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IMMERSIVE AUTHORING TOOLS GUIDE

Intellectual Output 2

ImTech4Ed: Immersive Technologies for Education

Intellectual Output	**O2: Immersive Authoring Tools Guide**
Responsible Partner:	International Hellenic University
Quality Reviewers	All partners
Status-Version:	Version 4.0
Date:	30/08/2023
Executive Summary:	In the dynamic realm of education, the integration of immersive technologies has emerged as a transformative force. This paradigm shift has not only redefined the essence of learning but also ushered in an era where students actively engage in their educational journeys. Central to this transformation is the profound impact of immersive technologies and the role of the adequate authoring tools in harnessing their potential. *ImTech4Ed* is based on the concept of interdisciplinary thinking utilizing of immersive educational technologies, aiming to help teachers and students that would like to make use of these technologies into educational practice in a sustainable way. *ImTech4Ed* sets forth a systematic approach for the selection of authoring tools. Initially, project partners established a set of specific criteria that the chosen software must meet. Subsequently, partners engage in a comprehensive review of available authoring tools pertinent to immersive software and game development, covering the domains of Augmented Reality (AR), Virtual Reality (VR), Immersive Video, and Game Development Engines. The chosen authoring tools are characterized by their adherence to predetermined criteria, including open-source availability, user-friendliness, robust community support, and compatibility with diverse learning methods This report serves as a comprehensive guide to the criteria and the selection of authoring software in the context of immersive technologies. It meticulously delineates the essential characteristics that each authoring tool must encompass for different immersive technologies, with a focus on STEAM education and game design. These considerations span both the university and secondary school levels. Subsequently, the report presents the selected authoring tools, examining each against the predetermined criteria. Detailed insights into their functionality, available educational content, pricing, and workshop environments are provided. For each immersive technology, the report offers a nuanced discussion on the suitability of available authoring tools, considering the unique context and author backgrounds. Finally it offers a number of comparative tables that serve as a practical aid, facilitating the selection of the most suitable tool to leverage the potential of immersive technologies effectively. After the study of this report participants will be able to: ● Describe basic concepts of immersive authoring tools. ● Identify and compare various technologies used in building immersive software and games.

	● Design basic immersive software considering limitations of the environment and the needs of the students. ● Bring together various innovative technologies in order to build digital experiences.

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This document is issued within the frame and for the purpose of the *ImTech4Ed: Immersive Technologies for Education*, funded by the European Commission-Erasmus+/ Key action 2, Cooperation for Innovation and the Exchange of Good Practices/ Strategic Partnerships for Higher education (Ref. #: 2020-1-DE01-KA203-005679)

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2. International Hellenic University (Diethnes Panepistimio Ellados) (EL)
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List of Abbreviations/ Acronyms

Abbreviation / Acronym	Description
CY	Cyprus
DE	Deutschland (Germany)
EL	Hellas (Greece)
ImTech4Ed	ImTech4Ed: Immersive Technologies for Education
EU	European Union
STEM	Science, Technology, Engineering, Mathematics
STEAM	Science, Technology, Engineering, Arts, Mathematics
AR	Augmented Reality
VR	Virtual Reality
3D	3 Dimensions

1 Deliverable Description

As outlined in the project proposal, this deliverable will encompass two actions: a) concluding on a specific set of criteria that the adopted software should incorporate and b) reviewing the available authoring tools.

Initially, project partners will determine the specific criteria that the adopted software should encompass. Subsequently, all partners will review the array of available authoring tools for immersive software and games.

Virtual reality, augmented reality, immersive videos, and educational games are increasingly being harnessed to create profoundly interactive and immersive educational environments and experiences. These technologies provide users with direct access to virtual content and environments, enabling them to interact with them directly (Lampropoulos et al., 2021). Such technologies offer a more lifelike and hands-on learning encounter that can captivate users more effectively than traditional methods. Furthermore, they can be employed to simulate real-world scenarios that might be excessively perilous or costly to replicate in reality.

Consequently, the following four technologies and topics will be addressed:

- Augmented Reality authoring tools,
- Virtual Reality authoring tools,
- Immersive video authoring tools
- Game development engines.

The authoring tools selected post the review process must be open source or free software, user-friendly, backed by a substantial community, and naturally, meet the pre-defined criteria. The chosen authoring tools need to support various learning methodologies, including inclusive learning, inquiry-based learning, problem-based learning, and game-based learning. They should also be capable of implementing digital storytelling scenarios and immersive experiences, among other functions. Additionally, the selected authoring tools should offer flexibility, empowering teachers to craft their own personalized experiences, such as interactive activities and educational games.

2 Criteria that the Adopted Software Should Implement

The adopted software should fulfill the following criteria:

1) Open Source or Free Software:

   Most of the systems provide both a free and a paid subscription. The guide will focus on systems that offer functional free subscriptions, enabling educators and students to benefit without the need for substantial payments. If users find the tool valuable or consider the paid features worthwhile, they can opt for the premium subscription. The list of tools will also encompass those that are useful and offer free trial versions.

2) Ease of Use:

   Ease of use is a pivotal criterion, as it significantly influences the adoption of any technology. According to the Technology Acceptance Model (TAM), ease of use is a

crucial factor impacting software usage. Software that educators find challenging to use will likely not be adopted in practice. Thus, this guide aims to provide non-programmers with user-friendly software.

3) Useful Functionality:

   The proposed tools must provide end users with practical functionality to create meaningful educational content. They should offer user-friendly and intuitive features, allowing users to efficiently produce educational materials without complications.

4) Supported by a Large Community:

   Ideally, the tools should be embraced and supported by a sizable community. This ensures that users can exchange ideas and receive support promptly when needed.

5) Portability:

   The proposed tools should be compatible with various operating systems and platforms, ensuring accessibility for all users. They should work seamlessly across multiple systems, including Windows, MacOS, Linux, and Android.

6) Support for Various Learning Methods:

   The tools should support a range of learning methods, including:

   a. inclusive learning,
   b. inquiry-based learning,
   c. problem-based learning, and
   d. game-based learning.

7) Implementation of Digital Story-Telling Scenarios and Immersive Experiences:

   The adopted tools should empower authors to create digital story-telling scenarios and immersive experiences. Authors can utilize these tools to craft interactive, engaging, and meaningful digital stories and immersive encounters, combining elements such as audio, video, animation, and interactivity to captivate their audience.

8) Availability of Novice-Friendly Tutorials:

   Since many individuals are still unfamiliar with immersive technologies, comprehensive tutorials are vital to facilitate a smooth start. The tools should offer easily accessible online documentation or video tutorials that cover the fundamental aspects of each technology and authoring tool. These resources will assist users in maximizing their experience and potential.

2.1 Criteria for Augmented Reality Authoring Tools

To achieve optimal outcomes, augmented reality authoring tools must adhere to specific criteria.

1) Usability:

   The tools should offer an easy-to-use, user-friendly interface, enabling individuals with limited technical expertise to create AR experiences effectively..

2) Platform Support:

   The tools should cater to multiple platforms, including smartphones, tablets, and smart glasses, in order to reach a broader audience. Given that Android and iOS are the predominant mobile operating systems, compatibility with both is essential.

3) Real-Time Rendering:

   The tools should facilitate real-time rendering of AR content, enabling users to promptly visualize the outcomes of their efforts. This capability enhances the iteration process, resulting in superior end results.

4) 3D Modeling Capabilities:

   The tools should possess robust 3D modeling capabilities, empowering users to import 3D objects. Additionally, if feasible, the tools should support the import and editing of 3D scenes. 3D modeling is pivotal for the tool as it allows for the import of 3D objects, a crucial aspect of the design process. The ability to import and edit 3D scenes enhances flexibility during design.

5) Asset Import and Export:

   The tools should support various file formats, links, and embedded code, facilitating seamless integration with other tools and platforms. This fosters convenient data sharing across diverse sources, enhancing overall productivity.

   The proposed tools should accommodate multiple types of multimedia content, such as:

   - Images
   - Videos
   - Sound
   - 3D Objects
   - Links

6) Content Management:

   The tool should include a built-in content management system, empowering users to organize and manage their AR assets efficiently. Such a system simplifies asset tracking and utilization.

7) Adequacy for Educational Reasons:

   The proposed tools should be apt for educational use, offering functionality relevant to educational contexts.

8) Collaboration:

Ideally, the tool should support collaborative efforts, enabling multiple users to collaborate on the same AR project. Collaboration facilitates the sharing of ideas and knowledge among users, leading to enhanced projects and mutual learning. The importance of collaboration has been extensively discussed in the IO1-A1 report “Methodological guidelines for creating the framework of the ImTech4Ed project”.

9) Analytics:

Ideally, the tool should incorporate analytics capabilities to monitor usage and user engagement, providing valuable insights for future enhancements.

2.2 Virtual Reality Authoring Tools

To achieve the best results, virtual reality authoring tools must meet the criteria described below.

1) Usability:

The tool should feature ease of use and a user-friendly interface, enabling individuals with limited technical expertise to create VR experiences effortlessly.

2) Compatibility:

The tool should be compatible with various VR hardware and software platforms, ensuring accessibility to a wide audience. Supported platforms and devices should encompass Android, iOS, Windows, as well as VR devices like Oculus Quest, and even mobile devices such as Android and iOS phones.

3) Interactivity:

The tool should empower users to interact with and manipulate virtual environments in real-time, fostering a sense of presence and agency through gestures, controllers, and haptic feedback. This enhancement contributes to a more immersive and engaging virtual experience.

4) Customization:

Users should have the capability to customize their virtual experiences according to their preferences. This could include adjustments to visual settings, personalization of avatars, and creation/modification of virtual environments. Such customization enhances both immersion and personalization within the virtual realm.

5) Multimodal Capability:

The tool should support diverse forms of media, such as 3D models, images, videos, and audio, to provide a rich and immersive experience. This enables users to interact with virtual environments in a more realistic and engaging manner, thereby heightening the overall sense of presence and immersion.

6) Collaboration:

Ideally, the tools should facilitate multiple users interacting and collaborating within the same virtual environment. This feature fosters teamwork, communication, and shared experiences.

7) Multiuser VR Environments:

   The tools should offer the ability to create multi user VR environments, enabling people to interact with each other within a shared virtual world. This functionality holds promise for applications in education, training, and entertainment.

2.3 Immersive and Interactive Video Authoring Tools

To enable instructional designers to craft effective and meaningful instructional videos, immersive video authoring tools need to satisfy specific criteria.

1) Usability:

   The tools should offer ease of use through a user-friendly interface, enabling even those with limited technical expertise to create compelling 360-degree and 3D videos.

2) Compatibility:

   The tools should demonstrate compatibility with diverse hardware and software platforms, ensuring broad accessibility. Supported platforms and devices should encompass Windows, Android, iOS, as well as VR devices such as Oculus Quest, and even mobile devices like Android and iOS phones and tablets.

3) Multimodal Capability:

   The tools should support a variety of file formats, including 360-degree video, 2D and 3D video, audio, and images.

4) Interactivity:

   Immersive video introduces a novel and innovative method of consuming video content. Consequently, the tools should facilitate interactivity for a more engaging experience. Features like hotspots, annotations, and navigation can contribute to achieving this goal.

5) Customization:

   The tool should empower users to create and edit the immersive video experience, allowing for tailored and personalized content.

6) Collaboration:

   Ideally, the tools should enable multiple users to collaborate and contribute to the same immersive video project, fostering teamwork and shared creative efforts.

2.4 Game Development Engines

The game development engines should fulfill the following criteria:

1) Usability:

   The tool should offer intuitive navigation, easy access to features and tools, and a streamlined game development process. This empowers creators to efficiently bring their visions to life with minimal obstacles.

2) Compatibility:

The tool should seamlessly function across various platforms, operating systems, and hardware setups. This ensures that games developed using the engine can be smoothly deployed and run on a wide array of devices and environments, enhancing accessibility and reach for both developers and players.

3) Interactivity:

   The tool should facilitate the creation of dynamic and engaging gameplay experiences. Robust tools and systems should enable the implementation of player interactions, manipulation of in-game objects, character control, user interface feedback, and responsive game mechanics.

4) Customization:

   The Developers should have the ability to tailor and modify multiple aspects of their games, including art assets, gameplay mechanics, audio effects, and user interface elements. This flexibility allows developers to personalize and distinguish their games, aligning with specific design goals and player preferences. The tool should provide a versatile framework for crafting unique and captivating gaming experiences.

5) Multimodal Capability:

   The tool should empower developers to create immersive games by utilizing a combination of audiovisual elements, interactive controls, and tactile sensations. This creates a multi-dimensional gameplay environment that engages players' senses and fosters deeper immersion and enjoyment.

6) Free to Use:

   The tool should be accessible without any upfront cost, allowing developers to utilize the engine without financial constraints. This encourages aspiring game developers and indie studios with limited resources to embark on projects, promoting innovation and democratizing game development.

7) Support for Immersive Technologies (AR/VR devices, Mobile devices):

   Support for immersive technologies enables developers to harness the unique features of AR/VR devices and mobile devices, enabling the design and optimization of immersive gameplay experiences that fully exploit these technologies.

8) Support for Both Beginner and Advanced Users:

   Ensuring support for both beginner (non-technical) and advanced (technical) users within game development engines is vital for inclusivity and accommodating diverse skill levels.

9) Availability of Documentation, Examples, and Content:

   Comprehensive documentation, tutorials, and guides assist users in comprehending the engine's features, workflows, and best practices, promoting efficient utilization.

10) Interoperability with Other Tools (3D Modeling, Scripting, Animation Tools, Integrated Development Environments):

    Seamless integration and compatibility with external tools enable developers to leverage preferred workflows, enhancing asset creation, scripting, animation, and code editing.

3 Augmented Reality Authoring Tools

The utilization of augmented reality (AR) has the potential to offer learners a more immersive educational experience, resulting in improved retention and comprehension of material compared to other technology-enhanced learning environments (El Sayed, Zayed, & Sharawy, 2011).

AR authoring tools can be categorized into two groups: AR authoring tools designed for programmers and those tailored for non-programmers. This report focuses on proposing AR authoring tools for individuals without programming backgrounds.

Liarokapis et al. (2010) propose that an ideal educational AR system should meet the following requirements:

- Simplicity and robustness
- Clear and concise information delivery for learners
- Easy and effective information input for educators
- Seamless interaction between learners and educators
- Transparency in conveying complex procedures to both learners and educators
- Cost-effectiveness and scalability.

Considering these requirements alongside the previously mentioned criteria, this report recommends the following AR authoring tools for educational use.

3.1 ARTutor

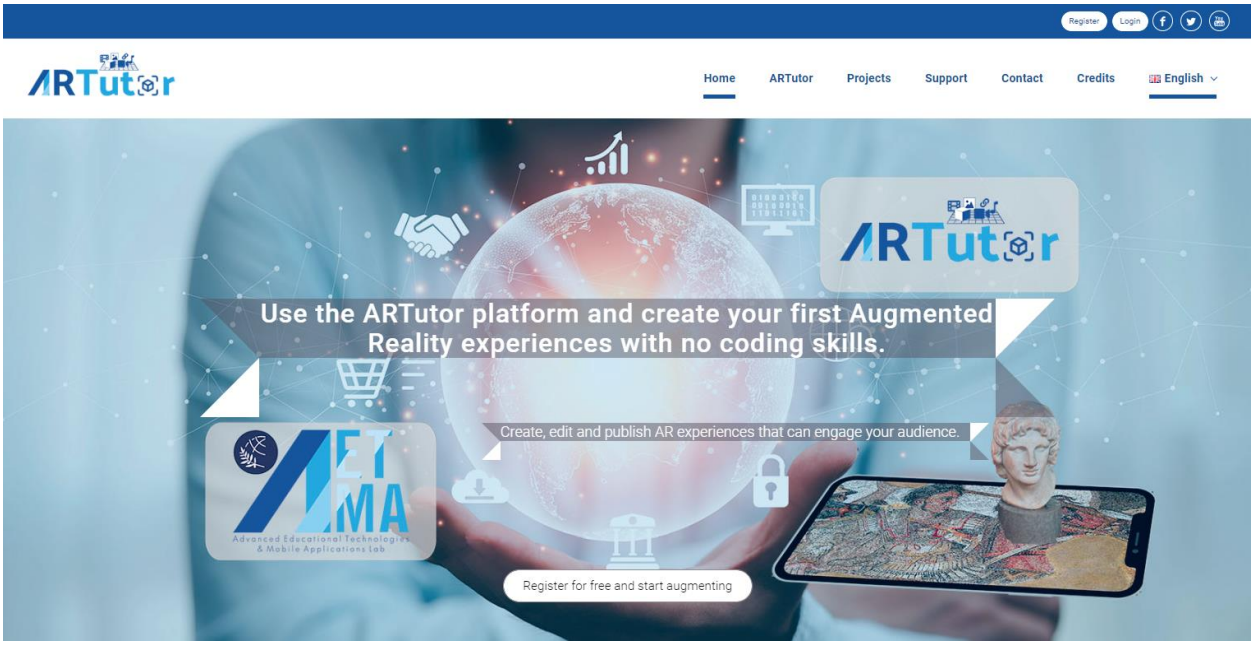

Figure 3.1 ARTutor Web Page

Developed at the AETMA Lab, ARTutor is an Augmented Reality educational platform comprising a web-based authoring tool and a mobile application.

The authoring tool allows for the creation of Augmented Reality books in an easy and user-friendly manner suitable for non-programmers. ARTutor is provided free of charge to educators and students around the globe, with the aim of aiding them in developing technologically enhanced educational material and enhancing their educational performance and experiences.

The mobile application serves as the gateway for students to access the augmented books generated using the web-based authoring tool. ARTutor is compatible with both Android and iOS devices.

The primary impact of ARTutor in the field of education can be summarized by the following objectives:

- Maximizing student engagement with educational material, including textbooks.
- Empowering teachers with limited IT skills to create augmented reality books and design highly engaging and immersive educational activities and experiences within the classroom.
- Implementation of a unified mobile application to grant students' access to all augmented reality books, promoting enhanced studying and facilitating independent, self-paced distance learning.

Content creators can develop their AR experiences through four simple steps:

- Register and login to the application.
- Create a new AR book on the ARTutor Web platform (Fig. 3.2).

- Develop an AR experience using images, videos, sounds, and models to incorporate augmentations into each scene (Fig. 3.3). Alternatively, utilize the AR Experience editor to create complex and interactive scenes.
- View the AR experience using the ARTutor mobile application and share it with others.

ARTutor is available in 10 languages.

