




The ARETE Ecosystem for the Creation and Delivery of Open Augmented Reality Educational Resources: The PBIS Case Study

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Abstract. Augmented reality (AR) is rapidly emerging as an increasingly useful technology in educational settings. In the ARETE (Augmented Reality Interactive Educational System) H2020 project, consortium members designed and implemented an ecosystem aimed at supporting teachers in building a collaborative learning environment through the use of AR in order to improve educational experiences. In particular, one of the pilot projects aims to introduce AR into school behavior lessons for the first time, leveraging the Positive Behaviour Intervention and Support (PBIS) methodology. Specifically, in this paper we will discuss the proposed architecture within the ARETE project that incorporates AR technology into the learning process of behavior lessons to support the teaching, practice and reinforcement phases of expected behaviors. Through the combination of different technologies and systems, it is possible to create an example of a technological and innovative ecosystem designed for creating behavioral lessons in AR.

Keywords: augmented reality · positive behaviour · behavioural learning · multi-user applications · PBIS

1 Introduction

In recent years, Augmented Reality (AR) has entered our lives and has spread into our daily activities. This technology is able to influence the way we live through a direct impact on our perceptions by enhancing them in terms of sensitivity and experience. Unlike Virtual Reality (VR) in which the user is fully

immersed in a computer-created fictional world, in Augmented Reality the real world in which the user is embedded prevails [1]. Computer scientists Paul Milgram and Fumio Kishino introduced the theory of the Real-Virtual Continuum [2] by asserting that there is a continuum between the real and virtual environments: starting from the real environment it is possible to arrive at the virtual environment by passing through augmented reality and virtual reality. Such technologies, although considered to be recent, have far more distant origins. One of the earliest examples of VR, in fact, dates back to the 1950s with Morton Heling, who created a machine called Sensorama whose goal was to extend the movie experience to all five senses, while in the 1960s, Ivan Sutherland created the first augmented reality viewer.

Today, these technologies are being applied in various contexts (cultural heritage [3], industry [4], medicine [5] and other fields) and particularly in education. The use of Augmented Reality in education, as a support for teachers, is one of the main goals of the H2020 ARETE¹ (Augmented Reality Interactive Educational System) project. ARETE project ensures that an interactive AR content toolkit is developed for the creation of 3D objects based on AR standards. ARETE includes standards-compliant AR/3D data infrastructures for educational purposes to ensure applicability, reproducibility, interoperability, accessibility and sustainability. The purpose of this paper is to show an ecosystem developed within the ARETE project that can support teachers of all levels with the creation and delivery of AR content during lessons. The ARETE ecosystem takes full advantage of the technological advancements in the field of AR to lay the foundation for a ground-breaking approach for competitive and sustainable interactive technologies. The effectiveness of this ecosystem will be tested through the assessment of specific skill sets and behaviors (STEM, English literacy skills and the impact of Positive Behavior Support in Schools).

This paper will discuss the relevant software components that are part of the ecosystem and the standards used to make them interoperable with each other. In particular, specific reference will be made to one of the pilot projects related to behavioral education through the use of the Positive Behaviour Intervention and Support (PBIS) framework [6]. Schools that adopt the PBIS framework teach positive behavior to students in the same way as any other subject. According to PBIS, combining the steps of planning, teaching and reinforcing expected behavior is a more effective way to ensure that all students understand behavioral expectations. This creates a positive environment in which students are taught respect, responsibility and safety.

The paper is structured as follows. Section 2 describes the related work. Section 3 presents the architecture and components of the ARETE ecosystem applied to PBIS. Section 4 gives an example of using the system in PBIS behavioral lessons. Finally, conclusions are given.

¹ <https://www.areteproject.eu/>.

