Disclaimer

ARETE – DELIVERABLE (D5.2)

“WP5 - D5.2: Interactive AR PBIS component”

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DISCLAIMER

Executive Summary

This deliverable reflects the work conducted for Task 5.3 “Development of an AR Interactive Components for PBS” involving the development of the ARETE PBIS-AR mobile app from the basic principles to the software prototype. The deliverable lays the foundations for introducing AR into a new teaching and learning context based on the teaching of human behaviour according to the School-Wide Positive Behaviour Intervention and Support (SWPBIS) theoretical framework.

This deliverable is based on PBIS as a practical preventative approach for decreasing problem behavior and improving instruction of expected behaviors, organization of consequence systems, redesign of environmental settings, and use of evidence based practices (Dunlap, Horner, Sailor, & Sugai, 2009).

The main aim of this report is to introduce the ARETE PBIS-AR mobile app and provide an overview of the development process integrating Augmented Reality with the requirements of PBIS practice as identified in the deliverable D5.1.

After a short reference to SWPBIS, the deliverable provides the vision underlying the development of the PBIS-AR app. The concept is based on the definition of a new theoretical paradigm that integrates Augmented Reality and behavioural learning creating an augmented space that we have called *Augmented Reality Behavioural Learning Space* (AR-BLS). The AR-BLS can be defined as a real learning space enriched with *AR Behavioural Learning Resources* (AR-BLR) that the teacher can create and use along the different phases of teaching, practice and reinforce according to the structure of a typical behavioural lesson (chapter 2). The concept inspires the design of an app for students enabling the use of AR-BLR linked to the school settings, values and expected behaviours.

According to the planned activities of task 5.3, the deliverable introduces the graphic designing and development of AR objects for the PBIS-AR app (chapter 3). Within this chapter, the assets (characters, objects and basic animations) needed for creating the behavioural routines are described.

Chapter 4 of the deliverable reports the presentation of the PBIS-AR app architecture as a component of the ARETE ecosystem. The functional and non-functional requirements are introduced in line with the architecture identifying the components and the functionalities that compose it, and the teaching process that the system will support. Finally, the use case model and wireframe of the application user interface are documented within the chapter as well.

1. Introduction

The main aim of WP5 - Interactive AR for PBIS - is to develop and evaluate an Augmented Reality (AR) solution (the PBIS-AR application) to support the implementation of educational interventions in school settings based on the **P**ositive **B**ehaviour **I**ntervention & **S**upport (PBIS) framework.

D5.2 is the second deliverable of WP5, which aims at developing a set of AR components that support management and monitoring of PBIS-practices at school. The designed technological solution is conceived as a mobile application, called PBIS-AR app. Specifically, the deliverable addresses the activities of task 5.3 covered so far; an update of this task activities will be released with deliverable D5.4 (M32).

In the following sections, we first introduce the PBIS theoretical framework and provide the rationale that guided the design and development of the PBIS-AR mobile app (Section 2). After this brief introduction, the development of the architecture of the PBIS-AR application and the set of related AR objects is fully described. Specifically, Section 3 presents the process implemented for designing 1) main and secondary characters, and 2) their actions and animations. Section 4 describes the outcome of the design and development process followed to deliver the current version of the PBIS-AR application; this process will be finalised in deliverable D5.4.

2. Augmented Reality for PBIS: define a domain of application

In the last decade, research in education and practitioners' interest have been focusing on emerging technologies, such as Augmented Reality (hereafter: AR), and their potential in teaching and learning processes have been widely explored. In this regard, research has clearly shown that AR solutions can enhance students' academic outcomes compared to traditional learning methods (Ozdemir et al., 2018). Research also indicated that AR solutions can have a stronger effect on learners' achievement in terms of content understanding and long-term retention, motivation, engagement, and satisfaction with the learning experience than traditional and other digital media-related educational experiences exert (Garzon et al., 2019; Radu, 2014).

Despite the amount of literature on the role of AR technology in the educational field, no existing research has yet investigated the potential impact of AR solutions on the promotion of students' behavioural outcomes at a school-wide level from a prevention perspective. In this regard, the AR solution developed in Pilot 3 tries to overcome this gap by specifically designing an application within the framework of **S**chool-**w**ide **P**ositive **B**ehaviour **I**nterventions and **S**upport (hereafter: SWPBIS), a well-validated school-wide approach aiming at supporting students' positive behaviour and promoting school outcomes. More specifically, the SWPBIS framework aims at preventing behavioral problems, such as disruptive classroom behavior, in order to support the development of a safe school climate and thus promoting students' social-emotional development and learning outcomes (Horner et al., 2009a; Sugai et al., 2000). Interventions delivered in SWPBIS schools follow a three-tiered system of behavior support (Horner et al. 2009b). The first tier includes universal interventions that are provided to the entire school population. The second tier focuses on group interventions to students who do not profit from the universal interventions, and the third tier provides individualized interventions for students who do not profit from the interventions provided in the first and second tier.

Basically, SWPBIS practices are based on the following pillars (Nelen et al. 2020):

- defining and teaching behavioral expectations based on shared values
- systematically reinforcing expected positive students' behavior,
- effectively addressing challenging student behavior,
- using behavioral data to identify students who require additional support.

SWPBIS interventions delivered at the primary-tier level usually include a set of universal interventions designed for all school members and across all school settings (e.g. classroom, hallway, corridor, et cetera) to create and guide a positive social culture. To reach this aim, a restricted number of contextually and culturally relevant behavioural expectations, generally three to five, are selected and taught to all school stakeholders (students, school staff, and community members) across all settings. They are defined, modelled, and practiced as other academic skills. SWPBIS practice also requires corrective and positive feedback being delivered during the educational intervention. More in detail, SWPBIS interventions comprises both 1) acknowledgement or rewards of students' adherence to behavioral expectations and 2) systematic responses to problem behaviours (Lynass, Tsai, Richman, & Cheney, 2012).

Further details on the SWPBIS theoretical framework, can be found in section 2 "Positive Behavioral Interventions and Supports (PBIS): A Description of the Framework" of D5.1 ("Analysis of PBIS Requirement for ARETE").

2.1 Definition: Augmented Reality Behavioural Learning Space

According to the aim of the ARETE project, an PBIS-AR application is being designed and developed to support educational interventions delivered within the first tier of a multi-tiered system of support. School staff, teachers, and students will use the app for teaching, practicing, and learning of expected behaviour following the guide provided by the PBIS framework (Sugai et al. 2000). Specifically, the application can support the following main processes underpinning PBIS practice:

- definition, modeling, and practicing of expected behaviour;
- acknowledgement and reinforcement of students' compliance with expected behaviours.

First of all, in order for the PBIS-AR application to be effectively and universally used across schools of different countries, it should support a teaching and learning process based on universal:

1. behavioural expectation matrix, and
2. positive reinforcement systems of students' compliance to expected behaviour.

Steps of the bottom up process for the design of the PBIS-AR software solution and its pedagogical integration in the PBIS practice are summarised in Figure 2 (Chiazzese et al. 2021).

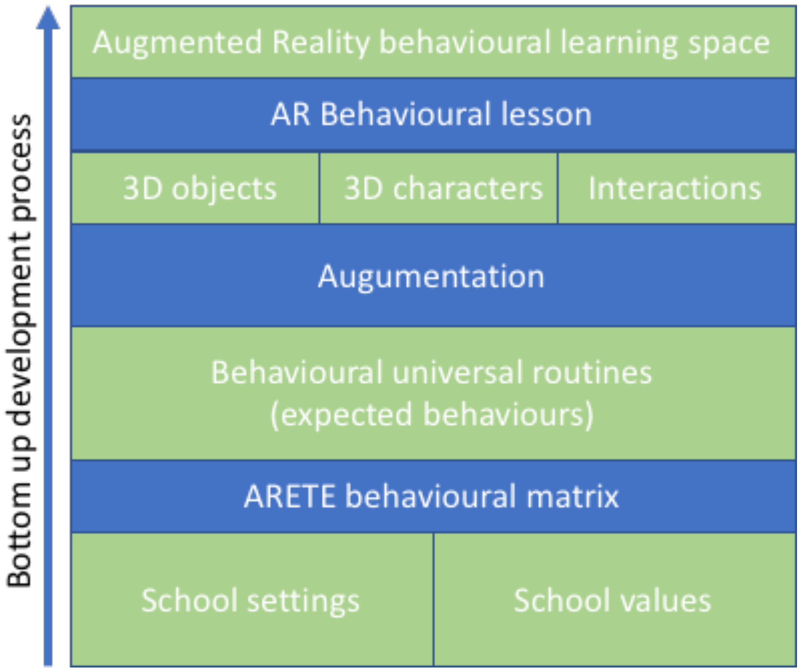


Fig. 2 Development of the PBIS-AR application and its integration in the PBIS practice

The process started with the first step, summarised at the bottom of the figure. It consisted of the development of the ARETE behavioural expectations matrix which comprises a set of universal behavioural routines based on different school values to be learned and practiced across all school settings. A literature review was first conducted with the aim of collecting data on the most common (Pronk, Goei, & Jongejan, 2020):

- PBIS school values,
- school settings,
- and behavioural expectations.

In order to perform a comprehensive analysis of requirements for the development of the PBIS-AR app, information on the most common reinforcement systems was also derived. In addition to the literature review, further data on behavioural expectations were collected from Dutch schools and a Google search. These primary sets of school values and settings, behavioural expectations, and reinforcement systems underwent a further validation process through the administration of an online questionnaire to a sample of European teachers and 4th to 6th grade students (Pronk, Goei, & Jongejan, 2021). For the purposes of the current deliverable, it should be acknowledged that a final shortlist of 12 behavioural expectations was derived as a result of the validation process. This shortlist represents the basis for the development of learning material to be augmented; in fact, the behavioural routines, as descriptions of actions performed in examples and non-examples of behavioural expectations, includes all those elements (e.g. characters, furniture, and other environmental characteristics) needed to create augmented 3D objects in terms of 1) characters, 2) objects and 3) associated atomic animations[2].

Augmented reality objects will be used in the last development stage, represented at the top of figure 2. In this stage, a small team of Dutch primary school teachers in collaboration with Dutch PBIS-experts have developed behavioural lessons to teach behavioural routines through the integration of AR technology into traditional PBIS practice. More in detail, the AR solution will support the creation of an augmented learning space aimed at teaching and practicing social behavior skills via teaching expected behavior. Figure 3 explains more in depth the Augmented Reality Behavioural Learning Space (AR-BLS) and shows how a behavioural lesson is articulated and supported with the introduction of Augmented Reality.

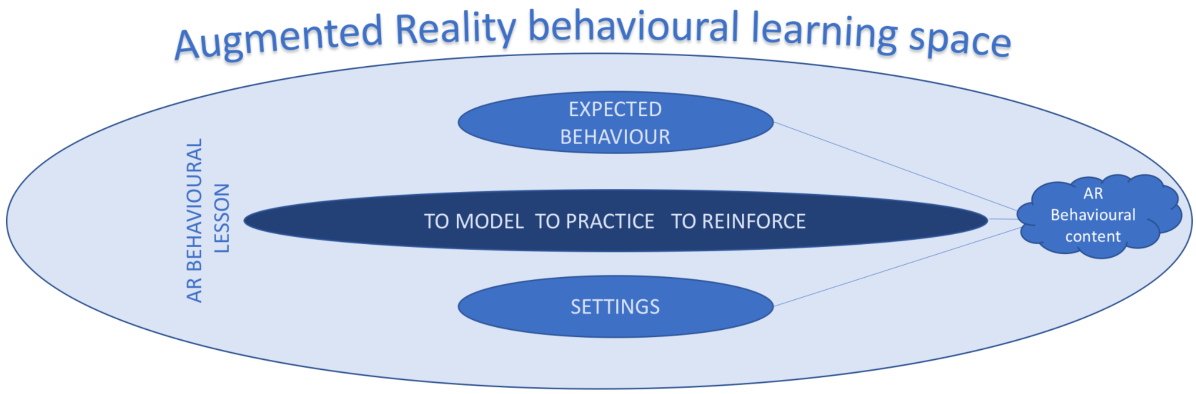


Fig. 3 Visual representation of Augmented Reality learning space

An AR-BLS can be defined as a real learning space enriched with *AR behavioural learning resources* (AR-BLR) that the teacher can create and use along the different phases of teaching, practice and reinforce according to the structure of a typical behavioural lesson. In the *teach phase* the teacher demonstrates or models the expected behavior. The teacher clarifies the difference between expected and unexpected behavior by providing positive examples and a negative example (or non- example). Augmented Reality can be embedded in this process for supporting teachers in the creation of AR examples and non-example behaviours that can explain to the student how to perform the different steps. In the *practice and reinforce phase* students are involved in multi-user interactive activities aimed at giving them the opportunity to practice and reflect on new learned skills in a variety of settings (arrival/dismissal, corridors, breaks/lunch, playground, restroom, and classroom) where the behaviors should be used (Chiazzese et al 2021).

[2] Outcomes of the full research and development process in terms of the definitive list of school values, school settings, behavioural expectations, and reinforcement systems can be found in sections from 3.2 to 3.4 of deliverable D5.1.

3. Graphic designing and development of AR objects for the PBIS-AR app

The following session describes the design and development process applied to the creation of necessary assets (characters, objects, and atomic animations) for supporting teachers in creating examples and non-examples of the behavioural routines identified and described in annex D of deliverable D5.2. The assets are part of the development process of the PBIS-AR app. The designing and development process of the assets, including the set of principal and secondary characters, objects, and atomic animations, has already been started, and will be completed and fully described in the update of the current deliverable released in June 2022 (i.e. Deliverable D5.4).

3.1 The design of the main character of the PBIS-AR app: the alien

The background of SWPBIS is social learning and behavior analysis and according to this theoretical perspective, an evidence-based strategy to teach behavioural skills is social modeling that involves different characters playing behaviours in different social scenarios (Cartledge et al., 2009; Marquez et al., 2014). Recent studies have revealed how virtual characters can influence people's attitudes and behaviours to their traits used in virtual environments (Ratan et al., 2020; Kellems et al., 2020; Charlton et al., 2020).

The implementation of PBIS approach at school is useful to make the school environment more proactive through explicit visualization and sharing of values and behavioural expectations. In fact, the use of explicit rules helps students to always know what is the expected behaviour in specific settings. This facilitates the role of teachers in creating a safer school climate and preventing maladaptive behaviours (Caldarella et al., 2011; Bradshaw et al., 2012).

According to the behavioural lessons defined in deliverable D5.1, the support of AR is introduced to enrich real settings with objects and characters that are assumed to motivate learners to interact with and learn through them, and transforming the real scenario into an augmented training ground for learning positive behavioural routines. In particular, the use of AR in PBIS approach, delivered through the PBIS-AR app, empowers the traditional sequence of a behavioural lesson - prompt, teach, practice and reinforce - with the creation of a realistic environment in which both students and virtual school characters are involved.

The teaching phase enriched with the use of the PBIS-AR app basically applies the video-modeling technique showing AR examples of expected (and unexpected) behaviours to users in which different characters (teachers, students, principal) demonstrate how to perform a behaviour in a specific setting. In terms of designing and construction of AR learning resources, the teacher can build a specific AR behavioural content in terms of animations that show example and non-example of a behaviour through the selection of virtual characters, actors of the scene and the compositions of the different steps of the animation itself. In other terms, augmented reality 3D characters can be used for showing to children the performance of simple expected behavioral routines that are claimed to be particularly attractive and motivating to young students.

To this aim, a set of virtual characters were designed and developed. The main character is an alien coming from space that is completely unaware of life on Earth, so that it can be considered as a neutral behavioural coach. Following, the design and development process of the main character and its basic assumptions are presented; design and development of the secondary characters will be described in section 3.2 “The secondary characters”.

The alien character was chosen as the main actor to interpret the behavioural rules in the identified scenarios (Goei et al., 2021). This choice is supported by the following reasons:

- PBIS practice makes abundant use of visuals, metaphors and social stories to show all stakeholders (students, teachers and school staff, community members) in the school setting what positive behaviour is (e.g. Carter & Pool, 2012; Ennis et al., 2018). The power of these metaphors is that self-management strategies can be learned in a less intrusive way. The main metaphor underlying the design of the PBIS-AR app is that an alien is new to planet Earth and has to explicitly learn all values, procedures and routines.

- The alien is a boundary crossing object for behavioral learning (Akkerman et al., 2011); it has no feelings, expectations, or emotions and can be 'told' and 'learn' what to do and in this way can automate the expected behavior via prompting, teaching, practicing, and reinforcing the new behavior. For non-responders and resisters (i.e. children who need more intensive and layered instruction in behavior management and self regulation), this is a practice-based way to let the alien model the expected behaviour.

- The alien has no gender implications; this because gender specification could have made students’ gender salient in the process of identification with the character (i.e. making identification of male students more likely or intense in case of a male character and vice versa) thus contributing to some extent to the outcome of the learning process;

- If the avatar is a human character there can be dissociation with this character as the children - especially non-responders - will not identify with the values, procedures and routines related to this character, and they will not be triggered or motivated to exhibit the expected behaviour.