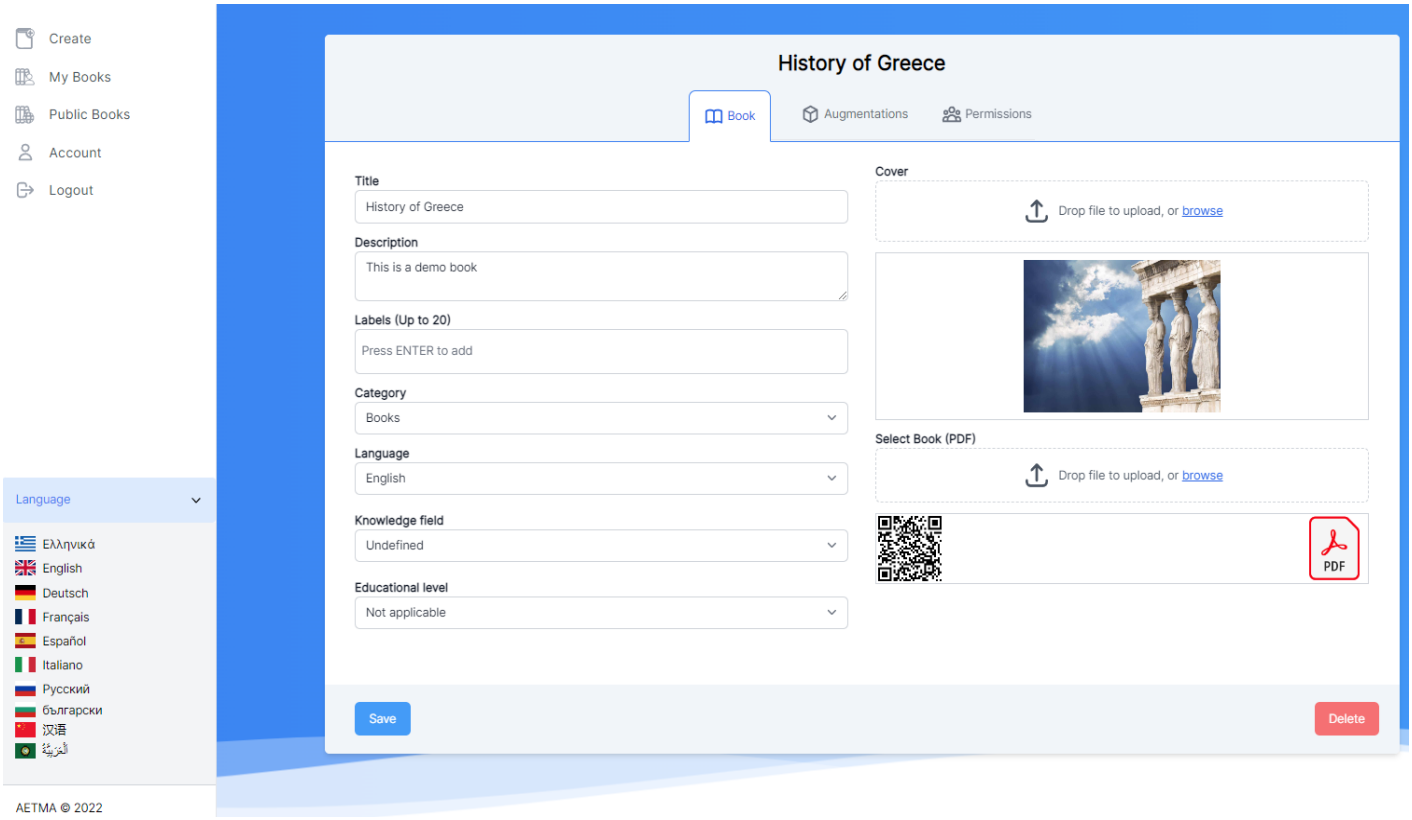

Figure 3.2 Create or edit an AR book on ARTutor

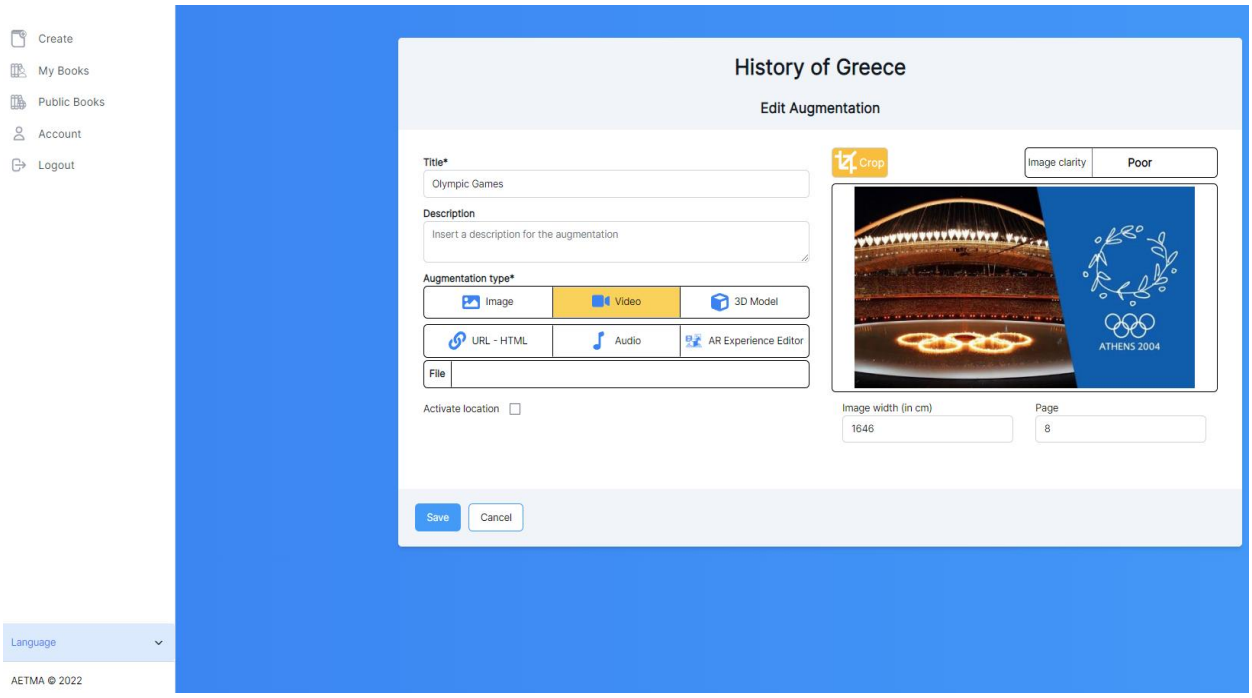

Figure 3.3 Create or edit an augmentation on ARTutor

AR Tutor stands as a versatile tool that lends support to a wide spectrum of learning methodologies, including inclusive learning, inquiry-based learning, problem-based learning, and game-based learning. Notably, it prioritizes accessibility by furnishing supplementary educational content such as sound assets, catering to the needs of visually impaired learners. Through a range of formats like videos and interactive activities, ARTutor embraces distinct learning styles and preferences, thereby delivering differentiated instruction.

Within the realm of inquiry-based learning, AR Tutor champions independent exploration and critical thinking. It achieves this by introducing intricate augmented scenes that beckon learners to embark on their own investigative journeys. Encouraging hands-on experiences, the application allows users to manipulate virtual objects and delve into phenomena, nurturing curiosity and self-directed learning. Augmenting this, ARTutor employs data visualization techniques to present information interactively, fostering engagement and participation. Learners are empowered to analyze data, detect patterns, and derive meaningful insights, thereby sharpening their inquiry and critical thinking faculties.

In the context of problem-based learning, AR Tutor extends its support through interactive AR simulations. The AR Experience Editor enables students to collaboratively engage, experiment, solve intricate problems, and exercise critical thinking. These simulations furnish practical experiences, nurturing problem-solving acumen within a secure and controlled environment.

Moreover, ARTutor seamlessly integrates game-based learning by incorporating gamified elements and partnering with educational games. The learner's journey involves engaging with interactive AR augmentations alongside traditional printed materials, fostering an immersive and enjoyable learning experience. This gamification facet significantly enhances engagement, motivation, and knowledge retention. Table 3.1 below provides a comprehensive overview of ARTutor's functionality.

Table 3.1 ARTutor functionality and characteristics

ARTutor								
Platforms		**Pricing**	**Ease of use**	**Gamification Elements**	**Collaboration**	**Asset Library**	**Interactivity**	**AR Triggering**
Android, iOS		Free	Very High	Manually by the user	✓	---	Available in AR Scenes	Image, GPS
Augmentations								
Text	**Image**	**Sound**	**Video**	**360 Video**	**3D Models**	**Links**	**AR Scenes**	**Animation Effects**
Through AR Scene	✓	✓	✓	---	✓	✓	✓	---

Related Links

Cost: Free for non-commercial use

Link: http://artutor.ihu.gr/

Platforms: Android mobile App

https://play.google.com/store/apps/details?id=com.aetma.artutor3

iOS mobile App, https://apps.apple.com/gr/app/artutor3/id1573116812

Online authoring tool http://artutor.ihu.gr/artutor/php/login.php

Tutorials: http://artutor.ihu.gr/support/

YouTube: https://www.youtube.com/watch?v=USJVQb4e8J8&list=PLI1D6U6pmP3BSHXaHlSwygDxhBR0xtbio

Facebook: https://www.facebook.com/AetmaLab

3.2 Metaverse

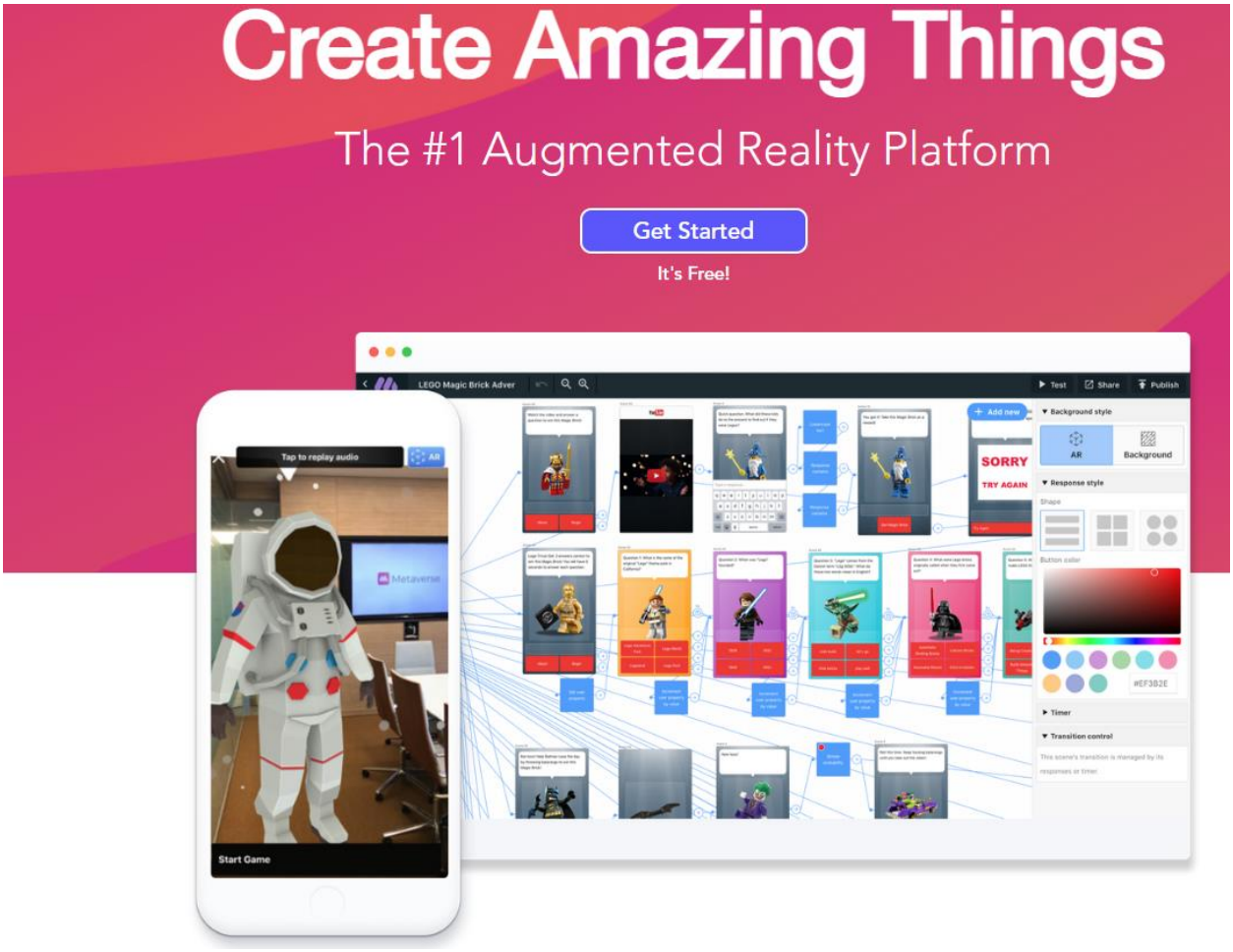

Figure 3.4 Metaverse Web Page

Metaverse stands as a scene-centered platform that simplifies the creation of augmented reality and interactive content.

This platform comprises a web authoring tool (Fig. 3.5) and a mobile application designed for the creation, sharing, and interaction with augmented-reality "experiences". Users seamlessly link scenes to craft partial or comprehensive experiences that dynamically adapt to viewers' responses. Once an experience is fashioned, it can be replicated and modified, enabling the creation of new ones. This innovative platform empowers users to both develop and partake in augmented reality activities while cultivating essential 21st-century skills. Metaverse AR experiences possess a remarkable capacity to captivate users and gamify the learning process, offering them the capability to generate experiences that stimulate creativity and foster critical thinking. In educational contexts, Metaverse has been widely embraced across various subjects and grade levels. Its utilization extends to bolstering student digital literacy, introducing them to fundamental computer science skills. Furthermore, Metaverse has demonstrated its efficacy in fostering student ownership of the learning journey.

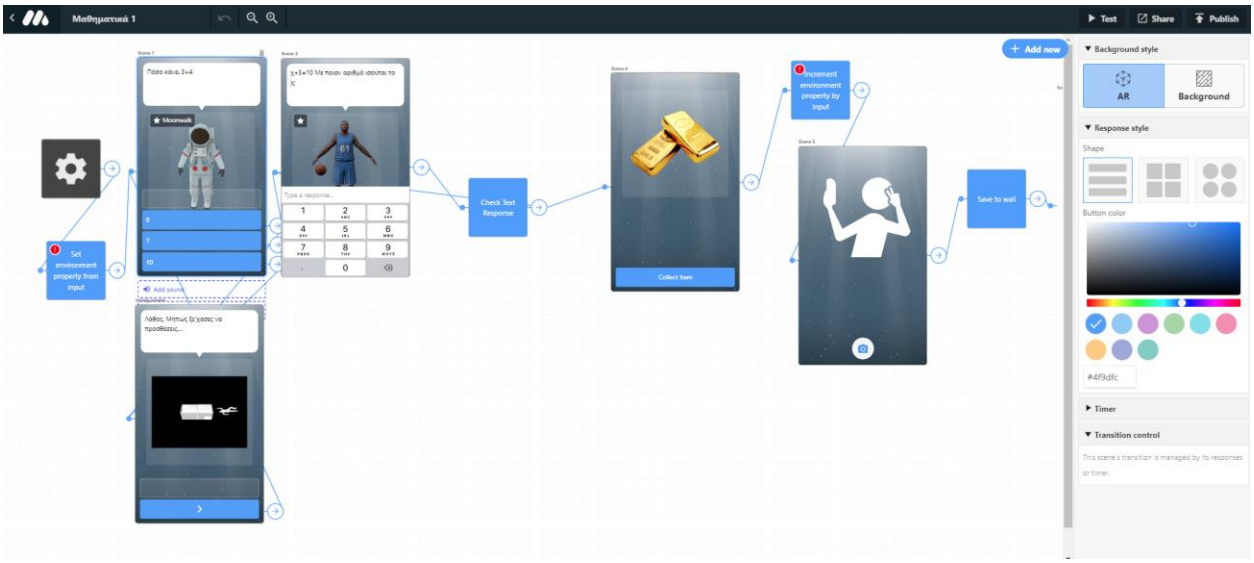

Figure 3.5 Metaverse storyboard

The Metaverse platform stands as a robust pillar supporting a wide array of educational methodologies, including inclusive learning, inquiry-based learning, problem-based learning, and game-based learning. This expansive range of applications empowers educators with a dynamic toolset to cultivate diverse and engaging learning experiences. Notably, the platform empowers authors to craft AR apps that dynamically adjust educational content based on user preferences and behavior. Each user's choices can lead to distinct learning paths, ensuring a tailored and personalized educational experience. Significantly, this functionality is thoughtfully extended to users with disabilities, facilitating the delivery of accessible content that caters to their specific needs.

Leveraging the web-based Metaverse studio, users can seamlessly create interactive virtual experiences infused with 3D objects, animations, multimedia, and interactive elements. These immersive AR encounters invite learners to proactively explore and engage with content, nurturing a hands-on approach that fosters curiosity and inquiry, promoting inquiry-based learning.

Metaverse offers a diverse set of advanced features that empower authors to construct interactive challenges and puzzles, enriching problem-solving experiences. This inclusive toolkit encompasses support for variables, user properties, inventory, items, time controls, and more. By seamlessly incorporating these problem-solving elements, learners are prompted to apply their knowledge and critical thinking skills to navigate solutions. The app's design actively encourages active experimentation, emboldening learners to explore diverse approaches, test hypotheses, and refine their comprehension—a testament to effective problem-based learning.

Moreover, Metaverse provides an array of game-based blocks that seamlessly integrate into the created scenes. Beyond the aforementioned functionalities, it encompasses additional features such as dice rolls, bonus points, leaderboards, RPG-related blocks, user lives administration, and the capability to award points or shields, among other options. These gamification assets unlock the potential for crafting intricate AR mobile educational games, thereby providing comprehensive support for game-based learning initiatives. Table 3.2, below, provides a succinct overview of Metaverse's diverse functionalities.

