engagement,

motivation, and learner autonomy in L2 learning, and this suggests that immersive and interactive learning environments can have a positive impact on the affective as well as the cognitive aspects of L2 development (Mulders et al., 2020).

In the existing body of research suggests that VR- and AR-based language learning technologies have come a long way in terms of scope and methodological rigor; however, a gap still exists between the technologies' capability and evidence of classroom communicative outcomes such as fluency and willingness to communicate, which the present study aims to close with its integrated design and pilot evaluation.

Conceptual Framework for VR-Based Immersive Second Language Learning

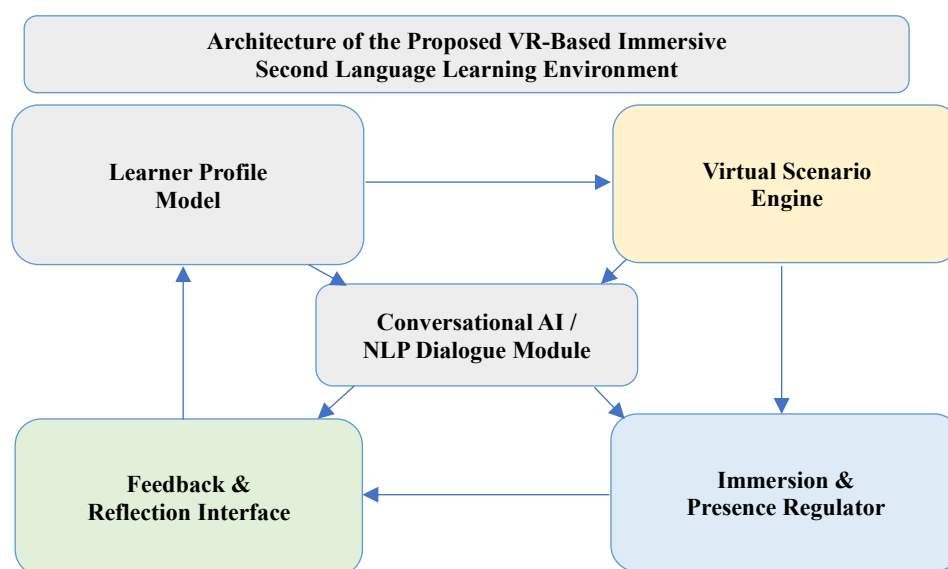


Figure 1: Architecture of the Proposed VR-Based Immersive Second Language Learning Environment

The architecture of the VR-based immersive environment for second language learning proposed in this study is shown in figure 1. The framework consists of five main components: learner profiling, virtual scenario generation, dialogue processing, immersion control, and feedback mechanism. All components of the framework work in an interactive mode to lead to adaptive learning experiences, personalized communication practice, and improvement through reflection.

Learner Profile Model keeps an up-to-date transcript of each learner's level of achievement in pronunciation, common problems (e.g., grammar), comfort level with immersive technology, and preferred pacing level, which enables audiences to be assigned to different scenes and dialogue complexity to be adjusted as needed. The Virtual Scenario Engine is a repository for the 3-D communicative scene library and is extensible to allow for new scenarios to be added as curriculum demands change.

Using data from the Immersion and Presence Regulator, which constantly checks for signs of discomfort in participants (such as length of session, participant self-report discomfort, and interaction hesitancy), visual intensity, avatar proximity, and scene pacing are continually modified to reduce cybersickness while maintaining a sense of presence. The Feedback and Reflection Interface provide post-task feedback on words used, pronunciations, turns taken in conversation, and introduces brief learner reflection exercises to promote metacognition with regard to progress. The Conversational AI and NLP Dialogue Module is designed to continuously adapt the environment as learners learn, enabling the architecture to be more and more responsive to the learner's input during the course of the instructions.

Study Design and Learner Cohort

To address this, the research method used in this study was a mixed-method design, a quasi-experimental type, which was a combination of prototype scene development and a classroom-based pilot evaluation to measure the learning outcomes as well as qualitatively gain insight into the learning process.

