Co-funded by the
Erasmus+ Programme
of the European Union

ISENSE WP3
3.3 VR Scenarios

Co-funded by the
Erasmus+ Programme
of the European Union

Summary

Co-funded by the Erasmus+ Programme of the European Union

Introduction – VR, Deaf communities and ISENSE project

Virtual reality (VR) offers immersive, interactive environments that reshape how people learn, communicate and engage with culture, and it is particularly promising for supporting the visibility and empowerment of deaf communities and sign languages. Within this landscape, the European ISENSE project stands out as an initiative designed to reduce the barriers that deaf and hard-of-hearing students encounter in higher education. ISENSE develops advanced digital tools that use virtual reality, augmented reality and holographic technologies to improve orientation, provide accessible information and promote inclusive learning experiences at universities. Its platforms integrate three-dimensional content, gesture-based resources and immersive training scenarios that help students navigate academic environments, support the acquisition and practice of sign languages, and raise awareness among teachers, peers and university staff.

The connection between VR and the diffusion of deaf culture is especially significant because deaf culture is grounded in visual communication, spatial awareness and embodied expression. Virtual environments allow learners to encounter sign languages in rich, spatially accurate contexts where handshapes, movements and facial expressions can be observed from multiple angles. This strengthens comprehension and retention, and it enables authentic interaction that often surpasses what is possible through two-dimensional video. VR can also simulate real-life communicative situations, promoting more intuitive and confident use of signs. Moreover, immersive experiences can foster deeper understanding and empathy among hearing users by allowing them to explore the communicative challenges and cultural perspectives of deaf individuals. This supports broader cultural recognition and can help build more inclusive educational and social environments.

Another important contribution of VR is its potential for cultural preservation and creative expression. Visual storytelling forms closely linked to deaf culture, such as performance art in sign language or Visual Vernacular, can be captured and presented in three-dimensional digital spaces where their spatial and kinetic qualities are fully appreciated. VR thus becomes not only a teaching tool but also a medium through which cultural heritage can be documented, shared and experienced by wider audiences. In combination with repositories of sign-language gestures, interactive learning platforms and accessibility guidelines produced through projects like ISENSE, VR can contribute meaningfully

to the dissemination of deaf culture and to the recognition of sign languages as complete, vibrant linguistic systems.

To achieve these goals, ISENSE employs an approach based on immersive technologies and artificial intelligence (AI).

For more details, visit the website www.isenseproject.eu

Document aim

This document contains all the details related to the VR scenarios developed within SONAR (WP3), designed for training and validation in sign language, as well as for fostering empathy through immersive experiences in noisy environments with different sound profiles. Through this document, research groups can understand how the VR scenarios have been created, how users interact within them, and how these environments can be employed for educational, evaluative, and awareness-raising purposes.

Scenario 1 – First class

The VR scenario for the first class (see Figure 1) is an immersive experience designed for **training and validation in Sign Language** within the framework of WP3 – SONAR. The application allows users to experience a practical case firsthand for learning Sign Language: the scene is set on a **university campus**, where the user takes on the role of a **hearing student** who must communicate with a **deaf student** on the **first day of class**. This narrative approach is intended to recreate realistic interaction situations and promote awareness, empathy, and the gradual acquisition of communicative skills in an everyday academic context.

The application is developed in **six different languages** (English, Spanish, Italian, German, Austrian, and Polish) and uses two complementary systems to present sign language: **avatar animation**, which reproduces signs and facial expressions through high-precision kinematic models, and **video selection**, which features statements recorded in sign language by real signers to ensure gestural fidelity and natural communication. The user can therefore benefit from different modes of linguistic representation. Regarding interaction, the experience is optimized for both motion controllers and **hand-tracking interaction**, allowing users to move by extending their hands, select items by pointing with the index finger, and confirm actions by closing the corresponding fist. This hybrid interaction

system improves accessibility and allows different user profiles to interact comfortably within 6DoF VR environments.

The sign languages used in the scenario include International Sign Language (ISL) for the English version and the corresponding national sign languages for the other languages. The strong presence of ISL in the English version has been essential for the global diffusion of the scenario, enabling adoption in countries outside the partner consortium. The virtual environment also integrates optimized 3D models, low-latency textures, and 3D spatial audio that recreates both the campus setting and the different sound profiles required for empathy-based experiences in noisy environments.

