EDUKA: Design and development of an intelligent tutor and author tool for the personalised generation of itineraries and training activities in inmersive 3D and 360° educational environments

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Abstract:

Nowadays, Virtual and Augmented Reality have begun to be integrated in the educational field for the creation of immersive learning environments. This research presents the results of a project called "EDUKA: Intelligent tutor and author tool for the personalised generation of itineraries and training activities in immersive 3D and 360° educational environments", funded by the Basque Government (BG) (Economic Development, Sustainability and Environment Department). The project started in April 2018 and was completed in December 2020. Nowadays, an improved version is being developed in a project called IKASNEED, also supported by the BG. The aim of the study was to develop research around a set of latest generation technologies that offer interdependence to educational centres for the adoption, development and integration of Virtual Reality (VR), Augmented Reality (AR) and immersive content technologies in their study plans.

Key words:

Virtual Reality, Augmented Reality, Immersive 3D, Intelligent Tutor.

1. Introduction

Numerous studies have investigated the dependence of education centres on technology centres for the adaptation and integration of technology in their educational plans and policies. This scenario focuses on the use of Virtual Reality, which resolves disadvantages such as: i) High technical complexity when developing new immersive environments, ii) High development costs associated with the customisation of virtual environments and/or activities, iii) The market mainly offers basic immersive training activities, with an early design, iv) Deficiencies in the program user interface, and v) Low degree of use by teachers due to the complexity of virtual environment design programs.

The total adoption of Virtual Reality technology in the educational field is still far from experiencing high rates of use due to the technology barrier associated with the lack of autonomous and automatic

development of new environments and immersive educational content by the trainer community and the economic barrier linked to high development costs.

With the aim of remedying this situation, EDUKA project proposes developing research around a set of latest generation technologies that offer interdependence to education centres for the adoption, development and integration of VR, AR and immersive content technologies in their study plans.

EDUKA project is presented by a consortium composed of the following entities:

- ARIZMENDI IKASTOLA S.COOP., as project leader, a school specialising in the development of innovative pedagogical projects with a high technological component.

- MONDRAGON LINGUA S.COOP., as a company specialising in providing advanced language training services to companies, institutions, individuals and education centres.

- INNOVAE AUGMENTED REALITY AGENCY S.L., as a technology company specialising in augmented reality and virtual reality, with a team that has over 15 years of experience and more than 300 projects behind it.

- FUNDACIÓN TECNALIA RESEARCH AND INVESTIGATION, as a research centre and member of the Basque Science and Technology Network, a benchmark in the field of advanced technologies and software development.

- ISEA S.COOP., as a private R&D centre and member of the Basque Science and Technology Network, specialised in launching new business initiatives in the field of education.

2. Literature Review

This chapter will focus on the understanding the following topics: i) VR and its application in education, ii) AR and its application in education, iii) Author tools, iv) AI-based intelligent tutor, and v) Gamification.

2.1. VR and its application in education

In recent years, VR has greatly increased its presence as an alternative approach to traditional learning experiences, mainly due to the ability of this technology to provide a highly interactive visual environment very similar to that offered by the real world, also allowing students to experience the sensation of being present within an environment with greater possibilities of interaction with objects.

Current research has shown a series of encouraging learning results with the use of VR, showing an improvement mainly in topics such as science, chemistry, physics and mathematics, among others.

In the academic areas, mentioned above, success for a student depends largely on their ability to anticipate and manipulate abstract information. Finding a way to help people recognise patterns, to qualitatively understand physical processes, to move between different frames of reference and to more easily understand dynamic models that can contain intangible information must be very important and useful in many educational situations.

The traditional methods of visualisation and the current visualisation of models and data on the computer screen or in books is done through two-dimensional diagrams, despite the fact that they attempt to describe a reality that is by nature three-dimensional.

VR not only facilitates the visualization of these models and the data in a more appropriate three-dimensional context, it also enables their interaction with them when necessary, observing them from several different points of view, including changing sizes and the perspective from which users experience them. Moreover, it is stated that a VR system is different from other computer applications, due to the fact that it gives the user the feeling of being present in the virtual world and being able to act accordingly, and this notion of presence increases within a Virtual Environment (VE) where VR is used, which has two key components that other technologies do not have: immersion and interaction. In order to be considered a complete system, a VE applied to education must not only ensure the user's presence but must also make something happen, without this necessarily being the result of an action carried out by the user.