The following steps (Table 1) guided the designing and development process of both the principal and secondary characters:

	Creation of 2D sketches of the characters (characters design).
	3D modelling of the characters with high polygon density in neutral pose (sculpting high poly).
	Creation of 2D sketches of the characters (characters design).
	3D modelling of the characters with high polygon density in neutral pose (sculpting high poly).
	Low density polygon derivation of 3D characters (retopology).
	Surface micro details transfer into texture from the high poly model (normal mapping).
	Creation of colour textures (colour mapping).
	Creation of the skeletal structure of the character (rigging / skinning).
	Simple motion test of the complete low poly character (motion test).
	Final release of 3D model with Legacy shader

Table 1 Characters designing and development process

With specific regard to the alien character, the first step was the design of a set of 2D character models. Several models were proposed until the final model of the alien was defined and selected. A full description of the selection process of the 2D model of the current alien can be found in Annex A. After the approval of the 2D model of the current principal character, the sculpting process started in high poly aimed to give form to the 3D alien in neutral pose. A conversion process from a high polygon density model to a low polygon density character model (retopology) was applied in order to create a lighter model more adapted to be animated. Details of the model at high polygonal resolution have been preserved applying the normal mapping technique and the color mapping to obtain a realistic rendering of the character was applied. The next step was aimed at building the character’s movements, putting bone and joints in the character (rigging) and attaching the mesh of a 3D model to the rig (skinning) so that the geometry of the character moves when the joints are moved. The final 3D model of the alien has been released as OBJ format and used as a prefab within Unity engine.

The following figures show some characteristics of the 3D alien model that has been developed. Figure 4 shows the outcome of the design process implemented for the 3D alien face.

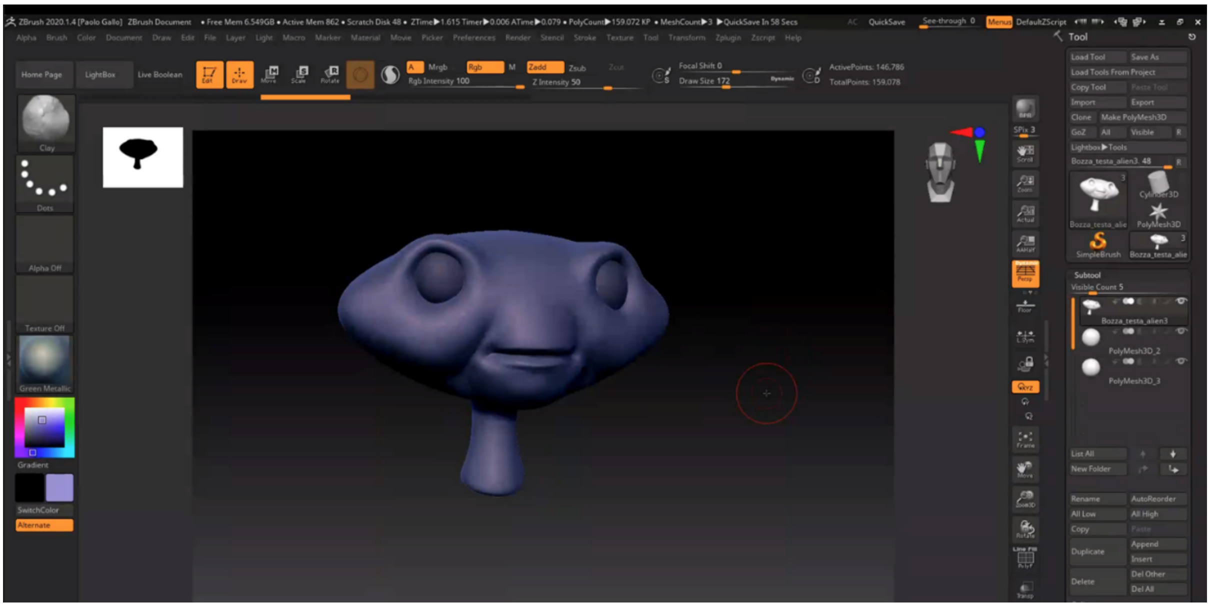


Figure 4 The 3D alien face design

A random eye blinking and the antenna movement were programmed (Annex B) and some facial expressions to convey happiness, sadness, surprise and anger have been implemented in the alien character. These were implemented using blend shapes, by interpolating different sets of geometry. A technique that is used in facial animations to switch between expressions. By combining the various shapes together, it is possible to create new expressions (Figure 5 to 9).

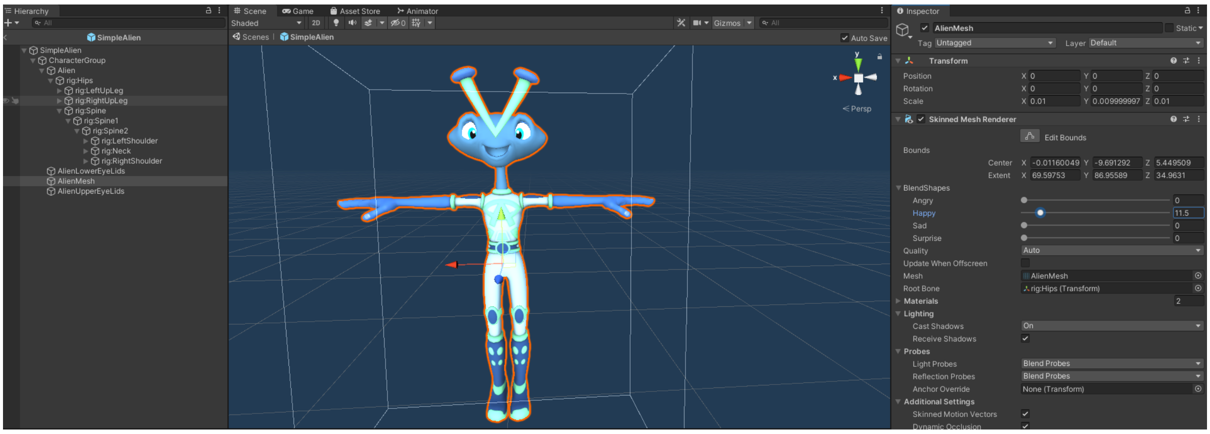
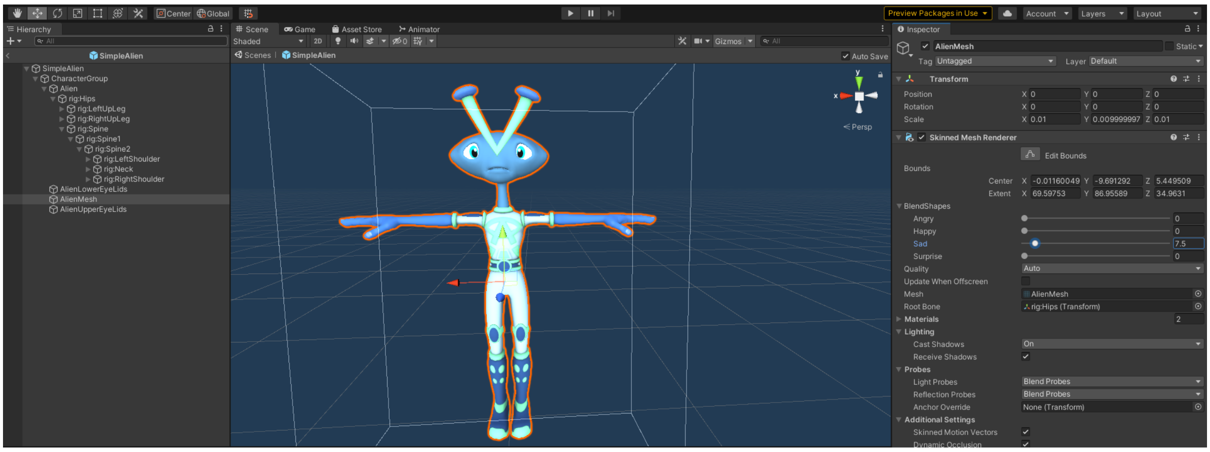
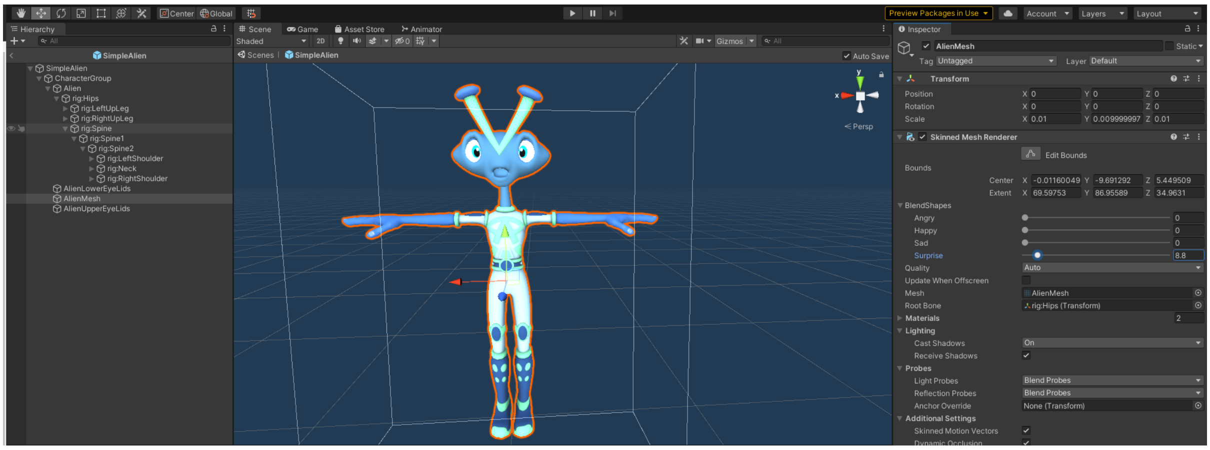


Figure 5 Happiness facial expression



Figures 6 Sadness facial expression



Figures 7 Surprise facial expression

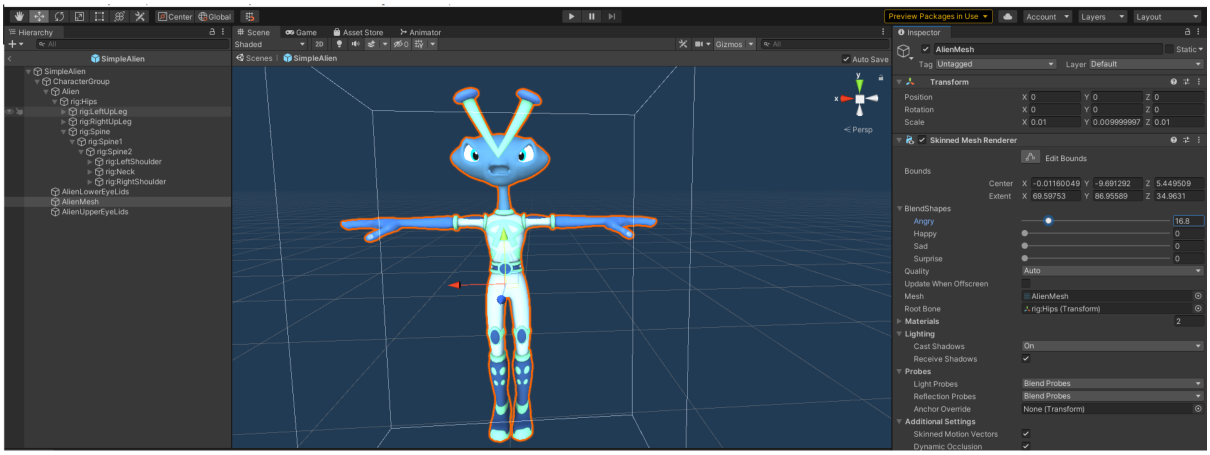


Figure 8 Angry facial expression

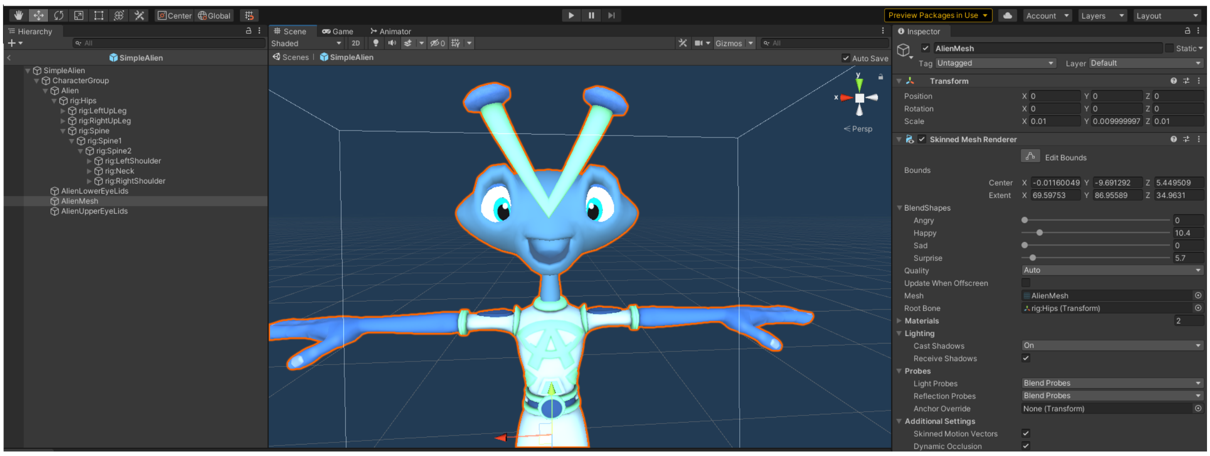


Figure 9 Facial expression combining happiness and surprise

3.2 Secondary characters

The alien is only one of the characters which can be involved in the creation of examples and non-examples of a behavioural routine in the PBIS-AR application. At school he should indeed have relationships with other characters, such as teachers, the administrator and fellow peers.

Secondary characters are being designed and developed following the same process described in table 1. They are conceived in a more basic way since they are assumed to provide only a visual aid to the main character; they are less detailed and able to perform only simple animations. Given their nature, they are being designed to be modular while keeping the anatomical characteristics unchanged.

In development terms, a single model has been made for children and one for adults. Different hairstyles and elements, such as glasses, beards, freckles, clothes, etc., make it possible to customise male and female characters. It is also possible to change the colours of the characters as desired to diversify their appearance. Figures from 10 to 15 show examples of children (students) and adults (teachers or the administrator) characters.