2 Related Works

Various experiences of using AR in educational settings are reported in the literature. In [7] a study investigating the effects of AR on learning science subjects, shows how the technology contributes on the long-term retention of physics-related concepts and students show interest in AR calling it very useful, realistic and interesting for their learning, helping them to understand and analyze problems. Other studies [8–10] show that AR provides an attractive and functional learning environment that can improve student motivation by making learning a more engaging activity. In the survey [11] an interesting reflection is posed on how AR, although an effective and motivating learning tool, has many aspects that could be improved. Regarding the use of specific AR tools in the context of behavioral interventions [12], most solutions designed for educational purposes are marker-based and use smartphones and tablets. The user experience can be enhanced not only through immersive features, but also through a plurality of interactions and the wealth of information disseminated in the environment. Panciroli, et al., [13] state that AR should be seen as a dynamic edifying and didactic tool. In that sense, effective AR design and development should consider not only the user experience but also the pace, time, space and modes of learning, all of these factors can attribute to higher levels of attainment and reuse of the tools. Recent research survey [14] focused on the readiness of the educators for eXtended Reality (XR) applications in education, revealed the lack of expertise and training for the teachers at all levels, given the urgent need for availability of an XR marketplace and open-source authoring toolkit. The results provided the specific level of educators' awareness on XR applications, which is crucial for the future applications [15].

Over the years, the use of interactive and collaborative learning environments has greatly increased in many fields of education. This is due to the importance of the intrinsic motivation of students that comes from playing the applications [16,17]. Even though most educational AR applications described in the literature are intended to be single-user, researchers have been investigating collaborative AR experiences since the seminal publication of Billinghurst et al. [18]. A systematic literature review [19] on interactive, multi-user and collaborative apps for education shows that there are many studies analysing multi-user educational apps from different point of views. Some of them focus on specific school subjects such as maths [20,21] or sciences [22], while other focus on the analysis of the gameplay style, such as López-Faican et al. [23] that compares competitive vs. collaborative styles and their impact on user communication and motivation, or [24] which is a multi-user geography application where teachers and students play together and answer questions on different topics. However, many of the studies mentioned above do not take into account the human collaboration factor for promoting positive behaviour.

3 ARETE PBIS Ecosystem

The solution that the ARETE project presents is to introduce the use of AR for creating activities in the real environment where the lessons will take place. In the proposed use case, the ecosystem is used for behavioral lessons [25].

The ecosystem of the AR solution for PBIS is based on 3 components (Fig. 1):

1. The use of the MirageXR authoring toolkit, which allows teachers to create the AR educational resources.
2. The Moodle ARETE repository to collect the resources created with MirageXR.
3. The PBIS-AR application that allows students to view resources created with MirageXR with an easier interface and also supports the process of teaching, practicing and reinforcing expected behavior.

The combination of these technologies and systems creates an example of a technological and innovative ecosystem designed for creating behavioral lessons in AR. In the following subsections, these three components and the standards used to make the system interoperable will be shown.

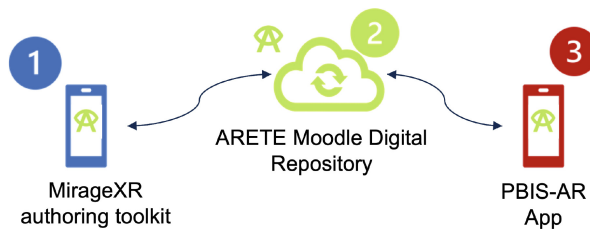


Fig. 1. ARETE PBIS Ecosystem

3.1 Standard Used to Share AR Educational Content

Researching the available interoperability standards that could support the project's needs for creating and sharing AR educational content, the ARETE team came up with the recently published *IEEE Standard for Augmented Reality Learning Experience Model*² (ARLEM). The standard provides a conceptual model for the representation of activities, learning context and environment for AR learning applications as well as the corresponding data model specifications, aiming to support the use of AR technology in training and educational systems [26]. Specifically, it aims to facilitate the discovery, retrieval, transfer and execution of

² <https://standards.ieee.org/ieee/1589/6073/>.

interchangeable AR-enabled educational content to support online repositories and marketplaces [26]. ARLEM standard was used by ARETE project to support the interoperability of learning content developed through MirageXR so that it can be stored and executed on different types of platforms and devices. MirageXR has been used as a reference implementation of ARLEM to support the development of the standard by demonstrating the use of the AR authoring tool to create real-life educational applications [27]. Leveraging MirageXR and ARLEM, the ARETE project enables participants to create and exchange standardized and interoperable AR learning content.