Table 3.2 Metaverse functionality and characteristics

Metaverse								
Platforms		**Pricing**	**Ease of use**	**Gamification Elements**	**Collaboration**	**Asset Library**	**Interactivity**	**AR Triggering**
Android, iOS		Free	High	✓	---	✓	✓	QR Code
Augmentation								
Text	**Image**	**Sound**	**Video**	**360 Video**	**3D Models**	**Links**	**AR Scenes**	**Animation Effects**
✓	✓	---	✓	✓	✓	✓	✓	---

Related links:

Cost: Free of use

Link: https://studio.gometa.io/landing

Tutorials: https://community.gometa.io/

https://studio.gometa.io/learn

Platforms: Android mobile App

https://play.google.com/store/apps/details?id=com.gometa.metaverse&hl=en_US

Online authoring tool https://studio.gometa.io/landing

YouTube: https://www.youtube.com/channel/UCum7uPJBXug0HfqNi4AfQmQ

Facebook: https://www.facebook.com/gometainc/

3.3 AR – media

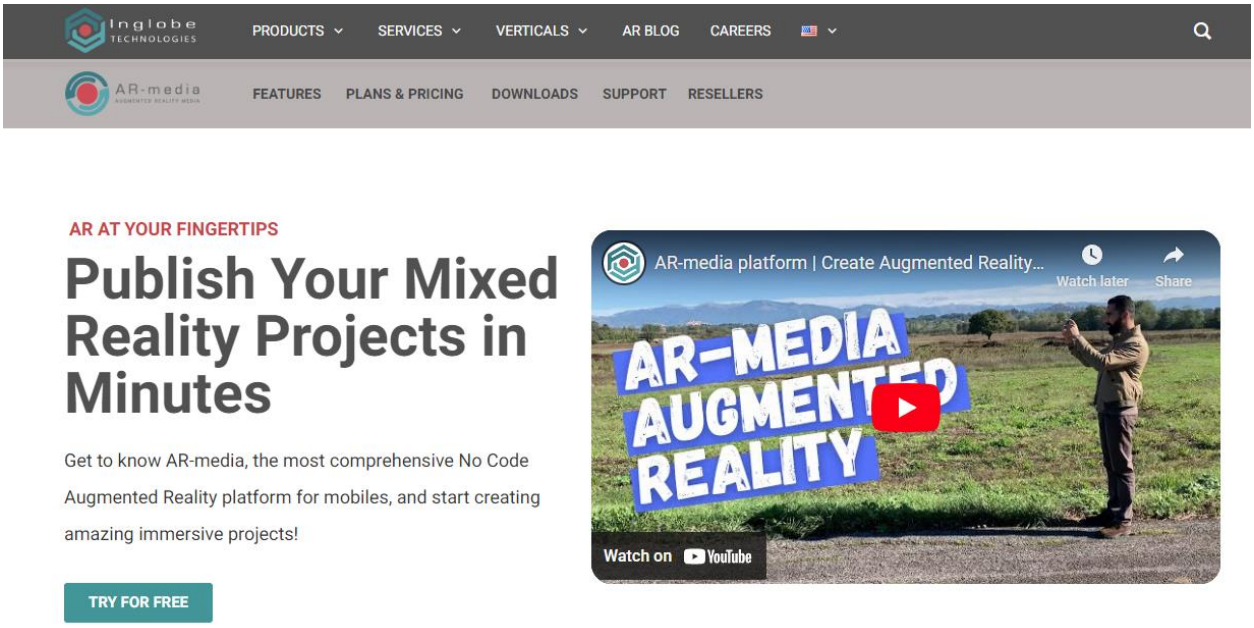

Figure 3.6 AR-media Web Page

This platform offers a comprehensive suite for designing, implementing, and sharing creations, enabling the realization of immersive experiences without the need for coding. It excels in crafting compelling Mixed Reality Experiences, finely tuned for both iOS and Android devices. With this versatile platform, users effortlessly access an extensive repository of AR digital assets. These encompass an array of components such as 3D models, animations, images, videos, 360-degree content, and audio files. The system supports integration with popular design software like Trimble SketchUP and Autodesk 3ds Max through dedicated plugins.

Highlighted within Figure 3.7 are several examples of augmentations produced through AR-media.

AR-media proves its flexibility by supporting the creation of mini games and apps (utilizing HTML5) alongside data collection and analytics. Specifically, users can upload assets to their private area within the system through the Asset Manager. Subsequently, they can initiate projects and curate new experiences within each project. For each experience, users have the option to choose between AR, 360, or HTML5 formats (Fig. 3.8).

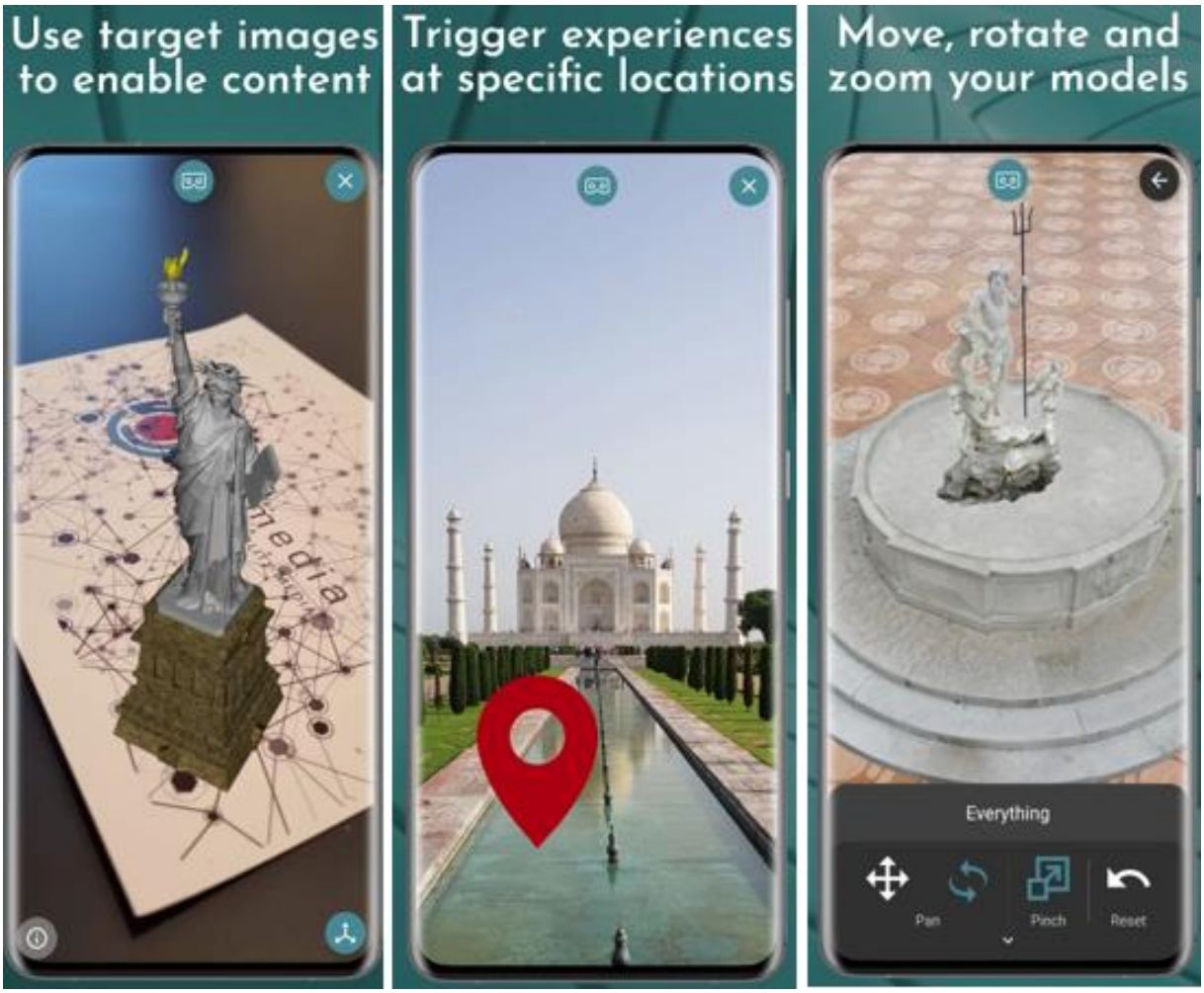

Figure 3.7 AR-media mobile app

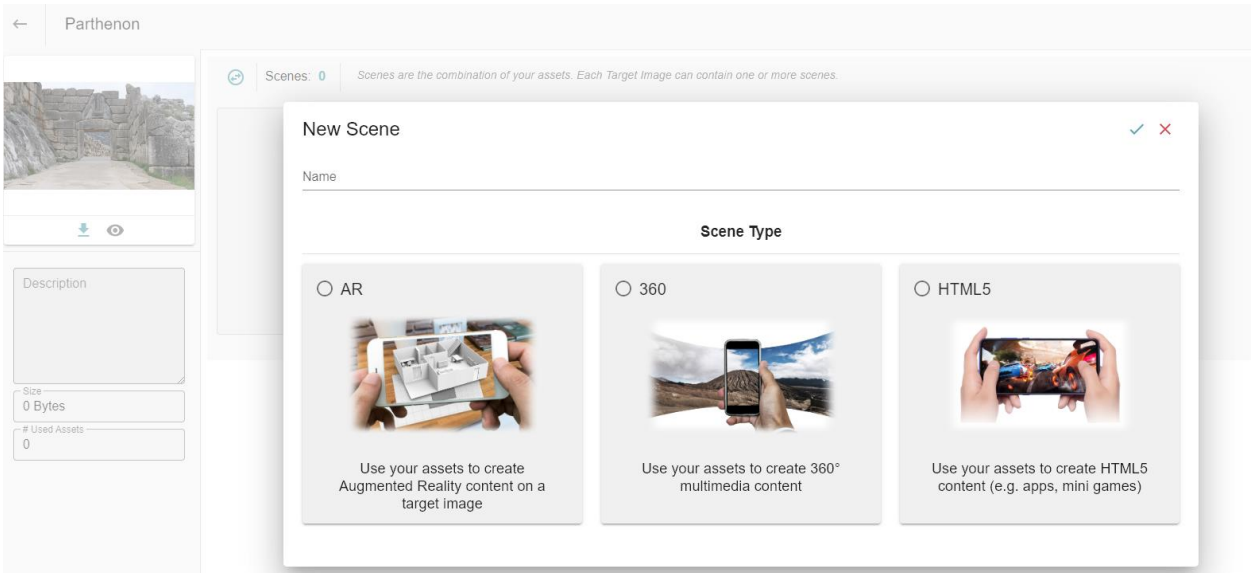

Figure 3.8 AR-media Scene available types

A standout attribute of this specific system lies in its unwavering support for a multifaceted range of learning methodologies. These encompass inclusive learning, inquiry-based learning, problem-based learning, and game-based learning. The platform serves as a vanguard for inclusive learning, thoughtfully catering to diverse audiences, including individuals with disabilities or special needs. It achieves this by presenting educational content through an array of alternative media, ensuring accessibility and equity for all.

In the realm of inquiry-based learning and problem-based learning, the system shines through various distinctive features. Notably, educators are empowered to forge collaborative workgroups among students (Fig. 3.9), fostering an environment that kindles teamwork and collective exploration. This collaborative dynamic catalyzes inquiry-based learning, inspiring students to embark on shared investigations into topics of mutual interest. Moreover, the platform becomes a conduit for problem-based learning, offering students the opportunity to collaboratively tackle intricate tasks and construct their own experiences guided by the parameters set forth by their instructors, transforming the learners from passive individuals to active content creators.

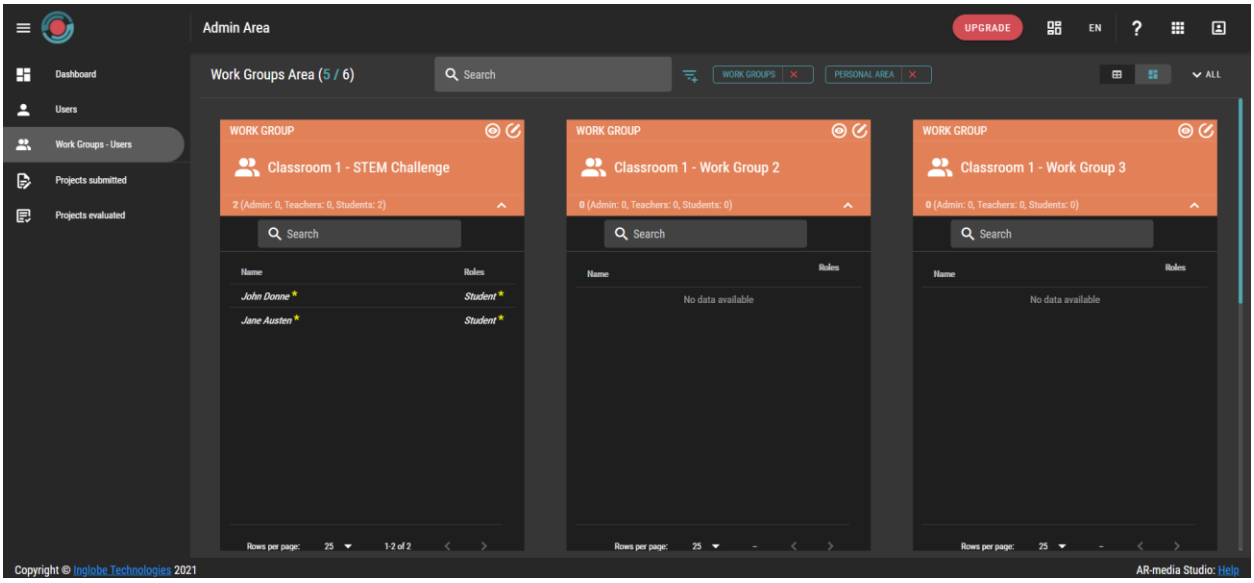

Figure 3.9 List of workgroups and their composition

(Source: https://www.inglobetechnologies.com/ar-media/documentation/ar-media-plans-for-education/)

Expanding its capabilities further, the platform features an authoring application that empowers users to craft mini HTML5 games. These games can integrate into diverse game-based learning activities. Notably, the platform introduces QR code-enabled games, infusing the learning experience with interactivity and gamified elements. This strategic fusion significantly elevates student engagement and motivation, rendering learning a captivating endeavor. Table 3.3 presents a comprehensive overview of ARMedia's functionality.

Table 3.3 AR-media functionality and characteristics

AR Media								
Platforms		**Pricing**	**Ease of use**	**Gamification Elements**	**Collaboration**	**Asset Library**	**Interactivity**	**AR Triggering**
Android, iOS		Free & paid	High	Through HTML5 apps	Student Workgroups	✓	✓	Image, Spatial
Augmentation Types								
Text	**Image**	**Sound**	**Video**	**360 Video**	**3D Models**	**Links**	**AR Scenes**	**Animation Effects**
✓	✓	---	✓	---	✓	HTML5 apps	✓	---

Related links

Cost: Free with limitations (1 project per account, 10 experiences per project, 500MB storage available, support for 3D Models, Media Files, Tracking, Event manager). Additionally, low-cost student and teacher plans are available.

Link: *https://www.inglobetechnologies.com/ar-media*

Tutorials: https://www.youtube.com/watch?v=0MEQj8c6PJU&list=PL203AE3371D6C8C05

Platforms: Android mobile App

https://play.google.com/store/apps/details?id=com.inglobetechnologies.ARMediaPlayer

iOS mobile App https://apps.apple.com/us/app/ar-media-player/id502524441

HUAWEI app gallery https://appgallery.huawei.com/#/app/C103136841

Trimble SketchUP Exporter

https://extensions.sketchup.com/extension/1a70d71a-732a-40e4-b362-a471a9b2d2c1/ar-media

Autodesk 3ds Max

https://apps.autodesk.com/3DSMAX/en/Detail/Index?id=4081607145537256692

YouTube: https://www.youtube.com/user/inglobe

Facebook: https://www.facebook.com/inglobe

3.4 BlippAR

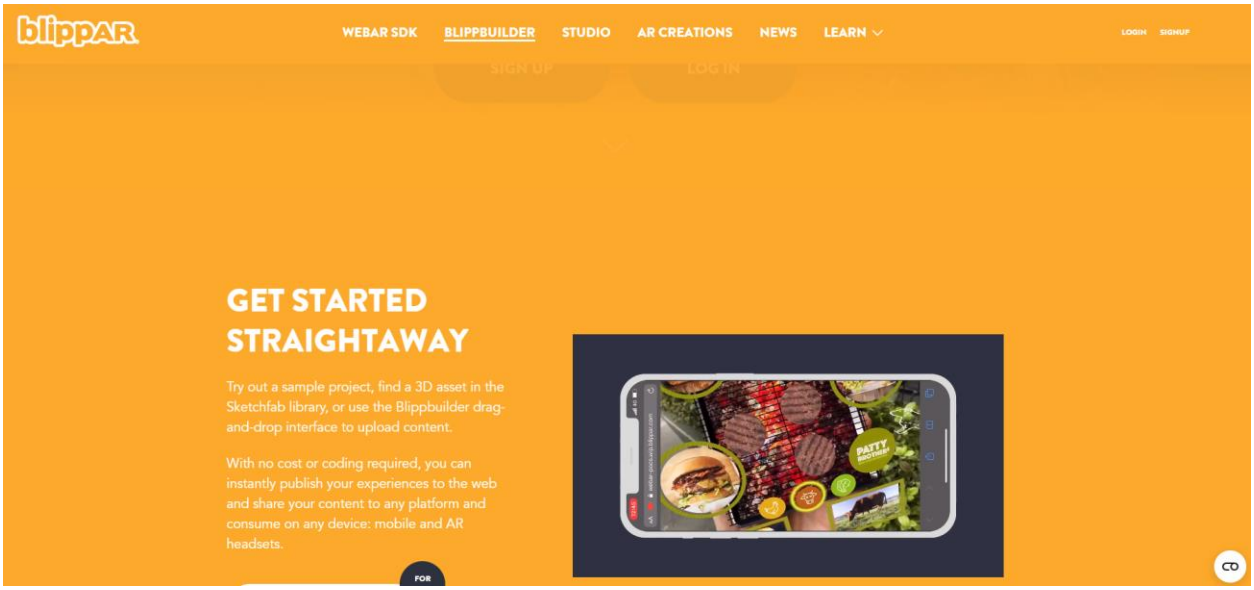

Figure 3.10 BlippAR Web Page

Blippar's AR Suite stands as an extensive toolkit meticulously crafted to empower users in the creation and deployment of augmented reality experiences. This comprehensive suite includes a variety of features, including image recognition, object recognition, visual search, and AR content creation tools.

Blippbuilder is one of the standout tools within the suite, a user-friendly web-based application that simplifies the process of developing and managing AR content. With the drag-and-drop interface, users can add interactive elements like animations, videos, and 3D models to their AR experiences. Blippbuilder operates within an integrated web environment (Fig. 3.11), which facilitates seamless content creation. Moreover, Blippbuilder offers a diverse selection of widgets (Fig. 3.12), encompassing audio, gallery, email, social media, and go-to-scene functions. These versatile widgets infuse AR content with added functionality, thereby enriching the overall interactive experience.

Another remarkable facet of BlippAR lies in its support for the implementation of complex scenes with multiple assets. The "Animation layers" functionality empowers users to create dynamic animation effects for their assets. This strong feature allows precise control over the timing, placement, and behavior of each object within the scene. With the ability to apply effects like movement, rotation, scaling, fading in and out, and more, the visual experience is elevated.

Much like ARTutor, BlippAR allows authors to define specific actions triggered by clicks on AR objects. Notably, BlippAR supports the execution of various widgets as part of these actions.

Figure 3.11 Blippbuilder environment

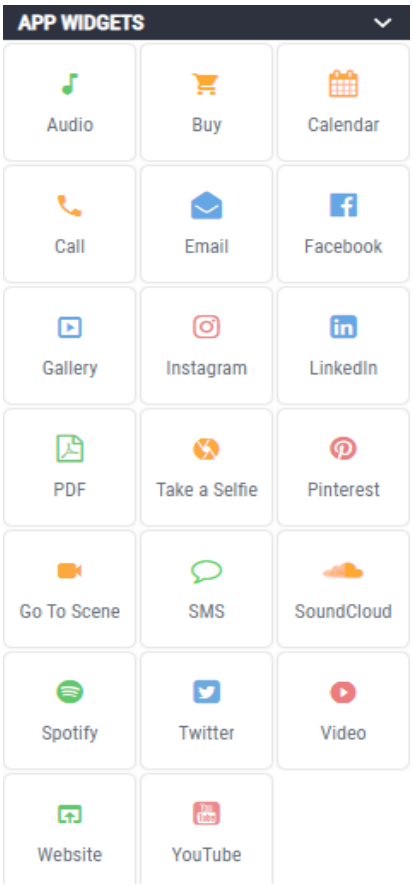

Figure 3.12 Blipparbuilder widgets

BlippAR emerges as a versatile platform that seamlessly accommodates the entire spectrum of requested learning methodologies. By enabling the creation of AR interactive experiences, it inherently fosters problem-based and inquiry-based learning paradigms. Moreover, authors find themselves empowered to curate captivating game-based learning activities, ingeniously harnessing the potential of AR technology to deliver educational content in an engaging and interactive format. A noteworthy aspect of BlippAR lies in its extensive array of interactions, paving the way for diverse scenes tailored to user choices. This dynamic functionality extends its utility to inclusive learning and problem-based learning scenarios, forging pathways to personalized experiences that cater to the unique needs of each learner. Table 3.4 presents the summarized functionality of BlippAR.