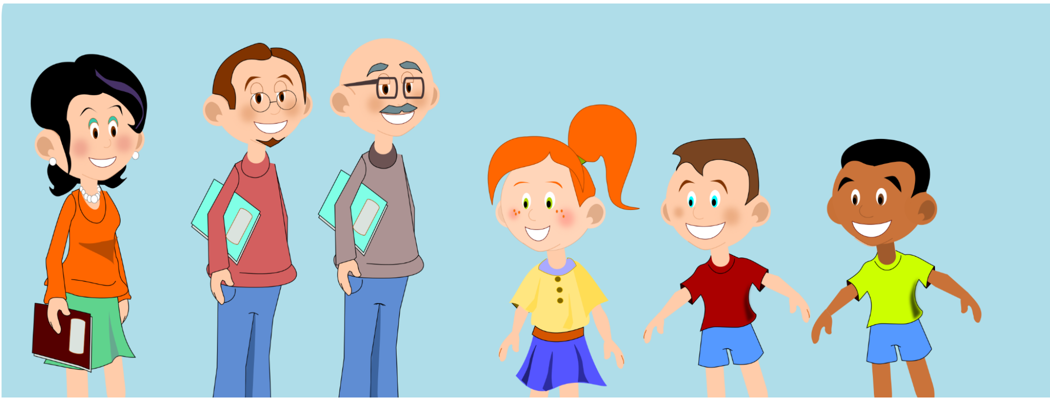


Figure 10 Examples of fully designed children and adults characters

Figure 11 Examples of adults characters

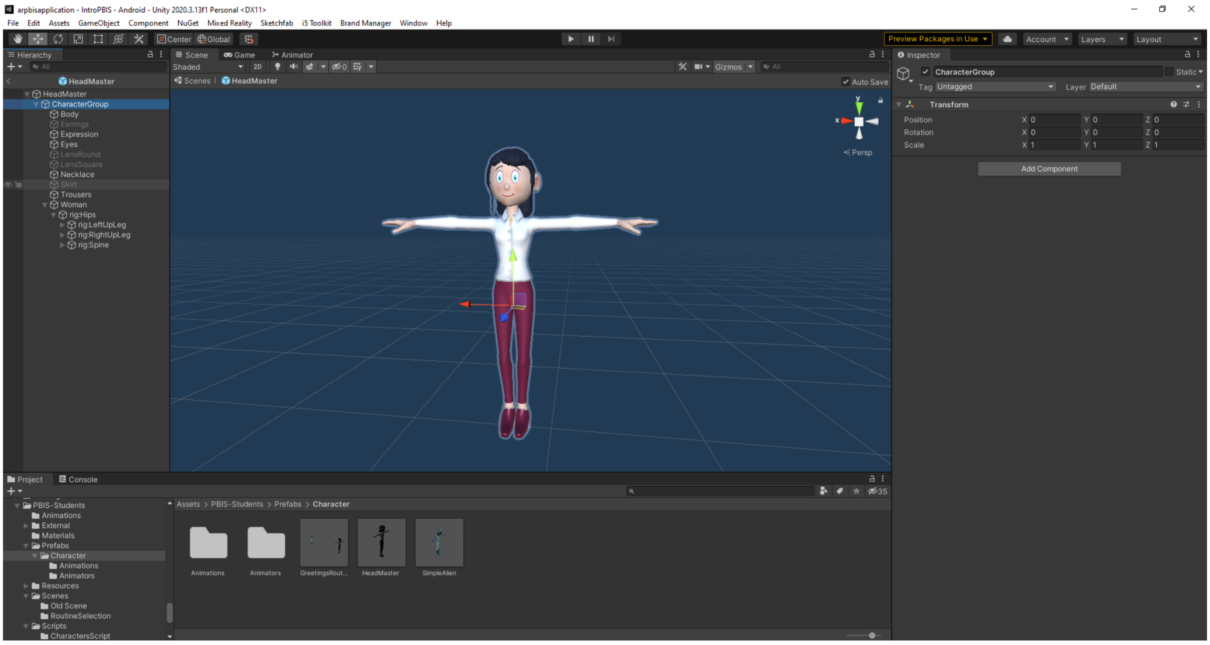


Figure 12 Example of adult character

Figure 13 Example of boy character

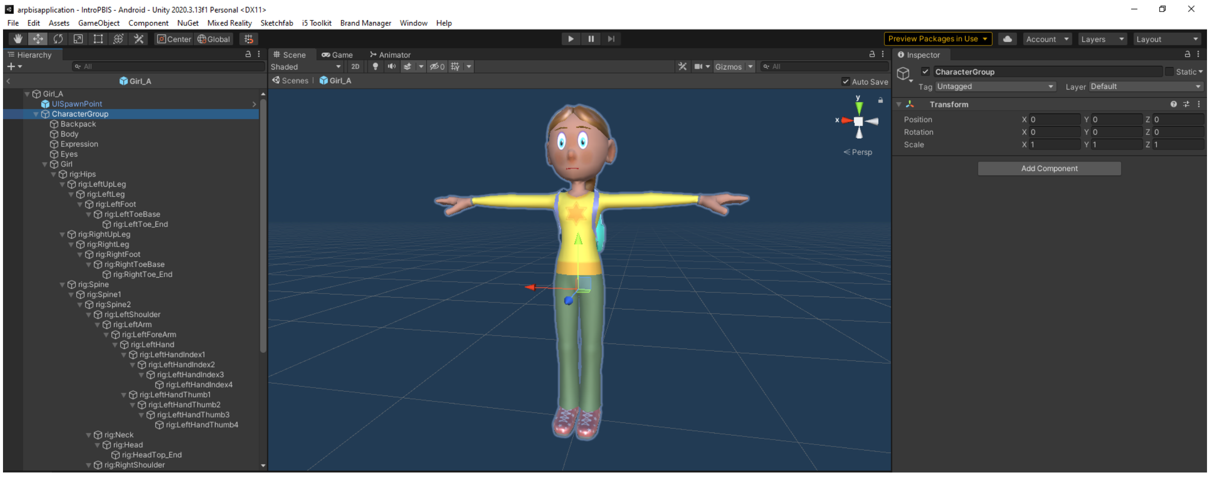


Figure 14 Example of girl character

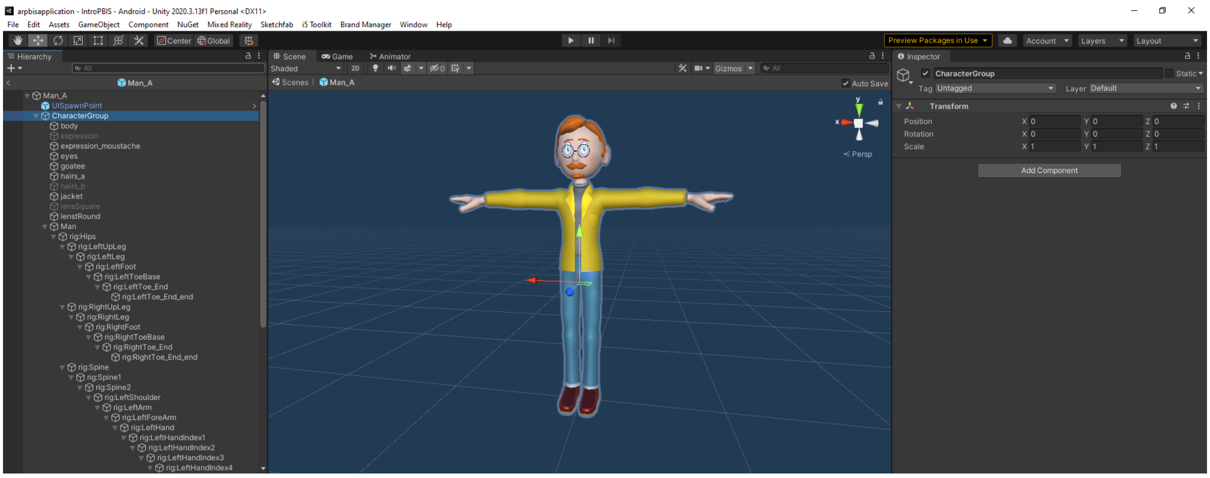


Figure 15 Example of adult character

3.3 Design of character's actions and animations

As described before, the PBIS-AR app is mainly designed for the fruition of AR behavioural contents created on the basis of PBIS behavioral expectations (see Table 2 and D5.1). Augmented reality behavioral content basically takes the form of structured animations superimposed to real settings and involves the alien performing examples and non-example of behavioural routines with the aid of secondary characters. The short descriptions of behavioural examples and non-examples described in the Annex D of deliverable D5.1 have been analysed to identify the characters involved and the set of self-consistent elementary descriptions of actions. An atomic animation is produced for each action description. Atomic animations, appropriately composed by teachers, can give rise to several animated clips related to different examples and non-examples of behavioural routines (See Figure 16).

From a development point of view, animation clips with Unity Engine are being progressively created on the 3D models of the main and secondary characters. These clips can animate the position, rotation and size of the model, modify material properties and some animations will be processed from clips produced by motion capture and imported into Unity.

Table 2

Shortlist of behavioural expectations (Pronk et al., 2021)

General/all settings	1. Greet others
	2. Keep your hands/feet to yourself
	3. Walk with a goal
Classroom setting	4. Keep your working space organised
	5. Store your belongings
	6. Work independently at your desk
Social skills/all settings	7. Stand up for others
	8. Use stop/ walk/ talk to solve problems (a)
	9. Use stop/ walk/ talk to solve problems (b)
	10. Use stop/ walk/ talk to solve problems (c)
	11. Help others with questions

12. Let others be (let others play)

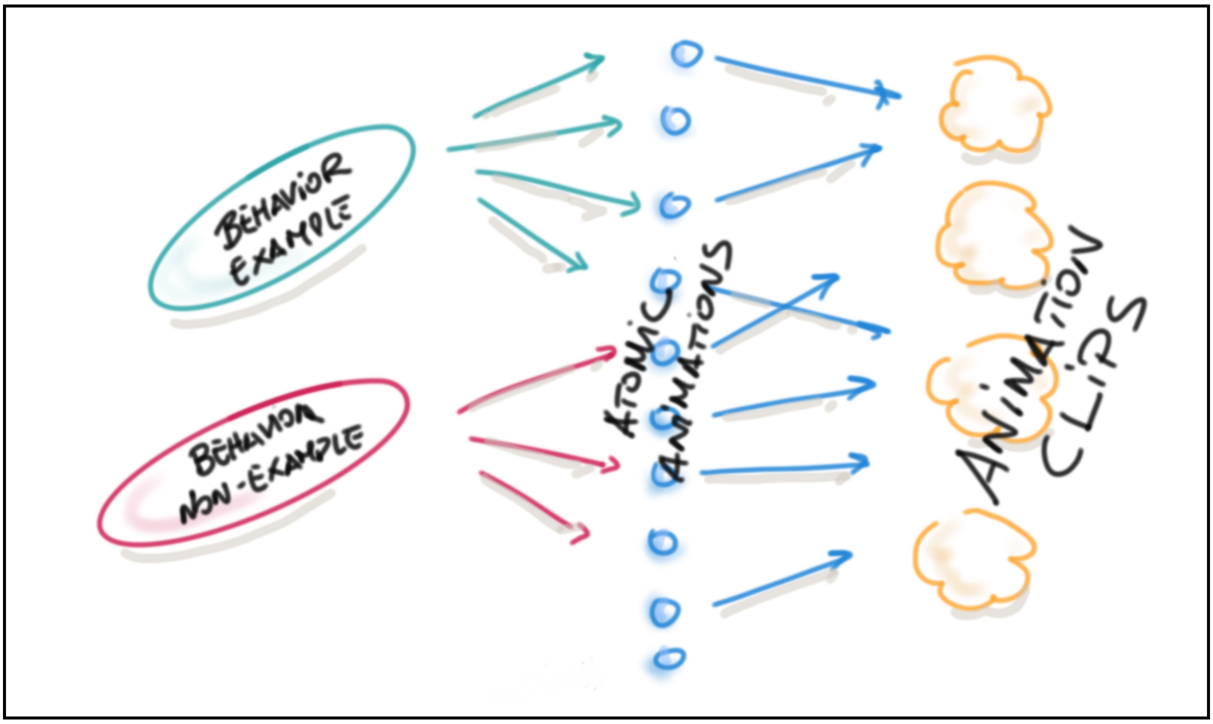


Figure 16 Graphic representation of composition of AR animation clips

The atomic animations which are going to be developed in the short term are listed in Table 3 according to the different characters (student, alien, teacher/school staff) involved in the creation of animation clips. Each atomic animation is identified through an alphanumeric code. Other atomic animations related to a number of other examples and non-examples have not been identified yet and will be developed later on. Updates on the process of development of characters' actions and animations will be provided in deliverable D5.4.

Table 3
List of Atomic Animation per Character

Character	Alphanumeric Code	Atomic Animation
Student		
	S1	Sitting on the chair.
	S2	Getting up from the chair.
	S3	Talking to the other party while sitting down - frontal interlocutor position.
	S4	Talking to the other party while sitting down - side interlocutor position.
	S5	Talking to a partner while standing up - frontal interlocutor position.
	S6	Talking to the partner while standing up - side interlocutor position.
	S7	Whispering to a seated partner - lateral partner position (student puts hand in front of mouth and tilts head towards hypothetical partner's ear).
	S8	Whispering to an interlocutor while standing - lateral interlocutor position (student puts his hand in front of his mouth and tilts his head towards hypothetical partner's ear).
	S9	Laughing while sitting - frontal position.
	S10	Laughing while standing - frontal position.
	S11	Writing while sitting on the desk - frontal position.
	S12	Writing standing on the wall - frontal position.
	S13	Using the click-clack of the click pen while sitting - frontal position (the student holds the pen with one hand and uses the other hand to operate the click-clack at the top of the pen or the student holds the pen with one hand and taps it against the palm of the other hand or against the back).
	S14	Using the click-clack of the click pen while standing - frontal position (the student holds the pen with one hand and uses the other hand to operate the click-clack at the top of the pen or the student holds the pen with one hand and taps it against the palm of the other hand or against the back)
	S15	Greet others with the hand
	S16	Walk (from a point to another)
	S17	Run (from a point to another)
	S18	Push back

Alien		
	A1	Sitting on the chair.
	A2	Getting up from the chair.
	A3	Screaming at a standing interlocutor - frontal position of the interlocutor (Arpro puts one or both hands near the mouth which opens).
	A4	Talking to an interlocutor standing up - frontal interlocutor position.
	A5	Talking to an interlocutor while standing - lateral interlocutor position.
	A6	Making the "No!" gesture with the hand while standing - frontal interlocutor position (Arpro shows a "neutral" expression).
	A7	Signal "Stop" with the hand while standing - frontal interlocutor position (Arpro extends his arm in front of him and shows the palm of the hand gathered towards the interlocutor)
	A8	Walk calmly (from a point to another)
	A9	Greet others with the hand
	A10	Run (from a point to another)
	A11	Push
Teacher/ School staff:		
	T1	Talking to an interlocutor while standing - frontal interlocutor position.
	T2	Walk (from a point to another)
	T3	Greet others with the hand

The principal and secondary characters with their related atomic animations will be integrated within the MirageXR authoring toolkit[3] as character models. Using the toolkit as a user, a teacher can compose new examples and non-examples of behavioural routines as AR behavioural content to be uploaded in the ARETE repository. Once uploaded in the repository, AR behavioural content is accessible to students from the PBIS-AR app for the purposes of behavioural lessons. Annex D "Test of MirageXR app authoring toolkit for creating behavioural routines" shows some behavior examples and non-examples created by teachers.

[3] The description of the MirageXR authoring toolkit is available in deliverable D3.8.

4. The PBIS-AR app architecture as a component of ARETE ecosystem

The PBIS-AR app is an integral part of the ARETE ecosystem and contributes to creating a behavioural learning space in augmented reality.

Starting from the PBIS Requirements Analysis for ARETE (D5.1), the design of the ARETE PBIS-AR application will have as main objective the effective implementation of the requirements, aiming to introduce efficiently the AR for creating an Augmented Reality behavioural learning space where add, play, practice and reinforce in the real setting behavioural expectations during a PBIS lesson.

In particular, based on D5.1 there are three main school values that should be supported: safety, respect, and responsibility. Moreover, with regards to school settings, the PBIS-AR app shall be usable in: (1) arrival/dismissal, (2) corridors, (3) breaks/lunch, (4) playground, (5) restroom, and (6) classroom.

Likewise, with regards to the reinforcement system, findings of the requirements analysis for the PBIS-AR application suggests that, since the preferences of teachers and students do not converge, it is important to give priority to students' preferences as the end goal of reinforcement is to motivate students to perform well. For this to happen, the reinforcement systems to include in the app will be: (1) leaderboards, (2) badges, and (3) points.

All of the above, the designing of the ARETE PBIS-AR application has been integrating functionalities and technologies aiming to support AR PBIS interventions in the previous six school settings and provide AR contents for the lesson series described in D5.1. To this end, an application with a specific interface for students (8-12 years old) is being designed to allow simple, intuitive and effective access to AR learning resources. The application will allow to use the AR behavioural learning resources of the behavioural lessons designed by the teachers through the authoring tool described in the D3.8 of WP3, adhering to the IEEE ARLEM (Augmented Reality Learning Experience Models) 2.0 standard (the teach section), but also to access a series of PBIS educational contents that foresee, through gamification, the activation of specific didactic reinforcement activities (the discovery/reinforcement section).

In addition to the teach and reinforcement sections, the PBIS-AR will have a practice section where students will work collaboratively to carry out PBIS behavioural tasks.

The AR-based learning analytics data of user interaction within the PBIS-AR app are collected, designing and specifying a first version of xAPI vocabulary needed to the AR-based learning analytics of user interaction with PBIS-AR app.

4.1 PBIS-AR app Architecture

Taking into account the requirements described above, in Figure 17 we present the architecture of the PBIS-AR app.

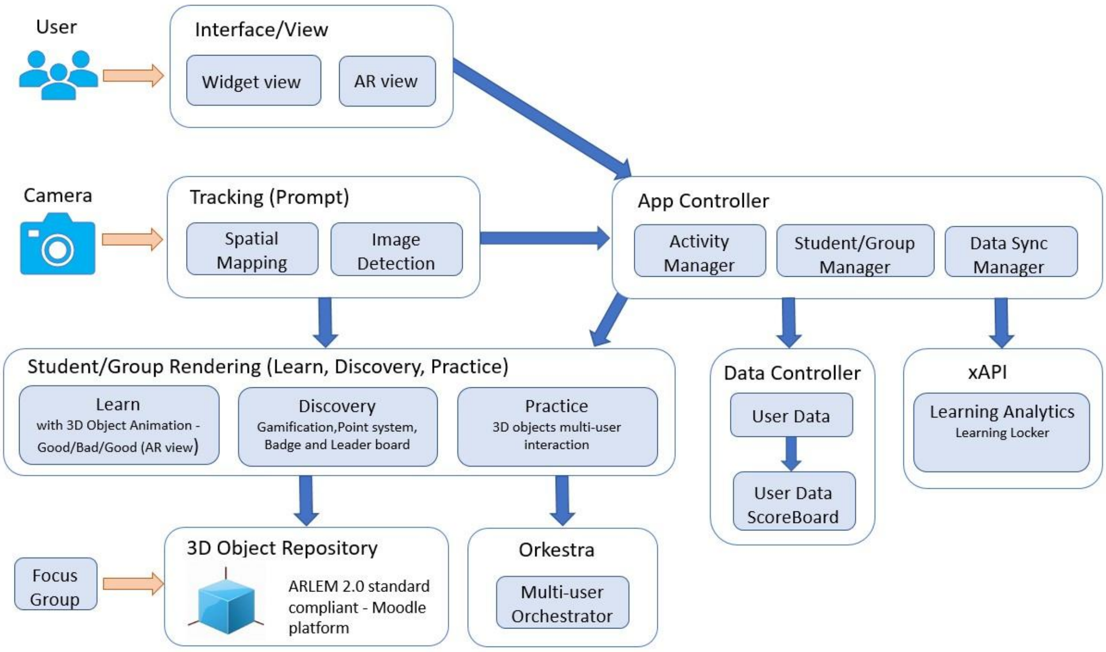


Figure 17 Architecture of the PBIS-AR app

Users of the application will be students or groups of students (depending on the number of available devices). As shown in figure 17, an app controller manages activities, user profile and data synchronization. In particular, the PBIS-AR controller interacts with: the tracking system, which is responsible for managing the AR-content tracking; the data controller to manage user data and leader board; the xAPI for learning analytics.
Moreover, the 3D object as well as 3D animations, described previously in section 3, are stored in a repository on a Moodle server using ARLEM 2.0 standards.
Finally, as introduced in section 4.3.4.3, the Orkestra library will be used as a multi-user orchestrator.
Therefore, in the next sections the functional and non-functional requirements, designed for PBIS-AR app, are introduced in line with the architecture presented above. The functionalities that the app should offer to their users are detailed in 4.2, instead, the non-functional requirements about the quality constraints that the system must satisfy are presented in detail in section 4.3. Then, a student use case will be introduced in section 4.4 and the user interface navigational paths are shown in section 4.5. Finally, in section 4.6 some research about the monitoring behavioural learning experiences is reported.