Figure 1. Screenshots of the gameplay for the First Class: Sign Language Training and Validation (EN, ES, IT, DE, AT, PL). SONAR – ISENSE.

The impact of the scenario is already significant (see Figure 2): the application has reached 844 downloads exclusively from VR devices, a notable number for a specialized educational and accessibility-focused tool. According to the data shown in the attached image, most downloads come from the United States, followed by Spain, Italy, Germany, Poland, Russia, Ecuador, Ireland, the United Kingdom, Mexico, and other countries. Importantly, many of these countries do not belong to the original consortium, confirming the international reach achieved thanks to the availability of the

app in English and the use of International Sign Language, and also in Spanish, which has facilitated engagement well beyond Central Europe.

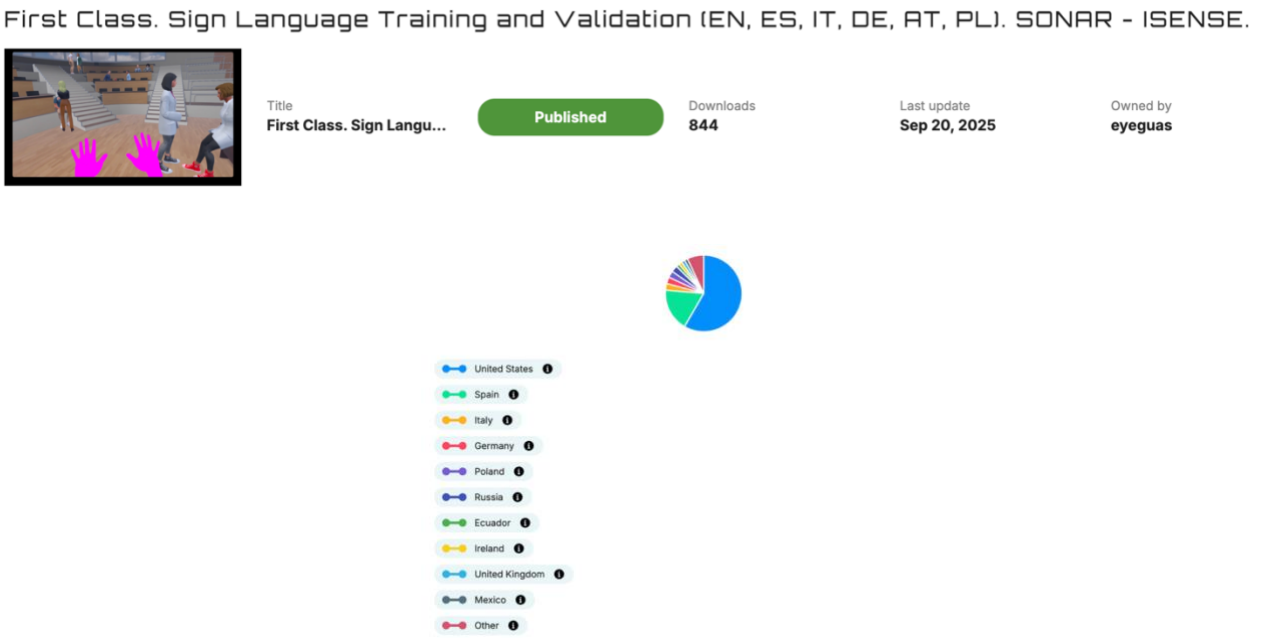

Figure 2. SideQuest download stats for the First Class: Sign Language Training and Validation (EN, ES, IT, DE, AT, PL). SONAR – ISENSE.

Furthermore, the scenario is freely available through open VR distribution platforms, including SideQuest (https://sidequestvr.com/app/37864), which has supported organic adoption and strong cross-border growth. From both a technical and educational perspective, this first scenario demonstrates strong potential for formal Sign Language training as well as for raising awareness and reducing communicative barriers, making it a highly impactful resource within the ISENSE project and across the wider international community.