Participants

The subjects were 84 intermediate-level second language learners (ages 16-19) in two parallel classes of a language preparatory program at a university. Both the experimental ($n = 42$) and comparison ($n = 42$) groups were instructed for a total of 6 weeks, but the experimental group received the proposed VR-based immersive environment, while the comparison group received the traditional curriculum and a teacher-led approach. Instruction in both groups was supervised by two language teachers, each having over six years of experience in the classroom, and involved structured interviews after the pilot.

Data Collection Instruments

Four instruments were used for data collection, and triangulated. Learning gains were measured using standardized pre-test and post-test assessments on oral fluency, word knowledge, and listening comprehension for both groups. The questionnaire used was a structured Likert scale questionnaire, which was only filled out by the experimental group at the end of the study, and this questionnaire measured learner perceptions of immersion, engagement, and speaking confidence. The experimental group was observed for scenario completion rates, the number of turns at which spoke during the session, and the amount of time spent in each virtual environment. For the experimental group, logs of session interaction were created to determine completion rates for scenarios, the number of turns the interaction took place and the amount of time spent in each virtual setting. Finally, a smaller number of seven learners and both the active teachers were interviewed informally to collect qualitative data from the learner and teachers' perspective of the immersive learning experience.

Data Analysis

Descriptive statistics such as percentage gains, and group comparison were performed on quantitative pre- and post-test and Likert scale data to describe general trends in performance. Thematic coding was used to analyze the qualitative data gathered from the interviews and open-ended questionnaire items to identify emerging themes of communicative confidence, immersion comfort and usability. The mixed methods approach enabled them to capture a more comprehensive picture of measurable learning outcomes as well as the subjective learner experience.

Ethical Considerations

Data collection was approved and consent was gained from the program administrators, participating instructors and student participants. Students' participation was optional, and the students' right to withdraw from the program was respected throughout. The desktop version of the environment, not using a headset, was provided to learners known to be prone to motion sickness. Each participant was given a code number and all of the collected data were anonymized, securely stored, and only used for the purpose of this study.

Immersive Scene Design and Interaction Mechanics

The prototype VR environment was designed to be used with consumer grade standalone headsets and was equipped with a parallel desktop interface for those learners who preferred or required a non-headset option so that could complete scenario based conversational tasks, object interactions using the vocabulary and short pronunciation exercises in one application, with an immersive virtual environment at fingertips.