To collect and store data, ARLEM uses the Experience API (xAPI) model that allows the collection of data obtained from user experiences. xAPI³ is a specification that facilitates the documentation and communication of user interactions with the system and uses a specific structure to define experiences labeled as statements. The format of a statement is actor, verb (action) and object, where actor indicates which user performed an action, verb describes the action performed by the user and the object defines the thing that was acted on. xAPI provides an interoperable layer to track users' activities and facilitate the development of learning analytics tools. The use of this specification can support the development of comprehensive views of the individual's learning [28]. Once captured, the data/statement is stored in a Learning Record Store (LRS), ready to be consumed through learning analytics applications. A LRS is a repository for learning records that can be stand-alone or part of an Learning Management System (LMS) or other learning systems. In Learning Analytics (LA), data quality is a key issue and xAPIs play an important role in the processes of collecting and storing events in the LRS. In the ARETE project, the LRS that has been adopted is Learning Locker⁴, developed by H2T LabsTM. The statements to be recorded are defined at the application level and can be customized, and Learning Locker also provides a user interface to access all collected data. In particular, dashboards are available to perform in-depth analysis of the collected statements and custom queries.

3.2 MirageXR in a Teacher's Perspective

MirageXR⁵ is designed for creating and experiencing augmented reality activities. For the ARETE project MirageXR is used by teachers as an authoring toolkit, providing them with the tools required to create their own educational activities for their students in AR. The practicality of Mirage is in its structure, every activity is split into steps which each contain augmentations which are the augmented reality content. Splitting activities up into steps this way allows teachers to create a clear narrative with progression through the activity. The augmentations come in a few different forms, some are more rudimentary such as labels and images whereas others provide much more advanced AR feedback making true use of the medium.

³ <https://xapi.com/>.

⁴ <https://learninglocker.atlassian.net/wiki/spaces/DOCS/overview>.

⁵ <https://wekit-ecs.com/documents/miragexr>.

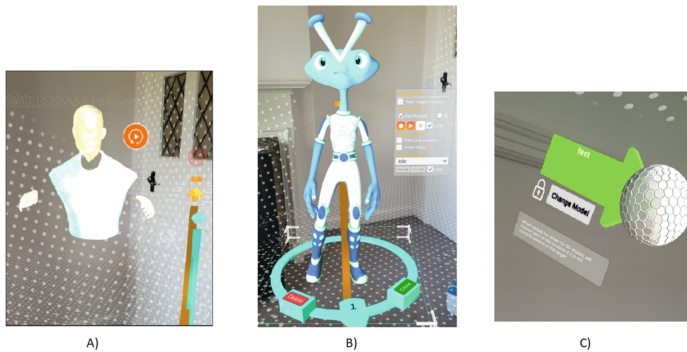


Fig. 2. Mirage Augmentations. A) Ghost, B) Character, C) Pick and Place

For example the ghost augmentation (Fig. 2 A) can record the voice and movements of the author while performing a task, this is then played back at real time speed via a 3D avatar which mimics the author's hand and body movements. Another augmentation worth noting would be the AI Character model (Fig. 2 B) which can be designed to either repeat predefined audio recording or respond dynamically to conversation via IBM Watson⁶. Character models can also move along set paths avoiding obstacles or can be told to follow the current activity user. In order to aid the learner, character models have a predefined set of animations they can perform such as wave, point, and image display in which they hold up a card showing an image. Pick and Place (Fig. 2 C) is another augmentation designed for teachers and is currently the only objective based augmentation in Mirage. From an author's point of view the pick and place augmentation has two objects: a target and an arrow. The goal for the learner is for the arrow to be placed correctly in the target. The arrow object can also be changed to mimic any 3D model available on Sketchfab, this means this augmentation can be used to pin flags on a map or to add labels to parts of the brain. Once an activity has been created an author can then upload it to the Moodle repository where it can be downloaded by students.