4.2 Functional requirements

Considering the functionalities that the PBIS-AR app should offer to their users and according to the PBIS-AR architecture the identifies functional requirements are:

- Interactive introduction to the system

- Environment setup
- Play of the teacher behavioural routines
- Behavioral reflection game in AR
- Multi-user interactive behavioral activity
- Leaderboard and rewards.

These functionalities will be implemented using the augmented reality technology and following the graphic designing defined in section 3. Moreover, the proposed system interacts with the Moodle platform to access the behavioural routines created by the teacher using Mirage XR. Moreover, the PBIS-AR app records any student interaction into the Learning Locker platform.

4.2.1 Interactive introduction to the system

As introduced in section 3, the alien character was chosen as the main actor to interpret the behavioural rules in the identified scenarios. Thus, through an interactive presentation the alien is introduced to the student (more details in D 4.1). In fact, this is the first feature that is proposed starting the app where the alien introduces itself and the student begins to interact with the new friend through an interactive cognitive dialogue. The dialogue will be developed in AR mode using the balloon system. The choice of visual feedback (such as balloons) over a speech synthesis system was dictated by the need to use the PBIS-AR app in the classroom by several students simultaneously with their own devices.

Furthermore, the interactive introduction will help the learner to become familiar with the user interface of the application and feel more involved in the learning process. In fact, the choices selected by the student will allow them to customize the presentation of the alien by presenting information in line with the answers provided by the student at this stage.

These answers will then also be used in the next phase of setting up the environment.

4.2.2 Environment setup

After the interactive introduction, the user will be guided by simple wizards to a simple configuration of the working environment. To this end, the user will be asked to enter a nickname that will be used to track all student interactions in an anonymous way and to set up the necessary settings to start the app in a personalized way.

The level of personalization is very light in order to maintain the user's anonymity as much as possible, while still allowing the configuration of the environment variables necessary for the functioning of the PBIS-AR app and to provide the specific learning contents developed by the teachers for the class to which the student belongs.

4.2.3 Play of the teacher behavioural routines

Through this feature, students will be able to access the behavioural routine created by the teacher in the specific setting with the MirageXR toolkit. As shown in figure 17, this is the "Learn" section.

The content will be proposed as 3D AR animations directly in the classroom environment where the student is to learn. Then the animations will be displayed in the position decided by the teacher so that the student can learn in his or her daily learning environment.

Then, the student can visualize one or more behavioural routines by following the sequence consisting of steps and according to the good/bad examples to show as models. The animations will always have the alien as the main character.

Specifically, the app will interact with MirageXR components in order to access the ARETE Moodle digital repository (more details will be provided in section 4.3.4.1).

4.2.4 Behavioral reflection game in AR

According to the reinforcement aspect introduced in the requirement analysis (D5.1) a gamification learning content will be provided to the students. This is the "Discovery" section defined in figure 17. Using this feature, students participate in a behavioural reflection game in AR.

Through a series of markers located in the various settings, examples and non-examples of behaviour are displayed on which the student is invited to reflect through quizzes whose positive answer determines the assignment of a score/badge and the updating of an overall ranking (leaderboard). The definition of the game design and setting is up to the teachers who have to design according to their learning goals a specific scenario.

4.2.5 Multi-user interactive behavioral activity

Another relevant feature designed for the PBIS-AR app is the 3D AR multi-user interaction, in figure 17 the "Practice". This feature is designed to give students the opportunity to practice behavioral activities through augmented reality, using 3D objects and characters, to interact with in a mixed environment.

As introduced later in section 4.3.4.3, the Orkestra library will be used to support the Practice. Using this library, the application will enable students to participate in a multiuser interactive behavioural activity. Students will interact through their mobile devices in an AR scenario to practice the PBIS lessons. For this to happen, a use case related to PBIS to be tested as an exercise for students in pilot 3 will be designed.

4.2.6 Leaderboard and rewards

As introduced in the section 4.2.4, during the discovery phase, students are involved in a behavioural reflection game in AR, where they have to answer a series of quizzes about the best behaviour to adopt in specific scholastic contexts.
Every time they guess right, they can gain reinforcement from those that were selected as most desirable during the interview administered to both teachers and students (D5.1). In particular, the rewarding system is very important to improve the students' motivation to perform well. It will include leaderboards, badges, and points combined (i.e., points and leaderboards), according to the different behavioural expectation to practice in the AR environment.

4.3 Non-Functional requirements

In this section some of the quality constraints that the system must satisfy will be introduced. In particular, the non-functional requirements identified and analyzed are:

- Usability
- Performance
- Error Management
- System application Interface
- Security

4.3.1 Usability

Since primary school students are the main target group of the PBIS-AR app, usability becomes a particularly important design consideration given that young children in general have limited experience with AR. To enable these end-users to learn behavioural routines during PBIS lessons with high effectiveness, efficiency, and satisfaction, the following usability design requirements are formulated based on the ARETE systematic literature survey (D4.1), analysis of user requirements (D4.2), students questionnaire results (D5.1), and general usability design guidelines (Nielson and Molich, 1992; LaViola et al., 2017; Joyce, 2021; Law and Heintz, 2021) to ensure that the design requirements are suitable for PBIS-AR app:

1. **Learnability**: AR applications should enable students who are inexperienced with the app to quickly comprehend the tasks inside the app and carry out the necessary steps to complete the tasks. To improve learnability, a quick start guide will be provided to the students in order to provide a simple introduction to the app features. Thus, this guide will be designed with simple child-friendly language, for instance, using iconic language. Furthermore, AR interaction will be designed by adapting the real-world objects to take advantage of the interaction metaphors that students are familiar with.
2. **Simplicity:** AR applications should be straightforward, aesthetically pleasing, and easy to use. Based on the human processor models (Card et al. 1983) of human-computer interaction, complex user interfaces require additional processing time and cognitive

load to understand a task. Therefore, the user interface design should be as simple as possible. To keep the user interfaces simple, information or components that are irrelevant or redundant will be removed from the PBIS-AR app. In addition, user interfaces will use the same design throughout the app to improve consistency and simplicity.

3. **Engagement:** AR applications should be engaging and fun to use. Engaged students are motivated and likely retain more knowledge from the lesson. PBIS-AR apps are designed to improve the students' engagement via alien character design and narrative; thus, the user interfaces design will be based on this alien character ranging from colour schemes to interactive interface elements that are inspired by the alien such as spaceships or UFO saucers. Moreover, gamification elements such as a leaderboard and scoring system can be added to introduce light competition in the app to further motivate students. Badges or tokens systems can also be used to motivate students and provide students with a sense of achievement.
4. **Help:** AR applications should present appropriate instructions and/or help options to students. While the PBIS-AR app will be used under the supervision of the teachers, adding help options can help reduce the teacher's workload. Thus, a simple help button will be added to provide simple instruction and remind the students of the app features.
5. **Suitability:** Since the students will interact with the system in the classroom situation; therefore, the app and lesson design should also consider real-world classroom scenarios and limitations. For instance, AR activities will be designed to be short enough to fit in a lesson and encourage breaks to avoid fatigue. The system will also avoid AR interactions that require a lot of space around the students to prevent accidents in the classroom.
6. **Feedback and Error Handling:** AR applications should provide timely, contextual and meaningful feedback to students, especially when students interact with the AR elements. Feedback ensures students that the input has been registered, allowing the students to understand the current state of the task. Therefore, a combination of sound and visual feedback will be included in the PBIS-AR app. Feedback will also be used to notify the students of errors and possible ways to fix the system. As a simple way to fix possible errors and mitigate the student's error, the back button will be provided for the students to undo actions, so students do not have to redo the entire task if the error occurs.
7. **Customizations:** AR applications should be flexible and allow customization. Teachers should be able to customize the AR contents to suit their class, enable the teachers to develop AR-based learning content and design learning activities without difficulty. To do so, the PBIS-AR app has been designed to use in conjunction with AR authoring toolkit (MirageXR), allowing the contents that are created in MirageXR to be viewed in the PBIS-AR app. From the students' perspective, a customization feature that enables the students to customize virtual objects and use them in the lesson could also improve the students' engagement.

8. **Marker:** AR applications should have appropriate marker's design and usage. The marker design will be based on the design of the alien character to ensure that the students can recognize and understand the purpose of the markers, and the markers will be positioned near the lesson objectives to help students better associate the PBIS lessons to real-world situations. The size of the marker should be sufficient for multiple students to use the marker simultaneously without occlusion, while markers and augmented objects still fit within the students' device camera field of view.
9. **Virtual object:** AR virtual objects should be clearly visible on students' devices and provide students with a sense of co-presence. To improve visibility, the virtual objects should fit the target device camera's field of view and the virtual objects should face the students when the objects first appear on the screen, so students do not have to adjust their position to view the virtual objects. Some types of virtual objects such as textboxes or labels should always face students to improve readability. A sense of co-presence can be improved by ensuring that the virtual objects are anchored in the real world without positional and orientational errors. In addition, lighting and shadows can be used to improve realism to convince students that virtual objects exist in front of them.
10. **Interactions:** AR applications should have a suitable interaction design to match the physical devices. Since the PBIS-AR app system will be installed and configured on mobile common devices (like tablets), physical properties such as weight and dimensions of the device should also be considered in the interaction design. Specifically, primary school students with small hands may struggle to hold the tablet in one hand and use another hand to manipulate the virtual objects on the screen. Moreover, students without enough strength may struggle to place the virtual objects due to shaky hands. To alleviate this issue, user interfaces for tablets can be positioned close to the grabbing positions for easier thumb access when holding the device with two hands. Furthermore, constraints can be introduced to reduce the degree of freedom of the students' input to improve manipulation precision; for example, students can lock the virtual objects to move only on the floor, which make positioning the virtual objects easier and more precise.
11. **Reliability:** AR applications should be fast and reliable. The virtual objects in the PBIS-AR will be optimized to ensure fast-loading time. Furthermore, the system will be tested on the recommended devices (refer to section 4.3.2) to minimize errors and interruptions.

4.3.2 Performance

Since the system is designed to run on the latest generation of mobile devices, some minimal hardware and software requirements are needed in order to grant the system performance.
The minimum hardware specification to operate ARETE apps has the following characteristics.

Apple devices (iOS):
- iPad Pro (2016 model) - 9.7-inch/12.9-inch – or later
- iPad Pro 10.5-inch - or later
- iPad (2017 model) - 9.7-inch – or later

Android tablet devices requirement:
Processor (CPU) Manufacturer: Arm compatible
Processor Count: 4 core minimum
Processor (CPU) Speed: 1.4 GHz minimum
Minimum Display Resolution: FHD 1280×1024
RAM Size: 2 GB (3GB or more recommended)
FREE Memory Storage Capacity (Hard Disk size): 16 GB or more recommended
Operating System Minimum: Android 7.x+
Accelerometer: Required
Gyroscope: Required
Magnetometer: Required
Connectivity Type: Wi-Fi to download app or send statistics data
Camera: 720p minimum
Front Webcam Resolution: better if available
Video: FHD

A list of specific device models that are currently supported by ARFoundation library are listed here: https://developers.google.com/ar/discover/supported-devices

It is preferable to buy a mobile device with 4G+ module for sim card in order to have Internet connection without the presence of WIFI network available at school.

4.3.3 Error Management

When the user is performing an operation that requires an Internet connection, the system will show a message warning him if the operation was not successful: in this case the user knows that he/she must check again that his/her device is connected to the Internet.
In case of connectivity problems with the Moodle server, the system will show the user a message informing him/her of the problem and inviting him to wait until the system is working again.

4.3.4 System application Interface

The PBIS-AR App will communicate with other existing systems like ARETE Moodle 3D digital repository, Orkestra and Learning Locker.

4.3.4.1 ARETE Moodle AR repository

The PBIS-AR app will integrate some MirageXR components in order to access the ARETE Moodle digital repository[4]. In particular, as shown in Figure 18, the Learn module will access the AR behavioural learning resources stored in the Moodle repository. These resources are 3D objects, as well as 3D animations, representing the PBIS routines created by teachers with MirageXR.

The ARETE Moodle 3D digital repository represents in the educational context of PBIS an example of a hub for creating and collecting contents for the behavioural lessons. They are AR behavioural resources created by the teacher and to be used with their students. The communication features for accessing the collection of behavioural learning resources are implemented through the development of a moodle plugin. The plugin uses Moodle web services and Rest protocol for this purpose. It uses different Moodle APIs which make the plugin more secure and efficient. These APIs include data manipulation API, form API, backup API, file API, access API, page API, upgrade API and web service API. The plugin creates four tables in the Moodle database. arete, arete_allarlems, arete_arlem and arete_rating. arete is the main table which will keep a record for every new activity of type mod_arete. arete_allarlems keeps the data of all activities that exist on the server. arete_arlem will link an activity to a course. arete_rating keeps the rating information of the activities.

[4] The ARETE Moodle 3D digital repository description is available in the deliverable D3.4 and accessible at https://arete.ucd.ie.

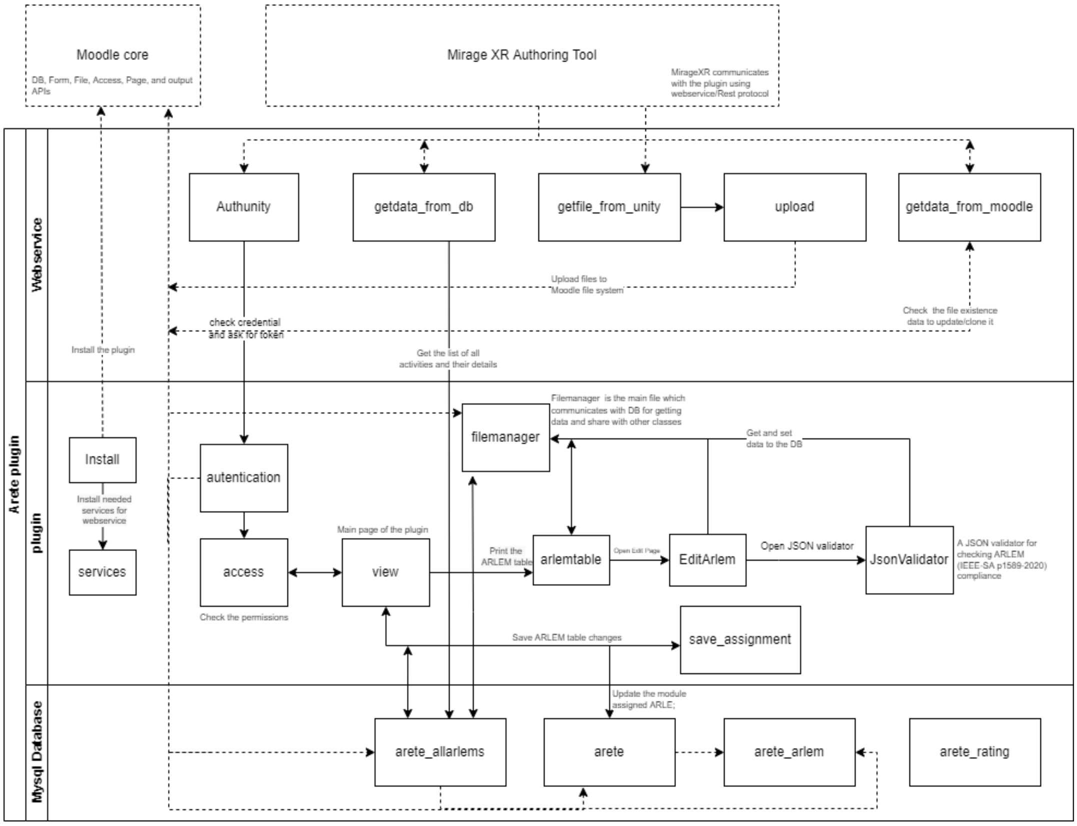


Figure 18 Moodle Digital repository

The plugin is responsible for both displaying the uploaded activities in Moodle on browsers and for communication with MirageXR. On the course page, the plugin due to the user role will list the permitted activities. Access API checks the user role and then lets the main component (view) know what data should be displayed. "arlemtable" gets these data and creates tables using them. The teachers and admins will see the list of available activities and can delete or edit their own activities. However the admins have the right to edit or delete any activities. "save_assignment" will check and update these changes on the database. On editing activities, the edit button of each activity sends some data about that activity (Eg. itemid) to the class EditArlem. EditArlem uses that information to fetch and save data on the database. Also on the edit page, a third party plugin called Json Validator, allows the user to view, edit or validate the format of the main JSON files of the activity i.e. activity.json and workplace json. The modified data of the edited activity will be sent to "updatefile" and it will update the database by using the methods in "filemanager". "filemanager" is responsible for almost all data and file manipulations. On MirageXR apps, the request for getting the list of available activities will be sent to "getdata_from_db", and it checks if the user id exists and will return the list of the public activities and the user's activities if any exist. Uploading a file starts with sending a request to "getfile_from_unity". This request includes all needed file info and data. After converting the data to base64 strings, it will be sent to "upload.php" for saving the file in the Moodle file system using File API and inserting the record of the activity into the database using DB API.