In general, the systematic and random variability of the contexts has been presented as an essential condition for abstraction, and therefore for the transfer of knowledge (Mendelsohn, cited by Bossard et al. 2008). The varied practice, through the succession of different situations (but in a similar way), produces interferences between the situations that contribute

to forgetfulness: only the points between two situations that have something in common are taken into account. Simulations (numerous repetitions) and the use of virtual reality (a wide range of situations, due to the autonomy of the agents) offer interesting perspectives to achieve the transference. The virtual simulation also offers the possibility of multiple practice sessions, including practice where different factors are connected. In this sense, many training VEs additionally provide performance information, and in this way the participants' progress can be monitored and electronically recorded.

For Gorzerino et al. (cited by Staretu, 2012), training is the result of actions arranged by the user in an environment, while learning outcomes are the result of contextual inputs. At present, the application of VR in education is not usual. All current uses of VR technology in education are, at least to some extent, exploratory in nature, and when no explicit evaluations have been made, researchers and teachers are forming their own opinions about the value of this technology.

Currently, in the field of education, two types of content are used for VR. The first is the one that attempts to imitate the real world, i.e. creating a virtual museum to strengthen the study of history, art and the cultural heritage of a country, or through the development of materials to show how bacteria enter the human body and cause disease. The second type of content consists of computer simulations of 3D objects, which will later be reproduced in an interactive VR environment (i.e. the generation of a machine design from a 2D diagram).

2.2. AR and its application in education

Augmented reality is a technology that superimposes virtual elements (2D or 3D) on the real environment, thus making it appear that these new elements are integrated into it (Chen et al., 2017).

Undoubtedly, one of the fields benefited by the advances in AR technology is education, where several institutions at the primary, middle and higher levels have already implemented the use of this technology as a new pedagogical tool that contributes to learning, research and innovation (Tsekhmister et al., 2022), highlighting the following points:

- AR can provide learning experiences outside the classroom, more contextualised and based on discovery.

- In disciplines that require practical training, students can visualise the process through AR by capturing details which are unnoticed in a two-dimensional environment.

- It is a very suitable tool to explain "complex" concepts, related to mechanics, physics, chemistry or mathematics.

- AR applications on mobile devices and in combination with collaborative software favour the social construction of learning in interaction with the physical environment.

In addition to the multiple references to experiences reported, there are many authors who support the integration of AR in the educational field, finding references such as Estebanell et al. (2012), who talk about how technologies in mobile devices overcome the limitation of time and space in learning environments but also add that AR applications «not only respond to this type of demand but also extend it in a qualitatively significant way by providing contextualised information from the place and time the consumer needs it.» (p. 290). Billinghurst (2002), creator of the first AR book «Magic Book» mentions advantages of AR that could be very valuable in education:

«Support for a fluid interaction between the real and the virtual environment. The use of the metaphor of the tangible interface for manipulating objects.» Along the same lines, González (2013) gives three other reasons to invest in AR: «It enables didactic contents that are otherwise unfeasible. It provides interactivity, play, experimentation, collaboration, etc.»

2.3. Author tools

Author computer programs are tools that facilitate the design of educational activities using predesigned schemes provided by the software itself, which teachers can customise and adapt to the characteristics and needs of their students.

Thus, the user only has the need to create one of these activities using the three-dimensional environments and elements provided by the program, and providing content for the activity, including the images, texts, sounds or other necessary elements. The program, therefore, will only serve as a basis, providing the structure of the activities, but the content itself will always be provided by the teacher himself (Montero & Herrero, 2008).

The main characteristics of an efficient program are:

- **Simplicity of use.** These are programs created to be used by education professionals, regular users of ICTs who are not necessarily experts in programming or design (Montero & Herrero, 2008).

- **The ability to design interesting materials in a reduced amount of time.** Programs should facilitate the design of activities with little time spent on "technical" issues, given that the creation of curricular materials in itself involves a significant investment of time and effort in planning the activity content. Therefore, the program that conveys this content must be a facilitating element for their creation. It is an aspect with an important practical repercussion (Sánchez, 2003).

- Finally, **the standardisation of the educational materials created,** and their simplicity to be used, stored and filed on different platforms, is important. In this regard, it is interesting to note that the author programs reviewed in this paper are all distributed with different licenses for free use, and in recent years significant efforts have been made by educational administrations to create repositories of digital educational materials in which educational materials of different levels and subjects are stored for public use (Gertrúdix, et al., 2007).