Through the use of MirageXR teachers have been afforded the role of authorship administration, thereby enabling them to develop their own teaching and learning experiences. This has offered teachers the opportunities to craft learning experiences to match their students learning needs. Linked with Moodle learning repository, MirageXR has focused on usability making new user interactions with the interface more enjoyable. The impact of this is the teachers focus is

⁶ <https://www.ibm.com/it-it/cloud/watson-text-to-speech?lnk=flatitem>.

directly on the content of the learning experiences. The increased accessibility of MirageXR is designed to attract more teachers to feel more at ease when working with the application on-the-fly.

MirageXR, also holds the potential to become a shared resource, a resource for teachers to use to collaborate in the development of learning experiences. By uploading the content of the learning activity into Moodle, other teachers can contribute to a particular activity or to use a finished learning activity. The collaborative nature of augmenting learning could result in the development of a rich battery of learning activities, as well as a convenient teaching resource, that could inspire new pre-service as well as long standing in service professionals.

3.3 ARETE Moodle

Within the educational context, there is a growing body of evidence of the impacts of informal education on learners – e.g., valuing science and the natural environment, increasing self-efficacy, making scientifically influenced decisions and developing 21st century skills. Knowledge about informal learning experiences is published in the fields of science education and has become increasingly accessible to the STEM research community in repositories such as InformalScience.org. The data management landscape for educational initiatives in Europe is characterised by a very large number of individual and domain-specific data initiatives and scientific databases, with only a small number of the data initiatives federated. Long-term sustainability is a major issue for all data initiatives, and not only a problem limited to the underlying hardware infrastructure but also for the software access and exploiting the data. Current e-learning systems focus on the data infrastructures only and not on the content management for 3D reconstruction and visualisation associated with teaching and learning. A key barrier to adoption of XR in the classroom is the lack of XR-enabled content, the affordability of hardware and the lack of understanding of pedagogical arrangements that teachers need to put in place to be able to integrate AR in their teaching. To address this and to facilitate the design of XR content that will be well aligned to the curriculum, ARETE team has further developed the MirageXR software, also complementing it with a plugin for Moodle⁷, an open-source learning platform, to enable teachers to manage and schedule content efficiently. Interoperability issues in data management are very important to ensure that scientific data is reachable and useful to other scientific fields, i.e. to enable cross-disciplinary data intensive science.

ARETE promotes development and access to AR 3D content data that has not yet become a reality in many scientific domains and it will facilitate effective and efficient use of digital content through the open source availability of both the platform and the 3D content ARETE Marketplace. It provides mechanisms to collect, manage and process data from multiple abstractions adhering to standards of learning objects. Through the digital learning ecosystem, both

⁷ <https://arete.ucd.ie/>.

content-based data and educational data, in all their diversity and complexity, can be integrated.

3.4 PBIS-AR App

The PBIS-AR application is designed for students and leverages AR technology in the behavioral lesson learning process to support the teaching, practice, and reinforcement phases of expected behaviors in the school environment. The architecture of the PBIS-AR application consists of several modules, each devoted to a specific function and described below.

Intro App, Authentication and Setup. The student is introduced to the use of the application through a dialogue with an alien named Arpro that is the main character of the app. The alien introduces himself and begins an interactive dialogue with the user. The first time the system is started, a setup procedure will be run by the teacher to specify the school and the Moodle account from which to take the information needed to use the app, like for example animations created using MirageXR. The student will have to enter the nickname provided by the teacher, which will be used to track the interactions thus maintaining users' anonymity.