4.3.4.2 Learning Locker and xAPI

In the ARETE project, PBIS behavioural lessons will be developed and piloted to investigate the effective value of integrating AR technology within PBIS interventions and supports to encourage expected behaviors school-wide and classroom-wide. The assessment of these interventions can be supported by the use of the ExperienceAPI (xAPI) standard. In the framework of the ARETE project, this standard could be adopted for monitoring and recording students' behavior. Moreover, the use of this standard could foster the integration of the AR ecosystem with a cloud-based learning record repository and PBIS analytics tools. However, an xAPI profile to support PBIS methodology in the specific context of AR based learning experiences does not exist yet and has to be developed.

The xAPI specification has been developed by an open community led by the Advanced Distributed Learning Initiative (ADL) (ADL Initiative/xAPI specification, 2016) and is used to capture a variety of experiences that a user may have using different technologies or tools. This standard supports emerging technologies such as mobile learning, serious games, augmented reality and in general innovative technologies related to computer-based learning. When applied to AR, the xAPI provides a way to track students' interactions with augmented content in order to get a complete view of an individual's learning and its impact on his/her performance.

From the technical perspective, each event tracked in a learning activity is defined as a Statement. The main attributes of a Statement are *actor*, *verb* (action) and *object* (Vázquez et al., 2015). The Actor identifies who performed the action (a person or a group of persons). The Verb identifies the type of activity performed by the actor and is often linked to a human readable description of the event. The Object is related to what the Actor experiences. Each Activity is represented through its name, description, type, and a URL with additional information. A statement can have also additional attributes including supplementary information about the experience: *result*, which contains the results of the statement; *context*, which represents the learning environment; *authority*, which specifies who ensures the veracity of the statement; *timestamp* that stores the date and time when the statement is created; *extensions* consist in the definition of the activity, context and result; *attachments* allow us to define a list of files that can be attached to the statement.

Statements are stored in a Learning Record Store (LRS) ready to be consumed by the learning analytics services. A LRS is a repository for learning records that can be stand-alone or part of an LMS or other learning system. It can be accessible from other LRSs, reporting tools, or complete systems such as LMSs. One of the most common LRS is Learning Locker, developed by H2T Labs™ (LearningPool, 2021). This tool allows to manage different learning processes through different roles. It is possible to define different organisations, administrators, databases and clients that could be combined with pedagogical centres, teachers, subjects or skills and students respectively. The statements to be recorded are defined at application level and are customisable. Associated metadata, such as the user generating the statements, the time or the LRS in which they were stored, can also be stored. Learning Locker also provides a user interface to access all the data, dashboards to do in-depth analysis of the collected statements and custom queries to filter the statements that are most interesting to the user.

As a standard, xAPI helps to capture data without any limitations, preventing reporting errors. Creating a taxonomy is a fundamental step to identify which data points are important, to inform the design of robust reporting, and to decide which xAPI profiles, if any, can be reused.

4.3.4.3 Orkestra

The PBIS-AR app will integrate the Orkestra for creating AR multi-user interaction behavioural activities during the Practice (more details are provided in next sections).

The Orkestra Library, described in section 7.1 of Deliverable D3.7 and in Annex A of Deliverable D3.8, is a library that allows the creation of multi-device and multi-user applications and enables communication and data-sharing between different users. Common functionalities of the Web version of the library include sharing data between users, sending peer to peer or broadcast messages, providing timing and synchronization mechanisms, distributing content across multiple devices using several layouts or exchanging multimedia data using the WebRTC protocol.

As mentioned in D3.8, the ARETE project required creating a C# port of Orkestra from the original web implementation, due to the fact that the AR applications developed for the three pilots are built using the Unity environment and thus a purely web solution could not be easily integrated in their codebase.

In this context, the first version of the port in C# presented several performance and compatibility problems and that is why a refactoring and simplification has been carried out. Apart from changing the design patterns and decoupling the external libraries, the WebSocketIOClient[5] socket library was replaced by H.Socket.IO[6]. The reason behind this change is that the former included several dependencies that caused incompatibilities with some operating systems. Therefore, the compatibility was limited to PC and Android when

[5] https://github.com/doghappy/socket.io-client-csharp

[6] https://github.com/HavenDV/H.Socket.IO

building with the Mono compiler and this prevented Orkestra from being used together with AR foundation[7], because AR foundation requires native compiling of all the external libraries in the app. However, the H.Socket.IO library, which is much better structured, provides compatibility with PC and both Android and iOS using native buildings, making it possible to use Orkestra together with AR foundation.

All of this enables us to describe Orkestra as a library that allows the development of cross-platform multi-user AR applications, since it enables communication between Web and Unity (Android/iOS/PC) applications. The library has been tested on Android and iOS operating systems, both on newer and older models, and we verified that the software is compatible with the devices that will be used for pilots 1, 2, and 3.

The communication mechanisms of Orkestra C# cover both broadcast and unicast messages that include different data structures. More in detail, in the field of education, different students could share a collaborative and interactive AR experience while the teacher controls what is happening in real time. For data shared at high frequencies, Orkestra enqueues all the messages and then dispatches them according to an interval time that can be selected at the application level and allows developers to balance the smoothness of the animation with the amount of data to process. Data shared less frequently, or only after specific user interactions, is sent directly to the server and processed immediately upon reception.

In the ANNEX E, some Orkestra proofs-of-concept are presented in order to show the potential, performance and compatibility of the library. Moreover, in the next sections details about the use of this library during the PBIS activities will be introduced.

4.3.5 Security

The user has to login into the app with a nickname. All communications with other systems components will be carried out using a ssl channel. In this way all information is protected and privacy will be guaranteed. The use of the nickname is required only to track the user interaction with the system through the xAPI statement and in this way any correlation to the student identification data is preserved.

4.4 Use case model

In the following table an overview of the actors that can interact with the system and the relative main use cases is presented.

Student	User already registered in the system. He/she has access to all the functions of the system.

[7] https://docs.unity3d.com/Packages/com.unity.xr.arfoundation@4.2/manual/index.html

Moodle	Actor that interacts with the system when interrogated to provide data and information retrieval services.
LearningLocker	Actor that interacts with the system to track user interactions.
Orkestra	Actor that interacts with the system to implement multi-user interactions.

Specifically, in figure 19 the student-related use cases diagram is detailed.

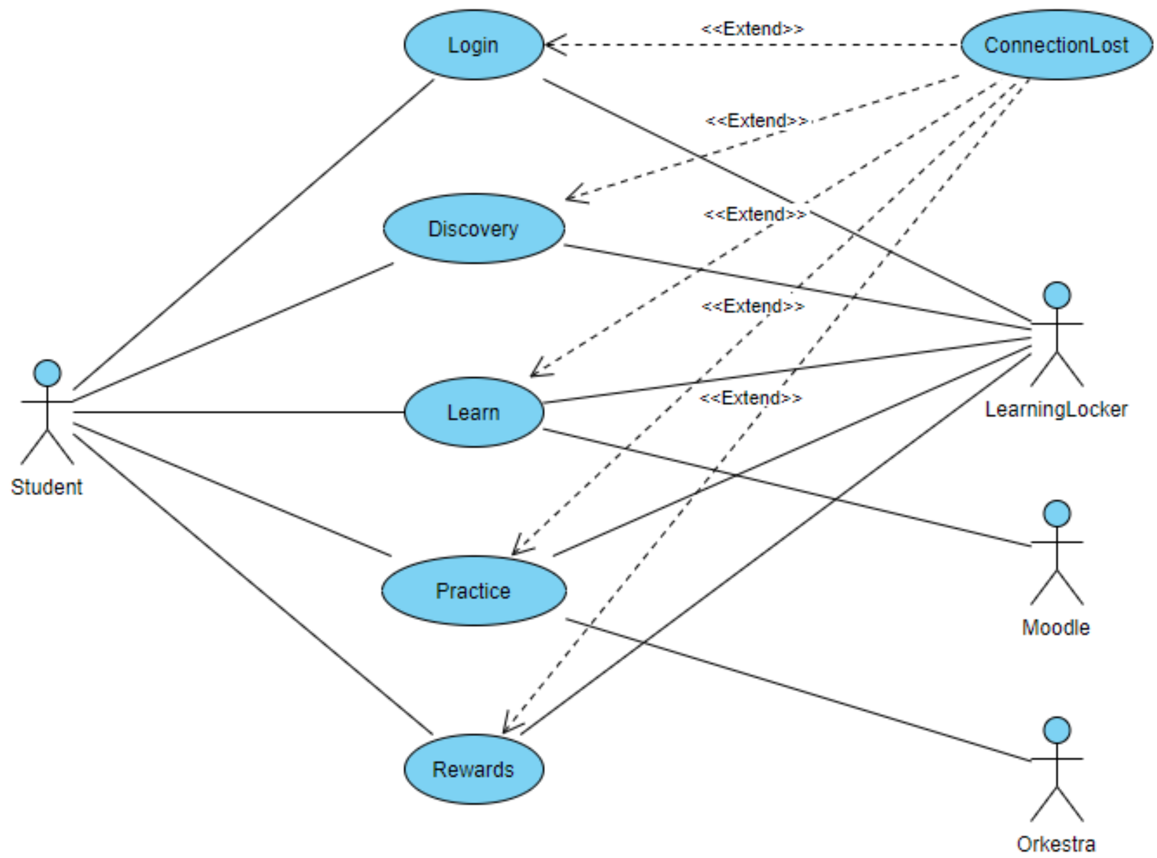


Figure 19 Student use cases diagram

4.5 User interface – navigational paths

In this section it is possible to see the "Wireframe" that provides a prototype UI/UX outline for the app with a visual representation of the user interface, showing the user flow through the app (Figure 20).

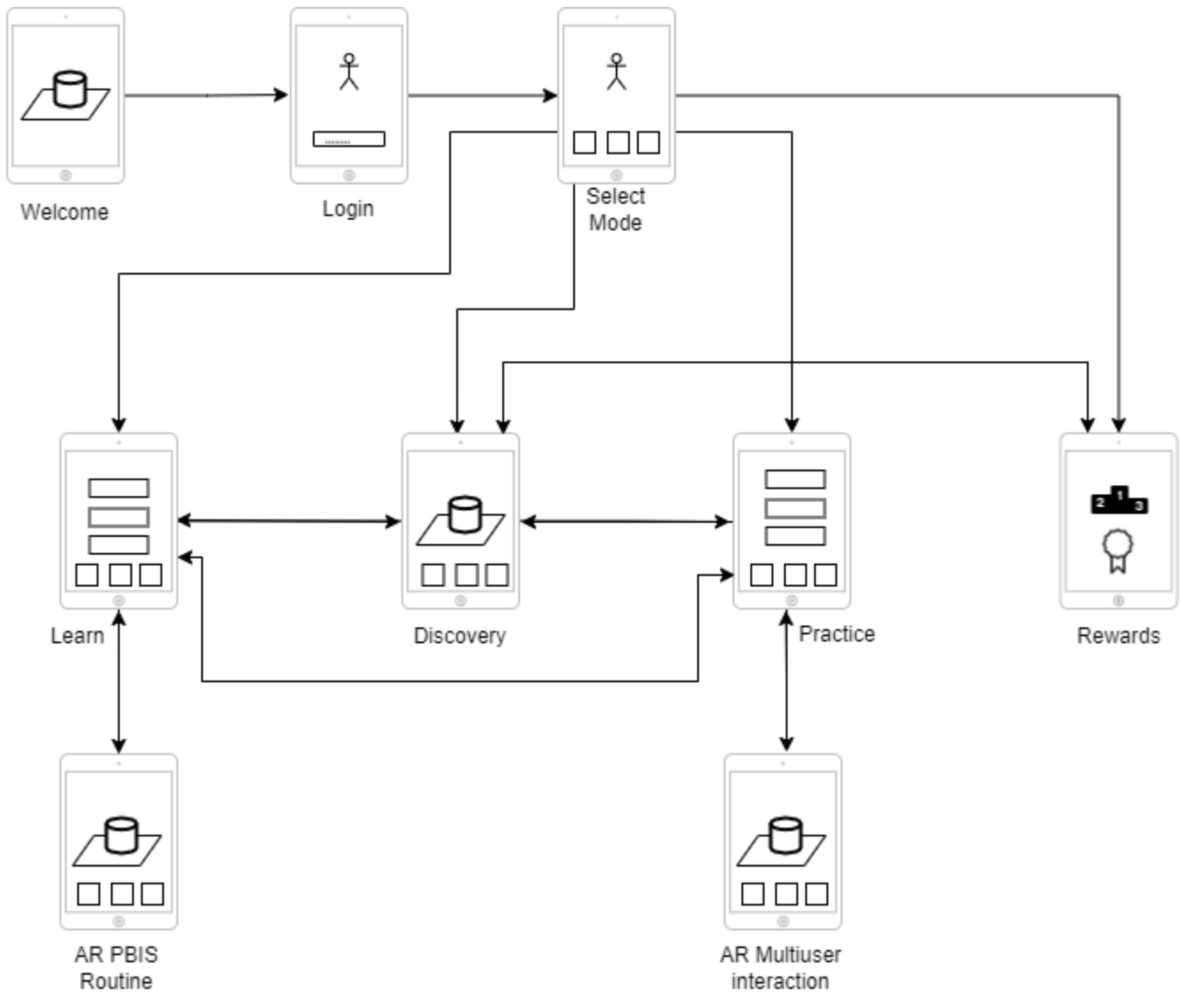


Figure 20 User flow through the app

In the ANNEX C it is possible to see a first version of the mockups related to the proposed system.

4.6 Monitoring behavioural learning experience

To support the tracking of user interactions with augmented objects related to PBIS, it is necessary to have a vocabulary to describe them (Farella et al., 2021). In the xAPI, a vocabulary profile describes a collection of verbs that are used to define a specific use case.

In the literature there are few examples of the use of xAPI in combination with Augmented Reality (Angeloni et al., 2021; Secretan et al., 2019).

To achieve this objective the standard xAPI vocabulary has to be extended and a specific xAPI profile has to be defined. In an initial phase, the w3id.org, activitystrea.ms, adlnet.gov, id.tincanapi.com, brindlewaye.com registries were analyzed in order to find useful profiles for the PBIS-AR app. These registries were used as examples of best practice guidelines. From these registers we extrapolated all the possible verbs and objects that can be used in this kind of AR based application.

From the analysis of these registers, there is a lack of verbs and objects that better describe user's interactions with augmented reality components, for example in the case of a user searching for a marker used to display augmented content in the environment. The main elements of such a statement are:

Actor: User - Verb: Looked for - Object: Marker

Where:

- The verb "Looked for" to identify the action the user does when having to search for a Marker in the environment.
- The object of type Activity "Marker" represents a target for Augmented Reality content. For instance, an image, a QR code, a flash card etc... This type of AR is marker-based and adds the AR content after the device found the marker.

Conclusion

This document reports the activities carried out until now in designing and developing the ARETE PBIS-AR mobile app, an essential component of the ARETE ecosystem. This app will allow the integration of AR contents within the context of behavioral lessons conducted in accordance with the PBIS approach. The main effort was devoted to obtaining an innovative app, able to involve and engage children and young students, encourage the adoption of PBIS vision, sustain teachers' and students' activities, throughout the behavioral learning process. This result was pursued adopting new AR standards and technologies permitting the authoring of context-aware and purpose-aware AR objects and animations, the tracking of the user's experience with AR learning objects and multi-users interactions with them.

The report started with a brief overview of SWPBIS and introduces a new theoretical paradigm with the definition of Augmented Reality Behavioural Learning Space guiding the development of the PBIS-AR app for Pilot 3 (i.e. Chapter 2). Following this introduction, the report focused on a description of:

1. The designing and development process that resulted in the creation of graphic designing and development of AR objects for the PBIS-AR app including the main character of the PBIS-AR app (the alien ARpro), the secondary characters and the design of character's actions and animations (i.e. Chapter 3).
2. The PBIS-AR app architecture is presented with the description of functional and non-functional requirements and communication with other components developed for the ARETE ecosystem (i.e. Chapter 4).

Because of an unexpected project delay due to the emergence of the COVID-19 pandemic, the development process is still ongoing and the final results will be presented in the update deliverable D5.4.

