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Extended Reality Model for Accessibility in Learning for Deaf and Hearing Students (Programming Logic Case)

Martha Segura*
Universitaria Agustiniana/Faculty of Engineering, Bogotá, 110811, Colombia
E-mail: martha.segura@uniagustiniana.edu.co
ORCID ID: https://orcid.org/0000-0002-1572-1447
*Corresponding Author

Ramiro Osorio
Universitaria Agustiniana/Faculty of Engineering, Bogotá, 110811, Colombia
E-mail: ramiro.osorio@uniagustiniana.edu.co
ORCID ID: https://orcid.org/0000-0003-0007-9452

Adriana Zavala
TecNM Tecnológico Nacional de México TESCI (Tecnológico de Estudios Superiores de Cuautitlán Izcalli) / School of Public Accounting Department, Cuautitlán Izcalli, Mex., 54748, México
E-mail: adriana.zm@cuautitlan.tecnm.mx
ORCID ID: https://orcid.org/0000-0003-1338-6259

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Abstract: A group of researchers and developers from Colombia and Mexico have recognised that the development of state-of-the-art Extended Reality software, a key technology for the Metaverse, has great potential to improve teaching-learning processes in educational institutions. However, the development process does not take into account accessibility, universal design and inclusion, especially for the deaf student community. An extended reality model is proposed for the creation of this type of software as a tool to support access to knowledge, based on information gathering, requirements analysis, user-centred design and video game programming, including the ludic and didactic. The aim is to minimise the barriers that limit the learning of programming logic by students with hearing disabilities through the use of new technologies, creating spaces in virtual worlds that are understandable, usable and practical in conditions of safety, comfort and as much autonomy as possible. To validate the model, a mixed reality software prototype was designed and programmed to train students in programming logic, both deaf and hearing. User and heuristic tests were carried out, showing how immersion can improve knowledge acquisition processes and develop skills in higher education students.

Index Terms: Model, Extended Reality, Accessibility, Gamification, Immersive educational environment.

1. Introduction

Virtual Reality is a technology that has been around for decades, and its development has accelerated in recent years with new devices and sophisticated software, and changes in hardware components that have made it more affordable and accessible to many more users. Tailor-made software is developed for this cutting-edge technology, adapting to specific needs in different fields of knowledge; however, there is little tendency in the world to develop accessible and inclusive software designed for people with different abilities, such as deaf people. Creating accessible software for the latest extended reality technologies, defined as the fusion of virtual, augmented and mixed reality, is an opportunity.

Nowadays, with the opportunity to acquire virtual reality devices, many users can experience a great deal of immersive content. At the same time, there have been important innovations in this technology, which allow us to think that it can be used to enhance the teaching-learning processes in higher education institutions. For this reason, the group of researchers has been studying for several years how to improve the development process in immersive virtual reality, and has explored new methods to combine virtual, augmented and mixed reality in extended reality, looking for a real application in education. A development methodology has been proposed for this type of applications based on the methodology for video games SUM, since virtual reality applications present very similar characteristics to video games when programmed and integrated, consequently software products have been built using virtual reality glasses. As technology advances, researchers along with developers have seen the opportunity to optimise such applications. Software prototypes have been created in immersive and augmented virtual reality for all people, with special interest in blind and deaf people.

Immersive experiences initially focused on virtual tours based on photos and 360 ° video, then on 2D and 3D animation, and finally on 3D virtual spaces online. These experiences were characterised by the integration of code in the C# language for the Unity video game engine with images, audio, immersive sounds, subtitles and videos. The latest advances have proposed the use of virtual reality on the latest generation of devices, such as the Oculus Quest 2 glasses, and have managed to provide applicability in the teaching-learning processes in engineering faculties. For this reason, the group of researchers and developers proposed the use of Extended Reality in the classroom, in a specific course that can improve the skills of deaf and hearing students in the universities participating in the project. The aim of using Extended Reality is to remove the communication barriers between deaf and hearing people in the virtual world, overcoming the differences by interpreting the sign language of the real world. In order to achieve this interaction, efforts have been focused on creating a model for accessibility to knowledge in Extended Reality, applied to a basic programming logic course for deaf and hearing students.

In 2022, a study was carried out to determine the characteristics of the model and a preliminary version was defined [1]; in order to create more interactive content in line with the realities of deaf and hearing students, in a first iteration, the content of the basic programming logic course was generated and fed in parallel to the model with the experience gained from the development of a mixed reality prototype on Oculus Quest devices [2]. This development followed the SUM methodology, which includes analysis, design, coding and testing with end users.

For the last year, the Extended Reality model has been created, which integrates immersion, accessibility, gamification, user experience, inclusion and didactics, not as a sum of requirements, but as a whole that serves as an abstraction for the development of software in education. Extended reality involves the integration of virtual, augmented and mixed reality, each with a specific purpose within the system; interaction and overlapping in an environment of real-looking scenes and objects. Adaptation of this cutting-edge technology is required to ensure understanding and ease of use by both hearing and deaf students, allowing them to develop their programming skills in a creative and motivating way. The model is created as a tool in the study of Extended Reality technology for education, helping to understand the teaching-learning process of deaf and hearing students in the basic foundation for learning to program in a language, this process turns out to be complex and with multiple interactions.

In [1] the question was posed to achieve the research objective: How can the teaching-learning process of programming logic within the deaf and hearing community be improved through the use of technologies such as Extended Reality, by creating a model that can be applied to other subjects?

The model is then built to achieve the research objective. First, a qualitative study was conducted to build the model [1], then a mixed reality prototype was implemented for the Oculus Quest [2], designed using Unity on the content of a basic programming logic course, based on the real needs of deaf and hearing students. The software prototype was validated through user and expert testing. Finally, the extended reality model for knowledge accessibility is defined as a functional model that takes into account the essential factors and ignores the superfine details, defining the principles to be met by the model and the main requirements. The analysis of the results determines recommendations for future research.

2. Related Works

This section presents the state of the art in Extended Reality and relevant research topics. Reference is made to Extended Reality in education, the use of Immersive Virtual Reality, Augmented Reality in learning, Gamification as a didactic strategy in teaching processes, Methodologies for the design and development of virtual content or online materials, and Inclusion in Extended or Mixed Reality.

2.1. Extended Reality in Education

The article [3] Education is an important driver for sustainable social development. Emerging technologies such as Extended Reality (XR), including Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR), have been widely used. Recently, a large number of theoretical and empirical studies have emerged on the use of XR in the field of education for sustainable development. This paper uses bibliometric analysis to analyse the publication and citation trends of articles, prolific authors, institutions and countries, influential works, current topics, emerging trends and knowledge structure to explore the overall productivity and XR research trends in the field of education for the period 1991-2021.

The study [4] Higher education in the Republic of Serbia is in need of reform. The research was carried out by analysing the theoretical foundations of available knowledge and experience. In addition, articles and academic papers and studies on artificial intelligence, machine learning and Extended Reality were consulted. The authors believe that these technologies could be of great help in developing a new strategy for higher education. Furthermore, this research is exploratory, as information from the 100 Serbian students from the selected higher education institutions was used to better understand whether these technologies are well received by students. Based on SmartPls software, the research analysis showed that Extended Reality (XR) facilitates increased motivation, engagement and hands-on learning activities among students by providing a realistic learning environment.

Referencing [5], in an environment of constant evolution, what emerged as augmented reality is evolving towards extended reality. Augmented reality is a tangible fact that can be found applied to culture, with the possibility of expanding more information on works in museums, games, or decorations. Although it is a technology that may seem different, it does not require high resources. It focuses on three experiences developed at the Don Bosco University Center. Among the advantages obtained from using this technology, it is reflected that students acquire an improvement in grades since it improves their degree of motivation and academic performance. The future of extended reality and its application to teaching will largely depend on the maturity of the technology and its costs. Technological manufacturers have already developed the first tools that allow these technologies to be applied, but their prices are still high for their use to become widespread.

2.2. Use of immersive virtual reality

In this paper [6], in recent times serious environmental changes are expected, such as global warming, climate change, and environmental pollution, so environmental education is becoming essential. Environmental education aims to educate students to recognize and solve environmental problems. VR provides students with a real-like spatial and temporal experience and can increase their understanding of knowledge through immersion and interaction compared to traditional learning. In previous studies, virtual reality for education has mainly focused on experience, but it is difficult to find examples for environmental education. Hence, this research proposed an Immersive Virtual Reality simulation for environmental education based on the virtual ecosystem model. Two applications developed from this simulation are also presented. This research aims to foster the active participation and motivation of students to solve environmental problems while experiencing the results of the interaction related to environmental factors in a virtual environment.