Scenario-Based Conversational Modules

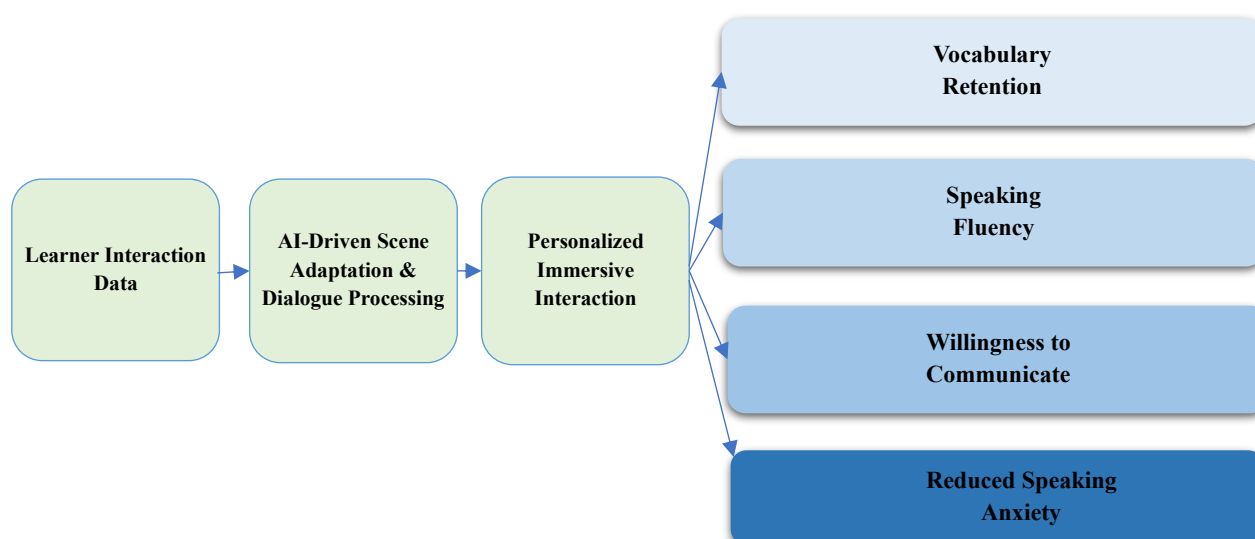


Figure 2: Conceptual Model of VR-Enabled Second Language Learning Outcomes

Figure 2 shows the conceptual model of VR-based second language learning. AI-driven scene adaptation and dialogue processing are used to analyze the data from the learner's interaction such as gaze direction, speech input, gesture, and response time. The personalized immersive interaction in turn results in improvements in vocabulary retention, speaking fluency, willingness to communicate and decreased speaking anxiety, thereby leading to improved and personalized second language learning outcomes.

In the first stage, the learner's gaze and proximity provide contextual cues to activate object labels and vocabulary cues, enabling incidental vocabulary exposure to happen naturally as the learner explores each scene. The second stage involves the automatic speech recognition of learner speech towards non-player characters (NPCs) and mapping it into a pre-recorded dictionary of responses, which are specifically selected for context appropriateness and complexity level, based on the learner's score in the Learner Profile Model (LPM). Pronunciation and/or word error will not be corrected in the middle of the conversation, with the exception of maintaining the flow of the conversation, but will be identified and recorded for the post task feedback summary generated by the Feedback and Reflection Interface described in Section III.

At stage 3, scenario difficulty and multiple branching of dialogue are dynamically varied as a function of the learner's success in previous sessions, such that if the learner successfully completes a scenario (e.g., ordering a meal, asking for directions), related scenarios that are increasingly challenging are unlocked. In all modules, interaction information such as number of conversational turns completed, length of hesitation, and self-corrections, are recorded and incorporated into the Learner Profile Model to further refine the environment's scenario-based recommendations for each particular learner over the six-week pilot duration.

Learning Outcomes and Learner Experience

Learning outcomes were evaluated by comparing pre-test and post-test performance for both the experimental and comparison groups, alongside learner-reported perceptions collected through the post-study questionnaire administered to the experimental group. On average, the experimental group demonstrated a post-test improvement of 22 percentage points in oral fluency compared with 9 percentage points in the comparison group, and a vocabulary retention improvement of 19 percentage points compared with 8 percentage points in the comparison group. Learner questionnaire responses, summarized in table 1, further indicate strong positive perceptions of the immersive environment across several dimensions of the learning experience.

Table 1: Learners' Perceptions of the VR-Based Immersive Second Language Learning Environment
(n = 42)

Survey Item	Agree / Strongly Agree	Neutral	Disagree / Strongly Disagree
The Environment Increased Willingness to Speak in the Target Language	83%	11%	6%
I Felt Less Anxious About Making Mistakes Than in Classroom Speaking Practice	79%	14%	7%
The Scenarios Felt Relevant to Real-World Communication Situations	86%	10%	4%
The Level of Immersion Was Comfortable for Extended Practice Sessions	74%	17%	9%
Feedback on Vocabulary and Pronunciation was Clear and Useful	81%	13%	6%
I Would Recommend this Environment to other Language Learners	88%	9%	3%

Learning outcomes have been assessed by comparing pretest and post test results of the experimental group and comparison group and by the self-reported feelings of the experimental group as measured by post-test questionnaires. In general, there were 22 points of improvement in oral fluency in the experimental group, while there were 9 points of improvement in the comparison group; and, there were 19 points of improvement in vocabulary retention in the experimental group, and 8 points of improvement in the comparison group. The responses to the questions in the learner questionnaire also suggest that the immersive environment is viewed positively in a number of aspects of the learning process, as summarized in table 1.