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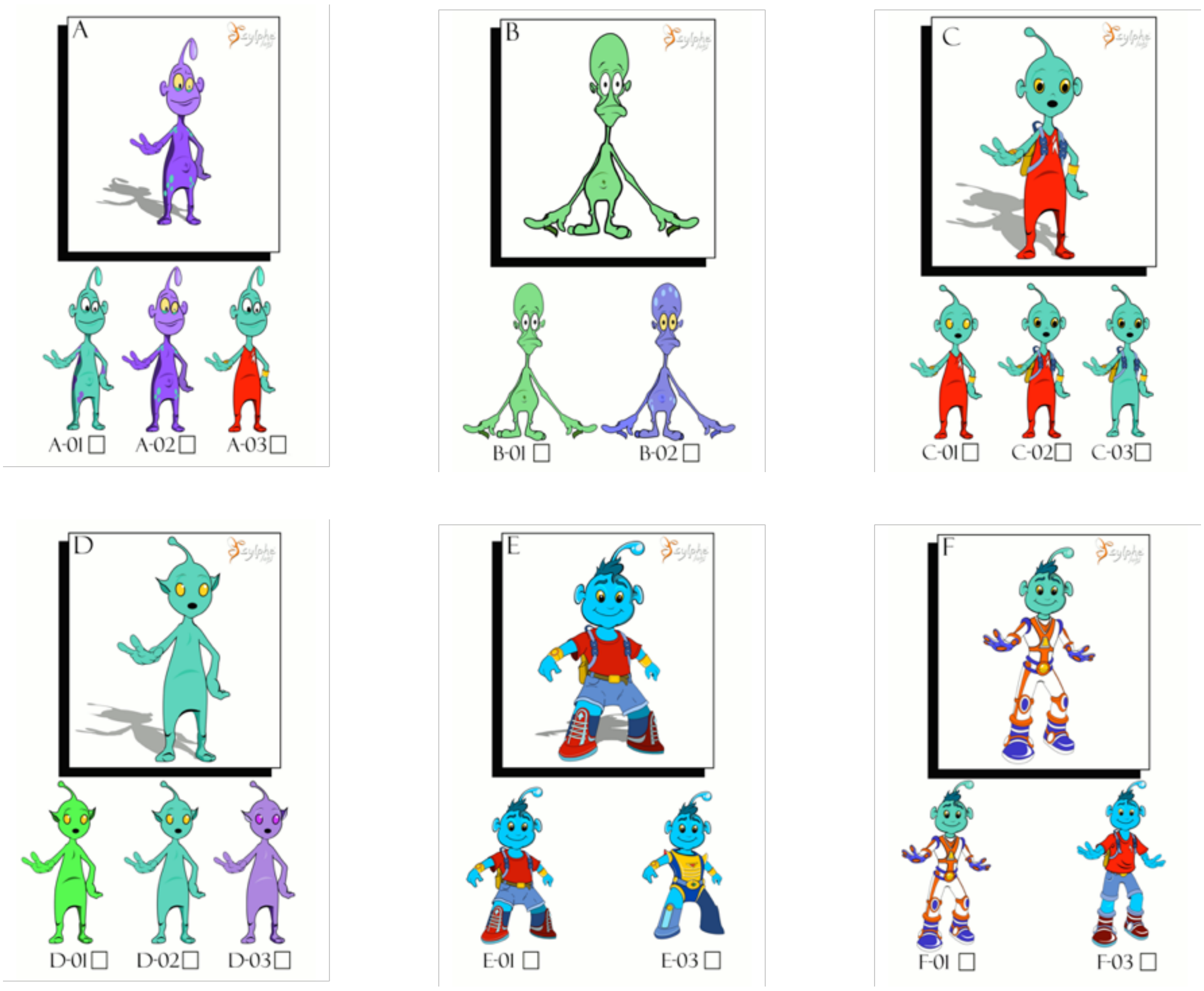
ANNEX A PBIS principal character design process

The first series of characters proposed by SylpheLabs included 6 different proposals:



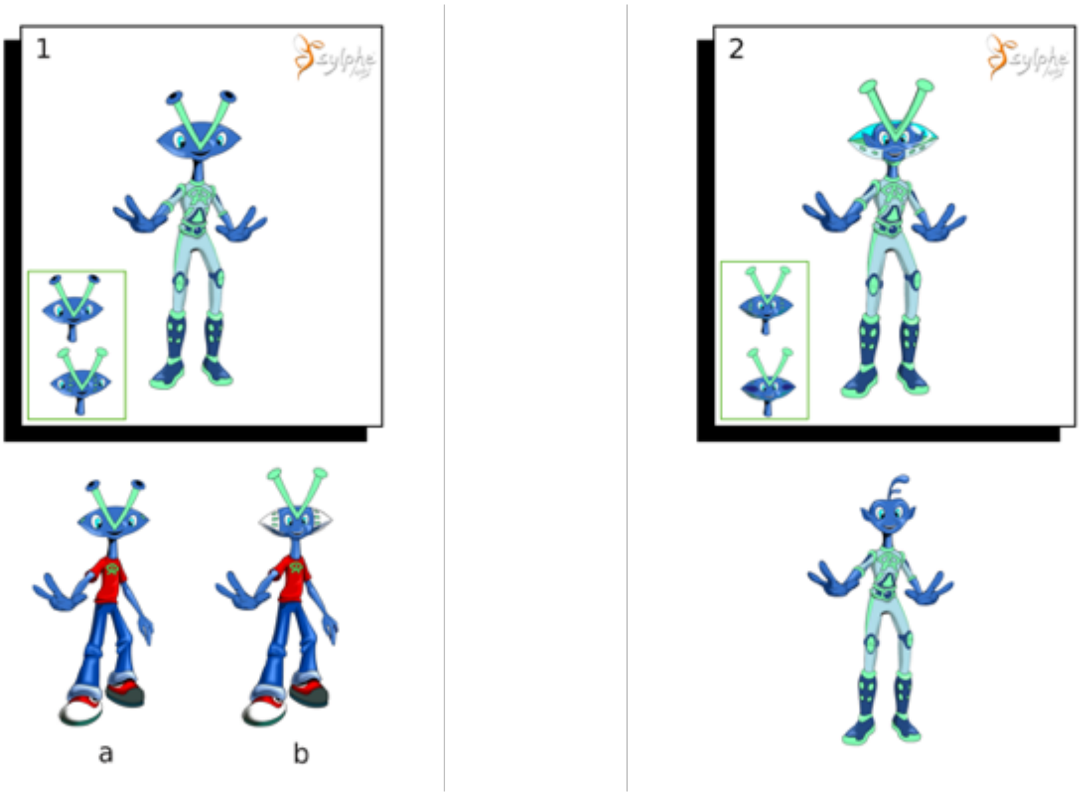
The collection of partners' comments and preferences on this first set of characters allowed CNR and SVU to draw up a set of criteria to guide SylpheLabs in the production of new characters. The document with the collection of criteria was shared with the graphic design company and ten criteria to follow have been identified in order to design the new set of characters. Following, the list of the 10 adopted criteria:

1. It is an alien
2. It should be for children aged 10-12 years
3. Curious
4. Likeable (friendly facial features)
5. The alien could have 2 antennas
6. The alien should be clothed, and not naked

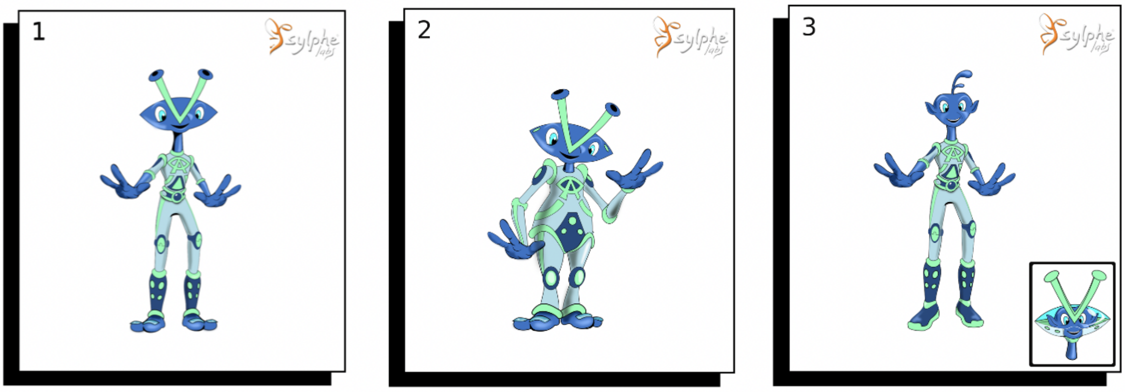
7. The logo of arete can be an emblem on the shirt of the alien
8. The alien should not be human like so that the child can model his behaviour in a less intrusive way.
9. As genderless as possible
10. Link to ARETE project logo

The new proposal has been designed taking into account the identified 10 criteria and starting from the main criteria «An alien» all other criteria around the ARETE logo have been fulfilled.

The next figure shows the different variants of the new proposal. In particular, the head was inspired by rotating the logo figure by 180 degrees in one proposal[8].



[8] https://drive.google.com/file/d/1WnAexxBPWWnqODY6s0XiZ9uhxQFsu_oh/view?usp=sharing



The following three variants have been produced according to the comments collected and a quick poll submitted to children between 9 and 12 years N = 39 (56.4% boys; Mean age = 10.69 years, SD = 1.34 years) for selecting the character provided the following results.

While the responses diverged a little between Netherland and non-Netherland countries polls, the majority vote went for Alien character 1, i.e. the skinny alien with the inverted ARETE logo head. Some small suggestions have been collected from children

1. The feet with the two toes should be replaced with the boots as worn by alien 3.
2. The face was viewed as too pointy on the sides and participants asked if the face on the sides could be rounded off a little bit more to make it look more natural.
3. The antennas on the head were liked, but suggestions were made to put them a little higher (away from the nose, to differentiate between nose and antennas).
4. Some children found the character too skinny, but as the pudgier character was liked least, so the skinny character will be considered.

The WP5 partners according to the indication of the children approved the alien 1.

The final 3D character model has been produced with the ankle boots and the head a little more rounded on the sides. The colours of the ARETE logo has been used for the alien's texture (skin colour and clothes)[9].

[9] https://drive.google.com/file/d/1RyxhSRDqOe3AJLBoErTpIuCOjarLuMNA/view?usp=sharing

ANNEX B Code to animate face elements

Below there is the Unity FaceManager.cs script for managing the animations related to the eyes and the movement of the antennas.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class FaceManager : MonoBehaviour
{
    private const bool debugLid = false;
    private const float blendMult = 10f;
    private const float defaultAntennaSpeed = 0.1f;
    private const int blendNumber = 4;

    public Vector3 eyelidLocalPosition = new Vector3(0,0.1128434f,0.06117219f); //0.001174, 0.000564

    private SkinnedMeshRenderer skinnedMeshRenderer;
    private Material material;
    private int idx, _blendValues;
    private float[] blendVal;
    private float i, speedTime, lowerLidXRest = 30f, upperLidXRest = -60f, blendDiv, antennaSpeed;
    private Vector3 lowRot = Vector3.zero, upRot = Vector3.zero, veloL, veloR, lkDirL, lkDirR;
    //private WaitForEndOfFrame oneFrame = new WaitForEndOfFrame();
    private Transform lowerLid, upperLid, headBone, baseBoneL, baseBoneR, capTrnL, capTrnR, capTrgtL, capTrgtR, leafBoneL, leafBoneR;

    private void Awake()
    {
        headBone = transform.Find("Alien").Find("rig:Hips").Find("rig:Spine").Find("rig:Spine1").Find("rig:Spine2").Find("rig:Neck").Find("rig:Head");
        lowerLid = transform.Find("AlienLowerEyeLids");
        upperLid = transform.Find("AlienUpperEyeLids");
        baseBoneL = headBone.Find("rig:AntennaLeft");
        baseBoneR = headBone.Find("rig:AntennaRight");

        lowerLid.SetParent(headBone, true);
        lowerLid.localPosition = eyelidLocalPosition;
        upperLid.SetParent(headBone, true);
        upperLid.localPosition = eyelidLocalPosition;

        skinnedMeshRenderer = GetComponentInChildren<SkinnedMeshRenderer>();

        for (idx = 0; idx < skinnedMeshRenderer.materials.Length; idx++ )
            if ( skinnedMeshRenderer.materials[idx].name.Contains("AlienHead") ) { material = skinnedMeshRenderer.materials[idx]; break; }

        _blendValues = Shader.PropertyToID("_blendValues");
        blendVal = new float[blendNumber];
        blendDiv = 1f / blendMult;

        leafBoneL = baseBoneL.Find("rig:AntennaLeftTop");

        capTrgtL = new GameObject("capTarget_L").transform;
        capTrgtL.SetParent(baseBoneL.parent);
        capTrgtL.position = leafBoneL.position;
        capTrnL = new GameObject("capTransform_L").transform;
        capTrnL.position = leafBoneL.position;

        leafBoneR = baseBoneR.Find("rig:AntennaRightTop");

        capTrgtR = new GameObject("capTarget_R").transform;
        capTrgtR.SetParent(baseBoneR.parent);
        capTrgtR.position = leafBoneR.position;
        capTrnR = new GameObject("capTransform_R").transform;
        capTrnR.position = leafBoneR.position;

        antennaSpeed = defaultAntennaSpeed;
    }

```

```
    private void Start()
    {
        if (!debugLid) StartCoroutine(_Blink());
        else
        {
            upRot.x = 0; upperLid.localEulerAngles = upRot;
            lowRot.x = 0; lowerLid.localEulerAngles = lowRot;
        }
    }

    private void Update()
    {
        for ( idx = 0; idx < blendVal.Length; idx++ ) blendVal[idx] = skinnedMeshRenderer.GetBlendShapeWeight(idx) * blendDiv;
        if ( material != null ) material.SetFloatArray(_blendValues, blendVal);
        else Debug.LogError("Alien does't have correct materials");

        capTrnL.position = Vector3.SmoothDamp(capTrnL.position, capTrgtL.position, ref veloL, antennaSpeed);
        capTrnR.position = Vector3.SmoothDamp(capTrnR.position, capTrgtR.position, ref veloR, antennaSpeed);

        lkDirL = capTrnL.position - baseBoneL.position;
        lkDirR = capTrnR.position - baseBoneR.position;

        baseBoneL.rotation  = Quaternion.LookRotation(Vector3.Cross(lkDirL, -headBone.right), lkDirL);
        baseBoneR.rotation  = Quaternion.LookRotation(Vector3.Cross(lkDirR, -headBone.right), lkDirR);
    }

    private IEnumerator _Blink()
    {
        yield return new WaitForSeconds(Random.Range(0.5f, 6f));

        upRot.x = -30f;
        upperLid.localEulerAngles = upRot;

        yield return new WaitForEndOfFrame();

        upRot.x = 0;
        upperLid.localEulerAngles = upRot;
        lowRot.x = 0;
        lowerLid.localEulerAngles = lowRot;

        yield return new WaitForSeconds(0.1f);

        lowRot.x = lowerLidXRest;
        lowerLid.localEulerAngles = lowRot;

        yield return new WaitForEndOfFrame();

        speedTime = Random.Range(5f, 6f);

        for (i=0; i<=1f; i+=Time.deltaTime*speedTime )
        {
            upRot.x = Mathf.Lerp(0, upperLidXRest, i);
            upperLid.localEulerAngles = upRot;
            yield return new WaitForEndOfFrame();
        }

        upRot.x = upperLidXRest; upperLid.localEulerAngles = upRot;
        yield return new WaitForEndOfFrame();