In the article [7] the purpose of Immersive Virtual Reality (IVR) has been frequently proposed as a promising tool for learning. However, researchers have routinely implemented a plethora of design elements into these IVR systems, making it unclear what specific aspects of the system are necessary to achieve beneficial results. In this context, this study aims to combine the present literature with learning theories to propose that the ability of IVRs to represent three-dimensional objects to users enhances the presence of these objects in the virtual environment compared to virtual ones. two-dimensional objects, which leads to higher learning performance.

2.3. Augmented reality used in learning

This study [8] shows how alternative ways of learning and teaching anatomy have increased in recent years, especially since the COVID-19 pandemic. Virtual reality (VR) and augmented reality (AR) are two promising alternatives. This paper analyses the suitability of using VR and AR for anatomy training by comparing an optics-based AR setup and a VR table-based semi-immersive setup, using the same anatomy training software and interaction system. The AR-based setup uses a Magic Leap One, while the VR tabletop setup uses stereoscopic TV screens and a motion capture system. This experiment builds on a previous experiment [9] in which the AR-based configuration was improved and the complexity of one of the two tasks was increased. This new experiment aims to confirm whether the changes in the configurations alter the previous conclusions. The hypothesis is that the enhanced AR-based configuration will be more suitable for anatomy training than the VR-based configuration. For this reason, an experimental study will be conducted with 45 participants, comparing the use of anatomy training software. Both objective and subjective data were collected. The results show that the AR-based configuration is the preferred option. Differences in measurable performance were small but also favourable for the AR-based configuration. In addition, participants gave better subjective scores to the AR-based configuration, confirming the initial hypothesis. However, both configurations offer similar overall performance and provide excellent results in subjective measurements, with both systems approaching the highest possible scores.

The study [10] comments that the arrival of information and communication technologies (ICT) in the educational system has led to the arrival of numerous innovative resources of great didactic interest in the classroom. This is the case with Augmented Reality, a technology that has become popular due to its ability to combine virtual and real elements at the same time. The present work has tried to investigate the scientific literature to verify if the application of Augmented Reality in the classrooms promotes a motivational improvement in the student body of the different educational stages. For this, the methodology corresponding to the systematic reviews and meta-analyses proposed by the PRISMA declaration was used, taking the Scopus and Web of Science databases as data sources. A total of nine quasi-experimental methodologies were analyzed around the measurement of the motivation variable. The results elucidated a favorable diagnosis for the experimental groups, so it could be inferred that experimentation in the classroom with Augmented Reality motivates students in different educational stages. However, there is a need to carry out a greater number of experiences with Augmented Reality in the classroom to establish an opinion around a more solid body of scientific papers.

2.4. Playfulness as a didactic strategy in teaching processes

Taking into account the proposed preliminary model [1], a literature review was conducted based on theoretical aspects of the research topic, which include playful, gamification, and didactic content.

Ref [11], play and its relationship to children's learning and development is well described in the research literature. However, the application and implications of play in higher education (HE) appear to be less systematically addressed. This article presents a scoping review of playful learning (PL) in teacher education (TE) and early childhood teacher education (ECTE). The review shows that the relationship between curricular learning objectives and PL is often vaguely described, with a focus on generic competences and motivation. Furthermore, the theoretical underpinnings of PL appear to be ambiguous. The article concludes by discussing implications for future research and for the design of PL in higher education.

This study [12] examines the relationship between play-based learning and mathematics achievement in Palestinian primary school children. Forty teachers from eight schools received training in play-based pedagogy and follow-up support visits from programme staff (intervention group); four matched schools served as the control group. Grade-appropriate tests were administered to all students in two consecutive school terms. A total of 859 students (458 females, 401 males) and 832 students (477 females, 355 males) completed the mathematics tests in terms 1 and 2, respectively. The results showed that the intervention group achieved higher test scores than the control group in both terms ($P < 0.01$). Furthermore, an interaction effect between group and gender was found in term 2 ($P < 0.05$), with girls in the intervention group achieving the highest scores. Our findings suggest that play-based learning approaches can improve academic performance.

The article [13] analyzed the competency-based educational model of Higher Education in the 21st century from the perspective of its fundamental piece, the competencies acquired in the environment of multiliteracies. The research argues for the analysis in four dimensions: first, the Web as an educational space, an emerging element in the generation of knowledge, in which to propose educational innovation as a method and factor of information behavior, connectivity as the ideal pedagogical model for cyberspace education. , and networks as an appropriate means of transmission; then, digital competence as a priority didactic objective for lifelong and cooperative learning, taking into account its definition and application regulatory frameworks; it continues the study of Gaming as an educational object and web teaching material suitable for educational programs with competences, due to its pedagogical effectiveness; finally, the consideration of Academic Skills Centers (ASC) as the necessary space for the correct treatment of Gaming as learning objects and for the development of competency-based didactic programs. The investigation ends with a proposal of how a competency educational program in an ASC should be, presenting its instructional design, which is modular and progressive, its teaching dynamics as a didactic methodology for its greater educational effectiveness, and the design of its didactic program structured in twelve didactic units.

2.5. Methodologies for designing and developing virtual content

As input to create the model, articles related to VLO Virtual Learning Objects and the ADDIE model for the creation of virtual content and online materials are referenced.

The present research [14] aimed to investigate the effectiveness of the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model as used in online teaching in the LMS of Blackboard; and its facilities such as discussion boards, forums and blogs in improving the creative writing skills of EFL university students. The researcher used a quasi-experimental method with a pre-test, post-test and control group design. Sixty students were randomly selected from the freshman class of the English department to participate in the study and were equally allocated to the research groups. The experimental group was exposed to the e-learning environment designed to develop students' creative writing skills, while the control group was exposed to the traditional teaching method. Using a creative writing checklist and a writing test designed to assess the specific features of creative writing (originality, accuracy, self-expression, fluency, flexibility and overall writing performance) to assess the creative writing of the research participants, the results of t-tests and eta-squared statistical tests showed that there were statistically significant differences between the mean scores obtained by the experimental group and those obtained by the control group writing performance post-test in favour of the experimental group participants. Conclusions and pedagogical implications were drawn at the end of the article.

In this paper [15], the era of 'metaverse', virtual environments are gaining popularity among new multimedia content and are also recognised as a valuable means to deliver emotional content. This is facilitated by cost reduction, availability and end-user acceptance of virtual reality technology. Creating effective virtual environments can be achieved by exploiting several possibilities: creating artificial worlds capable of generating different stories, mixing sensory cues and making the whole interactive. The design space for creating emotional virtual environments is vast, and there is no clear idea of how to integrate the various components. This paper discusses how to combine several design elements to elicit five different emotions. We developed and tested two scenarios for each emotion. We present the methodology, the development of the case studies and the results of the tests.

2.6. Inclusion in extended or mixed reality

According to the article [16], Extended Reality (XR) technology is an innovative tool for meeting today's challenges, as it allows new solutions to be experimented with in terms of content creation and its consumption by different types of users. The potential to modulate the experience according to the needs of the target audience and the objectives of the project makes XR suitable for creating new accessibility solutions. The "Includiamoci" project was carried out with the aim of creating workshops on social inclusion through the combination of art and technology. Specifically, the experiment involved ten young people aged between 28 and 50 with cognitive disabilities who participated in Extended Reality workshops and art therapy workshops. These activities resulted in two outputs: a virtual museum populated by the participants' works, and a digital set design for a theatre performance. Two tests, one on user experience (UX) and one on well-being, were used to evaluate the effectiveness of the whole project. In conclusion, the project demonstrated that the solutions adopted were appropriate to the objectives, increased our knowledge of UX for a target audience with specific user needs, and used XR in the context of social inclusion.