2.4. AI-based Intelligent Tutor

With the constant transformations in ICT and the search for improvements in teaching processes, new strategies have emerged in the educational teaching process, including ITS. They are helpful in that they imitate human tutors in their ability to determine in each case what to teach, when to teach and how to teach, as far as possible, in an autonomous way. These systems originated at a time when Artificial Intelligence (AI) was working on the transcendent purpose of imitating natural intelligence by creating machines that "thought" like humans. The emulation of human cognition with computers did not achieve the desired success because it started from a wrong principle: assuming that people think like computers. The resulting crisis gave rise to a review of the aims of AI, and consequently to the progress of the area in issues such as Expert Systems. These systems were productive because they focused on systems that were useful rather than creating "thinking machines" (Ainsworth & Fleming, 2006).

An intelligent tutor is a software system that uses AI techniques to represent knowledge and interacts with students to teach it, adapting in this way to the cognitive characteristics of each student (Caro et al., 2015). Therefore, its main advantages are:

- ITS (Intelligent Tutor Systems) have demonstrated their effectiveness in various applications of teaching-learning processes (Erümit & Cetin, 2020; Hooshyar et al., 2022). However, their construction is a complex and intense work of knowledge engineering.

- It promotes alternatives to the human tutor, by using strategies to guide their students and for students who seek to learn more autonomously.

- These systems focus the attention particularly on the student where their needs must prevail.

- From this perspective, an ITS is a type of interactive environment that is designed for individual learning and is distinguished from other types by its ability to model the cognitive state of the user, facilitating context-sensitive advice and feedback in all steps of a learning process (Graesser et al., 2005).

Its main objective, in addition to mastering a specific area of knowledge, is to develop a methodology that adapts to the student and interacts dynamically with it.

2.5. Gamification

It may come as a surprise to many proponents of gamification that almost 80% of efforts on gamification fail to produce the desired behavioural impacts and outcomes in the long term. Proponents argue that humanity needs constant feedback and progression in order to carry out daily activities (McGonical, 2011), whilst games supply these mechanism in abundance and are deemed highly engaging (Munz et al., 2007), one could borrow the game elements and integrate them into everyday activities to make them as engaging as games. (Zichermann & Cunningham, 2011). On the surface this seems entirely logical. However as one digs deeper, it is clear that not everyone is motivated through competition and that effort in quantifying actions and assigning virtual rewards can backfire through unintended consequences (Landers & Callan 2011).

A general observation can be made that the more time and effort developers spend on creating, testing and refining the most attractive system for user then the

user's motivation in using the system increases. This is supported by research in the fields of user experience and user interface design (Resnick et al., 2005). This observation is further supported by (Deterding et al. 2011) both of which reference the notion of 'meaningful gamification', to separate intrinsic and extrinsic motivation and to develop intrinsically motivating solutions through which the participants can carry out their activity more effectively.

In view of the above, studies can be discovered (Freina and Canessa, 2015), where it examinations the significance immersive Virtual conditions and contrasts them and VR work area based applications. According to some other studies (Papagiannakis et al., 2008), Augmented Reality empowers an ideal perception of social legacy giving certain key edutainment angles. Also, AR includes a totally extraordinary expanded climate which can be utilized to gamify new learning ideas (Vacchetti et al., 2004) in a more beneficial and agreeable way. Notwithstanding, the connection among client and the gadget should be pretty much as normal as conceivable to stay away from abnormal circumstances in broad daylight places (Carmigniani et al., 2011).

3. Methods

The main objective of EDUKA was to develop research on VR and AR based technologies to provide independence for the educative centres through the generation of immersive content.

For the development of this project there were three separate phases: i) Technological research and design of the global solution, ii) Application of research to the development of global solution tools, and iii) Integration and validation.

PHASE I

During the first phase, the methodological and technological foundations of the project were laid by developing exhaustive research on the set of technologies involved in the development of the EDUKA tool.

Likewise, all aspects related to the execution of the project were designed. This phase was intended to ensure that the objectives set out at the beginning were covered, designing an execution plan that would guarantee the overall success of the project.

Finally, during this phase the specifications of the global solution as well as of each of the tools to be developed were defined. In addition, a first architecture proposal for the solution was generated.