The VR based immersive environment perceived by the learners is summarized in table 1. The majority of participants felt the environment made them more willing to speak, less concerned with making errors, more relevant to real-world communication, and less uncomfortable than the other, more immersive, environments. The high recommendation level shows a high level of user satisfaction and the value placed on scenario-based and immersive practice in communicative confidence. The activity logs of the session interactions were analyzed, and the learners in the experimental group completed an average of 14.6 conversational scenarios during the six-weeks' timeframe, with this figure rising gradually each week as got more comfortable with moving around the environment. Learners reported especially that having no audience present during the spoken practice was important to them, with some describing it as a "safe space" in which to make mistakes without embarrassment. Teachers, on the other hand, said that session logs and completion dashboards enabled them to detect learners who were not participating sufficiently in

the spoken practice as would have in the classroom; both teachers also reported that a learning curve was needed to understand the data from the system regarding scenarios completed.

Interpreting the Pedagogical Value of Immersion

Based on the results of this study, it can be concluded that VR based immersive environment can be effectively applied in L2 learning to enhance the learning process by implementing scenario realism, learner profiling, and calibrated immersion regulation in L2 learning. The more favorable results found with oral fluency and oral vocabulary retention for experimental group learners suggest the advantages of situates, communicative training, an approach which is not well supported by the conventional classroom setting with its constraints of time and class size. The qualitative results, however, suggest that any perceived privacy that VR-based interaction may offer can help to reduce the affective barriers that often constrain the production of speech among anxious learners, and this is not just the realm of vocabulary or grammatical accuracy but of communicative confidence as well. Gradual reductions of language anxiety through low-stakes, high-frequency scenario-completion tasks compared to high-stakes, infrequent in-class scenario-completion tasks are supported by the steady improvement in scenario-completion rates that were seen throughout the course of the pilot period. The steady improvement seen in scenario-completion rates across the pilot period bolsters the pedagogical principle that low-stakes, high-frequency scenario-completion tasks are more effective at gradually reducing language anxiety than high-frequency, infrequent in-class scenario-completion tasks. The adjustment of teachers with respect to the use of the completion dashboards, however, indicates that the use of immersive tools will not necessarily be successful, as the same technology will only be used as an auxiliary tool if the professional preparation of the teacher is not appropriate. All considered, VR-based immersive environments can be used alongside, but not in place of, expert classroom teaching, and the most significant impact would be likely to be realized when teachers and VR technology are purposefully integrated into a common teaching and learning plan.

Conclusion and Future Work

The purpose of this study was to investigate the potential of VR to provide immersive contexts that can be used in meaningful ways to facilitate second language acquisition and the pilot results are promising for this approach. The proposed VR environment gave higher positive scores to the learners in oral fluency and also increased the vocabulary retention than the conventional method and the learners also experienced less anxiety in speaking and a significantly higher desire to communicate in the target language. The central features of engaging learners were the scenario based conversational tasks, adaptive dialogue prompts and contextual visual cues, all of which enabled learners to practice authentic communication in a low-risk private environment, which many participants found less daunting than speaking in front of peers. Pedagogical effectiveness in immersive environments is not just about technology, but also about thoughtful pacing and considering the nature of the embodied interaction design, as the Immersion and Presence Regulator built into the system design enabled learning intensity to be adjusted to fit the comfort level of each individual. Concurrently, researchers emerged with practical design challenges for future use, such as handling the effects of cybersickness for those who are sensitive, making sure that everyone has access to the headsets, and continuing the creation of quality immersive scenario content. The evidence also indicates that the use of VR for immersive learning is best when used in addition to classroom learning, rather than in lieu of classroom instruction, as the instructors' role cannot be fully replaced by current VR systems, which are not capable of structuring the sociocultural nuances and feedback required by the students. In the future, this work needs to be extended in terms of longer-term studies looking at retention, a greater learner sample across more languages, and comparison of different immersion and interaction

levels. There is also a need to focus more on multiplayer immersive learning spaces that allow for peer-to-peer target-language communication, embedding speech based conversational agents in virtual environments and creating guidelines for classroom-based VR implementation. All in all, the results of this study support the idea of the potential for enriching the authentic, engaging, and communicative confidence of second language learners in a variety of teaching and learning contexts via well-designed, immersive VR environments.

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