Referencing [17], Malaysian university students faced various obstacles and had unmet needs when it is no longer an option to carry out virtual learning during the COVID-19 pandemic. These challenges faced by students call into question their actual use behaviour and true acceptance of the virtual learning environment (VLE). Thus, this study investigated the students' actual use behaviour of VLEs, the factors that influence the actual use behaviour, the moderating effect of network connectivity on this relationship, and challenges faced by students while using this technology. The Technology Acceptance Model (TAM) and the Unified Theory Acceptance and Use of Technology 2 (UTAUT2) model were used as the theoretical basis of this study. An online survey was conducted among the International Medical University (IMU) students. The finding surmised that most of the students have adopted the VLE during the pandemic. The findings further revealed that factors such as hedonic motivation, perceived usefulness and perceived ease of use positively affect actual use behaviour, while network connectivity has no significant moderating effect on the relationship between the dimensions of the VLE and actual use behaviour. The key challenges include high cost associated with the VLE usage, and the students find the VLE is not entertaining or enjoyable. These results indicate that students will be inclined to accept the technology if there is high hedonic motivation, perceived usefulness, and perceived ease of use. Universities should focus on enhancing these factors to increase the acceptance of this technology among students, as VLEs have untapped potential for distance learning.

The article [18] examples of extended cognition typically involve the use of technologically low-grade bio-external resources (e.g., the use of pen and paper to solve long multiplication problems). The present paper describes a putative case of extended cognizing based around a technologically advanced mixed reality device, namely, the Microsoft HoloLens. The case is evaluated from the standpoint of a mechanistic perspective. In particular, it is suggested that a combination of organismic (e.g., the human individual) and extra-organismic (e.g., the HoloLens) resources form part of a common mechanism that realizes a bona fide cognitive routine. In addition to demonstrating how the theoretical resources of neo-mechanical philosophy might be used to evaluate extended cognitive systems, the present paper illustrates one of the ways in which mixed reality devices, virtual objects (i.e., holograms), and online (Internet-accessible) computational routines might be incorporated into human cognitive processes. This, it is suggested, speaks to the recent interest in mixed/virtual reality technologies across a number of disciplines. It also introduces us to issues that cross-cut disparate fields of philosophical research, such as the philosophy of science and the philosophy of technology.

A literature review of two studies on mobile technology and augmented reality for deaf adults and children has demonstrated the importance of augmented reality for the deaf community. In first study [19], the applications used for teaching-learning were analysed in terms of didactic topics, target audience and sign language used, showing a high predisposition to the use of mobile technology due to the ease of use of visual/tactile resources, although there is still a reduced but promising use of Extended Reality, which allows a field of application of new contributions for the development of the deaf community; and the second study [20], which focused on educational mobile applications for deaf children of primary school age, highlighting the type of methodology and support strategies used, as well as the type of extended reality, development and use of technology, concluding that there is little literature on teaching-learning applications for children that record the use of collaborative strategies, highlighting Android applications supported by multimedia elements, followed by the use of augmented reality and a minority for extended reality technologies.

Consequently, Extended Reality can be considered as one of the best technologies to improve the teaching-learning process; the development of specialised software for current educational environments is required, taking into account that students grasp knowledge better through immersive and interactive spaces. According to [3], there is a lack of teacher training to design learning experiences based on Extended Reality and a lack of interdisciplinary collaboration between the fields of technology and pedagogy. For this reason, defining an extended reality model for knowledge accessibility facilitates the understanding of its use in educational environments.

3. Methodology

To realise the extended reality model, we adapted the evolutionary development [21] and prototyping technique [22], taking into account that they use the iterative and incremental model, which allows developing a first version, then refining it as many times as necessary and adding complexity until reaching the final goal, even after its implementation. The extended reality model in a preliminary version provided an overview, its description in components and relationships; the software prototype became the mechanism for identifying the requirements of the model and its refinement through feedback from students and teachers until the final version of the model was reached. This project took into account the concurrent phases of evolutionary development, i.e. specification, development and validation, which are intertwined during the process. For the construction of the virtual reality software prototype, the SUM methodology for video game development was used, adapted to the specific needs of this type of software.

As far as the content of the basic course in programming logic is concerned, it was developed using the modified ADDIE model, based on the defined themes and the analysis of the problems raised by teachers and deaf and hearing students, which included the difficulty of understanding the logical structures of programming and problem solving. The first version of the software, or prototype, was programmed in the C# language and integrated into Unity, the multiplatform video game engine that stands out for its graphics and the quality of its tools. Unity can be used to create virtual, augmented and mixed reality experiences that interact intelligently with the real world. The result of this process is a mixed reality software for the Oculus Quest 2, with basic programming logic content, interactive learning activities and level-defined assessment, which strengthens the understanding and development of creativity in problem solving and solution finding.

The evolutionary development phases for this project are explained below:

Phase I. Specification. In order to specify the model, a survey was carried out with teachers, deaf and hearing students, sign language interpreters and software developers. The questions focused on identifying the characteristics that the Extended Reality model should meet. With this information and a model design study, the principles of the model and its main requirements were defined. The purpose of the model was defined, essential considerations were identified, superfluous conditions were discarded, and the graphical model was presented in a simplified form.

Phase II. Development. After the preliminary design of the Extended Reality model and its main considerations, the construction of the Mixed Reality software prototype for the Oculus Quest 2 was carried out using the Vuforia Augmented Reality SDK and the C# and Unity immersive virtual reality programming languages. The integration of 3D scenes, 2D and 3D objects, immersive sounds and images into the virtual environment was realised. The software organised the interactive content of the basic programming logic course, recognising from the model the needs of all those interested in the teaching-learning process of programming logic.

The content was designed using the ADDIE model, adapted for the creation of a mixed reality course. On the basis of the researchers' experience as teachers in the field of basic programming, the structure of the unit to be developed was defined, then the contents of the programme were organised and, from this information, the learning levels that the student had to achieve in order to reach the learning objectives were defined, articulated with explanations of the subject, examples, activities and challenges to be met or evaluation activities. Everything was programmed in a virtual environment that combines immersive virtual reality and augmented reality, which the student accesses through Oculus Quest 2 virtual reality glasses, from which the interactive content of the course can be observed, both by the deaf student, who has short descriptions, subtitles, colour graphics and sign videos, and by the hearing student.

The adaptation of the stages of the ADDIE model is presented to develop the didactic unit on the basic concepts of mixed reality based programming logic:

Analysis. The learning needs of the students were identified, taking into account the problems of the deaf student community. And the necessary resources (conceptual, graphical and interactive) were defined.

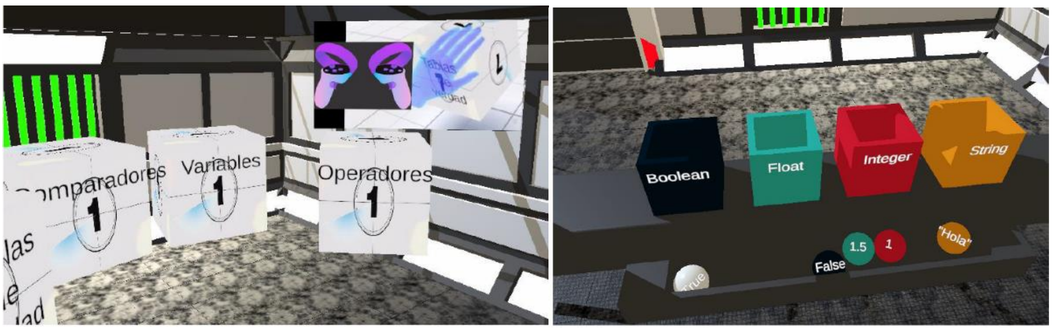
Design. Activities and assessment were designed to achieve the learning objectives of the unit.

Development. Multimedia elements related to definitions, examples, tasks (assessment activities) were created and validated for each of the levels: data types, variables, operators and conditionals.

Implementation. All components were integrated into the mixed reality software prototype.

Evaluation. This last stage of the ADDIE model was divided into two levels in the following phase: the degree of assimilation of the student's knowledge and the usability of the course on the basis of the scenes and the modelling of the objects. This stage was included in the validation phase III.

Figure 1 shows images of the scenes captured during the development of the mixed reality software prototype.



(a) (b)

Fig. 1. Pictures taken while developing a mixed reality prototype. (a) Learning levels; (b) Data type activity.

Figure 2 shows the development team during functional testing of the Oculus Quest 2 virtual reality glasses and software testing of the mixed reality prototype.

Fig. 2. Mixed Reality Software Prototype Development Team

Phase III. Validation. During this phase, the version obtained from the first iteration of the mixed reality software prototype was evaluated by a group of teachers, developers and deaf and hearing students on the basis of the criteria obtained from the model. Through the tests conducted, the group of testers provided feedback on the software. The development team was responsible for making the necessary adjustments after the evaluation. At the end of the phase, the software prototype was used to experiment with and understand the requirements of the model, and in a next iteration to improve the quality and functionality of the software.