Teach Section - Play Behavioural Routines. In this section, the student can play routines created by the teacher through the use of the MirageXR toolkit and stored in the Arete Moodle server according to the ARLEM standard. The student will select one of the behavioral expectations from a list (see Fig. 3) based on the behavioral lesson conducted by the teacher and view the content in augmented reality without the use of markers, but relying on environmental mapping. The content then is a 3D animation contextualized in the school environment. These animations have the alien as the main character and secondary characters such as teachers or students engaging in the display of routines.

Discovery Section - Behavioural Reflexive Game in AR. The discovery section allow students to access reflective games with the aim of practicing and reinforcing expected behaviors. The teacher will place markers in the school environment, and the student, by framing them with the device's camera, will view animations related to expected and unexpected behaviors. At the end of the animation, the student will display a dialog box with a question and answers. Based on the student's answer, a score will be given. The points earned will allow only the top 3 students to be ranked and displayed on a podium and to recognize student achievements and motivate them, avoiding the use of a ranking so as not to discourage students at the bottom of the list. These points will be accumulated with those in the practice section.



Fig. 3. Behavioural expectation list

Practice Section - Multiuser Activities Within Behavioural Lessons. In this section, students can experience collaborative learning activities to improve their behavioral skills. This section is composed of a main screen (see Fig. 4 A) in which the students find a menu with four activities prepared to work in pairs. Before selecting one of them, they have to select a group so that they are connected to the session they have been assigned. And then, both students in each group choose one of the four activities in the menu.

The four activities have been designed so that students can interact with each other in the augmented space in different ways. These activities are the following:

- Greeting others: This is a role-play game in which students learn how to greet the other (See Fig. 4 B). First of all, the students select a character that is shown virtually once a marker is scanned. Once both students are connected, they have to answer a quiz that asks them how to greet each other. When both students select their answer the augmented characters show the greetings through synchronised animations. If the answer is correct they earn some points and if it is not, they have two additional attempts, where in case of success they earn less points than in the first attempt.
- Stand up for others: This is a second role-play game in which students learn how to behave when they witness a bullying scene involving one of their colleagues (See Fig. 4 C). Again, first of all, both students select a character that is shown virtually once a marker is scanned. These characters are considered helpers and have to decide what to do once they see a scene in which a group of students is laughing at a colleague. The actions are selected through a quiz and once both students answer the characters show synchronised animations. This activity includes also the rewarding system explained in the previous case.

- Keep the workspace organised (Untidy version): In this markerless activity, students learn in pairs how to organise the workspace interacting with virtual objects they see after scanning a real surface such as a table (See Fig. 4 D). Once the surface is scanned, a virtual drawer is shown with disorganised school material and students are asked to take the maths book which is at the bottom and is not accessible in the first attempt. Once they achieve the goal they have to answer some questions to reflect about the time they needed to complete the task. And finally, they are asked to store all the objects they took out unnecessarily. Finally, when only the maths book is left on the surface, the application tells them they are ready for the lesson.
- Keep the workspace organised (Tidy version): This is a similar activity to the previous one but the lesson is addressed from the opposite point of view. In this case a tidy drawer is shown and the same task is requested, i.e. to take the maths book. The maths book is accessible directly and once they take it out, they have to answer a quiz to reflect again about the time they spent to complete the task.