Table 3.4 BlippAR functionality and characteristics

Blippar								
Platforms		**Pricing**	**Ease of use**	**Gamification Elements**	**Collaboration**	**Asset Library**	**Interactivity**	**AR Triggering**
Android, iOS		Free & paid	High	Manually by the user	---	✓	✓	Image, 3D Object, Spatial, Around the user
Augmentation Types								
Text	**Image**	**Sound**	**Video**	**360 Video**	**3D Models**	**Links**	**AR Scenes**	**Animation Effects**
✓	✓	✓	✓	---	✓	Widgets	✓	✓

Related Links

Cost: Free only for testing purposes

Link: https://www.blippar.com/

Platforms: Android mobile App

https://play.google.com/store/apps/details?id=com.blippar.ar.android

Blippbuilder authoring tool https://www.blippar.com/build-ar

Tutorials: https://www.blippar.com/learn/ar-learn/getting-started

https://docs.blippar.com/blippbuilder-documentation/

YouTube: https://www.youtube.com/user/blippar1

Facebook: https://www.facebook.com/blippar

3.5 JigSpace

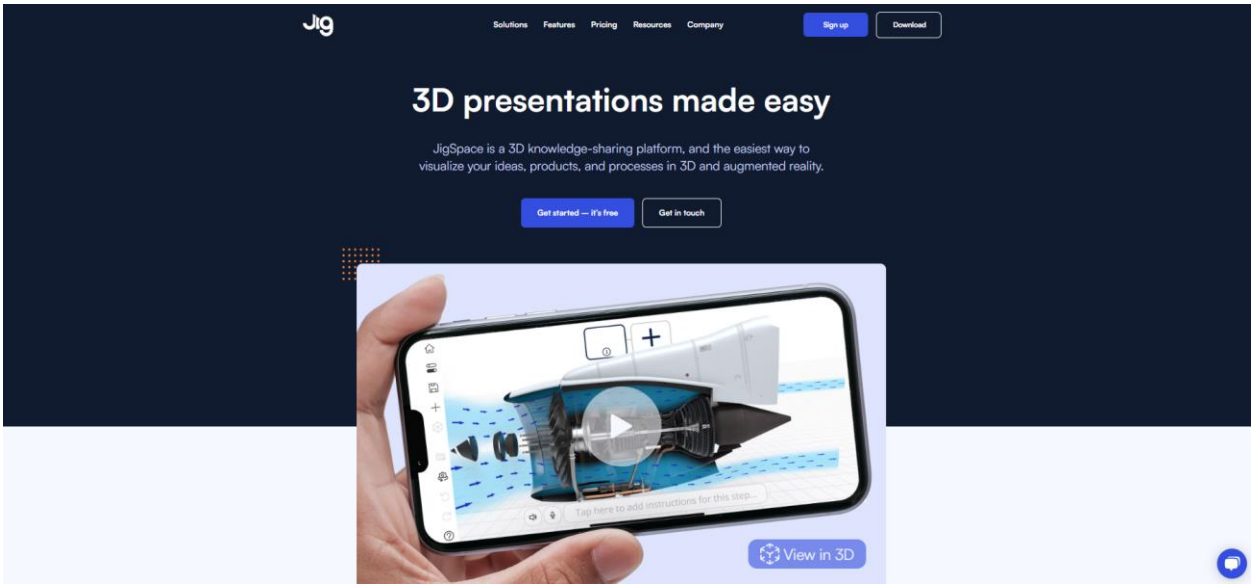

Figure 3.13 JigSpace Webpage

JigSpace stands as an application harnessing the power of AR technology to forge captivating and interactive learning environments. By seamlessly integrating 3D animations, videos, interactive simulations, descriptive tags, and more, it unlocks a realm where users can delve into an extensive spectrum of subjects. From the realms of science and technology to the realms of art and history, JigSpace seems to support inquiry-based learning.

An important feature of JigSpace is its capability to offer users a hands-on experience of the subjects they are studying. With detailed instructions and explanations, comprehension and knowledge retention become seamless for users. Additionally, JigSpace enables users to develop and share their own dynamic 3D models, promoting problem-based learning through an integrated environment (Fig. 3.14). Furthermore, JigSpace facilitates collaborative learning by incorporating team formation functionality. This feature allows any team member to view private content, while editors of a Jig (AR experience) can grant edit access to the rest of the team, encouraging collaboration and knowledge sharing.

Following suit with other AR systems, JigSpace provides a multi-sensory experience tailored to accommodate diverse learning styles and abilities. As the AR tool championed in its guide, JigSpace boasts support for the most formats, ensuring accessibility across various platforms and formats, including mobile apps, WebAR, and desktop apps for Windows and Mac (Fig. 3.15). This broad accessibility expands its user base significantly, fostering inclusive learning experiences. Notably, authors find it effortless to customize their Jigs to deliver game-based learning activities, further enriching the learning journey for end users.

Table 3.5 summarizes the functionality of JigSpace.

Figure 3.14 JigSpace workshop layout

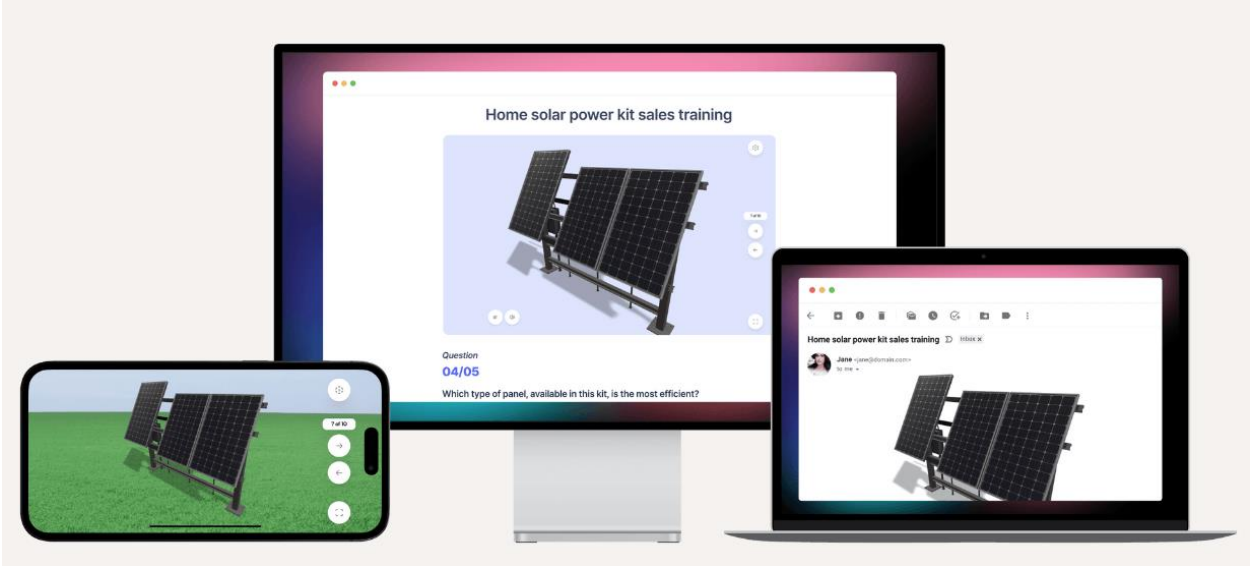

Figure 3.15 List of workgroups and their composition
(Source: https://www.jig.space/use-cases/training-support)

Table 3.5 JigSpace functionality and characteristics

JigSpace								
Platforms		**Pricing**	**Ease of use**	**Gamification Elements**	**Collaboration**	**Asset Library**	**Interactivity**	**AR Triggering**
Android, iOS, Windows, MacOS, WebAR		Free & paid	High	Manually by the user	✓	✓	✓	QR Code
Augmentation Types								
Text	**Image**	**Sound**	**Video**	**360 Video**	**3D Models**	**Links**	**AR Scenes**	**Animation Effects**
✓	✓	✓	✓	---	✓	✓	✓	✓

Related links

Cost: Free for testing purposes. Paid versions include increased functionality.

Link: *https://jig.space/*

Platforms: iOS, MacOS and Windows https://www.jig.space/download

Tutorials: https://www.jig.space/tutorials

YouTube: https://www.youtube.com/c/JigSpace

Facebook: https://www.facebook.com/JigSpace/

3.6 Discussion

Section three introduced a range of AR authoring tools and applications well-suited for educational purposes. A comprehensive comparison of their individual attributes is presented in Table 6. These tools collectively empower users to effortlessly craft AR experiences. While each tool boasts distinctive functionalities, they also share common features, including domain independence and support for image and text augmentations. Notably, both ARTutor and Metaverse stands out as entirely free options, granting unfettered access to their full suite of functionalities. Conversely, the remaining systems offer limited free access.

The selection of a particular system hinges upon the intended use. For instance, should educators or students seek to augment existing educational content, such as a school textbook, the optimal choices would be ARTutor, AR-media, or BlippAR, as only these tools support image AR triggering. On the other hand, those aiming to effortlessly create scenes while incorporating gamification elements would find Metaverse to be the most fitting option. It's worth noting that ARTutor also lends itself to manual enhancements in this domain. For scenarios where simplicity reigns supreme, especially when students transition into content creators, ARTutor emerges as the optimal choice, thanks to its user-friendly platform.

An overarching recommendation suggests that users, particularly students, seeking a blend of simplicity and robust functionality may find satisfaction in either ARTutor or Metaverse. Educators, who may require more intricate tools and are willing to invest, could explore BlippAR or JigSpace, with AR-media occupying a middle ground between the two.

Table 3.6 Comparison of AR Tools characteristics

Characteristics		AR Tools				
		ARTutor	Metaverse	AR Media	Blippar	JigSpace
End User Platforms	Android	✓	✓	✓	✓	---
	iOS	✓	✓	✓	✓	✓
	Windows	---	---	---	---	✓
	MacOS	---	---	---	---	✓
	WebAR	---	---	---	---	✓
Pricing		Free	Free	Free & paid	Free & paid	Free & paid
Domain		Independent	Independent	Independent	Independent	Independent
Ease of use		Very High	High	High	High	High
Gamification Elements		Manually by the user	✓	Through HTML5 apps	Manually by the user	Manually by the user
Collaboration		✓	---	Student Workgroups	---	✓
Asset Library		---	✓	✓	✓	✓
Interactivity		✓	✓	✓	✓	✓
AR Triggering		Image, GPS	QR code	Image, Spatial	Image, 3D Object, Spatial, Around the user	QR code
Augmentation Types	Text	Through AR Scene	✓	✓	✓	✓
	Image	✓	✓	✓	✓	✓
	Sound	✓	---	✓	✓	✓
	Video	✓	✓	✓	✓	✓
	360 Video	---	✓	---	---	---
	3D Models	✓	✓	✓	✓	✓
	Links	✓	✓	HTML5 apps	Widgets	✓
	AR Scenes	✓	---	✓	✓	✓
Animation Effects		---	---	---	✓	✓

4 Virtual Reality Authoring Tools

4.1 ArtSteps

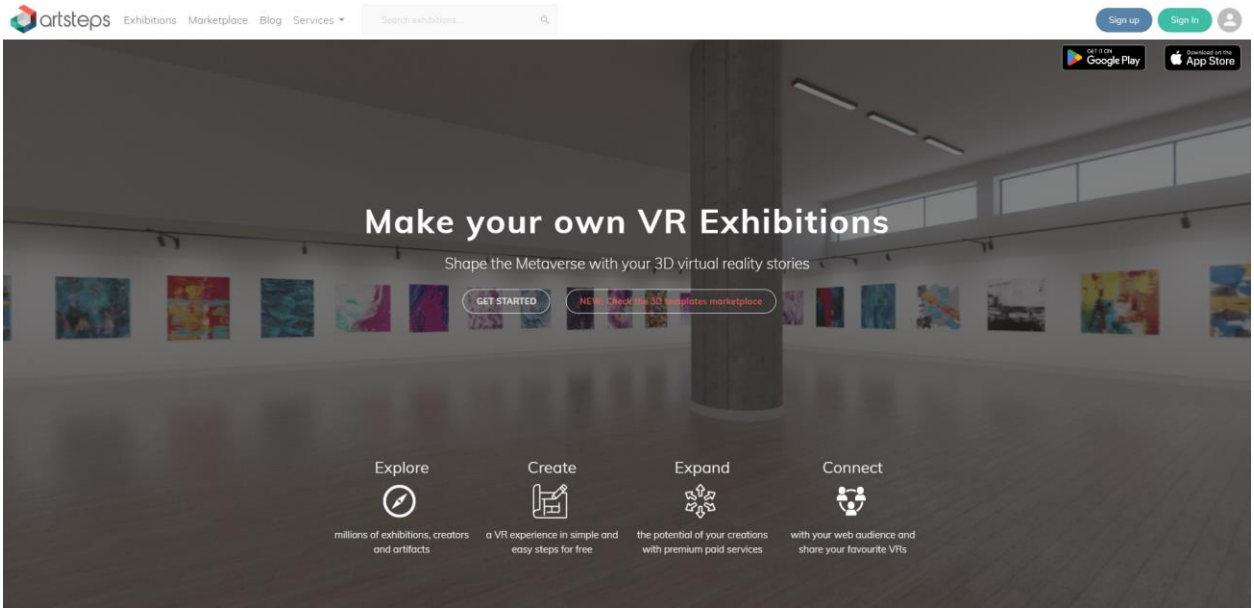

Figure 4.1 ArtSteps landing page

ArtSteps is available to artists, curators, and gallery owners, thanks to its user-friendly interface that doesn't require any technical expertise. Moreover, it offers a variety of options, including the ability to add interactive components like information panels and films, as well as customize lighting, wall colors, and floor textures.

With this tool, you can effortlessly create virtual spaces using the user-friendly editor. You can craft your own scripts, stage narratives, or virtual stories, showcase your work within a virtual 3D environment, connect with individuals around the world, and engage in a unique online experience.

ArtSteps promotes inclusive learning by providing a virtual environment for students to engage with art and cultural experiences, irrespective of their physical abilities or geographical location. Through its utilization of VR technology, learners can readily immerse themselves in the platform, enabling students to explore and appreciate art without encountering physical barriers.

Inquiry-based learning is supported by encouraging students to explore and investigate artworks within its virtual spaces. It empowers students to engage in self-directed experiences, fueled by their innate curiosity and interests. They can decide how they wish to approach the artworks on their own terms, thus navigating the 3D museum spaces at their own pace.

Given that ArtSteps permits users to construct their own art exhibitions, curate displays, or create art-related design projects, it effectively stimulates problem-based learning through teamwork and decision-making skills. ArtSteps empowers you to showcase your space within a virtual reality environment, delving into personal stories and sharing your narratives with a global audience. Users can upload their artwork, arrange it within a virtual setting, and manipulate lighting and settings to provide viewers with an immersive and captivating experience.

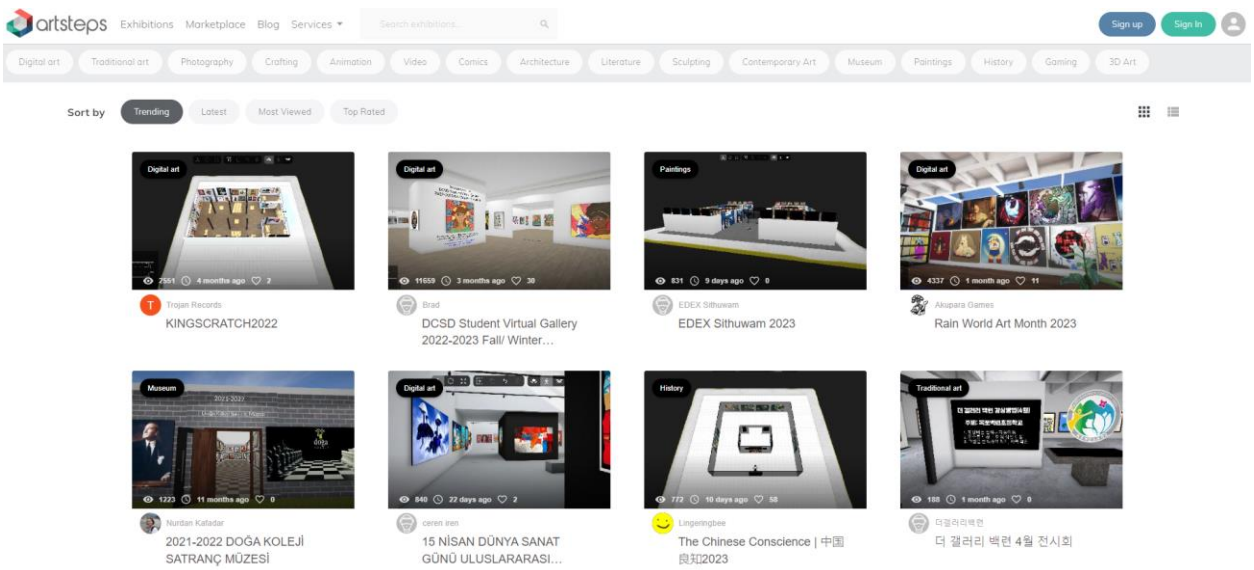

Figure 4.2 ArtSteps gallery of projects

Thanks to the ability to incorporate gamification elements, ArtSteps can facilitate virtual quests, puzzles, quizzes, or challenges within different VR scenarios. Additional game mechanics like scoring systems, rewards, and progression further serve to motivate learners, encouraging their active participation and task completion.

As a web-based tool, ArtSteps offers easy accessibility. Its educational emphasis primarily revolves around its capabilities as a visual aid tool, rather than simulating intricate interactivity. Nevertheless, it does cultivate a sense of curiosity by providing users with visual incentives through compelling yet straightforward scenarios that can be created using this tool. Furthermore, ArtSteps supports reflective art exhibitions on various topics. For example, some of the projects already available on their website include exhibitions that raise awareness on climate change and provide support to refugee families.

ArtSteps promotes communication among its users by fostering a community through its website. Creators can host and share their exhibitions with other users, facilitating the exchange of ideas and experiences.Table 4.1 summarizes the functionality and characteristics of ArtSteps.