4. Results and Discussion

During each semester, students in programming logic or algorithms courses learn in the classroom. They use flowcharts, pseudocode and practical examples. They use computers and programming languages such as Java and C++ in the university laboratories. In order to develop independent or autonomous work, they carry out their activities at home with their own resources. The teaching process is led by the teacher as a guide for the students. The teacher observes, analyses, verifies, compares, determines, evaluates and presents alternatives for learning. Students learn by doing. They test their ability to creatively solve programming logic problems. Deaf students have a sign language interpreter in the classroom who translates the teacher's instructions into sign language so that they can carry out the various activities.

New technologies such as Extended Reality should be used to create pedagogical tools that support the traditional teaching-learning process in the classroom, as they become powerful didactic strategies that allow students to develop new skills, increase their interest and motivation, as they can be personalised to progress at their learning pace.

The research results present an extended reality model for accessibility in learning. This model can be adapted to different engineering courses or other settings, including reasonable accommodations for the deaf student population.

4.1. Data Collection and Preprocessing

During the data analysis in the different phases of the project, the information from the collected surveys, notes and documents was systematically organised. The analysis focused on the specific aspects for the creation of the augmented reality model and its application in a course designed for a learning unit using immersive, multi-sensory interactivity and real-time simulation.

In the specification phase, Microsoft Excel was used to analyse the requirements survey. In this programme, the answers to 42 items were tabulated and grouped as follows Stakeholders, Assessing the Problem, Understanding the Environment, Assessing the Opportunity, Assessing the Solution, Assessing the Reliability, Performance and Support Needs, Other Requirements and Risk Analysis. Table 1 shows the aspects and elements. Part I has 2 items, Parts II, IV and VII each have 4 items, Part III has 7 items, Part V has 6 items, Part VI has 10 items and Part VIII has 5 items. The groups and items are shown in Table 1.

A total of 20 participants, including developers, sign language interpreters, teachers and students, responded to the open-ended questionnaire on the requirements of the model. The questions were designed to get the stakeholders' perspective on the model, to analyse their opinions and to get detailed information about the model.

Table 1. Model Requirements Survey

No. Section	Subscale	Items
I	Concerned parties	Q1. Name Q2. Rol
II	Problem assessment	Q1. What problems should the system solve? Q2. How are they resolved now? Q3. How would you solve them? Q4. What elements do not contribute to solving the problem?
III	Understanding the environment	Q1. Who will be the users of the system? Q2. What will be the level of control of those responsible for the project over the development and devices? Q3. What level of experience should users have in these types of applications? Q4. Are there relevant or similar applications/systems to consider? Q5. What are the usability expectations of the product? Q6. What are the expectations of orientation or training to users for the use of the system? Q7. What type of help will the user require (online help, primers, audio,...)?
IV	Evaluating the opportunity	Q1. Who in the educational community needs the app? Q2. How many user types will use the app? Q3. How would you rate the solution as a success? Q4. How would an end user assess that the solution has been a success?
V	Evaluating the solution	Q1. What key capabilities or features should the proposed solution provide? (indicate 5) Q2. Which do you consider to be a complementary capability or characteristic? Q3. Assign an order of importance to each of these capabilities. Q4. Which method do you think may be the best? narrative, progression, chronological, free navigation, competitive? Q5. What topics should be included in the development of this application? Q6. Indicate applications or games that you consider may be similar to what is required in this application.
VI	Assessing reliability, performance, and support needs	Q1. What are your expectations regarding system reliability? Q2. What are your expectations regarding system performance? Q3. What kind of support, tools, or documentation should be provided? Q4. There are special needs to support Q5. What are the information security requirements? Q6. What are the physical security requirements while using the devices? Q7. What do you think will be the installation and configuration requirements? Q8. There are special licensing requirements Q9. How will the software and documentation be distributed during releases and the final product? Q10. There are packaging or distribution requirements.
VII	Other requirements	Q1. There are legal requirements that must be met. Q2. There are content requirements. Q3. There are environmental requirements. Q4. There are other types of requirements. Indicate it with an example.
VIII	Risk analysis	Q1. List the risks below with an assessment of their impacts and possible mitigation actions (Indicate 5) Q2. Whom do you consider may be the key people to mitigate the risks in this project? Q3. Indicate the possible constraints and weaknesses that you can identify within the working group. Q4. Please indicate potential strengths and opportunities that you can identify within the working group. Q5. Considering the strengths and weaknesses identified within the group, what actions can be suggested to minimize the identified risks?

For the development phase, the responses from each respondent were reviewed and analysed, grouped and categorised into the following prerequisites to be met by the system:

PRQ1. The system must have a script.
PRQ2. Levels, rules, constraints and instructions must be defined.
PRQ3. Use storyboard sketches and mock-ups to design scenarios and activities.
PRQ4. Consolidate information into a requirements document.
PRQ5. Store system versions and models in a GIT repository.
PRQ6. Animations shall be provided with sound and sound effects.
PRQ7. 3D modelling must be done in Blender.
PRQ8. The system must have a manual for access and use of the equipment.
PRQ9. The system must have videos in Colombian sign language.
PRQ10. The system must work with Oculus Quest glasses.

PRQ11. The system must not have a scoring history.
PRQ12. Each software release can take up to 3 weeks.
PRQ13. The end users are hearing and deaf students in their first semester of engineering studies.
PRQ14. The modelling of the software will be 3D low poly.
PRQ15. To avoid accidents, the user must use the application while seated in a suitable place.
PRQ16. Use gamification to encourage use of the software.
PRQ17. The virtual world shall have all necessary communication elements for deaf people.

In the same phase, the mixed reality software prototype was designed to test the requirements of the Extended Reality model. The incremental software development model was used, which combines the characteristics of the waterfall model with the construction of prototypes. As the prototype is developed, the functionalities are incrementally added to the schedule over time, resulting in incremental software. The software evolves with each planned delivery or iteration. Table 2 explains the proposed functionality for each iteration.

Table 2. Planning the functionality of the mixed reality software prototype in each iteration

No. Iteration	Duration	Functionality/Increment
1	3 weeks	Basic entrance scenario with 3d model. Basic stage animation. Selection of elements to be used. Explanation of variable in a 3D board. Explanation of an IF/THEN conditional. Explanation of a WHILE/REPEAT/FOR loop. Storyboard model brought to the stages.
2	2 weeks	Animations to elements. Instructions to the user. Example of basic drawers, selection of variables in balls: strings, numbers, integers, booleans. Validate the animation option at the end of the exercise. Event to indicate the end of the level. Primer of use for the level.
3	2 weeks	Animations to elements. Instructions to the user. Example of connection for conditionals. Validate the animation option at the end of the exercise. Event to indicate the end of the level. Primer of use for the level.
4	2 weeks	Animations to elements Instructions to the user Basic recipe example IF + variable + condition + variable Validate the animation option at the end of the exercise. Event to indicate the end of the level. Primer of use for the level.

In the Validation phase, usability tests of the mixed reality software prototype were conducted with 30 deaf and hearing students in their first and last year of engineering studies at the Faculty of Engineering of the universities participating in the project. The usability tests evaluated criteria of immersion, learning, motivation, satisfaction, and excitement [23].

A purposive sampling technique was used to select the sample for the usability test of the mixed reality software prototype. The selected sample consisted of a total of 6 deaf students associated with the different academic programmes of the engineering faculties of the participating universities, who met the following selection criteria: affiliation to one of the programming logic courses or programming electives at the universities and having a hearing impairment. The sample consisted of 23 hearing students, using the same inclusion criteria regarding enrolment in one of the programming logic or advanced programming courses.

Table 3. Demographic profile of students surveyed

Category	Frequency	Percentage (%)
Gender		
Male	23	76,7
Female	7	23,3
Age Group		
16 to 20	28	93,3
21 to 25	2	6,7
Education		
Semester I-IV	26	86,7
Semester IX-X	4	13,3
Type of student		
Deaf man	4	13,3
Deaf woman	2	6,7
Hearing man	19	63,3
Hearing woman	5	16,7

The demographic profile of the students surveyed is shown in Table 3. 76.7% were male and 23.3% female. Almost all students were aged between 16 and 20 (93.3%). Most of the respondents were engineering students from the first to the fourth semester (86.7%) and from the ninth to the tenth semester (13.3%). Of these, 13.3% were deaf males, 6.7% deaf females, 63.3% hearing males and 16.7% hearing females.