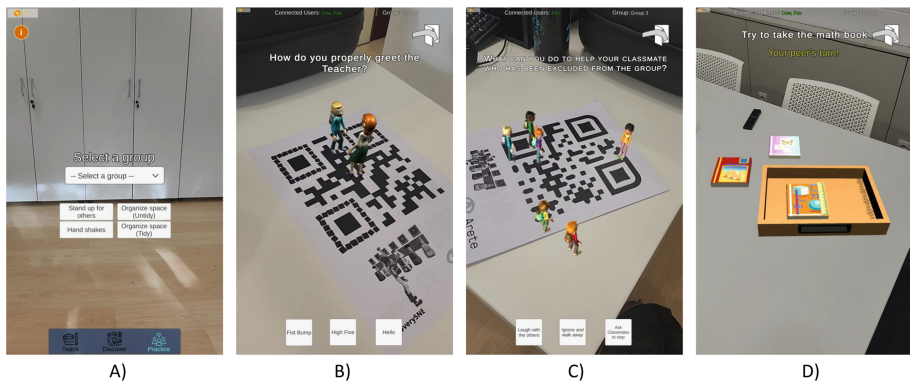


Fig. 4. Screenshots of the multi-user activities in the PBIS AR app. A) Main menu; B) Greet others; C) Stand up for others; D) Keep your workspace organised

All the interactions between users have been implemented through the Orkestra library, which provides communication between users connected to the same session and ensures coherence at the augmented space. More in detail, Orkestra is a technology agnostic library composed of a client side, called OrkestraLib, where most of the logic that allows multi-user communication and synchronisation is implemented, and a server side called OrkestraServer, which manages all the connections, messages and sessions of the users. In this case, a CSharp client of OrkestraLib has been integrated in the application, OrkestraServer has been deployed in AWS, and all the communication between both parts is done through web-sockets.

Regarding the features that Orkestra provides we could highlight:

- Session generation: it allows to create different isolated sessions though unique session and user IDs so that students can work in pairs without interfering with the other groups.
- Real time communication: it is possible to send messages between users in real time.
- Synchronisation: it allows the synchronisation of each activity between users and devices.
- Simple interactions: it provides the possibility to implement interactions that require a single message sharing to show the same behavior on both screens.
- Advanced interactions: it provides the possibility to implement interactions that require a lot of messages per second to track the movement of 3D objects and obtain a smooth and coherent interaction in both screens.
- Connection control: it allows to check the connection of users in the same session during the game so that in case one user is disconnected the other can not continue playing alone.

All of this will allow the students to do the exercises together, interacting in the augmented space which will improve their learning experience as seen in Fig. 5.

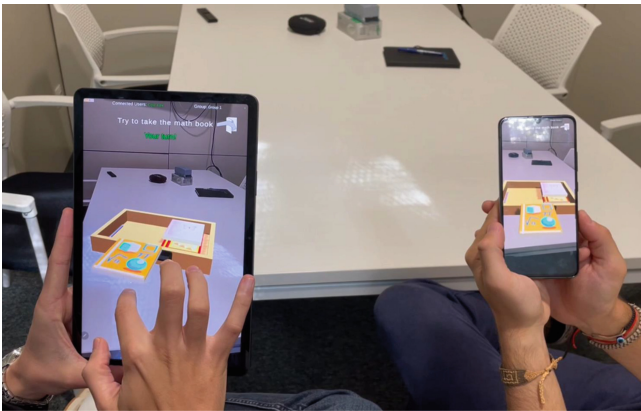


Fig. 5. Multi-user PBIS AR experience

4 ARETE PBIS Pilot

Following the design process carried out together with PBIS teachers from various European PBIS schools, behavioral expectations were chosen to be included within the pilot. In this section we report an example of using the ARETE ecosystem for the behavioral expectation “Stand up for others”. The teacher with the support of these systems can design and implement an Augmented

Reality Behavioural Learning Resource (AR-BLR) that models an example of expected behaviour. A good behavioural example is thus a 3D learning resource in the form of an AR animation built in the specific environment in which the teacher expects this behavioural expectation will be applied.

To create the behavioral resource and use it within his lesson “Stand up for others”, the teacher will need to perform the following steps:

- Create the AR-BLR using the AR toolkit MirageXR
- Publish AR-BLR in the Moodle ARETE repository
- Use the PBIS-AR application to view the AR-BLR

In this example, the teacher wants to make a behavioral learning resource that models a good example of behavior. So the 3D animation should show Arpro, the alien character, standing up for a classmate who is being teased by two other students.