Table 4.1 ArtSteps functionality and characteristics

Artsteps								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android, web-based.	Oculus Go, Rift, Quest, HTC vive. Mobile VR goggles, pico headsets.	Free version and paid versions	Independent	Limited	Manually by the user	High	✓	Annotations, Map, Guided tour, Spatial design, Chat function.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	---	✓	✓	---

Related links

Cost: Free

More details: *https://www.artsteps.com/*

Link: https://www.artsteps.com/

Tutorials: **https://blog.artsteps.com/**

YouTube: **https://www.youtube.com/user/ArtstepsCom**

Facebook: **https://www.facebook.com/ArtSteps/**

4.2 ThingLink

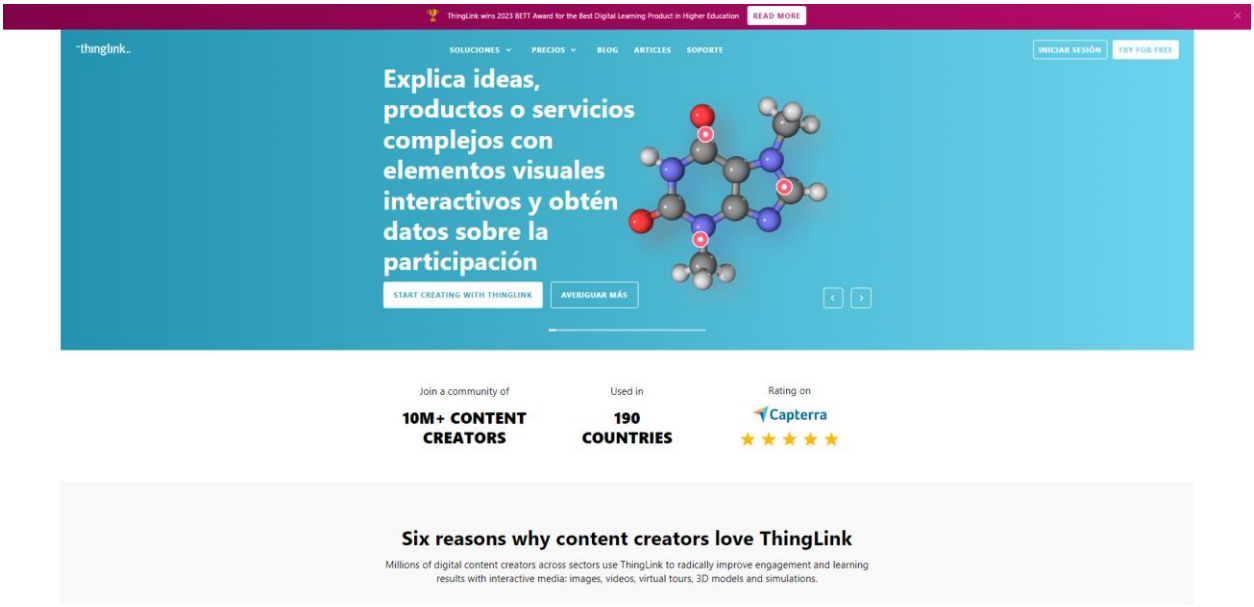

Figure 4.3 ThingLink landing page

ThingLink is an acclaimed education technology platform that simplifies the augmentation of images, videos, and virtual tours with additional information and links. Its iOS and Android mobile apps provide access to the ThingLink browser editor experience and all your content on the go, making it ideal for tablet-centric schools and interactive projects beyond the classroom. One of ThingLink's primary advantages is its user-friendliness, enabling individuals without coding experience to utilize it effectively. Furthermore, the platform offers a range of integrations with well-known platforms.

Thanks to its versatility, educators can craft interactive content that caters to a wide spectrum of learners. Interactive images and videos can be accessed via computers, tablets, and smartphones. This flexibility ensures that students with varying abilities can engage with the content, and the inclusion of text descriptions or audio further enhances accessibility for impaired students.

Learners have the freedom to explore and navigate through content independently, thanks to creators being able to infuse interactivity by adding additional information and links to specific spatial points within the VR scenario.

Virtual walk-throughs and tours grant students access to real-world environments and situations that might otherwise be beyond their reach. Interactive 360° images and videos foster contextual understanding, develop academic vocabulary, and cultivate skills related to remote locations, cultures, work environments, or social situations. Users can leverage pre-existing content from diverse sources or upload their own 360-degree content.

The platform's capacity to embed various challenges, puzzles, or problems requires students to analyze, synthesize, and apply their knowledge to solve real-world or discipline-specific problems.

ThingLink facilitates game-based learning by enabling the creation of interactive experiences that simulate game-like interactions. Educators can design interactive quizzes, puzzles, or challenges

within images or videos. Students can engage with the content, respond to questions, solve problems, or complete tasks, earning points or rewards. This gamified approach heightens student motivation, engagement, and knowledge retention.

From an educational standpoint, ThingLink offers an effective means of incorporating essential information into any experience intended for potential users. It can enhance any virtual environment previously established in Unity, affording a high level of customization and interactivity to convey intricate procedures in training or simulations.

The 360-degree footage can be enriched with various interactive features from ThingLink, including hotspots, links, videos, and music, to deliver a more captivating and immersive experience. Users can further personalize their VR experience by incorporating their own logos, fonts, and colors.

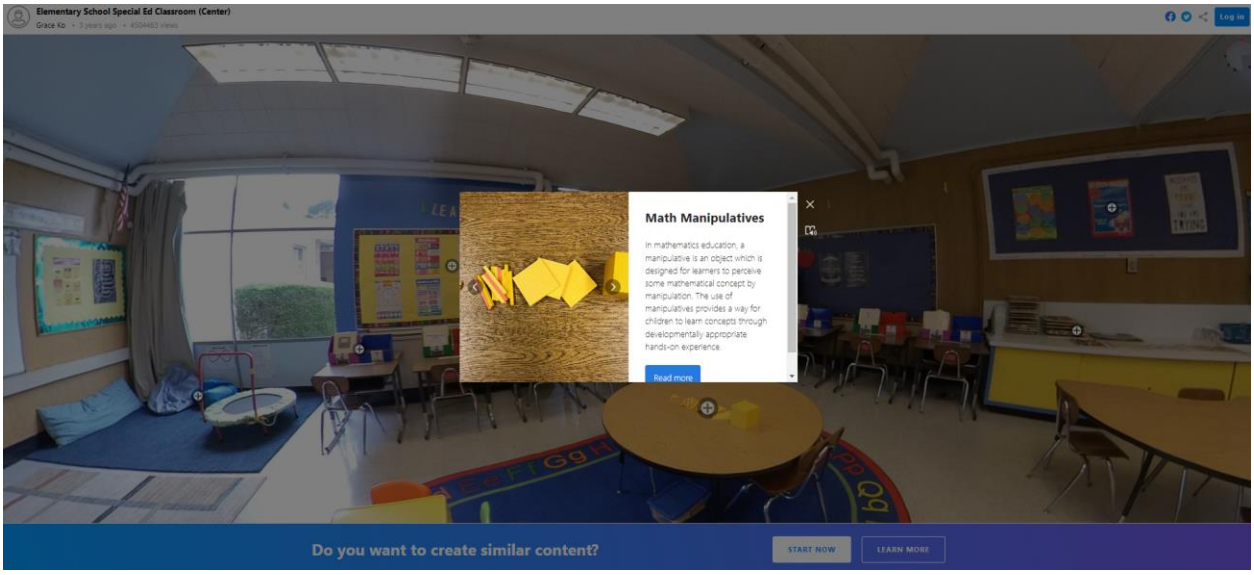

Figure 4.4 Screen from a Thinglink application

The Table 4.2 presents a comprehensive overview of Thinglink's functionality.

Table 4.2 Thinglink functionality and characteristics

Thinglink								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android, web-based, Windows and Mac.	Oculus Go, Rift, Quest, HTC vive. Mobile VR goggles, pico headsets.	Free and paid versions	Independent	✓	Manually by the user	High	ü	Annotations, Maps, Graphs, Presentations, Simulations.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	✓	✓	✓	✓

Related links

Cost: Professional Teacher License (Starting at $35/year), Premium Education License (Price per user seat: $2/year - Minimum order 500 seats), Academic Enterprise License (Price per user seat: $9/year - Minimum order 250 seats)

Link: https://www.thinglink.com/edu

Tutorials: https://www.thinglink.com/blog

YouTube: https://www.youtube.com/channel/UCoEFzyhf3bB8OyfNfHeuasQ/videos

Facebook: https://www.facebook.com/ThingLink/

4.3 CoSpaces Edu

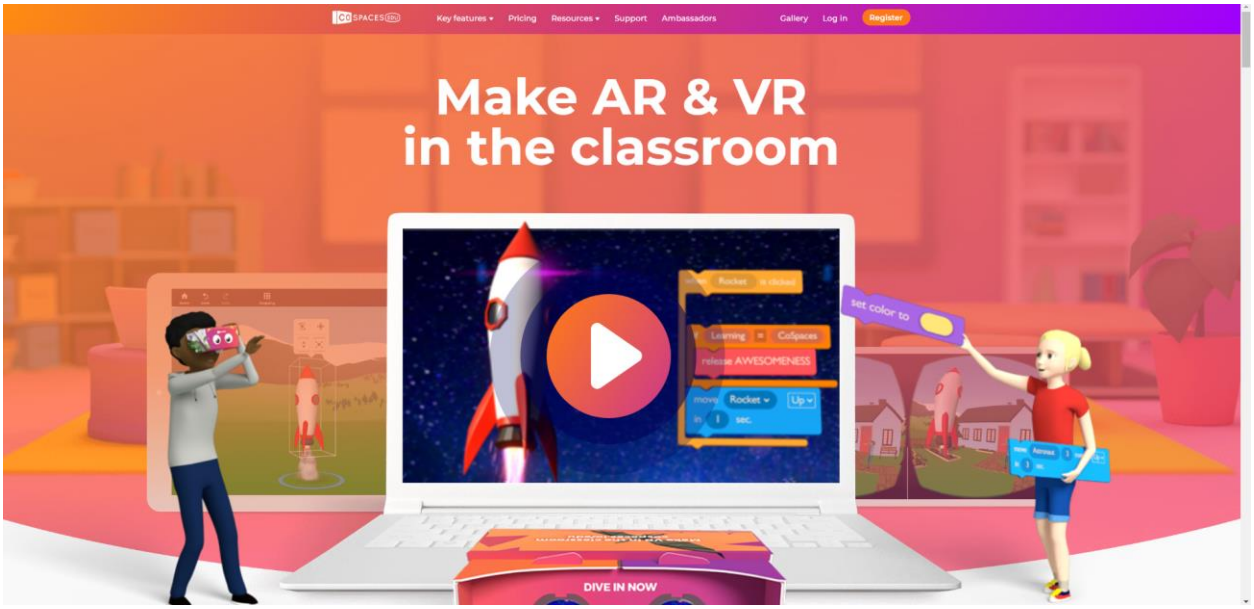

Figure 4.5 CoSpaces Edu landing page

CoSpaces Edu is an online platform designed for kids, ideal for learning at home on any device. It empowers students to create virtual scenes and construct 3D building blocks from basic geometric forms. Additionally, students can engage in block-based coding or advanced scripting to introduce interactions within their virtual world, which can later be explored in VR or AR settings. This tool also enables teachers to manage classes, facilitate student collaboration, and view real-time progress.

With CoSpaces Edu users can generate and share dynamic 3D settings and experiences. Geared primarily toward educational applications, it empowers educators and students to craft captivating learning experiences spanning diverse subjects such as science, history, and the arts.

CoSpaces Edu boasts compatibility with various devices, including VR headsets, computers, tablets, and smartphones. Its flexibility extends to multi-language support, facilitating access and interaction with the content for students from different linguistic backgrounds and greatly promoting inclusive learning.

CoSpaces Edu nurtures students' creativity and design thinking by prompting them to generate content rather than merely consume it. Crafting their own virtual worlds equips students with creativity, critical thinking, problem-solving, and design thinking skills. They cultivate their innovative faculties and acquire the ability to express their ideas in original ways, honing their skills in designing, refining, and perfecting their creations. CoSpaces Edu empowers students to construct and interact with 3D environments, enabling experiential learning. They can simulate scientific experiments, historical events, or intricate concepts that can be challenging to grasp within traditional classroom settings.

CoSpaces Edu encourages students to incorporate objects, characters, and interactive components into their scenes, inspiring them to design their own virtual realms using visual programming blocks to imbue behaviors and interactions. This approach fuels their curiosity,

motivating them to seek answers to their own questions. Through collaboration, users can collectively address genuine problems within a virtual domain, fostering inquiry-based learning.

Figure 4.6 Authoring at CoSpaces Edu

Students have the ability to create games within the VR environment using visual programming blocks or JavaScript coding. They can craft levels, define objectives, and integrate challenges, puzzles, or quizzes. This gamified approach effectively incentivizes students to actively engage, apply their knowledge, and achieve specific goals, thereby boosting their levels of engagement and retention.

Through CoSpaces Edu intuitive drag-and-drop interface, users can swiftly generate and modify 3D environments, interactions, and objects. Moreover, it offers an array of coding tools that empower more experienced users to design intricate behaviors and logic.

CoSpaces Edu excels in adaptability, making it compatible with a variety of VR devices and platforms such as the Oculus Rift, HTC Vive, and Google Cardboard. This feature stands as a key advantage of the platform.

The platform's interdisciplinary potential is also noteworthy, as it enables cross-curricular integration. This means it can facilitate historical simulations, science experiments, storytelling, and an extensive range of experiences, all enhanced through interactivity.

CoSpaces Edu capitalizes on VR immersive technology to infuse learning with excitement and motivation. The interactive and immersive nature of virtual reality sustains students' active involvement in the learning process, amplifying their motivation, curiosity, and willingness to delve into complex subjects deeply. CoSpaces Edu functionality and characteristics are presented on Table 4.3.

Table 4.3 CoSpaces Edu functionality and characteristics

Cospaces edu								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android, web-based.	Oculus Go, Rift, Quest, HTC vive. Mobile VR goggles, pico headsets.	Free and paid versions	Independent	✓	Manually by the user	Very high	✓	Annotations, Map, Quizzes and assesment.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	---	✓	✓	✓

Related links

Cost: Basic version (Free) and Pro version (From $74.99 per year)

Link: https://cospaces.io/edu

Tutorials: https://cospaces.io/edu/pd-training.html

Twitter: https://twitter.com/cospaces_edu

Facebook: https://www.facebook.com/cospaces

4.4 Modest tree Xplorer

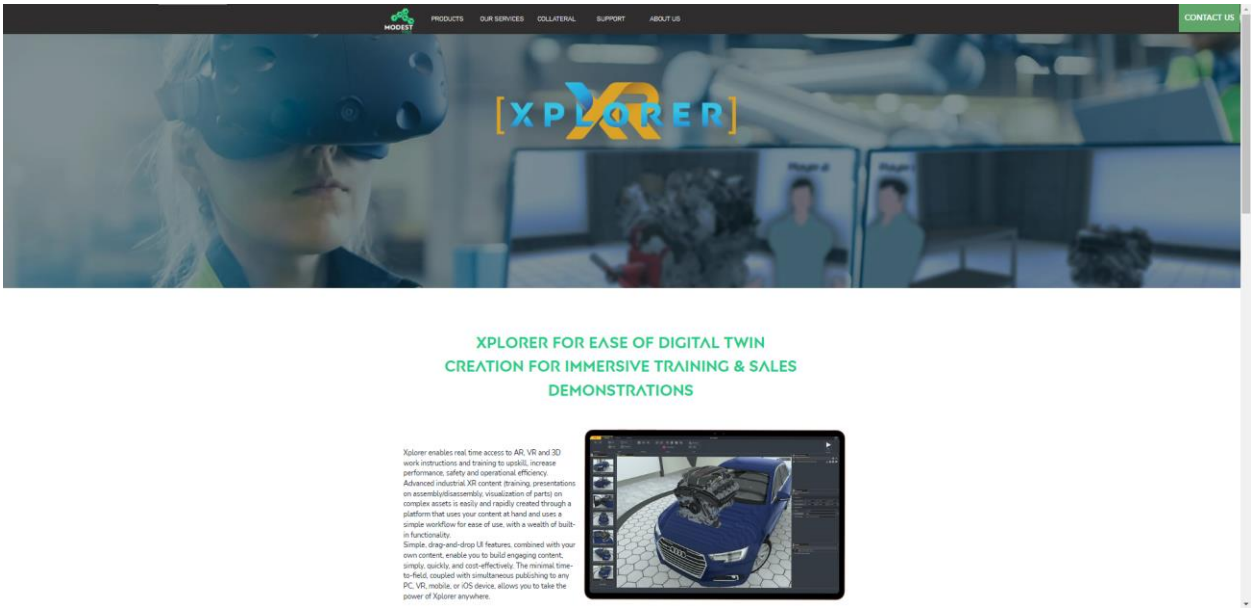

Figure 4.7 Modest tree Xplorer landing page

Users of Modest tree Xplorer (MtX) can import 3D models and utilize drag-and-drop features to build interactive scenarios and simulations. Moreover, the platform offers advanced functionalities such as scripting tools, physics engines, and multi-user support.

Modest Tree Xplorer empowers users to craft interactive 3D simulations and environments tailored for training and education. Its primary focus lies in sectors like aviation, defense, and medicine, where immersive training experiences are crucial.

A standout advantage of MtX is its ability to construct immersive, lifelike training environments that closely replicate real-world situations. This feature enables users to engage in practice within a controlled and monitored setting, reducing the potential for errors and accidents. The tool holds remarkable educational promise, particularly in delivering realistic training experiences with an emphasis on immersion and experiential learning.

It facilitates the creation of 3D, immersive, instructor-led courses that enable users to interact with challenging course content simultaneously from any location, utilizing the platform of their choice (PC, VR, iOS, or mobile). In conclusion, based on its functionality and characteristics (Table 4.4), MtX stands as a robust and versatile Virtual Reality Authoring Tool.