The survey was used as a tool to evaluate the effectiveness of the mixed reality software prototype, in addition to learn about the recommendations of the respondents. After using the prototype, the usability test questionnaire was applied and sent to each participant's mail during the test. The questions focused on the fulfillment of the functionalities of the software prototype, at the end of which the respondents were asked about their satisfaction when interacting with the prototype. The results of the percentage compliance with the functionalities are shown in Table 4.

Table 4. Results of the evaluation of the mixed reality software prototype

Question	Complies	Fails
The application must have a welcome tutorial or explanation the first time it is launched that allows the user to understand the system.	70%	30%
The application must have a loading screen of the elements.	100%	0%
The application must be immersive, and the controls in virtual reality will be represented by 3D hand models.	100%	0%
The application must have a menu to choose the topics to learn or activities to carry out.	90%	10%
During the execution of the activities, there must be a button to exit the activity.	100%	0%
The development of each level will be carried out as follows: 1) Explanation of the subject to be taught. 2) A brief explanation of how the activity is executed. 3) The execution or realization of the activity.	80%	20%
The system must have a field to present the topics that are proposed to be taught (board or canvas).	90%	10%
At the end of the activity, the user must go to the main menu.	90%	10%
The activities in the application will be organized in modules.	90%	10%
Each level is made up of the following modules: 1) Concept (Presentation). 2) Example (Guide for carrying out the activity). 3) Challenge (Learning Activity).	80%	20%
The application is suitable for hearing and non-hearing people.	100%	0%
The application must consider that it does not have a Cybersickness such as: a) Dizziness or disorientation b) state of panic or shock	90%	10%
The application must be aimed at higher education students interested in the area of programming.	100%	0%
The application must have a visual element in which it is transmitted to non-hearing users.	100%	0%
The application should limit the use of text or words to be pleasing to non-hearing users.	100%	0%
The app must be made for the Oculus Quest 2 device.	100%	0%
The application must use the Unity graphics engine.	100%	0%
The application must use gamification or gamification techniques for game design.	100%	0%

Finally, the students were asked a Likert-type question about their user experience with the Mixed Reality prototype, with a rating from 0 to 10, where 0 corresponds to the worst experience and 10 corresponds to the best experience. Table 5 shows the results of the last question of the user experience form using an eleven-point Likert scale.

Table 5. Results of the user experience level of interaction with the mixed reality prototype.

Question: How would you describe your user experience with the mixed reality prototype?			
	Level	Number of participants	Percentage
Worst experience	0	0	0%
	1	0	0%
	2	0	0%
	3	0	0%
Neutral	4	0	0%
	5	0	0%
	6	0	0%
	7	2	7%
	8	6	20%
	9	8	27%
Best experience	10	14	47%

Of the total of 30 students who took the usability test, 20% are hearing impaired. The deaf student population of the universities participating in the research has difficulty communicating in the classroom because they do not fully understand the Spanish language, they communicate through sign language, they learn in a very visual or graphic way;

the sign interpreters do not correctly handle the concepts of programming logic, the topics are dense and become monotonous, they must have basic knowledge in mathematics and they do not have a programming vocabulary for the deaf in sign language. For the execution of the usability test, the deaf students had some difficulty, however the mixed reality prototype represents an opportunity to understand the basics of programming logic in a personalized way, which in the classroom are complex to understand, practice and apply.

Fig. 3 shows the information collected in the user satisfaction survey about their experience with the Mixed Reality prototype. It can be concluded that the deaf and hearing students surveyed are satisfied with the software, showing a positive subjectivity.

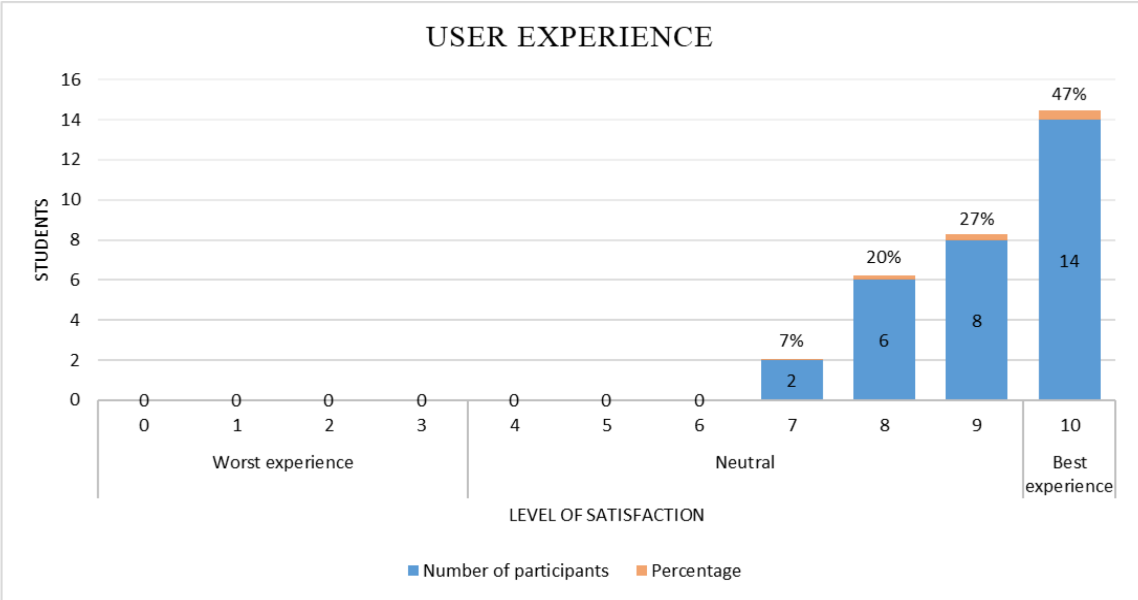


Fig. 3. Student satisfaction survey results

Of the total number of students who took the usability test, 14 (47%) assigned the highest value of 10, while 8 students (27%) rated their experience at 9, and 6 students (10%) rated their experience with the interaction with the prototype at 8, that is, 77% of the students surveyed showed their acceptance of the software as an innovative and motivating software, which indicates that this type of teaching support tool facilitates and improves the learning process for deaf and hearing students. The lower percentage of 7% with only two students indicates that there are functionalities to be improved. These will be taken into account for a later version.

4.2. Definition of the model principles

The principles of the Extended Reality Model for accessibility are defined to better understand the creation of software tools that will use this technology for learning in different disciplines or areas of knowledge.

1. The model will be used as a reference for the creation of virtual, augmented and mixed reality software tools.
2. Priority will be given to defining the requirements for accessibility, usability and inclusion of people with different abilities, such as the deaf.
3. Requirements for deaf people include sign language videos, subtitles, graphics and animations.
4. Gamification techniques that involve deaf and hearing people should be used.
5. A storyboard should be developed as a starting point for the story to be developed.
6. Manage levels that allow the user to achieve a goal and adapt to each new piece of knowledge.
7. It must have 2D and 3D multimedia resources to create the objects and scenes.
8. Define the concept, an example and a challenge for each level.
9. Define a scenario or environment and the change of scenes within the software.
10. The software development process will use video game development methodologies.
11. The modified ADDIE model will be used to develop interactive content.
12. Multimedia tools will be used to design the content of the activities, integrating text, graphics, audio, video, immersive sounds and animation to capture the attention of the students.

4.3. Implementation of the extended reality model

This section presents the model in its final version at different levels of abstraction, providing a basis for Extended Reality software solutions that aim to enhance the teaching-learning process by engaging deaf and hearing students in immersive, multi-sensory environments, stimulating their motivation and ability to acquire, process, understand and apply new knowledge.

Level 1: System Context

The first level or view of the XR-M Extended Reality Model describes the system context from a high level. This view represents the interaction of Virtual Reality VR, Augmented Reality AR and Mixed Reality MR with the user. The end user who will use the system is the deaf and hearing student and the external device used is the Oculus Quest 2 virtual reality glasses. Figure 4 illustrates the first stage of the model.