Scenario 2 - Library

This VR scenario, developed within the ISENSE project's SONAR work package, is a sophisticated training simulator designed for immersive sign language learning. The core experience places the user in a first-person perspective as a deaf student on a university campus, with the objective of interacting with a hearing librarian to borrow a book. This practical scenario is built as a guided

dialogue simulation where user choices drive the narrative forward (see Figure 3). A key pedagogical innovation is the dual representation of sign language within the interaction.

The first method is through automated character translation, where the hearing librarian avatar dynamically translates their spoken dialogue, presented via subtitles, into performed sign language. This simulates an ideal interaction with an interpreter or a signing hearing person. The second method is for user response, which is handled through video selection. The user chooses from multiple-choice options that are presented as pre-recorded video clips of a human signer performing different statements. This requires the user to comprehend the signs to progress, thereby validating their understanding.

Figure 3. Screenshots of the gameplay for the Library: Sign Language Training and Validation (EN, ES, IT, DE, AT, PL). SONAR – ISENSE.

From a technical standpoint, the application is built for the Meta Quest ecosystem and compatible standalone VR headsets. It is distributed freely via the SideQuest platform (https://sidequestvr.com/app/44466), a strategic choice to facilitate broader testing and access. The interaction modality is notably versatile, supporting both standard VR controller input and advanced

hand-tracking. The hand-tracking feature allows users to navigate by extending their hands, point with their index finger, and confirm selections by closing their fist. This controller-free interaction is crucial for mimicking the natural movements of sign language and significantly enhances immersion.

The application's multilingual framework operates on two distinct levels. The user interface and spoken language content are available in the six project languages: English, Spanish, Italian, German, Austrian German, and Polish. More importantly, the sign language representation is deliberately separated, employing International Sign Language for the English version and the corresponding national sign language for each of the other linguistic versions. This design respects the linguistic autonomy of deaf communities.

The educational potential of this scenario is substantial. It creates a safe, repeatable environment for practicing both receptive comprehension (by reading the librarian's signs) and productive decision-making (by choosing the contextually correct signed response). It simulates a real-world interactional pressure that is difficult to replicate with traditional learning tools, moving beyond passive video learning into active, situational practice.

The current impact, evidenced by 2,722 downloads specifically from VR devices, demonstrates significant organic traction for a niche educational title (see Figure 4). The geographic distribution of downloads, as shown in Figure 4, reveals a highly successful international uptake that extends far beyond the core ISENSE consortium nations of Spain, Italy, Poland, Austria, and Germany. The leading country for downloads is the United States, followed by the United Kingdom, Germany, Russia, Canada, France, Spain, Brazil, Mexico, Italy, and a notable "Other" category.

This distribution pattern highlights a critical success factor: the strategic decision to develop an English-language version featuring International Sign Language. This combination acted as a global gateway, making the application immediately accessible to users in major English-speaking markets like the U.S., U.K., and Canada, as well as to international users and educators worldwide who commonly use English as a second language or lingua franca. The strong showing in non-consortium, non-English speaking countries like Russia, France, Brazil, and Mexico further underscores the app's broad appeal, likely driven by VR enthusiasts, accessibility advocates, and educational professionals seeking innovative tools. The open distribution model via SideQuest was instrumental in enabling this global discovery and access.

For the ISENSE project and SONAR WP, the success of this library scenario serves as a powerful proof-of-concept. It validates the technical and pedagogical approach of combining avatar-based signing with video responses and hand-tracking interaction. The unexpected but robust global

download figures, particularly from outside the consortium, provide concrete evidence of a strong international demand for well-designed VR sign language training tools. This data is invaluable for guiding future development, advocating for the inclusion of VR-based accessibility training in formal programs, and securing further research and development funding. The scenario has effectively transitioned from a EU-funded research prototype into a genuinely global educational resource, demonstrating the universal potential of immersive technology for social inclusion.