PHASE II

During this phase, the knowledge acquired in the research phase was applied and the modules that were to make up the EDUKA solution were developed and implemented, as well as a series of catalogue experiences forming part of the content with which teachers can generate different training itineraries. Modules:

- An innovative Authoring Tool to create and edit their educational activities in immersive 3D and 360º environments, both at the immersive scenario level and in the configuration of training exercises.

- A management tool for teachers to organise training plans for students by combining "traditional" content already available in schools, such as videos, audios, or documents, along with state-of-the-art content based on augmented and virtual reality.

- An Intelligent Tutor based on AI that facilitates the identification of behaviour patterns in students, generating a proposal of training itineraries adapted and tailored to their skills and weaknesses.

PHASE III

In this last phase, the tools developed during the previous phase were integrated, resulting in a fully functional prototype. This prototype was validated in the scenarios described during Phase I, in order to measure its effectiveness and correct its possible deficiencies. At the same time, it will be disseminated and prepared for exploitation.

The work packages (WP) associated with each of these development phases were eight.

Table 1. Work Package 1.

WP 1. Capture and generation of new knowledge
Structuring of the scientific-technological bases of the project
State of the art in relation to the scientific-technological domains of the project
Identification of 3D virtual object repositories and interoperability analysis
Identification and selection of technological standards to be incorporated into the solution

Firstly, an analysis of the existing technologies related to the project was made. In this way, the identification of best practices and experiences of international success was arranged. Moreover, the sharing and homogenisation of common knowledge in the Consortium was necessary to define the scientific-technological bases for beginning to develop the project.

Finally, during this phase the identification of the existing 3D virtual object repositories and interoperability analysis was made.

Table 2. Work Package 2.

WP2. Technical specifications and solution architecture
Definition of the pedagogical and organisational program associated with each application scenario
Definition of measurement parameters and data analytics model
Requirements and functional specifications of the solution
Conceptual model and definition of functional prototype
Design of the architecture
Development and validation of the architecture

Initially in this phase the project was focused on the definition of the basic knowledge for the optimal development of the project in the fields related to VR technology, AR and intelligent tutoring.

Secondly, definition of the functional specifications was arranged, as well as the design of the system architecture and the description of the use cases for the validation of EDUKA.

Table 3. Work Package 3.

WP3. Development of the author tool
Development of the author web front end for DiY experiences
Development of the 360 video processing module
Development of the DiY experience manager module

This stage was based on the development of the set of modules for the generation of immersive DiY experiences.

Initially, for the front end definition the development of the web editor WebXR that facilitated the creation, modification and publication of DiY experiences was carried out.

This activity was combined with the implementation of the user interface layer, the implementation of user interactions, consumption of API Rest services exposed by the server, and implementation of the process of uploading multimedia elements such as 360 or 3D video.

Finally, definition and implementation of the life cycle of an immersive DiY experience was established.

Table 4. Work Package 4.

WP4. Development of the management backend
Specification of functionalities supported by the management backend
Development of server logic, databases and communication protocols
Implementation of own backend functionalities
Development of "catalogue experiences" (immersive and interactive VR)

The main objective of this phase was the implementation of the management backend. The communication protocols needed for interconnection with the solution components and the functionalities of the backend included in the memory were implemented.

The first task for this development was to define the functioning of the management backend. It was used as a guide for the next steps.

Secondly, the foundations for the implementation of all the functionalities were established. A server started functioning to deploy backend, and all the databases and communication protocols needed for the implementation of the EDUKA platform were designed and deployed.

Finally, the implementation of the two high-quality immersive VR experiences was done. Definition of interactive experiences was achieved through the use of HTC VIVE virtual reality glasses.

Table 5. Work Package 5.

WP5. Development of the intelligent tutor
Definition of the target behaviour of the smart tutor
Development of tutor module
Development of student module

The first task of this step in the process was to define the target behaviour of the intelligent tutor. This tutor will act as a private tutor for the students. As a result, it will be the key to facilitate personalised training itineraries based on the needs detected by the student and the knowledge of the system itself.

Initially, the target behaviour of the intelligent tutor was defined based on the domain of knowledge. This pedagogical strategy was then defined. Tutor module development was based on pedagogical protocols, learning itinerary definition, and analysis of the student profile based on the itineraries defined for each person.

Finally, development of the student module was made. Its main objective was the cognitive diagnosis of the student, and the modelling for an efficient feedback in the system. It was necessary to determine the type of parameters to be monitored by each student and at the same time adapted to their itineraries.

Table 6. Work Package 6.