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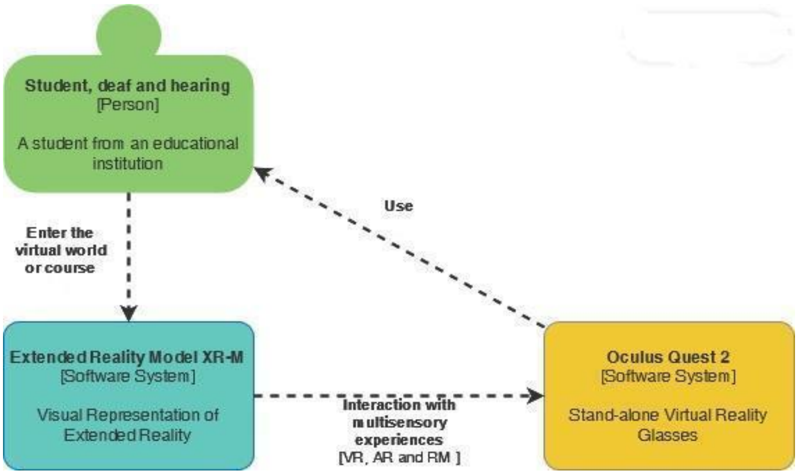

Fig. 4. Level 1 of the Extended Reality Model

Level 2: Container

This level is a look inside the model, an extension of the system to be developed, with the elements it contains and their interactions. All internal elements and external devices required for interaction are specified.

Among the containers, immersive, augmented and mixed virtual reality applications are illustrated, with the technologies that can be used, together with the resource databases required to create the virtual worlds and the APIs that allow new experiences to be developed in this technology.

Figure 5 shows the container diagram for the XR-M Extended Reality model, no additional support is included.

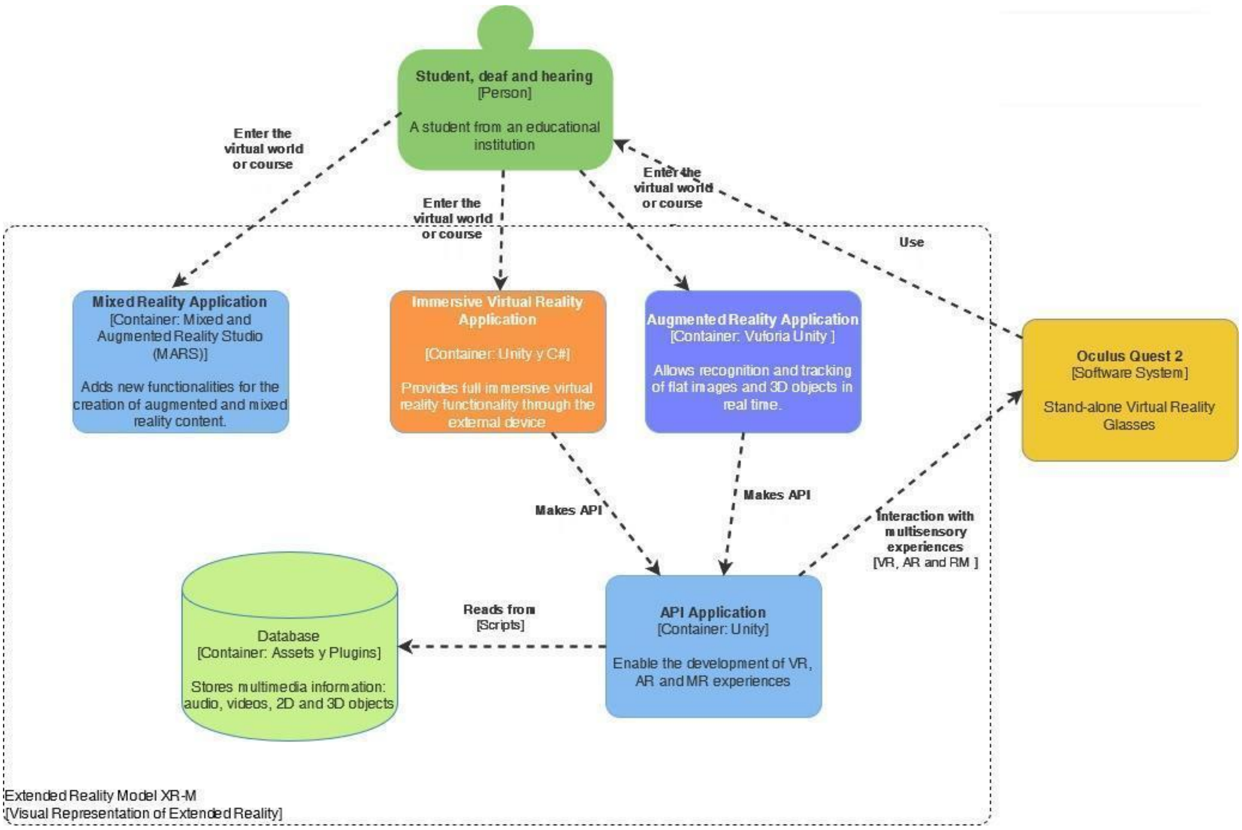

Fig. 5. Level 2 of the Extended Reality Model

Level 3: System Components

The third level is an extended view of each of the system containers, the diagram is made for each component.

Figure 6 describes the Mixed Reality Application container and the Immersive Virtual Reality Application container, which are linked to each of the defined components such as scene construction, 2D and 3D object deployment, game controller, game menu, gamification component, scripts to define the behaviour of physical, navigation and interaction events, and the connection to the asset and plugin databases.

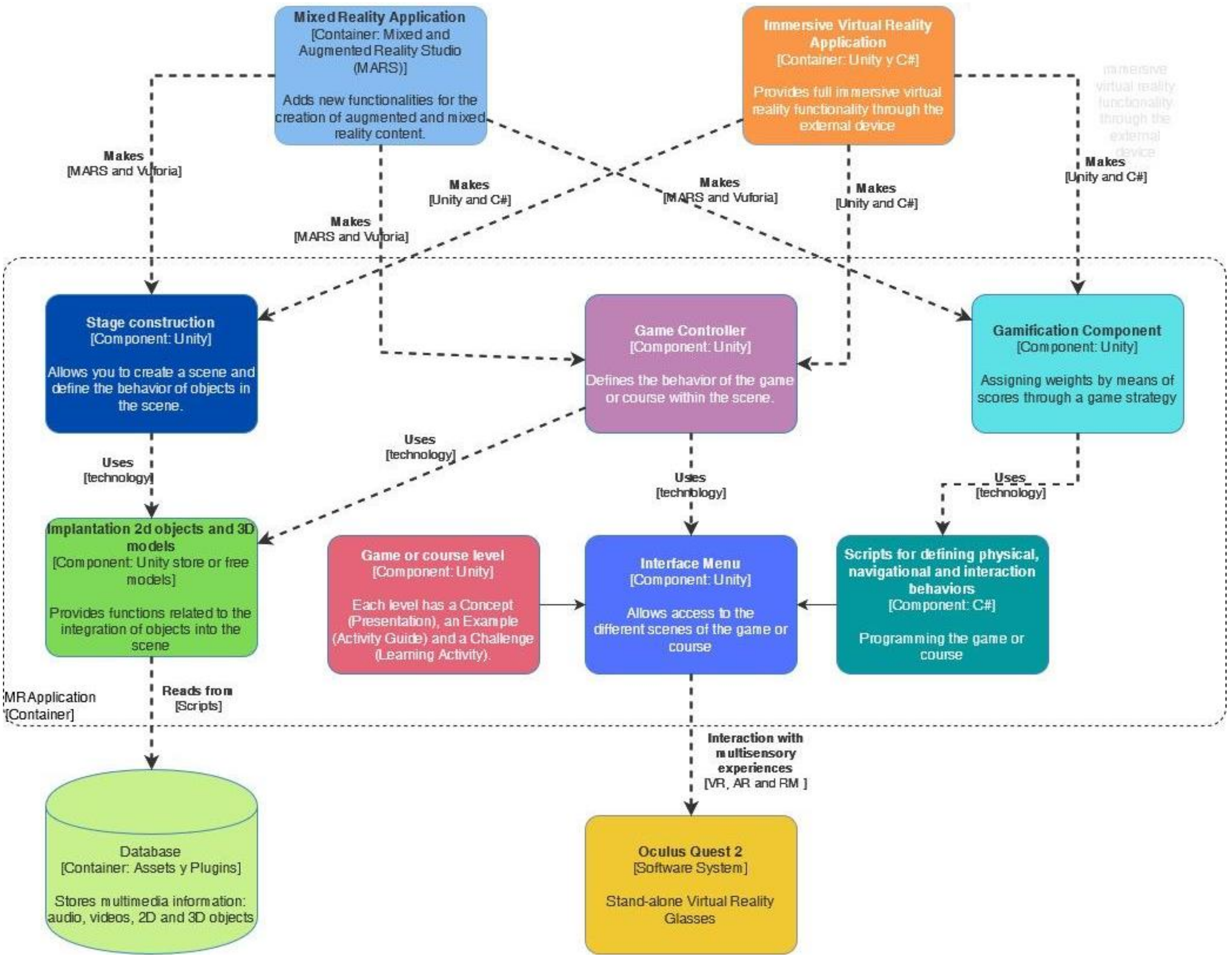

Fig. 6. Level 3 of the Extended Reality Model

Level 4: Code

The code level is the final view of the diagrams proposed in the model. At this level, each component is taken and placed in a diagram of classes, objects and their relationships.