Table 4.4 Modest tree Xplorer functionality and characteristics

Modestree Xplorer								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android, Windows.	Oculus Rift, Quest, HTC vive, WMR, pico headsets.	Paid	Independent	Limited	Manually by the user	Mid	--	Drag and drop Ui, branching, assesment, Real-time feedback.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	---	✓	---	---

Cost: Paid, variable cost

Link: https://www.xplorer.studio/

Tutorials: https://www.youtube.com/channel/UCHnE4gddI0QpqT53HGHQPWA/featured

YouTube: https://www.youtube.com/channel/UCIazDGcuckFcM4jx4DUCdGA

Facebook: https://www.facebook.com/modesttree

4.5 CenarioVR

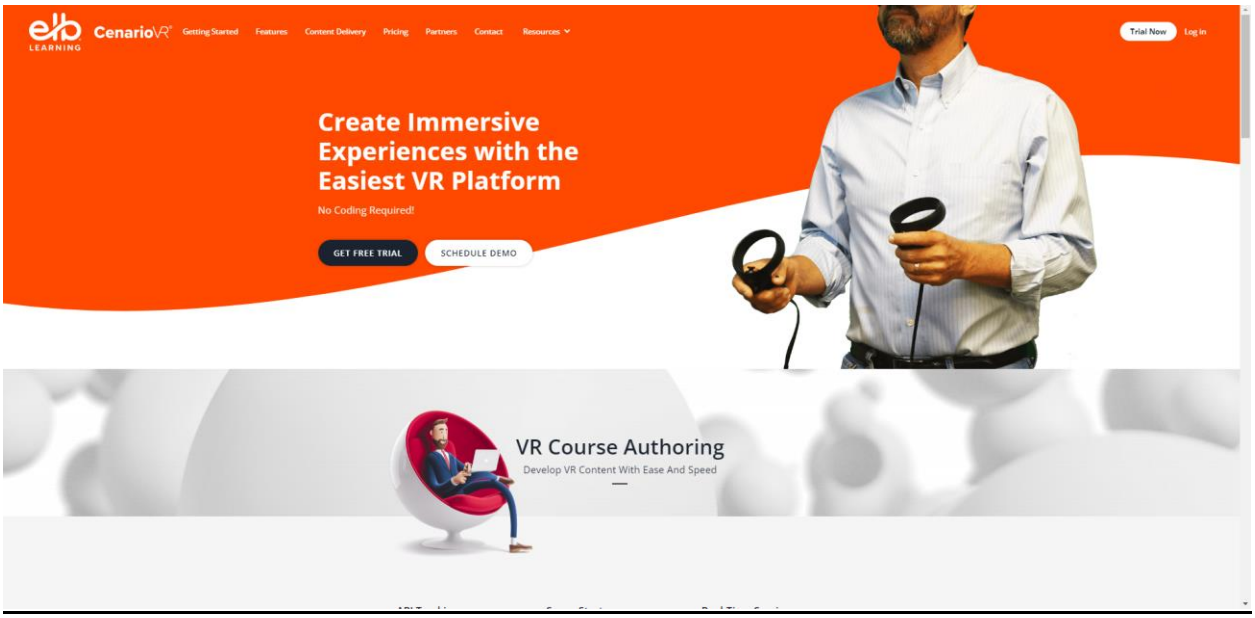

Figure 4.8 CenarioVR landing page

CenarioVR stands as a Virtual Reality Authoring Tool meticulously crafted to construct immersive and interactive training scenarios. Its primary utilization finds prominence in industries like healthcare, manufacturing, and emergency services, where the creation of lifelike and controlled training environments holds utmost importance.

Much like other major VR authoring tools, CenarioVR provides a conduit for experiential learning, offering users the opportunity to engage in situational experimentation within a 3D environment. This dynamic encourages iterative experiences and affords learners the chance to acquire knowledge within a secure space, thereby promoting inquiry-based learning.

By enabling students to fashion their own virtual realms, CenarioVR cultivates creativity, critical thinking, problem-solving prowess, and design thinking abilities. It empowers learners to harness their inventive faculties and express their ideas in innovative ways as they refine their creations. Notably, the platform allows for diverse forms of engagement, including conditional branching with varied outcomes, timed objects, actions, linked scenes, quizzes, multimedia, and hotspots.

Another feature of CenarioVR, among the others (seeTable 4.5) lies in its provision of timely feedback based on learners' choices and actions within the virtual realm. This real-time feedback mechanism facilitates an ongoing learning process by reinforcing appropriate behaviors and dispelling misconceptions. Additionally, educators can closely monitor student progress and effectively assess their performance, thus enriching the problem-solving and game-based learning experience.

Table 4.5 CenarioVR functionality and characteristics

CenarioVR								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android, Windows, Web.	Meta Quest and RIFT, lenovo Mirage S3, HTC Vive, Pico, Scorm, Igloo.	Paid	Independent	Limited	Manually by the user	Mid	--	conditional branching with varied outcomes, timed objects, actions, linked scenes, quizzes, multimedia, and hot spots.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	✓	✓	✓	Limited

Related links

Cost: Up to 100 Learners and 1 Author:

$399/mo, billed annually in USD.

Up to 250 Learners and 2 Authors:

$599/mo, billed annually in USD.

Up to 500 Learners and 5 Authors:

$799/mo, billed annually in USD.

Link: https://www.elblearning.com/create-learning/cenariovr

Tutorials: https://www.youtube.com/c/ELBLearning

YouTube: https://www.youtube.com/c/ELBLearning

Facebook: https://www.facebook.com/LectoraeLearning

4.6 Google Street View

Google street view offers a simple and familiar interface for new users, enabling even users with minimal technical skills to create impactful experiences.

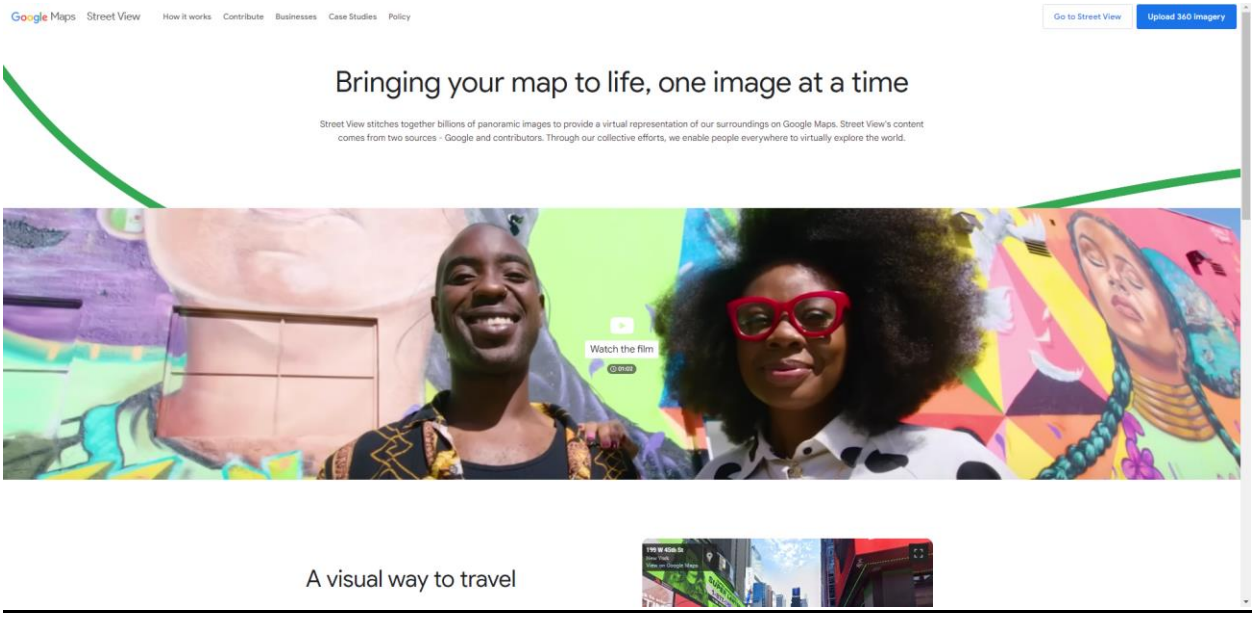

Figure 4.9 Google Street View landing page

Google Street View offers a unique chance to students to embark on virtual journeys around the globe, expanding their experiences by virtually visiting various locations. This is particularly beneficial for students with physical disabilities or limited mobility, as it grants them access to historical landmarks, museums, and natural wonders that might otherwise be challenging to experience.

This suggests a large potential of contributing to immersive learning in diverse cultural and geographical settings, igniting students' curiosity and motivation to learn about different places and their histories. Overall, it is feasible to think that this sparks a seed of curiosity in students and motivates inquiry-based learning.

Users can explore various sites all over the world with Google Street View, a potent and immersive tool. They are given the opportunity to observe and explore 360-degree panoramic views of roads, structures, and other sights. Google Street View is mostly utilized as a mapping tool, but it can also be used to create immersive, interactive videos. It is possible to create problem-solving scenarios based on realistic environments.

Its capability to record and present 360-degree panoramic views is one of its primary features that makes it a useful movie authoring tool. Because of this, users may produce immersive video experiences that can be viewed from any perspective.

It’s also possible to incorporate game-based learning by offering the students points and badges if they complete specific tasks or achieve certain objectives using, for example, Street View. These can also be supported by interactive quizzes related to them. Table 4.6 summarizes all the features and functionality of Google Street View.

Table 4.6 Google Street View functionality and characteristics

Google street view								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android, Web.	Oculus Rift, Quest, HTC vive, WMR, pico headsets.	Free	Independent	✓	Manually by the user	High	World locations	Virtual tours, 360 degree panoramic views.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	---	✓	✓	Limited

Related links

Cost: Free

Link: https://www.google.com/streetview/

https://www.google.com/streetview/contribute/

Tutorials: https://support.google.com/maps/?hl=en#topic=6275604

4.7 Discussion

Overall, the tools showcased in this section share many fundamental features that facilitate learning implementations in diverse settings. However, it is possible to identify which ones excel in specific criteria. In terms of developing serious simulations, Modest Tree Xplorer provides better support due to its inclusion of features that facilitate the creation of realistic virtual environments for training purposes. Users can interact with objects in these VR environments, enabling learning without the risks associated with real-world training. On the other hand, ArtSteps' primary focus is on virtual exhibitions and galleries, makes it an excellent tool for facilitating art education and exploration.

CenarioVR and ThingLink focus on immersive learning experiences and allow for the integration of gamification elements such as branching scenarios, quizzes, and assessments. They also offer the capability to create multiple interactive VR training modules and simulations. Google Street View benefits from its access to geographical data worldwide and opens up possibilities for learning in this context.

Table 4.7 provides a summary of characteristics for comparing the different tools available for VR.

Table 4.7 Comparison of VR tools

VR Tools		Artsteps	Thinglink	Cospaces Edu	Modest Xplorer	CenarioVr	Google street view
Platforms	Android	✓	✓	✓	✓	✓	✓
	iOS	✓	✓	✓	✓	✓	✓
	Windows	---	✓	---	✓	✓	---
	MacOS	---	✓	---	---	---	---
	Web	✓	✓	✓	---	✓	✓
Cost		Free & Paid	Free & Paid	Free & Paid	Paid	Paid	Free
Domain		Independent	Independent	Independent	Independent	Independent	Independent
Ease of use		High	High	Very high	Mid	Mid	High
Interactive features		Annotations, Map, Guided tour, Spatial design, Chat function.	Annotations, Maps, Graphs, Presentations, Simulations.	Annotations, Map, Quizzes and assesment.	Drag and drop Ui, branching, assesment, Real time feedback.	conditional branching with varied outcomes, timed objects, actions, linked scenes, quizzes, multimedia, and hot spots.	Virtual tours, 360 degree panoramic views.
Supported elements	Text	✓	✓	✓	✓	✓	✓
	Image	✓	✓	✓	✓	✓	✓
	Sound	✓	✓	✓	✓	✓	✓
	Video	✓	✓	✓	✓	✓	✓
	360 Video	---	✓	---	---	✓	---
	Links	✓	✓	✓	✓	✓	✓
	Templates	✓	✓	✓	---	✓	✓
Advanced scripting capabilities		---	✓	✓	✓	Limited	Limited
Collaboration		✓	✓	✓	Limited	Limited	✓
Gamification Elements		Manually by the user	✓	✓	Manually by the user	Manually by the user	Manually by the user

5 Immersive and Interactive Video Authoring Tools

Drastic improvements in affordable mobile technologies have sparked a growing interest in utilizing 360° videos in education. Unlike conventional videos, which offer a limited perspective, 360° videos provide a spherical view with multiple angles and perspectives. This enhances learners' sense of immersion (Ranieri et al., 2020) and creates the illusion that the experience surrounds them perceptually (Hodgson et al., 2019), leading to a heightened sense of presence. Furthermore, 360° videos positively impact emotional responses to the learning environment, offering cost-effective ways to enhance the effectiveness of e-learning (Lampropoulos et al., 2021). Immersive videos find various applications in education, including virtual field trips, interactive hands-on learning experiences, exploration of hazardous environments, language learning, simulations, and fostering creativity and critical thinking. Schoeffmann et al. (2015) classify video interaction methods in the following categories: Video Annotation, Video Browsing, Video Navigation, Video Editing, Video Recommendation, Video Retrieval and Video Summarization.

5.1 Insta360 Studio

Insta360 Studio, including the 2023 version, is a software application used to create and edit 360-degree videos. It allows users to import, edit, and export 360-degree footage, offering features like stitching, color correction, and motion tracking. It is typically utilized by videographers and photographers to create immersive video content for applications in virtual reality and other immersive media. Insta360 studio is a desktop software (Windows/Mac), available for users of Insta360 cameras, such as ONE RS/R, X3/ ONE X2/ONE X, GO 2, Sphere, EVO, GO, ONE, Nano S, Nano and Air. It is designed to be user-friendly and accessible to both novice and experienced video creators. On the other hand, Insta360 is a mobile app with full editing capabilities for Android and iOS platforms.

Figure 5.1. Insta360 interface

The software encompasses a range of features that empower users to enhance and edit their 360-degree videos, including:

- Stitching: the ability to seamlessly join multiple images and videos to create a cohesive and uninterrupted 360-degree video.
- Audio Editing: tools to adjust audio levels, incorporate background music, and integrate sound effects.
- Keyframe: it allows to define keyframes and specify smooth transitions between them.
- Virtual Reality (VR) output: the ability to export videos in a formats compatible with VR headsets and platforms.
- Object tracking: it enables users to select an object within the video and create a video sequence that follows the chosen object.

A summary of the Insta360 functionality is provided in Table 5.1.

It's noteworthy that several similar applications to Insta360 exist for handling 360° videos. While many of these tools offer features such as stitching, audio and text editing, and export to VR formats, they may lack interactive elements. Insta360 stands out as a representative example of 360° video editing tools for a couple of reasons: its association with a reputable company, its compatibility with a wide range of cameras, and its availability on Android and iOS platforms through related mobile applications.

Table 5.1 Insta360 Studio functionality and characteristics

<table>
<tr><th colspan="8">Insta360 Studio</th></tr>
<tr><th colspan="2">Platforms</th><th>Cost</th><th>Ease of use</th><th>Export formats</th><th>Stitching</th><th>Audio editing</th><th>Other Elements</th></tr>
<tr><td colspan="2">iOS, MacOS, Windows, Android</td><td>Free for Insta360 users</td><td>Moderate</td><td>Reframed video, 360 video</td><td>✓</td><td>✓</td><td rowspan="3">Keyframes, transitions, tracking</td></tr>
<tr><th colspan="7">Interactive elements</th></tr>
<tr><th>Text</th><th>Images</th><th>link</th><th>video</th><th>hotspots</th><th>Scenes</th><th>Quiz</th></tr>
<tr><td>---</td><td>---</td><td>---</td><td>---</td><td>---</td><td>---</td><td>---</td></tr>
</table>

Cost: Free for Insta360 camera users

Link: https://www.insta360.com/

Platforms: Android and iOS (Insta360)

Windows and Mac (Insta360 studio)

https://www.insta360.com/download/insta360-x3

Tutorials: https://www.insta360.com/support/supportcourse?post_id=11137

YouTube: https://www.youtube.com/@insta360/playlists

Facebook: https://www.facebook.com/Insta360

5.2 ThingLink

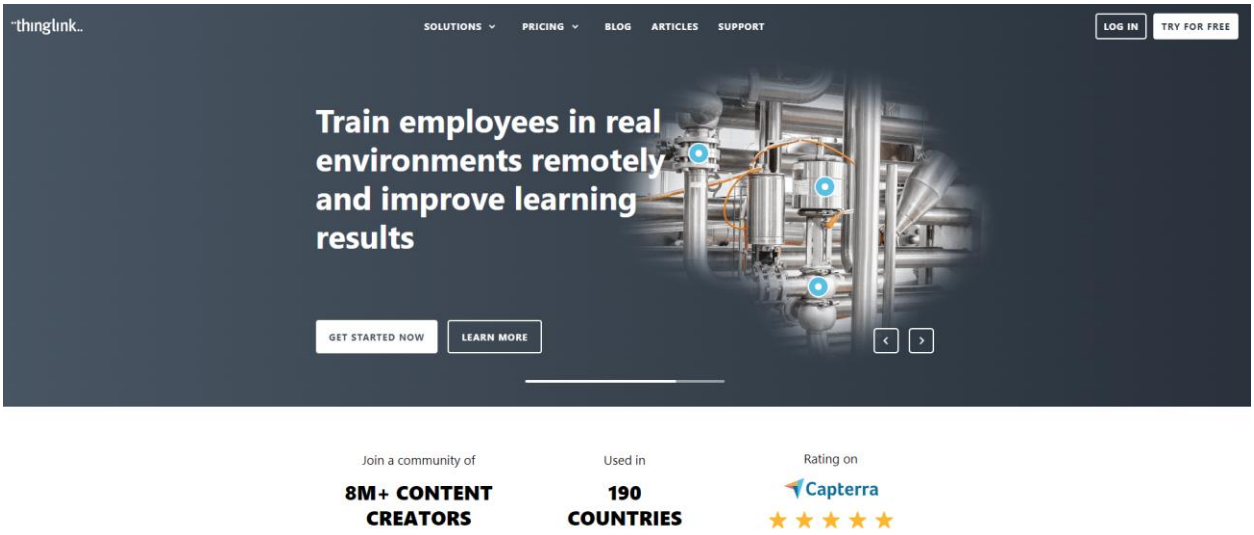

Figure 5.2. Thinglink landing page

The web-based application, ThingLink, offers users the ability to craft interactive photos and videos. This platform empowers users to incorporate interactive components, referred to as "tags," which encompass various multimedia elements such as text, images, videos, audio, and links. These tags can be strategically positioned within specified sections of an image or video, thereby enabling viewers to actively engage with the content and enhancing its interactivity and utility. Through the utilization of tags, individuals can explore and interact with information localized within specific regions of an image or video (Fig. 5.3). Additionally, ThingLink provides the means to generate interactive instructional content and 360-degree interactive videos within a web-based environment.