        StartCoroutine(_Blink());
    }

    public void SetAntennaSpeed(float val)
    {
        if ( val <= 0 ) antennaSpeed = defaultAntennaSpeed;
        else antennaSpeed = val;
    }
}
```

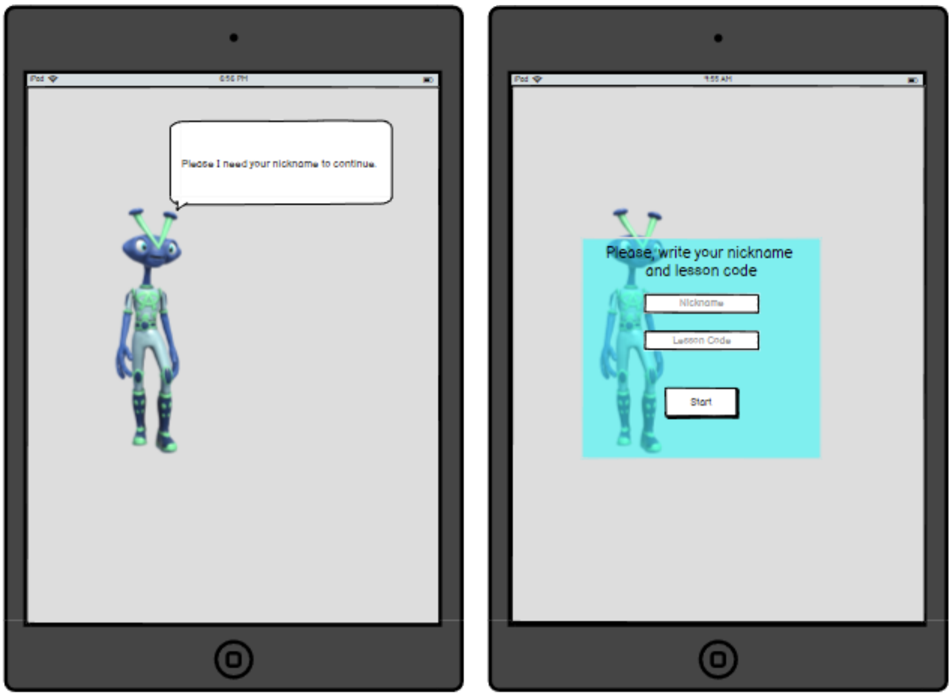
ANNEX C The mockup of PBIS-AR app

This document describes the first conceptualisation of mockups presenting some of the main areas of the application. These mockups will be updated and extended in deliverable D5.4 according to the progress of development.

1. Welcome - Interactive introduction to the system.
   This section shows the interfaces related to the initial phase of the application. The user, after scanning the environment, chooses where to display the alien and starts a dialogue between the alien and the user in which the alien presents itself.

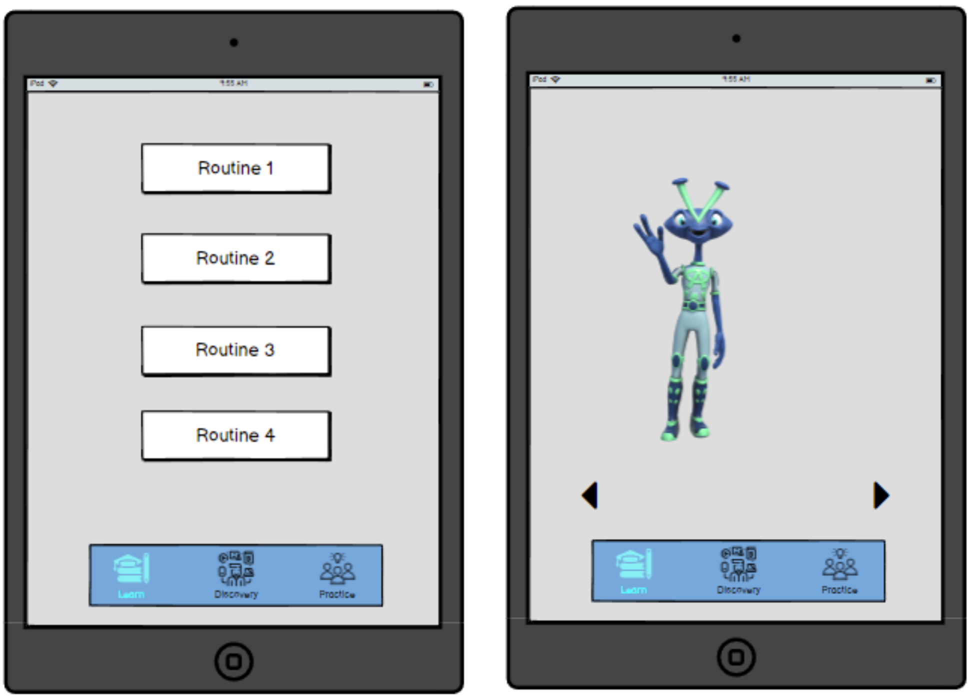
2. Login - Environment setup.

During the login phase, the alien asks the user to enter his nickname and lesson code to access the application.



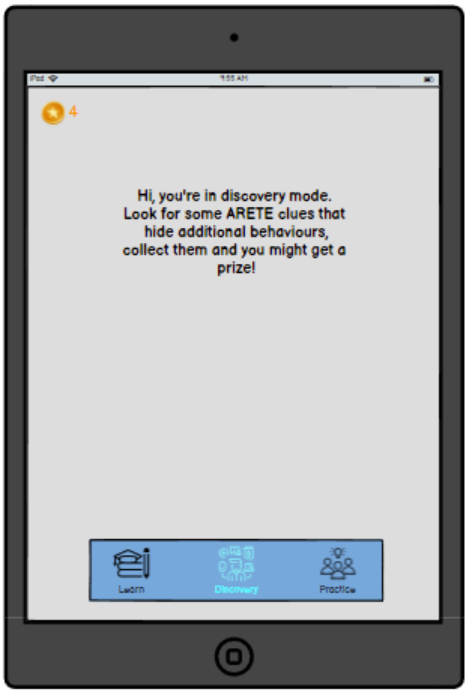
3. Learn - Play of the teacher behavioural routines created with the MirageXR app.

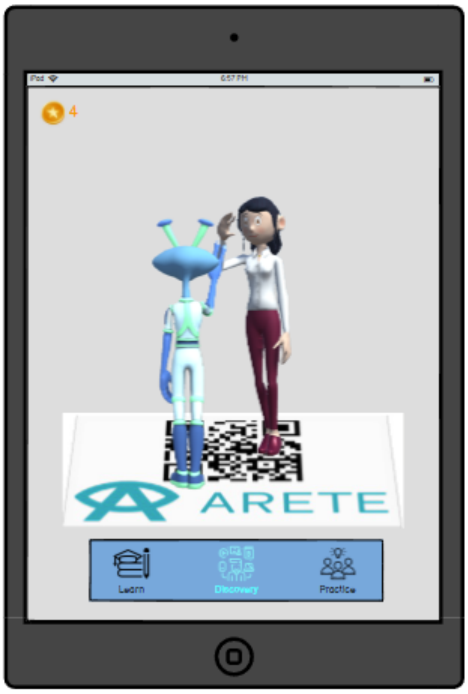
   The following screens show the Learn area with the list of routines created with MirageXR by the teacher. The system downloads and shows the selected routine.

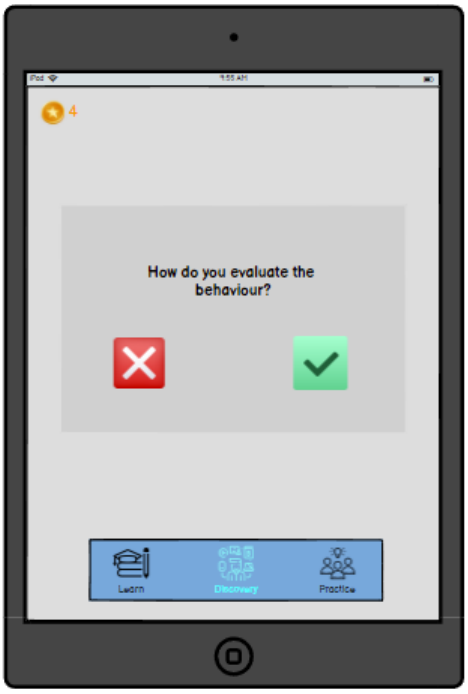


4. Discovery - Behavioral reflection game in AR

The user clicks on the Discovery section and searches for the marker. Once the marker is found and the associated animation is displayed, the user will answer the proposed question.







ANNEX D Test of MirageXR app authoring toolkit for creating behavioural routines

The following showcase highlights some behavioral routines created by the teacher using the developed basic animations of different characters integrated into MirageXR to compose different examples and non-examples of behaviours with the MirageXR app. The example has been produced making some preliminary tests of the MirageXR version 1.16.

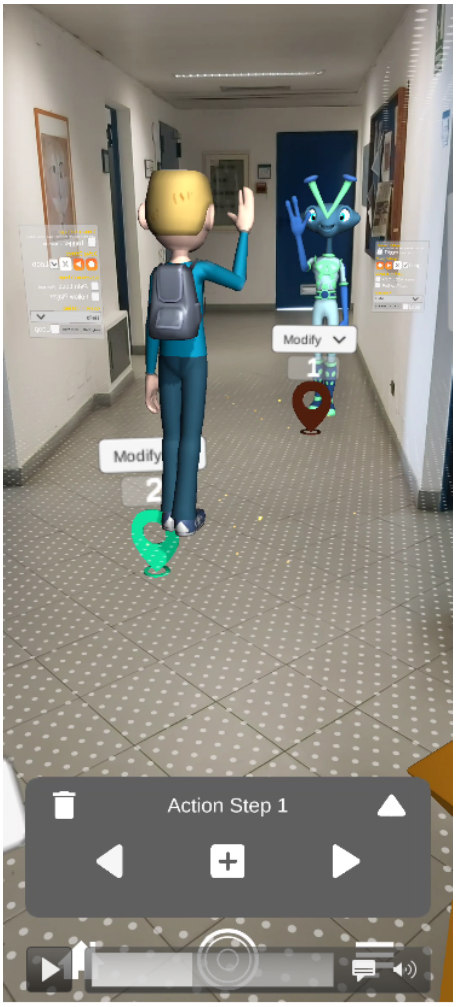
Test 1: Use case 1 - Behaviour Example of “greet others”

Single step: Arpro greets the peer who approaches him. The mate responds to the greeting

The teacher creates the step. First, he/she selects two characters (the alien and the student) and places them in the real setting. The alien is in front of the student and the student has to go towards the alien.
The teacher selects the atomic animation A9 Greet others with the hand according to which the alien greets the students.
The teacher creates the movement of the student from his/her original position to the alien.
The teacher selects the greet animation of the student for replying to the alien's greeting.

Animations used:

A9 Greet others with the hand
S16 Walk calmly (from a point to another)
S15 Greet others with the hand



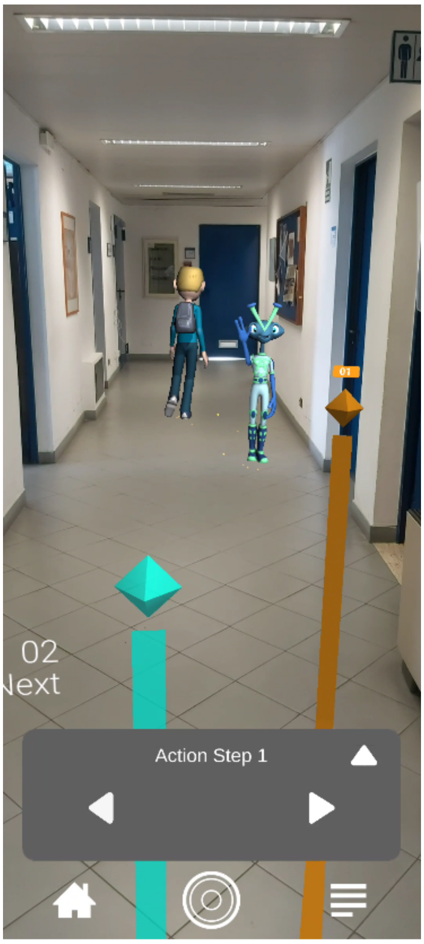
[Showcase test 1](#)

Test 2: Use case 2 - Behaviour non-example of "greet others"

Single step: Arpro greets a peer who approaches him. The mate doesn't respond to the greeting.

The teacher creates the step. First, he/she selects two characters (the alien and the student) and places them in the real setting. The alien is in front of the student and the student has to go towards the alien.
The teacher selects the atomic animation A9 Greet others with the hand according to which the alien greets the students.
The teacher creates the movement of the student from his/her original position beyond the alien.

Animation used:
A9 Greet others with the hand
S16 Walk calmly (from a point to another)



Showcase test 2

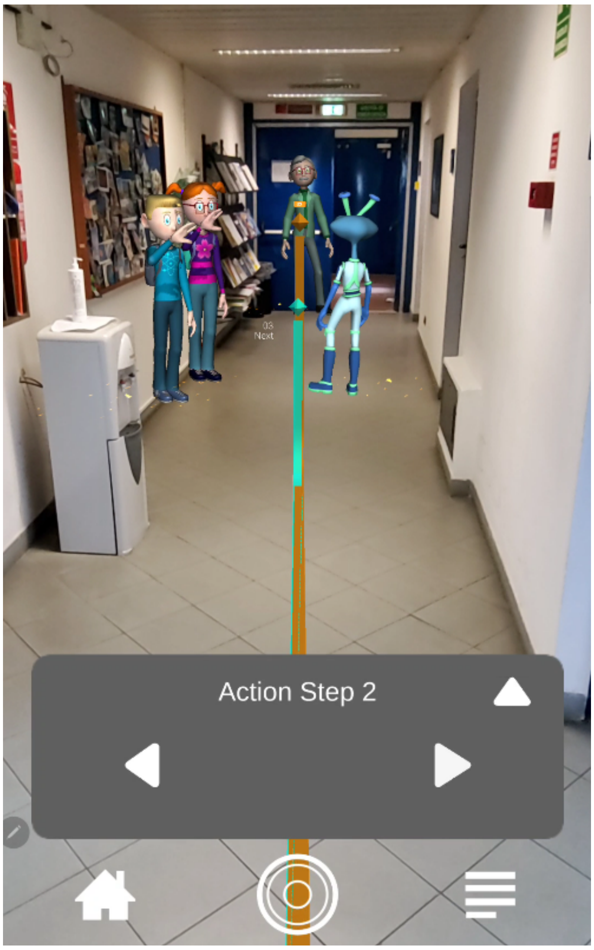
Test 3: Use case 3 - Behaviour example of “greet others”

Step 1: Arpro enters the school premises, greets the peers
Step 2: The peers respond to the greetings
Step 3 The headmaster greets Arpro and Arpro walks and responds to the greeting
Step 4: Arpro walks quietly and calmly through the main door

The teacher creates step 1. First, he/she selects a set of characters (the alien, some students and the headmaster) and places them in the real setting in different positions. The teacher selects the alien and plans a movement The alien walks towards the students and greets them.
The teacher creates step 2 where he/she selects the animation “greet others” on the students.
The teacher creates step 3 The teacher selects the animation of the headmaster T3 “Greet others with the hand” . The teacher creates the movement of the alien walks from the student towards the headmaster (A8 Walk from a point to another). The teacher selects the atomic animation A9 Greet others with the hand responding to the greeting of the headmaster. In step 4, the teacher selects the animation A8 “Walk (from a point to another)” moving the alien through the main door.