Figure 7 shows the class diagram of the component corresponding to the mixed reality application.

The Extended Reality model is applicable to the interactive content of a basic, intermediate or advanced academic course in any subject area. The sensory components of the Oculus Quest 2 virtual reality goggles are the best part of the Extended Reality technology, as students live learning experiences that engage the senses of touch, sight and hearing, highlighting those that are enhanced by a disability such as hearing impairment. The deaf and hard of hearing student becomes the centre of the teaching-learning process as an active participant who guides his own learning in the virtual world or metaverse.

The information presented in the interactive content of the course is simple and easy to understand, with visual or textual aids to understand each of the activities. The complex concepts are the accumulation of the simple concepts, so as not to saturate the student, especially the deaf student, with information, and so that he/she can progress at his/her own learning pace.

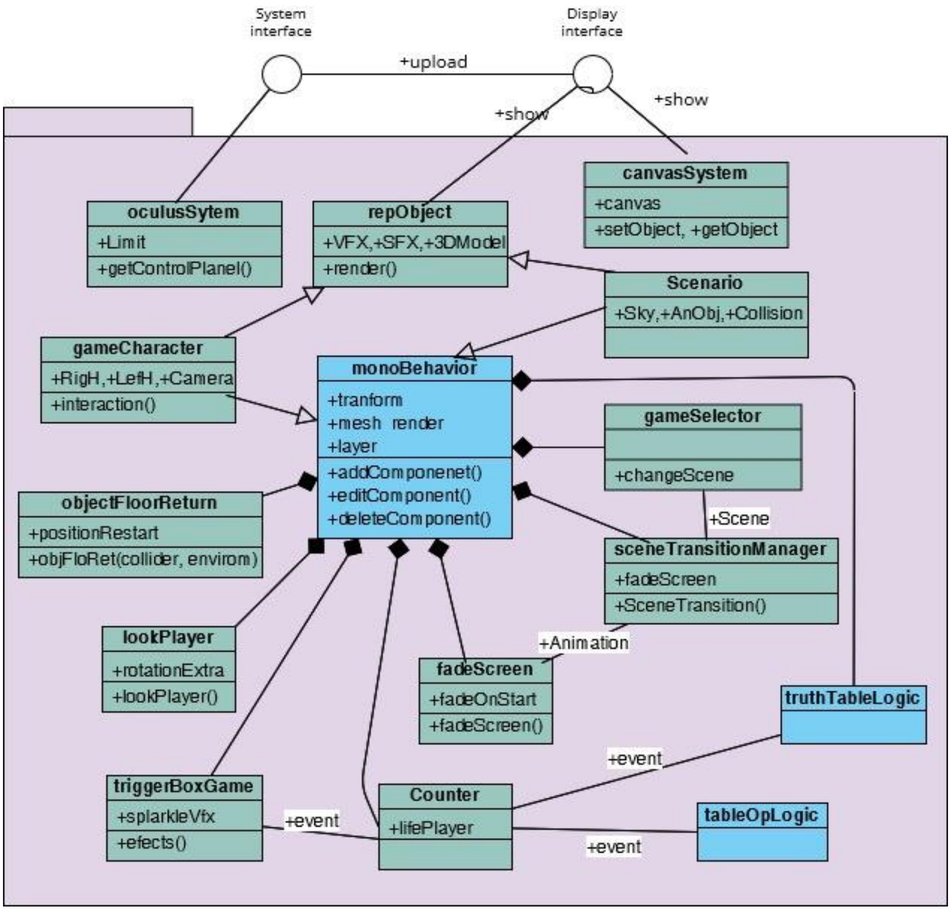

Fig. 7. Level 4 of the Extended Reality Model

The immersive experiences generated by Virtual, Augmented and Mixed Reality are able to capture the attention of deaf and hearing students to achieve learning that is more coherent with their information needs and their training process in the classroom. The student is at the centre of the learning process and the different ludic, didactic and gamification strategies ensure that knowledge is acquired in a better way, setting learning objectives according to the pace of development of each student. Bearing in mind that today's students are very graphic, consume large amounts of information, have low retention rates, but learn quickly.

According to [3], Extended Reality has drawbacks in terms of the cost of the equipment needed to use it, most teachers do not have the training to implement it, advances in pedagogy and technology in Mixed and Extended Reality have followed different paths without interdisciplinary work to advance the educational possibilities in education. He also mentions the challenges of Extended Reality, which are the high investments in digital laboratories in institutions, the personalisation of the training of each student, the integration of active methodologies and new technologies, and the achievement of meaningful learning as the combination of the student's previous knowledge with the new knowledge he or she acquires, in order to improve the teaching-learning processes in higher education.

5. Conclusions

The evolutionary development model was used to carry out the project. The research project started with the problem statement, which focused on the lack of user-friendly pedagogical tools using state-of-the-art technologies for learning programming logic, followed by a literature review in different databases and an analysis of the information to develop a state of the art.

From the information gathered, a survey was conducted among teachers, sign language interpreters, programmers and deaf and hearing students to determine the requirements of the Extended Reality model. In subsequent phases, the model was designed and the mixed virtual reality prototype was built based on the defined requirements. The prototype was built as a first practical approach to the model by adapting the SUM methodology for video games and the ADDIE design model for creating virtual content in the metaverse. The software prototype was subjected to a series of functionality and usability tests with real users, which served as a basis for the validation of the model. The final version of the model was refined based on the feedback from the prototype to complete the process. The model can be further improved to its optimal state and applied to any knowledge domain.

To answer the research question, the model was created and the mixed reality software prototype was built to consolidate a tool to support the teaching work and improve the teaching-learning process of programming logic within the deaf and hearing community. However, it is necessary to validate the model applied in other domains of knowledge to ensure accessibility in learning.

Extended Reality is a powerful technology. It can lead to breakthroughs in education when combined with research and pedagogy. It became clear that accessibility and inclusion must be transversal in the teaching-learning process in all its aspects: pedagogical, social, cultural, technological and communicative.

Based on the results of this research, it can be concluded that the extended reality model for accessibility in learning, applied to software development, allows the construction of applications that can improve the interaction of deaf and hearing students at different levels of learning, ensuring continuity in their educational process.

The type of didactic tools that will emerge from the application of the model have great potential in different areas of knowledge, motivating students in their learning process, having fun while acquiring new knowledge, and providing opportunities for all students to access content regardless of their different abilities, improving user experience and inclusion in education.

For future work, it is recommended to continue with the development of a second iteration of the software so that the model can be validated through time of use, evaluating the learning of deaf and hearing students through Extended Reality technology. The participation of other universities with deaf students and teachers from different fields of knowledge will allow to know if the results converge or show significant differences, and it is possible to achieve a better knowledge management of the research.

One of the limitations of this study was the communication barrier with the deaf students using the prototype, as they can only communicate using sign language, which is a barrier when they put on the Oculus Quest 2 glasses as they lose visibility with the sign interpreter and it is very difficult to guide them in interacting with the software. The students interviewed are generally first year students and are relatively new to using this type of technology. For future research it is intended to expand the sample of students.

Another limitation is that, as a mixed reality prototype, this is a preliminary study. The initial data collected in this study relates to a small representative but inconclusive sample and therefore cannot be considered a full validation study of the Extended Reality model.

Future studies should expand the population of deaf and hearing students to include several universities in Colombia and Mexico and other academic programmes, so that the extended reality model can be validated in other areas of knowledge.