WP6. Development of the players for access to content
Development of the mobile player
Development of the stand alone immersive player
Development of the immersive web player

This work package was based on the implementation of different players for the access of students to the content of the training itineraries. More specifically 3 different players were implemented, each of them for the support of a different type of content.

This task had the purpose of developing a web player, to facilitate access to the immersive DiY experiences created in the platform. This player offered access to immersive experiences that could be rendered in 360 or 3D video in real time.

Table 7. Work Package 7.

WP7. Integration and validation of the tools
Development of gateways for interoperability with currently existing training management platforms, devices and systems
Integration tests of the developed tools
Performance test of the EDUKA Solution
Small-scale pilot test

This phase was based on the development of the architecture for validation of the tools. First of all, the interoperability gateways were developed, together with partial integration tests and partial prototypes for the conceptual and technical validation.

For an effective evaluation of each prototype, close collaboration between the members of the consortium was necessary to properly guide design and implementation of the platform.

Table 8. Work Package 8.

WP8. Testing of EDUKA Solution through large-scale pilot testing
Implementation of the solution on each validation scenario
Development of Integrity Pilots
Validation of the effectiveness of EDUKA Solution
Identification of the critical success factors in the implementation of EDUKA Solution

The main objective of this last phase was the validation of EDUKA through large scale pilot testing. For this purpose there were three principal tasks: i) implementation of the solution, ii) a pilot test of each scenario, and iii) identification of the most critical factors.

4. Results

Five main results were obtained from EDUKA: i) Author tool, ii) Catalogue experience, iii) Specifications of the behaviour of the smart tutor, iv) Players for access to the content, and v) A pilot test of each of the scenarios.

4.1. Author Tool

In the first phase of the project, it was proposed to implement a series of "catalogue" experiences. In early 2019, various tests were arranged for its implementation with Unity, which facilitates high visual quality. They were complex experiences to update, requiring technical experience. In addition, verification of the simplicity of use with the teaching staff was done and also possible customisation of the content for a high degree of realism in its representation. Based on this, the technological approach was reoriented, and the research was focused on web technologies (AR.js, A-frame and webXR). The type of experiences developed were the following:

a) AR Experiences

The objective was to support three different types of augmented reality catalogue experiences.

1. Experiences where a marker is recognised and a 3D element appears overlaid

This is the simplest dynamic to configure. Basically, the user can upload a marker (with the central part customised), and associate the 3D appearing on the marker when focusing on it. This 3D can be selected from the database of existing models (previously uploaded or from Google's public database) or link any new one that is uploaded.

Additionally, you can define if you want a text to appear in the mobile UI once the marker is recognised, and if you want a sound to be played (just once or in a loop).

2. Multiple pattern recognition experiences

In this case, after uploading different bookmarks, a different content can be defined when the patterns are recognised individually, or when several are recognised at the same time (maximum 4) and are close to each other.

In this way, more complex experiences are supported, i.e. 3D models of atoms can be associated with different markers and, when they are approached in a certain order, represent the creation of molecules (e.g. H_2O).

Another type of dynamics that this functionality supports is related to language learning. In this case, each marker represents a syllable, and by putting different syllables together the user creates words. When that word is created, the visual representation changes and the 3D model of the element to be analysed appears (e.g. CA - SA = CASA).

3. "Challenge" experiences

In this case, one of the markers defines what is known as a "challenge", and the rest are "responses". When the system recognises a marker of the "challenge" type, a series of highlighted areas appear in the captured image, where the "response" markers must be placed in the appropriate way.

b) VR Experiences

The objective was to define 3D scenarios to be loaded. Users can create new scenarios and integrate content of a different nature in Figure 1: videos, questionnaires, etc.

These environments were collaborative; the aim is to create areas for dialogue, very useful especially for language learning, where in each environment a different topic can be dealt with. This will also be a meeting point not only between students but also between students and teachers.

Figure 1. Example of the VR experience.

4.2. Catalogue experience

As agreed in the second phase of the project, finally, instead of implementing a series of "catalogue" (closed) experiences on Unity 3D, the implementation of a solution that supports both students and teachers was created to personalise their own experiences (AR.js, A-Frame and webXR).

a) AR Experiences

The objective was to support three different types of experiences with augmented reality, from which teachers and students can perform various dynamics and exercises starting from the same base.