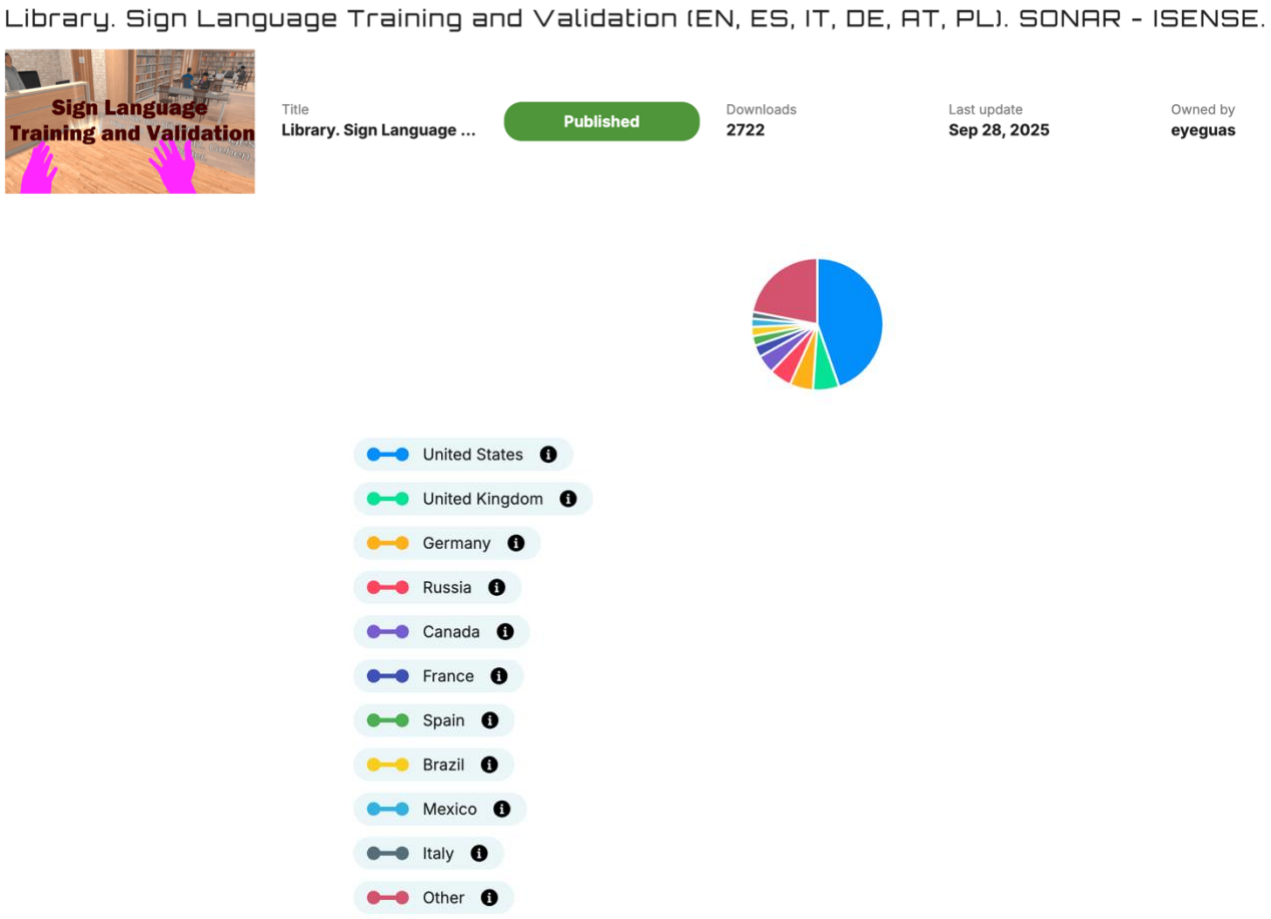

Figure 4. SideQuest download stats for the Library: Sign Language Training and Validation (EN, ES, IT, DE, AT, PL). SONAR – ISENSE.

Implementation. Sign Language Training and Validation

The preliminary implementation of the SONAR VR training in Sign Language was conducted with a full cohort of 120 students from the Faculty of Education Sciences, each completing an individual 30-minute VR session. Of the total participants, 86% (103 students) reported no prior experience with

Sign Language, and 56.1% (67 students) had never interacted with virtual reality before engaging with the SONAR scenarios.