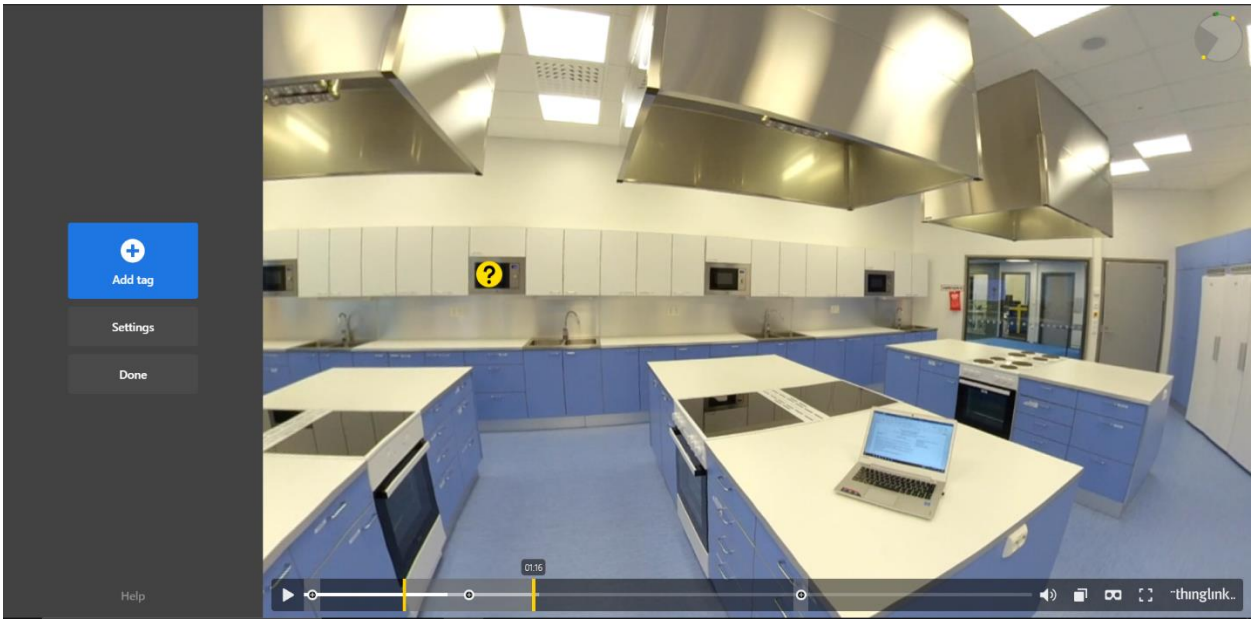

Figure 5.3 Adding tags to 360 video

ThingLink offers a user-friendly interface, particularly beneficial for individuals who are new to creating interactive content. The platform boasts compatibility across various operating systems including Windows, Mac, iOS, and Android OS, among others. Additionally, the authoring tool can be seamlessly integrated with Canva software, enhancing its versatility and accessibility.

ThingLink's functionality meets the unique needs and characteristics of educators and learners in the education sector. To achieve this, the platform prompts users to select the most suitable option based on their intended use of the platform (Fig. 5.4).

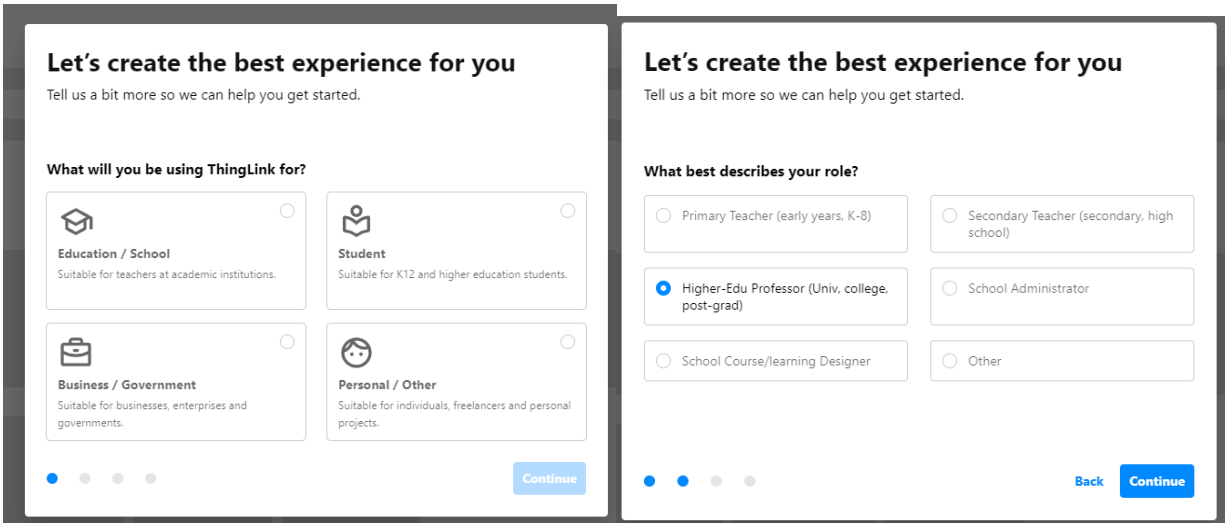

Figure 5.4 Thinglink screens for platform use

Utilizing this tool, both teachers and students can effortlessly generate interactive videos featuring straightforward functionality. The process involves creating a tag, also referred to as a hotspot, and associating it with one of the interactive elements outlined in Table 5.2. When the end user interacts with the video by clicking on the designated hotspot, the associated information is displayed, as illustrated in Figure 5.5.

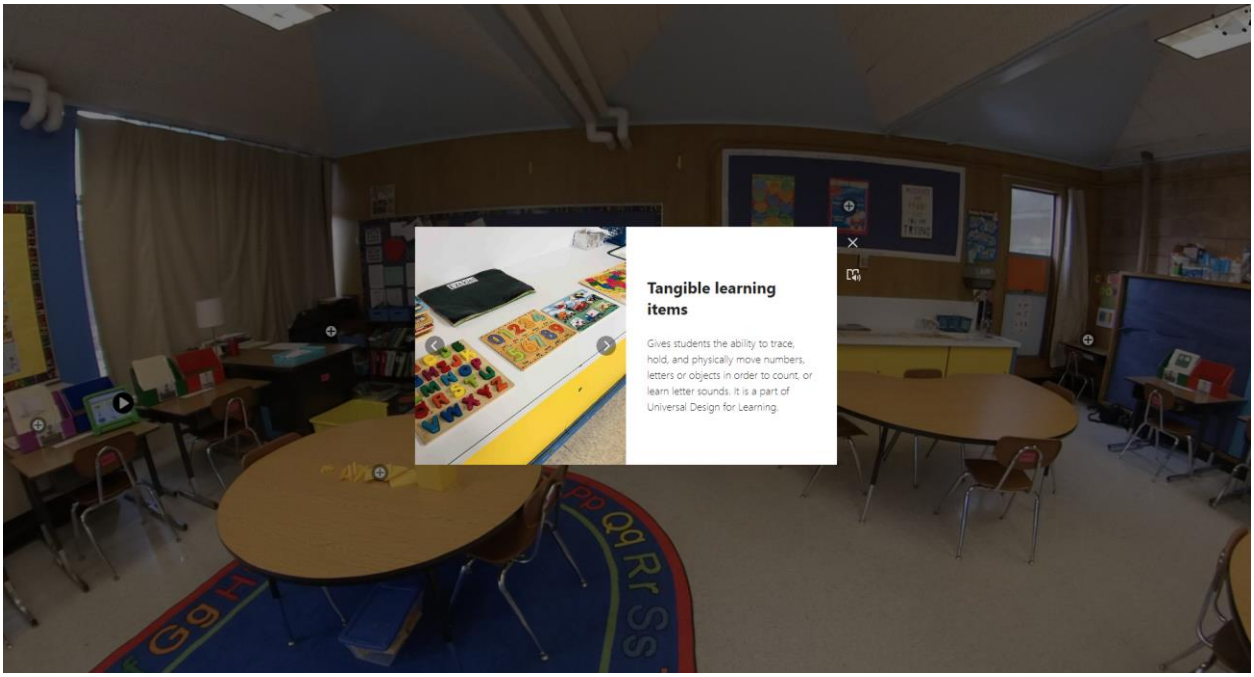

Figure 5.5 Thinglink 360-degree sample video with hotspots

It's worth noting that ThingLink has the capability to track users' interactions with the videos (Fig. 5.6). This tracking functionality provides valuable data that authors can utilize to construct diverse educational scenarios (Fig. 5.7).

Tag	Hovers	Clicks	H/C ratio	Interaction
Baskett Slough National Wildlife Refuge	543	33	6.08%	3.5 s
De Lacs National Wildlife Refuge	468	16	3.42%	3.6 s
Sleeper Spots: Aquatic Management Areas	553	18	3.25%	4.1 s
Sleeper Spots: Army Corps of Engineers Lands	568	25	7.92%	7.5 s
Sleeper Spots: Department of Defence Lands	355	45	7.04%	7.0 s

Figure 5.6 User actions tracking chart

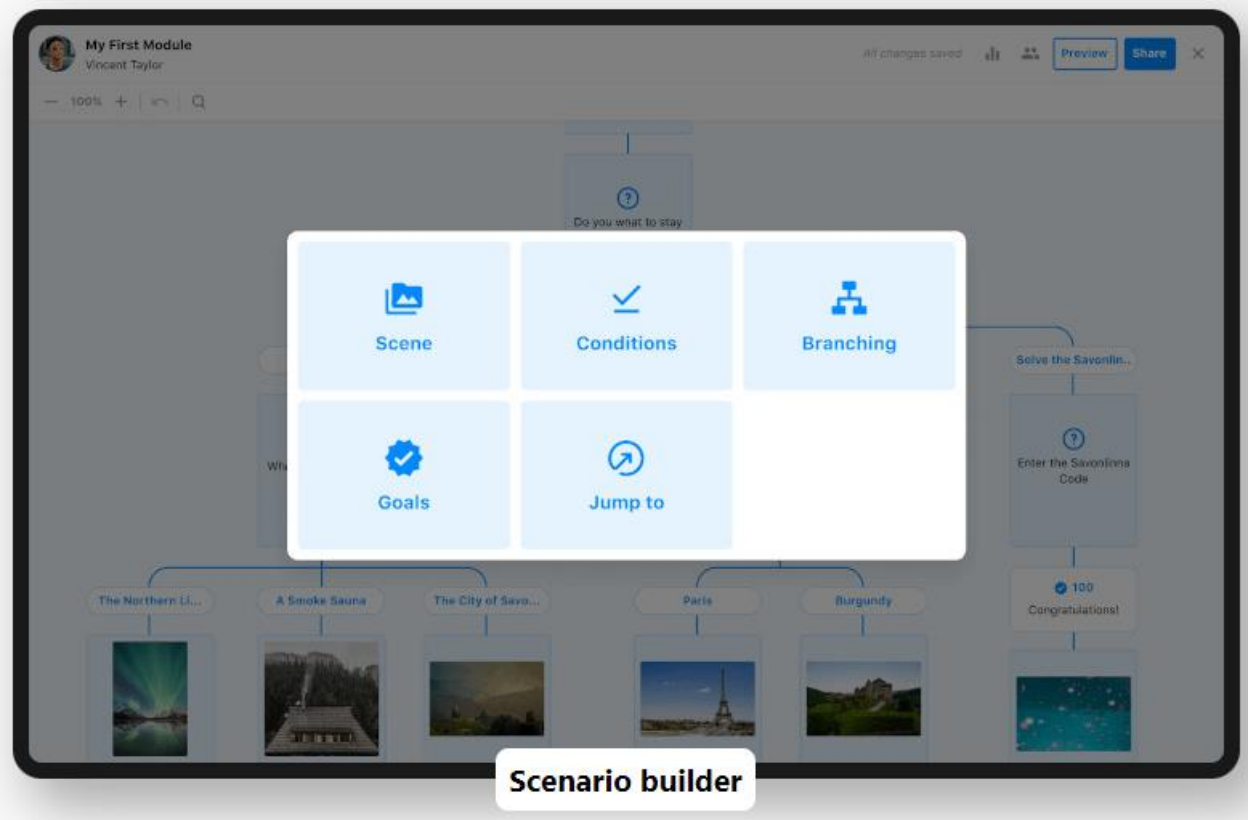

Figure 5.7 Thinglink Scenario builder

Furthermore, in its beta version, ThingLink offers some highly beneficial AI-powered tools. Notably, these AI tools can suggest suitable hotspots (tags) for video scenes. The process involves initially identifying the scene's content (Fig. 5.8), followed by the automatic addition of relevant hotspots (Fig. 5.9). Additionally, similar AI functionality extends to the scenario builder, where it can offer suggestions and augment the building process. This includes generating multiple-choice questions, proposing branching paths, providing concise summaries, and even revising existing text blocks to make them shorter (more info for AI tools available at https://support.thinglink.com/hc/en-us/articles/13920170120983--Beta-AI-assistant-tools-for-Scenarios-and-Image-editor).

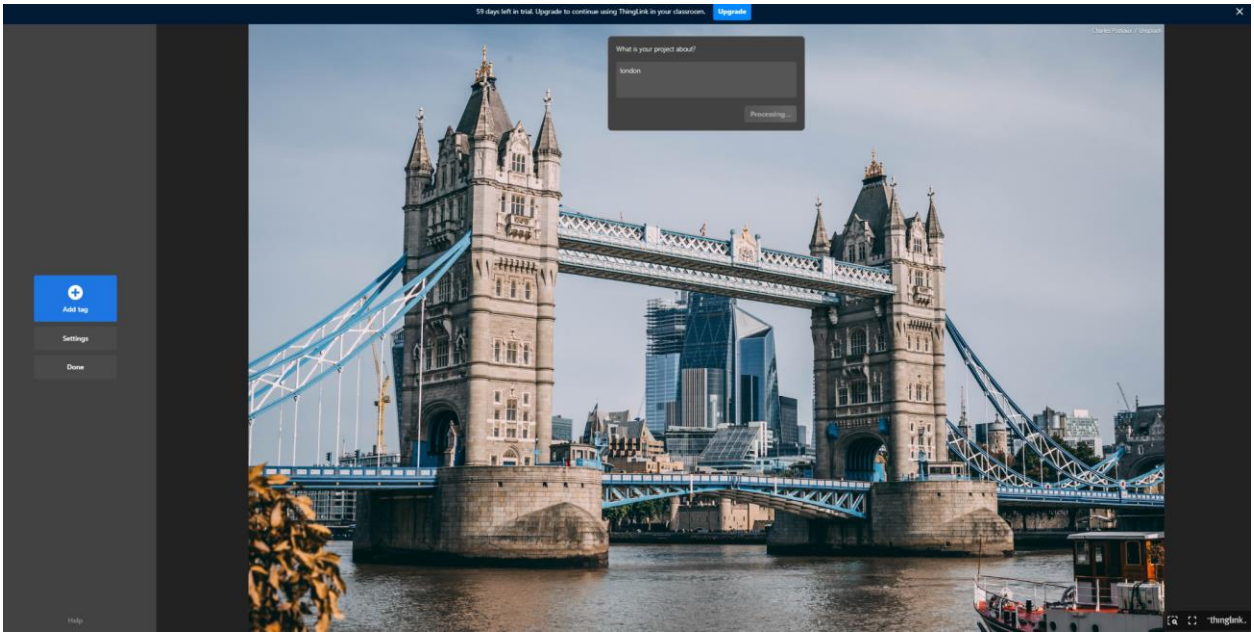

Figure 5.8 Thinglink prompts for video scene

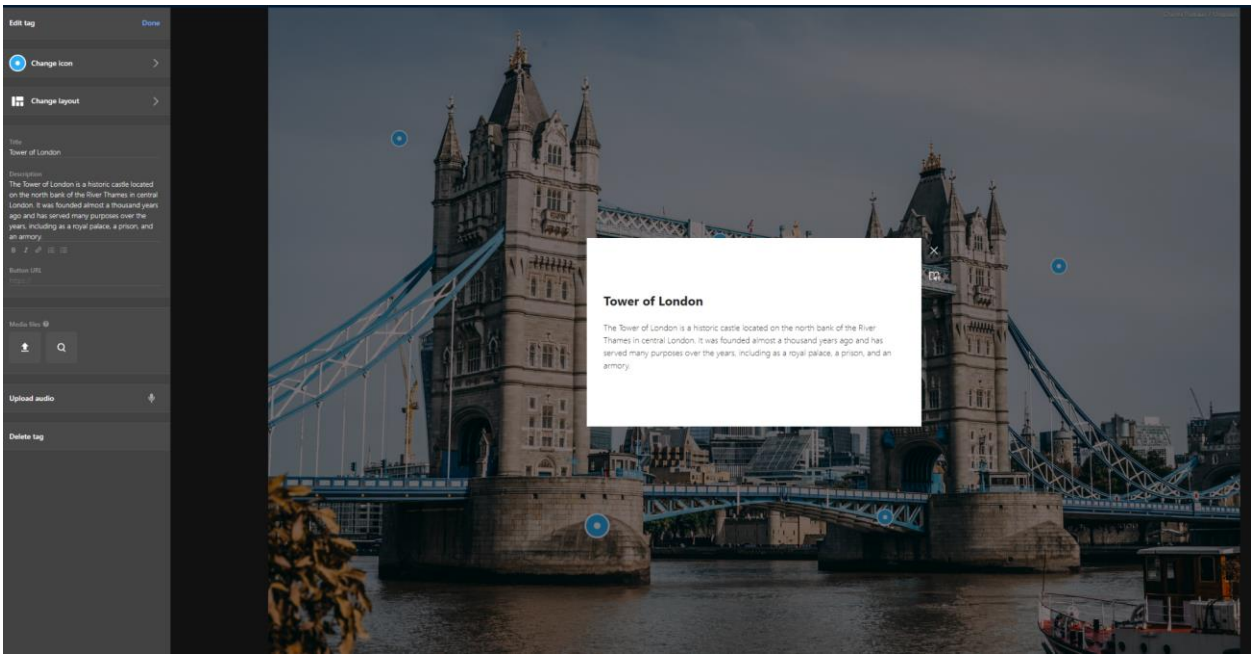

Figure 5.9 Thinglink automatically added tags

Another valuable feature of ThingLink is its provision of a variety of pre-designed layouts that users can readily utilize (Fig. 5.10). Finally, the overview of the platform's functionality is described on Table 5.2.