1. Experiences where a marker is recognised and a 3D element appears overlaid

This is the simplest dynamic to configure. Basically, the user uploads a marker (with the central part customised) and associates it with the 3D that will appear on it when focused with the camera of the device being used. This 3D can be selected from the database of existing models that has been created, or linked to any new one uploaded.

Additionally, you can define if you want a text to appear in the interface once the marker is recognised, and if you want a sound to be played (just once or in a loop).

2. Multiple pattern recognition experiences

In this case, after uploading different bookmarks, a different content can be defined when the patterns are recognised individually, or when several are recognised at the same time (maximum 4) and are close to each other.

In this way, more complex experiences are supported. For example, 3D models of atoms can be associated with different markers and, when approached in a certain order, represent the creation of molecules (e.g. H_2O).

Another type of dynamics that this functionality supports is experiences related to language learning. In this case, each marker represents a syllable, and by putting different syllables together the user creates words. When a word is created, the visual representation changes and the 3D model of the element in question appears (e.g. CA - SA = CASA).

As can be seen, with the same behaviour dynamics at the level of pattern recognition through augmented reality, valid dynamics can be created for students of different levels.

3. Challenge Experiences

In this case, dynamics based on the following behaviour are defined: one of the markers defines what we call a "challenge", and the rest of the markers define "responses". When the system recognises a "challenge" type marker, a series of highlighted areas appear in the captured image, where the "response" markers must be placed in the appropriate way.

The first use that has been given to this type of experience has been to work on the concepts of "elevation", "plan" and "profile" linked to geometric pieces. The value of augmented reality was clear in this case. In addition, synergies/collaborations have been created between students of different training levels, creating 3D content (new models of geometric pieces) at the highest levels, with the lower level students later using and applying it in their AR dynamics and VR.

b) VR Experiences

As in the previous case, the scope of this task was ultimately broader than defined at the time the original project was conceptualised. During its development, what became relevant was not the value of creating specific content, but rather that of creating tools facilitating the generation of new spaces and dynamics to teachers and students.

In the third year of the project, 3 specific scenarios have been created to support the dynamising of collaborative classes for language learning, taking students to collaborative virtual environments in which they can put into practice the vocabulary and grammar they have studied, even doing this remotely.

In addition, a complete editor has been implemented for:

a) Creating new environments based on 3D models from the library

b) Integrating support for other types of content, such as videos, in these collaborative 3D environments

c) Generating and integrating questionnaires related to the 3D content itself.

4.3. Behaviour specifications for the intelligent tutor

The tool developed is specially geared to supporting STEAM methodology, which seeks to educate students through practical experiences in five specific subjects: science (Science), technology (Technology), engineering (Engineering), art (Art) and mathematics (Mathematics). Linguistics is added to these five disciplines, due to the versatility of the tool and the use cases initially identified, providing support via vocabulary learning (one of the basic pillars in learning a language), in collaborative immersive environments.

Moreover, within the platform a tagging/labelling system for the uploaded content has been created, so that it can be categorised in each of the STEAM or Language areas, indicating the educational level to which it is directed and also the difficulty of the exercises (from 1 to 5).

Additionally, in each student's file, the grade obtained for each of the areas of knowledge described must be added, which is a manual process that the teacher will arrange periodically, since the platform does not seek to "evaluate" the students. Furthermore, the evaluation of each student will not depend exclusively on the activities carried out within the Eduka platform, they are dependent on the standard procedures determined at each education centre.

With all this, we consider that there will be a sufficient data set to be able to subsequently determine the strengths and weaknesses of each student in each area of knowledge, and to be able to recommend the execution of complementary exercises for their training within the platform. The point is that this task could not be completed basically due to two factors:

- Not yet having enough didactic content created by teachers on the platform.

- Not having enough data on the students' use of the aforementioned content.

Regarding the approach designed to implement this intelligent tutor, the creation of an intelligent system based on ART neural networks (adaptive resonance) deployed on Azure Machine Learning was considered.

This type of neural networks was helpful in solving the problem of stability vs plasticity of learning and has the following characteristics and structure:

- Learning occurs through a feedback mechanism created by competition between neurons in the output layer and the input layer of the network.

- Learning is unsupervised, although there is a supervised modality.

- The network creates its own classification based on the users' learning.