Table 1 describes a behavioural routine realisable with the MirageXR authoring toolkit using a single step.

Preparing this table helps the teacher design the activity, as in a script: which characters to introduce into the scene; how many MirageXR steps are needed to realise the scenario; the animations to be selected in the various characters and the actions to be performed in each step to realise the behavioural scene. The Fig. 6 shows an editing use of MirageXR for creating the AR-BLR “Stand up for others”.

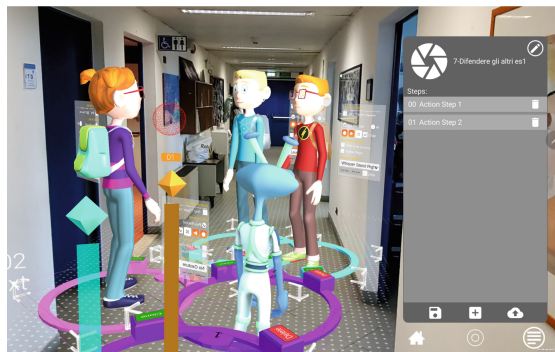


Fig. 6. MirageXR teacher’s authoring activity

Once the resource has been created, the teacher may decide to save the resource locally in the device or in the ARETE repository using his or her credentials. The behavioural resource is then saved on the ARETE repository and available to its students via the PBIS-AR application. At the teacher’s instruction,

Table 1. Stand up for others routine description

| | |
|---|--|
| Scenario Title | Stand up for others |
| Example or Non Example | Example |
| Short description | Two students are standing together on the corridor and ostracize another student (victim). The two students are laughing and whispering. Arpro sees this, walks up to the students and indicates that they should not be mean to the victim. |
| Setting | All settings/Social skills |
| Phase of the lesson where to be use the AR resource | Modeling/teach phase |
| Numbers of steps | 1 |
| Characters models | Students, Arpro |
| Character Animations to be use | Student 1 (victim): idle Student 2: Laugh stand Student 3: Whisper stand Arpro: walk from point A to the perpetrators |
| Step [1] creation | Position one student victim on a side and set the idle animation. Put two students (ST1 and ST2) on the other side in front of the victim and one next to the other. Set the ST2 “Wisper stand” animation. Set the “Laughter Stand” animation so that the other (ST1) laughs at the victim. Put Arpro before the group, clone it and move the Arpro number 2 next to the two students and select the “No gesture” animation. |

the student selects the behavioral expectation from the list accessible through the Teach section and views the list of behavioural resources created by the teacher for that lesson. Once the resource is selected, the student is able to play the AR animation and view the behavioural example of the specific behavioural expectation.

Figure 7 shows two frames of the AR animation created by the teacher in action within the PBIS-AR application. The image on the left shows a frame of the AR animation in which the students tease the victim, while the frame on the right depicts the arrival of Arpro who asks them to stop teasing their peer.



Fig. 7. Using “Stand up for others” AR-BLR in the PBIS-AR application

5 Conclusion

This paper presents the AR ecosystem developed within the H2020 ARETE project. Specifically, it has been applied within pilot #3 in which Augmented Reality will be used as support during behavioral lessons according to the PBIS method. One of the main goals is to achieve an interoperable and innovative system that engages students and encourages them during the process of learning behavioral rules. To obtain the ecosystem, new standards and AR technologies were adopted for creating educational activities in the school context by proposing multi-user interaction activities and tracking their interactions with the system. Currently, the ecosystem is being tested in some European schools where the PBIS framework has been adopted. The proposed AR solution for behavioral education provides an excellent starting point for the creation of an AR ecosystem for education. In fact, such an ecosystem can be adapted to different contexts and not only the behavioral one.

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