Despite these initial limitations, the overall reception of the VR experience was highly positive. In terms of usability, 46.6% (56 students) indicated that the SONAR application was intuitive and easy to use during the “First Day of Class” and “Library” scenarios. Students particularly valued the clear navigational cues, the responsiveness of both controller-based and hand-tracking interaction, and the structured progression of communicative tasks in the simulated university campus.

The immersive format proved to be a strong facilitator of learning. When asked whether the VR experience supported the acquisition of Sign Language, 44.8% (54 students) strongly agreed and 43.1% (52 students) agreed. This demonstrates the impact of combining avatar-based signing, videos featuring real signers, and contextualised challenges that require immediate visual comprehension.

A marked improvement in perceived self-efficacy was observed. Before the VR session, 71.9% (86 students) reported feeling entirely unable to understand basic messages in Sign Language within a university context. After completing their 30-minute immersive experience, this figure decreased dramatically to 3.4% (4 students). Students frequently attributed this shift to the opportunity to interact directly with a deaf avatar, practise recognition skills repeatedly, and situate communication within a meaningful scenario.

Motivation to learn Sign Language also increased. Prior to the implementation, 28.1% (34 students) expressed motivation to engage with Sign Language learning; after the VR training, this number rose to 41.1% (49 students). These results highlight the attitudinal value of immersive training even within short, preliminary sessions.

Overall, the findings from this preliminary deployment indicate that even short-duration VR interventions, in this case, 30 minutes per student, can yield significant improvements in learners’ perceived competence, engagement, and familiarity with Sign Language and deaf culture.

The preliminary implementation of the SONAR VR scenarios followed a structured process designed to ensure pedagogical alignment and technical efficiency while accommodating individual VR sessions per student.

A dedicated VR room was prepared, equipped with standalone 6DoF headsets, safe movement areas, high-speed Wi-Fi, and a monitoring station enabling instructors to supervise multiple devices

simultaneously. All headsets were preloaded with the SONAR application to ensure consistency and minimize session transition times, which was critical given the short, fixed time allocation per student.

Academically, the scenarios were integrated into modules related to inclusive education, communication, and educational technology. Prior to entering VR, students received a brief theoretical introduction to deaf culture, including the use of International Sign Language (ISL) in the English version and the respective national sign languages in the other language modes. These short pre-session briefings ensured that students could make the most of their individual VR time.

During the VR sessions, each student completed the "First Day of Class" and "Library" scenarios. In the first scenario, the user adopts the role of a hearing student communicating with a deaf peer on a university campus. In the second scenario, the user adopts the role of a deaf student communicating with a hearing librarian. The hybrid interaction system (supporting both controllers and hand tracking) allowed rapid adaptation, with students able to navigate by extending their hands, select options by pointing with the index finger, and confirm decisions by closing their fist.

Before and after completing their 30-minute session, students filled out structured questionnaires assessing usability, perceived learning, motivation, and self-efficacy (Pretest: https://forms.office.com/e/NkXqMQhZn8; Posttest: https://forms.office.com/e/cuV4EpNdun). The digital collection of responses enabled immediate analysis and supported the continuous improvement of the implementation. Observational data from facilitators and automatic behavioural logs from the SONAR application provided further insights into interaction patterns and user challenges. Given the preliminary nature of the deployment, iterative refinements were made throughout the process, including adjustments to hand-tracking sensitivity, improvements to avatar gesture clarity, and optimisation of signing sequences to better match varied student proficiency levels.

Overall, this preliminary implementation demonstrates that structured short-duration VR sessions can be integrated effectively into higher education, delivering meaningful improvements in learner engagement, motivation, and perceived communicative competence while providing a robust foundation for future large-scale deployments of the SONAR VR ecosystem.

Empathy: Coffee shop

The SONAR empathy application (Coffee shop) is an immersive virtual reality experience developed within the ISENSE project to help users understand the perceptual, cognitive, and communicative challenges faced by individuals with hearing loss. Designed for Meta Quest/Oculus standalone

headsets, the application recreates a university-campus café where hearing users can experience everyday situations through different auditory conditions, promoting empathy and awareness of the barriers faced by people with auditory impairments. A key technological component of the system is the 3DTI AudioToolkit Unity Wrapper, a sophisticated spatial-audio engine originally developed as part of the European Union's Horizon 2020 project 3D Tune-In (Grant Agreement No. 644051), whose results are publicly available at https://www.3d-tune-in.eu/

The toolkit provides advanced real-time manipulation of sound, enabling the simulation of hearing-loss profiles, cochlear-implant processing, frequency-dependent degradation, reverberation, attenuation, and spatialisation. Permission from the University of Málaga allows SONAR to incorporate these validated algorithms and concepts, ensuring scientific accuracy and a high level of auditory realism.