This type of solution is currently used in the implementation of recommendation systems (SR), which are those applied on platforms such as Netflix or Spotify, aimed at offering users content that may be of interest to them on comparing their behaviour with that of other users of the platform and which we believe could be extrapolated to the training field, but as indicated above thousands of records are needed to train the defined neural network, for the generation of which it is estimated that more than one year of use of the platform is required (depending on the intensity of use within the centres). In any case,

we consider that the exercise carried out has been of great value in laying a solid base of knowledge, and it is an area of great interest to continue researching in the future.

4.4. 4.4 Players for access to the content

Finally, players have been created for all the computers initially identified, to which the chromebooks have been added, which are portable devices with a measured computing capacity but with a large presence in the classroom. Specifically, this is what is being acquired by the Basque Government to equip both students and teachers with portable equipment, with €1.8M earmarked for this purpose in 2020.

Below in Figure 2, 3, 4 are a 3D content, AR content and DiY content viewed through different media:
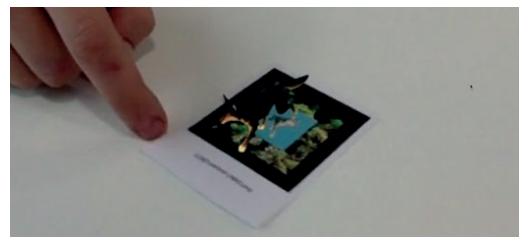

Figure 2. Example of a 3D content.

Figure 3. Example of a 3D model in browser (PC), Augmented Reality.
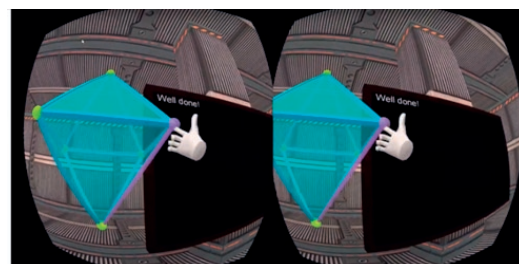

Figure 4. Example of DiY content seen through VR glasses.

4.5 Pilot test for each of the scenarios

Years of experience in education have shown that geometry is one of the leading disciplines in the realm of learning challenges. VR is a key tool in spatial and conceptual learning. These tools have the function of entering the geometric bodies and thus understand and identify each of the parts more easily.

In this project a VR classroom has been created with a blackboard simulating an environment close to theirs, where the figures are giant-sized and transparent in Figure 5. This feature will help students learn geometry from the basics, such as the simplest parts of geometric bodies, vertices, edges, faces, angles and heights. They will work on other concepts such as regular and irregular prisms and of course the most common geometric bodies in the real world will be identified, pyramids, cylinders, cones, etc.
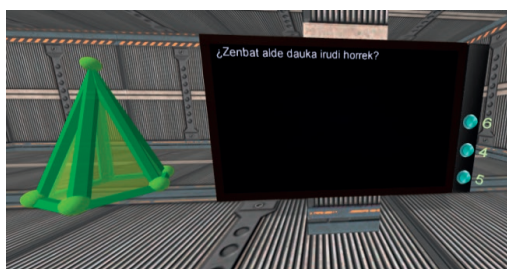
Figure 5. Example of a VR classroom simulating a real environment where the figures are giant-sized and transparent

The program offers immediate feedback. On the one hand, when the exercise is to touch/identify something like a vertex or a side, when the students pass the cursor over it the corresponding part lights up, so that they can confirm that this is what they want to point out. If the answer is correct, the message "ondo" (which means "good" in Basque) is accompanied by a sound. If the part indicated is not correct, feedback is given, there is another type of sound with the message "ez da zuzena" (meaning "it is not correct" in Basque) on the blackboard and in the figure itself the parts that would have been the correct answers are illuminated.

The second part of the program was with AR. In principle, the levels we intended to use this program with were from 5th grade to 2nd year of secondary school.

5. Discussion

The aim of the study was to develop research around a set of latest generation technologies that offer interdependence to educational centres for the adoption, development and integration of VR, AR and immersive content technologies in their study plans.

This paper collects the methodology and results obtained from a three year project funded by the Basque Government (Economic Development, Sustainability and Environment Department). The main activities developed to achieve the project's aim were industrial research on the technological possibilities on the market, development of tools for the definition of immersive educational environments, and integration and validation of the tools.

The tools resulting from the project were an Author Tool for the creation and edition of educational activities in 3D immersive environments, a management tool to facilitate the organisation of more enriching learning plans, and a smart AI-based tutor to identify behaviour patterns in the students. As a result, personalised learning itineraries adapted to the needs of each of the students were defined.

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