A comparative study can also be carried out between the teaching-learning processes with the tools used in the classroom and those mediated by the Extended Reality software, in order to compare the real behaviour of the students and their learning with the different didactic strategies.

It is also proposed to use the prototype to build an accessible and inclusive extended reality software for the metaverse, in order to validate the model proposed in this research.

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Conflict of Interest

The authors declare no conflict of interest.

References

[1] M. Y. Segura Ruiz, R. Osorio Díaz, A. Závala Martínez and C. A. Rodríguez Sánchez, "Estudio para la creación de un modelo de realidad extendida hacia el aprendizaje inclusivo (Study for the Creation of an Extended Reality Model for Inclusive Learning)", *Pistas Educativas*, Vol. 44, No. 143, pp. 80-95, 2022.

[2] Y. Sánchez Lozano, E. S. Buitrago Barreto, and M. Y. Segura Ruiz, "Desarrollo de un prototipo de realidad mixta como apoyo al proceso de aprendizaje de estudiantes con y sin discapacidad auditiva (Development of a mixed reality prototype to support the learning process of students with and without hearing disabilities)," in *Ingeniería y Desarrollo en la Nueva Era*, Ed. IAI: Medellin, Colombia, 2022, pp. 891–90.

[3] X. Guo, Y. Guo, and Y. Liu, "The development of extended reality in education: Inspiration from the research literature," Sustain., Vol. 13, No. 24, pp. 13776, 2021.

[4] M. P. Ilić, D. Păun, N. P. Šević, A. Hadžić, and A. Jianu, "Needs and performance analysis for changes in higher education and implementation of artificial intelligence, machine learning, and extended reality," *Educ. Sci.*, Vol. 11, No. 10, pp. 568, 2021.

[5] C. Estebala del Prado, "Realidad aumentada: hacia una realidad extendida (Augmented reality: towards an extended reality)", *Education and Digital Future*, Vol. 17, p. 175-180, 2018.

[6] Y. Cho, and K. Shin Park. “Designing Immersive Virtual Reality Simulation for Environmental Science Education”, *Electronics,* Vol. 12, No. 2, pp. 315, 2023.
[7] K. Jahn, F. M. Oschinsky, B. Kordyaka, A. Machulska, T.J. Eiler, A. Gruenewald, and B. Niehaves, “Design elements in immersive virtual reality: the impact of object presence on health-related outcomes”, *Internet Research,* Vol. 32, No. 7, pp. 376-401, 2022.
[8] R. Serrano-Vergel, P. Morillo, S. Casas-Yrurzum, and C. Cruz-Neira, “Exploring the Suitability of Using Virtual Reality and Augmented Reality for Anatomy Training”, *IEEE Transactions on Human-Machine Systems*, pp. 1–12, Jan. 2023.
[9] M. Vergel Ortega, O. Rincón and C. Cardona. “Comunidades de aprendizaje y prácticas pedagógicas (Learning communities and pedagogical practices)”, *Boletín Redipe*, Vol. 5, No. 9, pp. 137-145, 2016.
[10] G. Gómez García, C. Rodríguez Jiménez, and J. A. Marín Marín, “La trascendencia de la Realidad Aumentada en la motivación estudiantil. Una revisión sistemática y meta-análisis (The importance of Augmented Reality in student motivation. A systematic review and meta-analysis)”. *ALTERITY Revista de Educación*, Vol 15, No. 1, pp. 36-46, 2020. [online]. Available: https://doi.org/10.17163/alt.v15n1.2020.03
[11] M. S. W. Boysen, M. C. Sørensen, H. Jensen, J. Von Seelen, and H. M. Skovbjerg, “Playful learning designs in teacher education and early childhood teacher education: A scoping review,” Teach. Teach. Educ., Vol. 120, pp. 103884, 2022.
[12] E. M. Murtagh, J. Sawalma, and R. Martin, “Playful maths! The influence of play-based learning on academic performance of Palestinian primary school children,” Educ. Res. Policy Pract., Vol. 21, No. 3, pp. 407–426, 2022.
[13] García-Quismondo, M. Á. M., and Cruz-Palacios, E. “Gaming como Instrumento Educativo para una Educación en Competencias Digitales desde los Academic Skills Centres (Gaming as an Educational Instrument for Education in Digital Competences from Academic Skills Centres)”, *Revista General de Información y Documentación*, Vol. 28, pp. 489–506, 2018. [online]. Available: https://doi.org/10.5209/RGID.62836
[14] A. M. Almelhi, “Effectiveness of the ADDIE Model within an E-Learning Environment in Developing Creative Writing in EFL Students,” English Lang. Teach., Vol. 14, No. 2, pp. 20, 2021.
[15] N. Dozio et al., “A design methodology for affective Virtual Reality,” Int. J. Hum. Comput. Stud., Vol. 162, pp. 102791, 2022.
[16] V. De Luca et al., “Virtual Reality and Spatial Augmented Reality for Social Inclusion: The ‘Includiamoci’ Project,” Inf., Vol. 14, No. 1, pp. 38, 2023.
[17] N. Kumarasamy, V. Arumugam, P. Sinnappan, and M. R. Ismail, “Factors Affecting the Students’ Actual Use Behaviour of Virtual Learning Environments (VLEs) during the Movement Control Order (MCO),” Int. J. Mod. Educ. Comput. Sci., Vol. 15, No. 3, pp. 1–15, 2023.
[18] P. Smart, “Minds in the Metaverse: Extended Cognition Meets Mixed Reality,” Philos. Technol., Vol. 35, No. 4, pp. 1–29, 2022.
[19] E. Del Pezo Izaguirre, M. J. Abásolo, and C. A. Collazos, “Mobile Technology and Extended Reality for Deaf People: A systematic review of the open access literature,” *2020 XV Conferencia Latinoamericana de Tecnologías de Aprendizaje (LACLO)*, IEEE, Loja, Ecuador, 2020, pp. 1-8.
[20] E. Del Pezo Izaguirre, M. J. Abásolo, and C. A. Collazos, “Educational Methodologies for Hearing Impaired Children Supported by Mobile Technology and Extended Reality: Systematic Analysis of Literature", *IEEE Revista Iberoamericana de Tecnologías del Aprendizaje.*, Vol. 16, No. 4, 2021, pp. 410–418.
[21] I. Sommerville, *Ingeniería de Software*, Mexico: Pearson Education, 2011.
[22] R. S. Pressman, *Ingeniería del software Un enfoque práctico*, México: McGraw Hill, 2010.
[23] R. S. Contreras Espinosa, J. L. Eguia Gomez, and L. Solano Albajes, “Videojuegos como un entorno de aprendizaje (Videogames as a learning environment),” *ICONO 14*, Vol. 2, No. 9, pp. 249-261, 2011.

Authors’ Profiles

Martha Segura is currently a research professor at the Faculty of Engineering of the Universitaria Agustiniana in Bogotá, Colombia. She is a systems engineer, a specialist in the design and construction of telematics solutions, and a specialist in software engineering, having completed her Master's degree in Business Administration and Management at ITESM in 2018.

She has experience in companies in the information and communication technology sector, managing technology integration projects. She is interested in research areas such as virtual reality, augmented reality, mixed reality, artificial intelligence and accessible software engineering models and methodologies.

The junior researcher is recognised in the National System of Science, Technology and Innovation of the Colombian Ministry of Science, Technology and Innovation.

Ramiro Osorio is a civil engineer specialising in high-speed and distributed networks, with a Master's degree in Mobile Telecommunications from the Universidad Distrital, Bogotá, Colombia. He is a research professor at the Faculty of Engineering, Universidad Agustiniana, Bogotá, Colombia.

Mr Osorio works in the business sector, where he leads projects of cloud server setup with Amazon, network monitoring and IT security in several companies. He has led the research project Prediction of bandwidth consumption of web applications in the native cloud based on free software; with a publication in the International Research Journal of Computer Science (IRJCS); his research areas are Artificial Intelligence and Software Engineering.

Adriana Zavala has a bachelor's degree in computer science from the Tecnológico de Estudios Superiores de Cuautitlán Izcalli, a master's degree in information technologies, and is pursuing a doctorate in administration in Mexico. She is a full-time professor at the Tecnológico de Estudios Superiores de Cuautitlán Izcalli.

Mrs Zavala has participated in more than 17 articles, of which 7 have been managed as first author, participated in competitions, participated in TECNM summer workshops, moderator of inclusion, and has more than 13 diplomas in education and Microsoft.

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