Animation used:

A8 Walk (from a point to another)
A9 Greet others with the hand
S15 Greet others with the hand
T3 Greet others with the hand A8 Walk (from a point to another) A9 Greet others with the hand
A8 Walk (from a point to another)



[Showcase test 3]

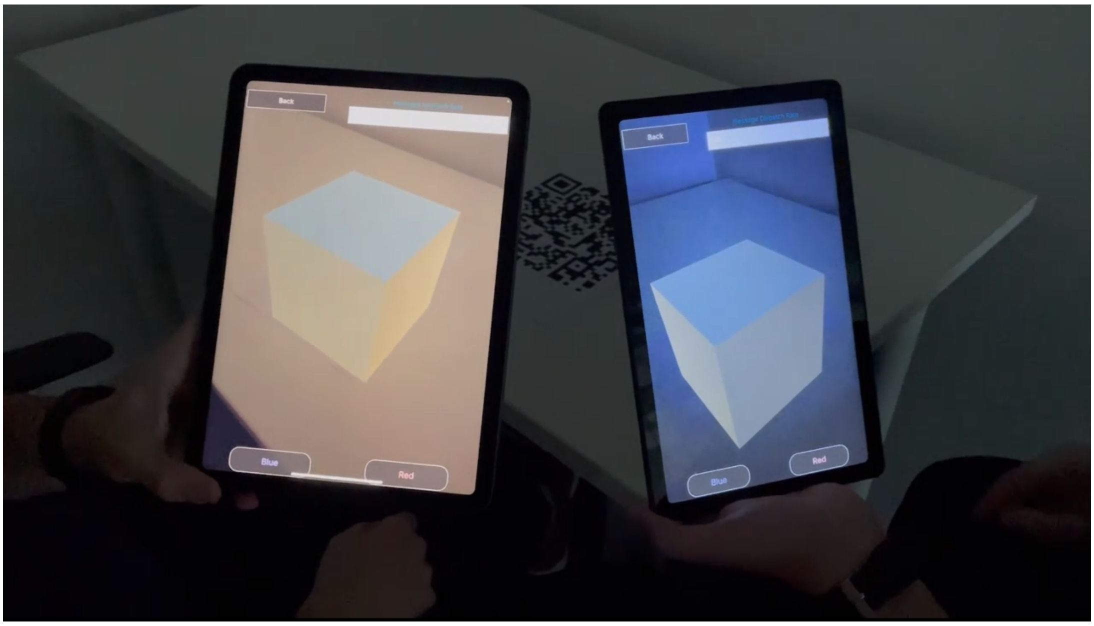
ANNEX E Orkestra proofs-of-concept

In order to show the potential of Orkestra, different proofs-of-concept have been created.

Basic AR example using Orkestra[10]

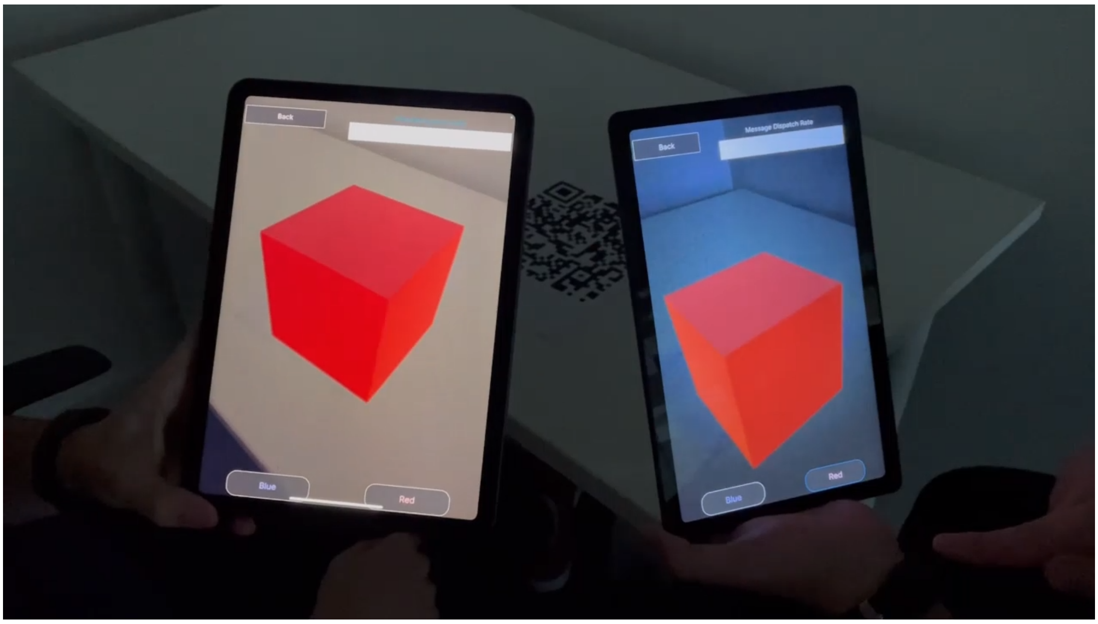
In this case we developed a proof-of-concept AR application in which two students interact with the same augmented content using an Android tablet and an iPad. This app aims to show the feasibility of using orkestra together with AR foundation and the possibility to share data at high frame rates (up to 100 times per second). The sequence in this use case is the following one:

1. Both students enter the application and scan a common marker to see the augmented cube. Each student sees the cube in his own perspective.

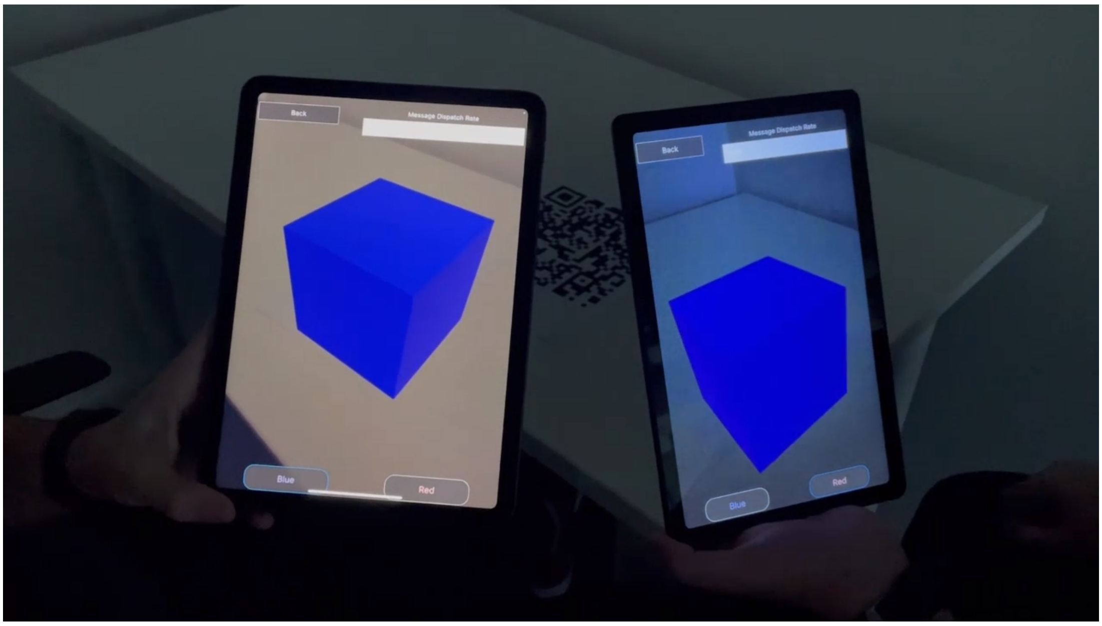


2. The student on the right changes the color of the cube to red by tapping the "Red" button. The color of the cube changes for both students.

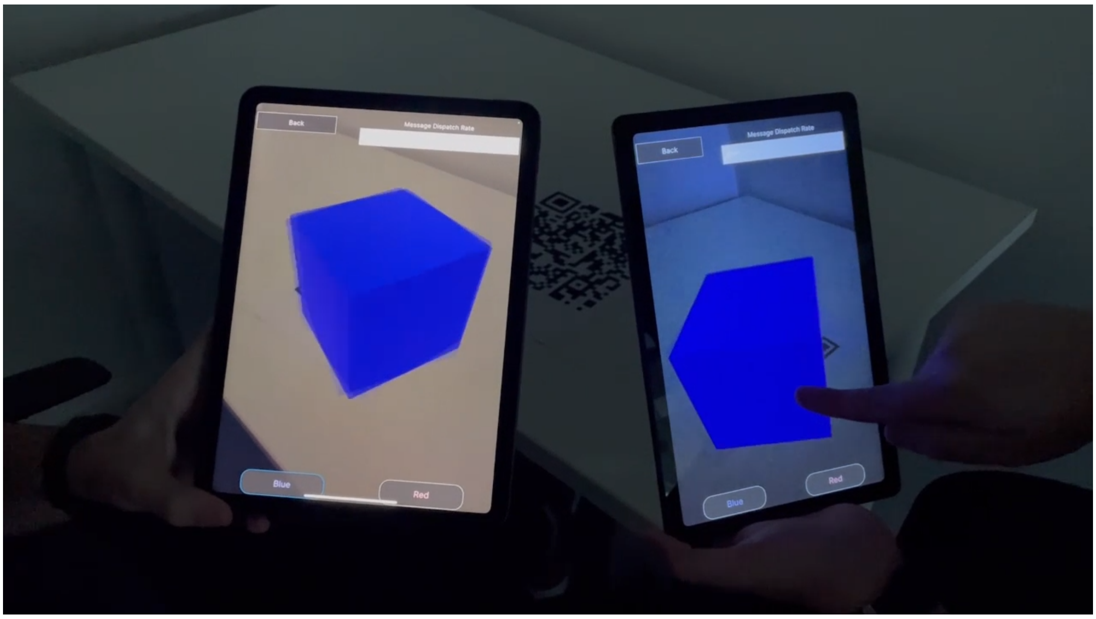
[10] https://vicomtech.box.com/s/85drzr9t46wku26rwdz5rbevqz5eeibx



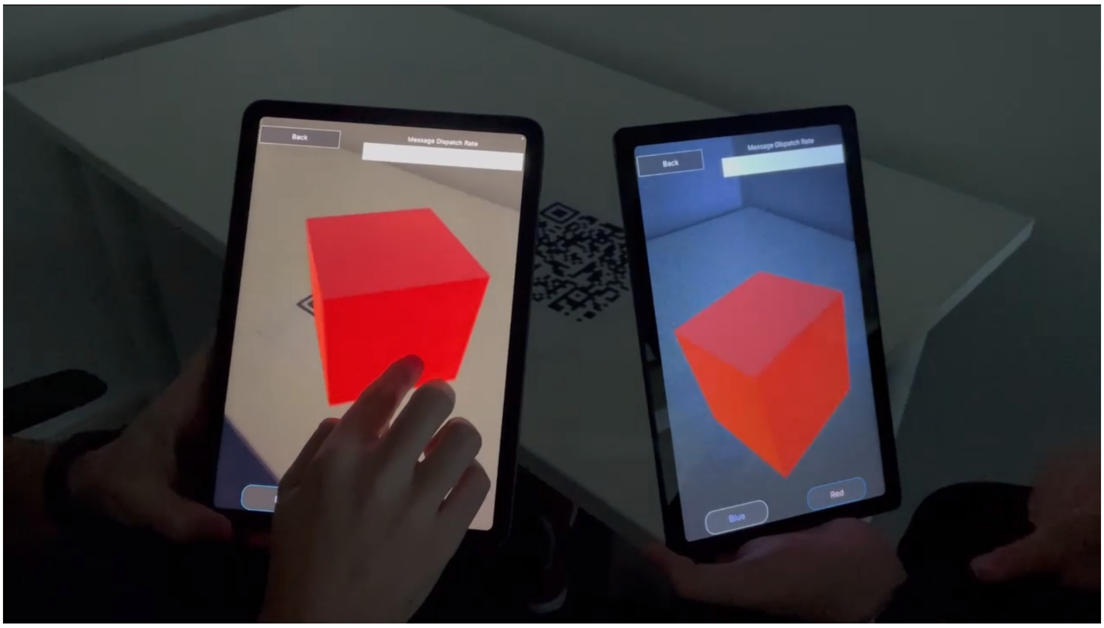
3. The student on the left changes the cube to blue by tapping the “Blue” button. The color of the cube changes for both students.



4. The student on the right rotates the cube towards the right by swiping the finger to the right.



5. The student on the right rotates the cube to the opposite side by swiping the finger to the left while the other student changes the color of the cube ro red again.



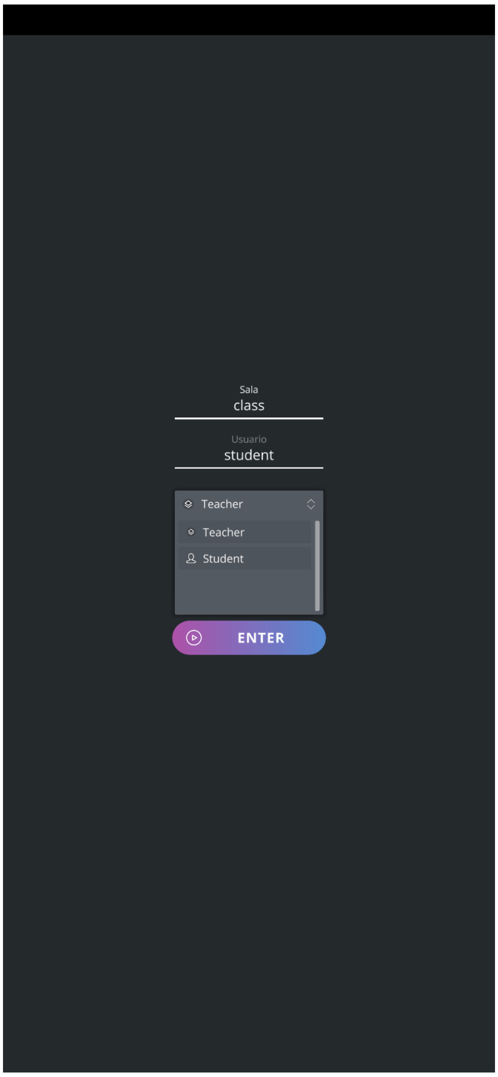
A video[11] has been created for a better visualisation of the app. As can be seen, both students can interact with the augmented cube at the same time and all the information is shared at application level just for simplicity.

[11] https://vicomtech.box.com/s/vdf0cb83mlkgmkramh9grhj4zz8frkju

AR app using Orkestra[12]

In this case, we are considering a scenario where teachers and students are all using an AR application. In this case we will see the screen of the teacher and one student, but this app also works with more than one student. The use case is defined as follows:

1. The teacher and students are logged in in the app specifying a username and their role.

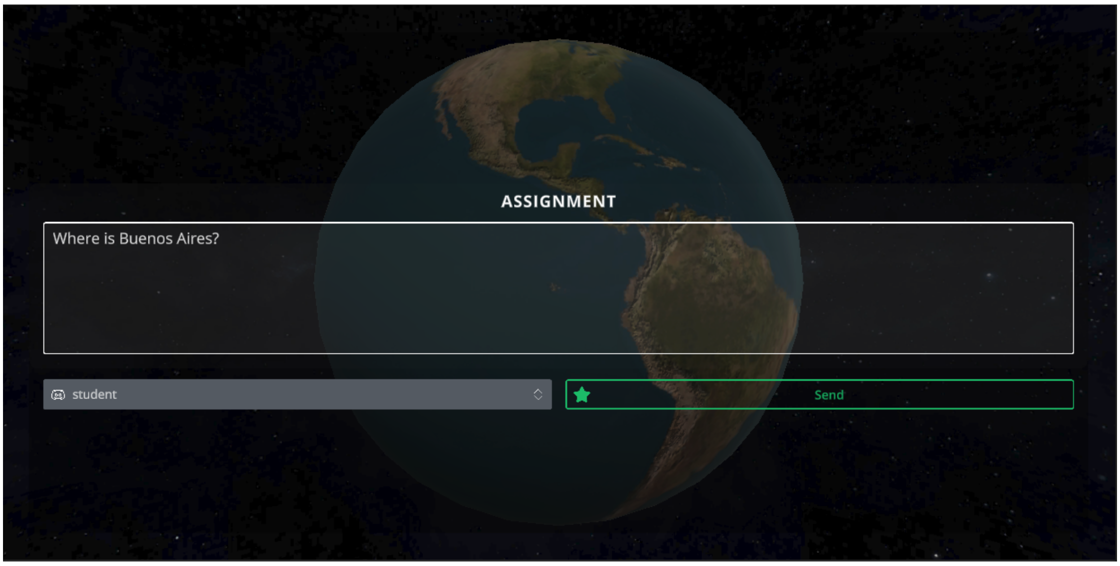


2. The teacher enters the application being able to interact with the globe while the students are maintained in observer mode. This allows the teacher to rotate the Earth and explain the lesson while the students watch what the teacher is doing, including all the interactions in real time. In order to do that, the rotation values of the Earth and the

[12] https://vicomtech.box.com/s/rtlknjrat3hcxeohwcenmuw56qosu2xz

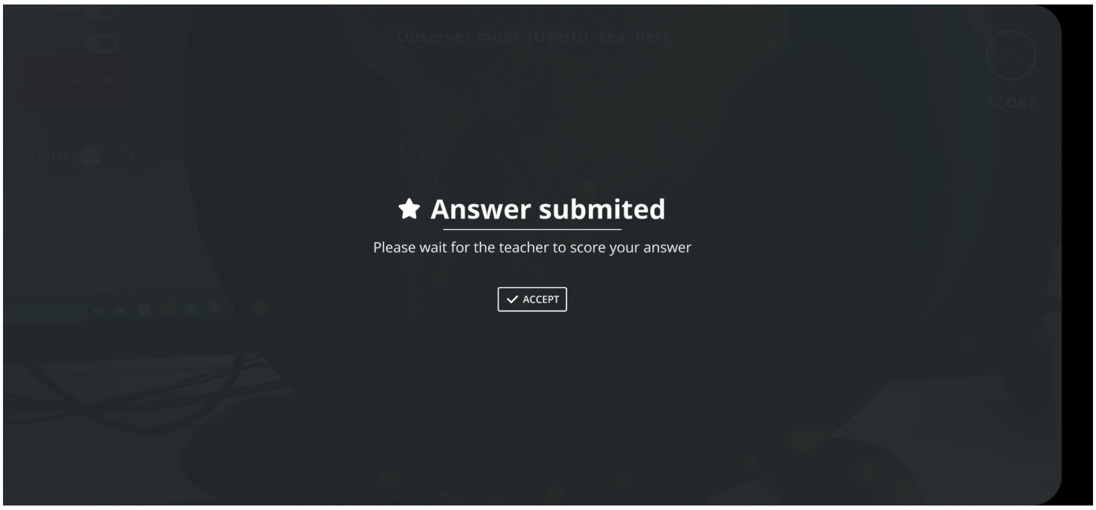
position of the camera of the user are shared at application level (in broadcast mode) and the students' applications render the Earth at the correct position.

3. The teacher assigns an exercise to a specific student asking him/her to place a city or a country. In order to do that the teacher sends a question through a chat. This is done by sending a message at user level (in unicast mode). Therefore, there is only one student that receives the question.

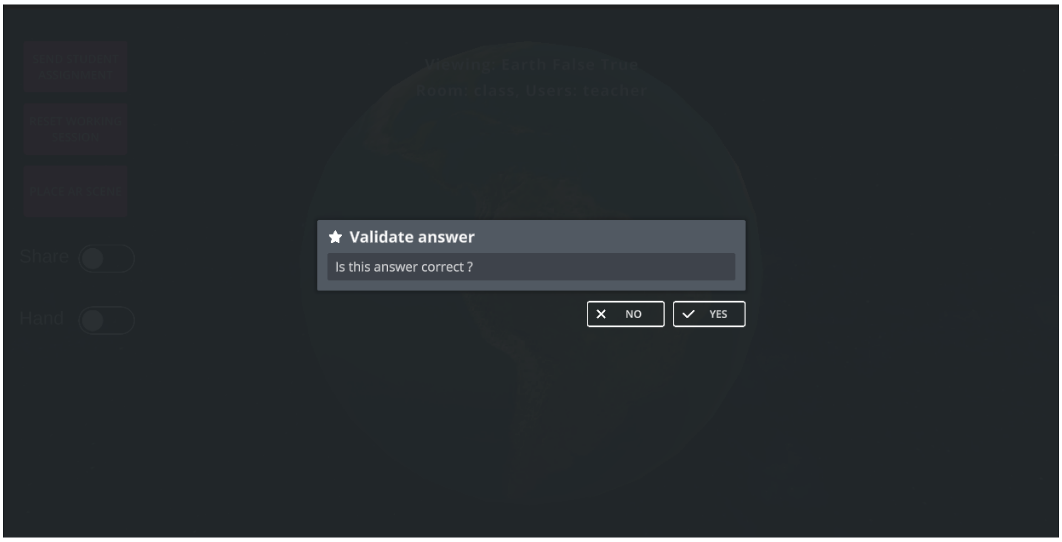


4. The selected student has now the possibility to interact with the globe in order to search the country. At this moment, the teacher application as well as the other students' applications will be in observer mode to see what the student is doing. To achieve this behaviour, the rotation of the Earth and the position of the camera are shared again at application level, and in this case the teacher app and the other students apps are the ones that render the Earth at the same position as the selected student.

5. The student places a pin over the country as the answer to the exercise. Again this information is shared at application level so that all the students and the teacher can see the result of the exercise.



6. The teacher receives the answer and corrects the exercise. At this moment the selected student returns to the observer mode and the teacher recovers the interaction control.



Once the potential, performance and compatibility of Orkestra have been shown, next steps include the definition of a use case related to PBIS to be tested as an exercise for students in pilot 3.