Within the empathy application, users can switch between several auditory profiles that represent different perceptual conditions: normal hearing; mild, moderate, and severe hearing loss (each progressively reducing clarity, spatial resolution, and intelligibility); hearing-aid and cochlear-implant simulations (with altered spectral detail, robotic timbre, and limited localisation); and complete deafness, where all environmental audio is removed. These profiles can be explored through two progression paths (hearing to deafness or deafness to hearing) allowing users to experience the gradual loss or recovery of auditory information. This dynamic modulation highlights the emotional, cognitive, and communicative impacts associated with changes in hearing capacity.

The virtual café scenario has been designed to maximise ecological validity, containing multiple competing sound sources, background chatter, machine noise, and reverberation, all of which interact differently depending on the auditory profile selected. Users face a sequence of challenges that reveal the complexities of real-world communication for individuals with hearing loss. These include requesting a ticket at the counter while managing turn-taking and background noise; reacting to a loudspeaker announcement that becomes progressively harder to understand; ordering a coffee under increasingly degraded auditory conditions; joining a group conversation where overlapping voices limit intelligibility; following a professor's explanation affected by reverberation; attempting to study while struggling with environmental noise; listening to music through virtual headphones with altered timbre depending on the profile; observing a group debate to experience how reduced clarity affects comprehension of different viewpoints; and assisting a classmate with hearing difficulties to better understand the communicative adaptations required in supportive interactions. These challenges

expose users to the practical, emotional, and cognitive load that hearing-impaired individuals experience daily.

The empathy application has been developed in two languages (English and Spanish) with all voice lines and textual content provided by the ISENSE team to ensure accessibility across linguistic contexts. A preliminary version of the SONAR empathy experience is freely available for download at:

https://drive.google.com/file/d/1eO9VUu37Evsd3kESR1Ofpu9V0sbXiDpC/view?usp=sharing

and gameplay demonstrations can be seen at:

https://youtu.be/Oils2T94ue8?si=i81wnz4yVYUVvCjP

https://youtu.be/PyZADFxpMGg?si=GUgpiCKuB_XfjZMG

The application is currently undergoing evaluation for publication on SideQuest, where it will soon be released as an open and freely accessible resource for educators, researchers, accessibility specialists, and the wider VR community interested in promoting empathy, inclusion, and auditory diversity through immersive technologies.

Conclusions

The results of the SONAR WP demonstrate that VR is an effective tool for promoting inclusion and education for deaf and hard-of-hearing individuals. The immersive scenarios developed provide authentic, contextualized learning experiences by combining animated avatars, videos of real signers, and three-dimensional environments that enhance comprehension and practice of visual communication. Preliminary sessions with university students showed significant improvements in perceived competence, sign language understanding, and motivation to learn, even in short-duration interventions. Furthermore, VR applications designed to foster empathy, such as the “Coffee Shop” scenario, allow users to experience various auditory conditions, raising awareness of the communicative and cognitive challenges faced by individuals with hearing loss and supporting the development of more inclusive educational and social environments. The availability of scenarios in multiple languages, including International Sign Language and national sign languages, alongside open distribution on free platforms, has enabled substantial international reach, with downloads from numerous countries beyond the European consortium. The combination of pedagogical and technological innovation, including hybrid interaction via controllers and hand tracking, advanced auditory simulations, and accurate gesture representation, enables users to develop communicative

and comprehension skills in realistic contexts that surpass the possibilities of traditional methods. Overall, the findings show that VR is not only effective for learning and practicing sign language but also serves as a valuable medium for disseminating deaf culture and raising awareness within the educational community, supporting the expansion and integration of ISENSE tools into formal programs and future research on inclusive immersive technologies.

For more details and assistance, please contact:

isenseproject@unitus.it