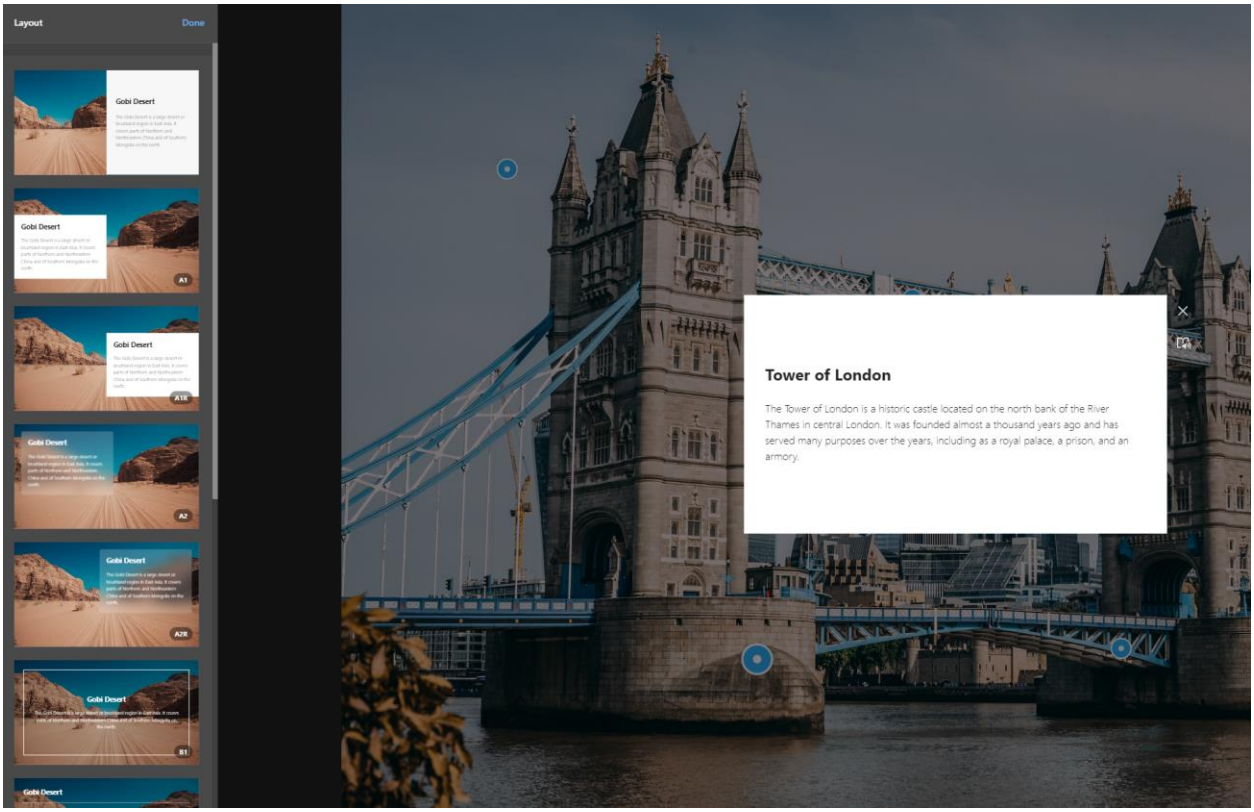

Figure 5.10 Thinglink layout templates

Table 5.2 Thinglink functionality and characteristics

Thinglink							
Platforms		**Cost**	**Ease of use**	**Export formats**	**Stitching**	**Audio editing**	**Other Elements**
Authoring Tool: MacOS, Windows Mobile Viewer App: Android, iOS, HTC Viva, MetaQuest		Trial and paid	High	Link or QR Code, iframe, direct link, VR link, standalone app for Windows or macOS	---	✓	Track user interactions, scenario builder, AI assistant tools (tag generation, scenario builder), tour creation, PowerPoint addon, display 3D models
Interactive elements							
Text	**Images**	**link**	**video**	**hotspots**	**Scenes**	**Quiz**	
✓	✓	✓	✓	✓	Link to another 360 video	✓	

Related links

Cost: 30 days free trial and a low-cost ($60/year) license for teachers

Link: https://www.thinglink.com/

Platforms: Windows, Mac, iOS, Android OS and others

https://play.google.com/store/apps/details?id=com.thinglink.android

https://apps.apple.com/us/app/thinglink/id647304300?ls=1

Tutorials:

https://support.thinglink.com/hc/en-us/articles/360025637174-Tagging-360-Videos

YouTube: https://www.youtube.com/channel/UCoEFzyhf3bB8OyfNfHeuasQ/videos

Facebook: https://www.facebook.com/ThingLink/

5.3 3D Vista Virtual Tour Software

Figure 5.11 3dVista Virtual Toor Pro landing page

3DVista Virtual Tour Pro can be used for educational purposes by creating virtual tours of educational facilities, historical sites, museums, scientific or industrial facilities, providing a valuable educational resource for students and teachers.

The software includes a variety of features that allow users to create highly immersive and interactive virtual tours, such as panoramic stitching, hotspots and navigation, 3D floor plans, voice-over, and audio, among others. It is important that the produced 360° content can be exported for Android, iOS, and many VR devices. The authoring tool is also available for both the Windows and Mac operating systems.

3DVista is perhaps the most powerful of the proposed tools since it provides a variety of additional features. It supports hotspots, similar to ThingLink, but it also enables video hotspots in static 360° panoramas. This allows users to watch 360° video content by clicking inside the image. Additionally, it supports the import of text, images, videos, and 3D models. Moreover, it can provide live hotspots, which are very useful when highlighting moving objects within the video. These live hotspots can dynamically move, appear, disappear, and change size in relation to the object. The software also supports interactive video functionality, where interactions, such as quizzes, appear at specific times in the 360° video.

A particularly useful feature for educational purposes is its built-in quiz cards and scenarios. With quiz cards, it can present various media types such as video, photos, 360° videos, or 3D models, along with simultaneous multiple-choice questions for the user (Fig. 5.12). 3DVista supports gamification through scores and badges, along with data visualization and automatic LMS integration. Additionally, it is compliant with SCORM standards.

Furthermore, 3DVista supports 3D CAD panoramas created by external CAD applications such as 3DS Max, Sketchup, etc.

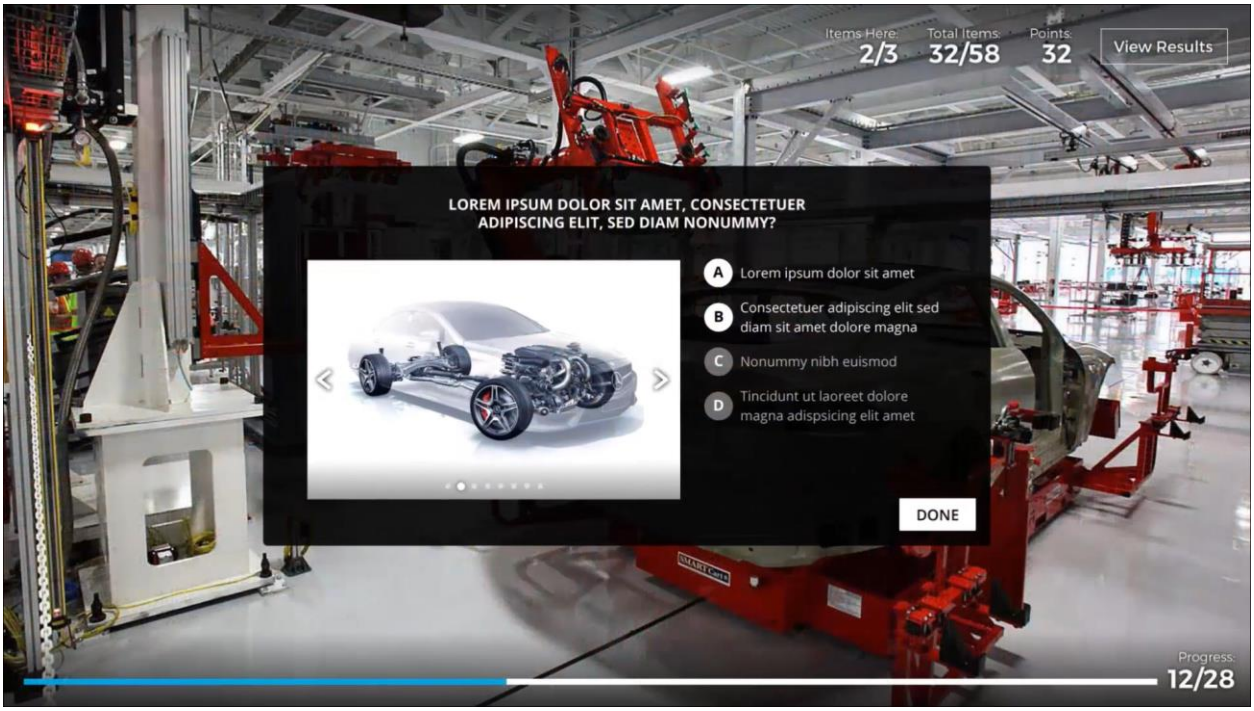

Figure 5.12 3DVista Quiz card

In terms of educational applications using gamification, integrating virtual tours into corporate training programs significantly enhances indicators of attention and engagement, leading to better memorization of the information. Additionally, incorporating a game strategy provides an extra, built-in motivation for improving performance. While refining their skills, corporate learners may explore new domains, tackle challenges, and earn badges.

Lastly, 3DVista Virtual Tour offers a variety of export options (Fig. 5.13). These exports are compatible with any web browser, MetaQuest, Pico, Vive, Google Cardboard, and VR BOX. Table 5.3 provides the summary of 3dVista Virtual Tour functionality.

Figure 5.13 3dVista Virtual Tour exports

Table 5.3 3dVista Virtual Tour functionality and characteristics

3dvista Virtual Tour							
Platforms		**Cost**	**Ease of use**	**Export formats**	**Stitching**	**Audio editing**	**Other Elements**
Authoring Tool: MacOS, Windows App: Android, iOS, HTC Viva, MetaQuest, VIVE, Google Cardboard, VRBOX		Trial and paid	Moderate	Web, Mobile, standalone player, 360° video	✓	✓	3d transitions effect, live video hotspots, 3d CAD support, preset skins, SCORM compliant, interactive video
Interactive elements							
Text	**Images**	**link**	**video**	**hotspots**	**Scenes**	**Quiz**	
✓	✓	✓	✓	✓	✓	✓	

Related links

Cost: Trial version and one-time paid subscription

Link: https://www.3dvista.com/en/products/virtualtour

Platforms: Android mobile App

https://play.google.com/store/apps/details?id=com.tdv.player.tdv&gl=ES

iOS mobile App

https://apps.apple.com/us/app/3dvista/id1181383999

MetaQuest and HTC Vive

https://www.3dvista.com/en/blog/introducing-3dvista-vr-app-for-oculus/

Authoring tool in Windows and Mac https://www.3dvista.com/en/products/virtualtour

Exports compatible with: Web browsers, MetaQuest, Pico, Vive, Google CardBoard and VR BOX

Tutorials:

https://www.youtube.com/watch?v=C0l8V6NZIb4&list=PL9XlSAoFCmllNXAR_2ix4lty6GfAOqTDo

https://www.youtube.com/watch?v=c138akjCDGc&list=PL9XlSAoFCmlkaTgbp2akGQUTOER2G8tEt

YouTube: https://www.youtube.com/@3dvista

Facebook: https://www.facebook.com/3dvista

5.4 VeeR

VeeR is a platform that allows users to create, edit, and share a variety of content, including 360-degree videos and photos, which can be viewed using VR headsets (such as MetaQuest, Pico, Vive, etc) as well as on regular computers or mobile devices with 360-degree video playback capabilities.

The VeeR VR editor offers users the ability to enhance their videos and photos using a selection of animated stickers and filters, which add stylistic elements to their content. Users can also import music or choose from VeeR Editor's library to craft a cinematic experience. Furthermore, they can select, rearrange clips, incorporate transitions, and export the final result as a single clip. Additionally, users can seamlessly switch between 360-degree and VR modes to preview their edits and effects in real time. The produced 360-degree videos can be embedded on external websites and shared across social media platforms such as Facebook and YouTube. The VeeR VR Editor mobile app (Fig. 5.14) has a user-friendly interface suitable for novice users, making it accessible with just a mobile phone.

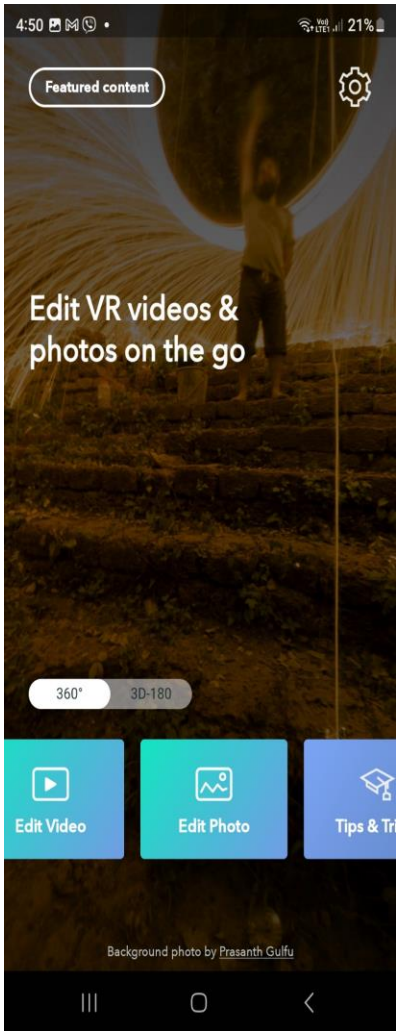

Figure 5.14 Veer VR Editor - Edit 360º Vid App main screen

Additionally, there is a professional web-based version tailored for advanced users and content creators, available at https://veer.tv/creator. However, access to this version is subject to VeeR's approval process.

VeeR creators have the capability to incorporate interactive elements into their creations, enabling users to navigate and explore the scene. This functionality results in a heightened level of immersion compared to a standard 360-degree video, as users can actively engage with and explore the environment. The platform further equips users with tools to edit and enhance their 360-degree videos, encompassing the addition of interactivity and hotspots (Fig. 5.15). Table 5.4 summarizes the functionality attributes of the VeeR.

Figure 5.15 Veer 360-degree sample video with hotspots

Table 5.4 VeeR functionality and characteristics

Veer Editor							
Platforms		**Cost**	**Ease of use**	**Export formats**	**Stitching**	**Audio editing**	**Other Elements**
Authoring Tool: Android, iOS App: Android, iOS, Windows		Free mobile version	High	360° Video, animated GIF, YouTube Video	---	✓	Speed, preview in VR, animated stickers
Interactive elements							
Text	**Images**	**link**	**video**	**hotspots**	**Scenes**	**Quiz**	
✓	✓	---	✓	Only for Veer Creators (under approval)	---	---	

Related links

Cost: Free mobile editor app, free mobile app for viewing 360º video

Link: https://veer.tv/

https://veer.tv/veer-editor

Platforms: Android https://play.google.com/store/apps/details?id=com.velotech.veereditor

iOS https://apps.apple.com/us/app/veer-vr-editor-edit-360-video/id1274467955

Tutorials: https://www.youtube.com/watch?v=DyYKlVGz3r4&list=PL-UKgukAVLuBOc1Idk5_QI3rHzoDIzwy3

Unoficial https://www.youtube.com/watch?v=o5mFJPA27m0

YouTube: https://www.youtube.com/@VeeRVR

Facebook: https://www.facebook.com/letsveer

5.5 Discussion

Section five introduceds an extensive array of 360-degree video authoring tools and applications specifically designed for educational purposes. A comprehensive comparison of their features is outlined in Table 5.5. These tools empower users to effortlessly create immersive VR scenes, 360-degree videos, and photos. Certain applications, such as Insta360, provide both desktop-based and mobile app editors, while others are exclusively desktop-based, such as ThingLlink and 3D Vista. Furthermore, some tools are primarily focused on mobile app editors, like VeeRr Editor. Moreover, the outputs generated by these tools are compatible with the majority of VR headsets. Notably, ThingLlink and 3D Vista take a step further by supporting the innovative WebXR framework, thereby enhancing the interactive experiences they can deliver.

Table 5.5 Comparison of 360-degree video tools characteristics

Characteristics		360° Video Editing Tools			
		Insta360 Studio	Thinglink	3d Vista Virtual Tour	Veer Editor
Authoring Tool / End User Platforms	Windows	✓/✓	✓/✓	✓/✓	---/✓
	MacOS	✓/✓	✓/✓	✓/✓	---/---
	Android	✓/✓	---/✓	---/✓	✓/✓
	iOS	✓/✓	---/✓	---/✓	✓/✓
	WebXR	---/---	---/✓	---/✓	---/---
VR Platforms & Headsets			MetaQuest, Pico, VIVE, Samsung Gear VR, Oculus Go, Oculus, Rift Google Cardboard, ClassVR	MetaQuest, Pico, VIVE, Google Cardboard, VR BOX	MetaQuest, Oculus Rift, Steam VR, Pico, VIVE, Windows Mixed Reality
Cost		Free for Insta360 users	Trial and paid	Trial and paid	Free mobile version
Ease of use		Moderate	High	Moderate	High
Export formats		Reframed video, 360° video	Link or QR Code, iframe, direct link, VR link, standalone app for Windows or macOS	Web, Mobile, standalone player, 360° video	360° Video, animated GIF, YouTube Video
Stitching		✓	---	✓	---
Audio Editing		✓	✓	✓	✓
Interactive Elements	Text	---	✓	✓	✓
	Image	---	✓	✓	✓
	Link	---	✓	✓	✓
	Video	---	✓	✓	✓
	Hotspots	---	✓	✓	Only for Veer Creators (under approval)
	Scenes	---	Link to another 360° videos	✓	---
	Quiz	---	✓	✓	---
Other Elements		Keyframes, transitions, tracking	Track user interactions, scenario builder, AI assistant tools, (tag generation, scenario builder), tour creation, PowerPoint addon, display 3D models	3d transitions effect, live video hotspots, 3d CAD support, preset skins, SCORM compliant, interactive video	Speed, preview in VR, animated stickers

The ease of use of these tools often correlates with the extent of their functionality. Those with more advanced features tend to have a moderate learning curve, while those with fewer features provide a simpler authoring experience. Among them, ThingLink and 3D Vista Virtual Tour stand out as the most feature-rich tools with extensive support for interactive elements.

Selecting the most suitable 360 video editor largely depends on its intended use. For instance, if educators aim to incorporate interactive elements like quizzes or educational scenarios into their content, ThingLink or 3D Vista are the exclusive choices that cater to these requirements. Notably, ThingLink offers a 60-day trial period followed by a monthly subscription fee, whereas 3D Vista also provides a trial version with certain limitations and an upfront one-time cost.

On the other hand, if educators prefer to instantly create straightforward 360 videos or photos to augment their lessons or educational material, Insta360 or VeeR are the more appropriate options. These tools are designed for ease of use and rapid content creation, making them ideal for seamless integration into educational contexts.

If students are to take on the role of content creators, the VeeR Editor emerges as the most straightforward and user-friendly option. It offers the added advantage of being accessible on both Android and iOS devices, enabling students to instantly produce their own 360 videos or images

without any unnecessary infrastructure expenses. With the VeeR Editor's intuitive interface and mobile compatibility, students can effortlessly unleash their creativity and bring their ideas to life with ease.

An overall recommendation is that users, particularly educators and students, carefully assess their specific needs and objectives when choosing a 360-degree video authoring tool. For educational scenarios that require interactive elements like quizzes and immersive experiences, ThingLink and 3D Vista Virtual Tour stand out as the prime contenders. These platforms offer a wide array of engaging features, making them ideal for creating captivating learning material and dynamic educational content. However, for educators and students seeking a quick and hassle-free way to enhance their lessons with simple 360 videos or images, the VeeR Editor emerges as a highly suitable choice. Its user-friendly interface and mobile compatibility make it an excellent option for those who prioritize ease of use and instant content creation without the need for complex setups or additional costs. Ultimately, the key is to match the chosen 360 video editor with the specific educational objectives, technical expertise, and creative ambitions of the users, ensuring a seamless and enriching experience for both content creators and learners alike.

6 Game Development Engines

6.1 Unity

Unity is a cross-platform game engine developed by Unity Technologies. The engine can be exploited for creating three-dimensional (3D), two-dimensional (2D), VR, and AR games, as well as simulations and other experiences. The engine has been adopted by industries beyond video gaming, such as film, automotive, architecture, engineering and construction.

Unity empowers users to develop games and experiences in both 2D and 3D environments. The engine provides a primary scripting API in C#, which serves both the Unity editor through plugins and the games themselves. Additionally, Unity offers a drag-and-drop functionality. Prior to C# being the primary programming language, the engine supported Boo, which was discontinued with the release of Unity 5, along with a version of JavaScript known as UnityScript. Unity also supports localization and multilingual capabilities enabling educational content to be adapted to different languages and cultures. Furthermore, Unity's visual scripting system, Playmaker, offers a user-friendly approach for those who are not well-versed in coding.

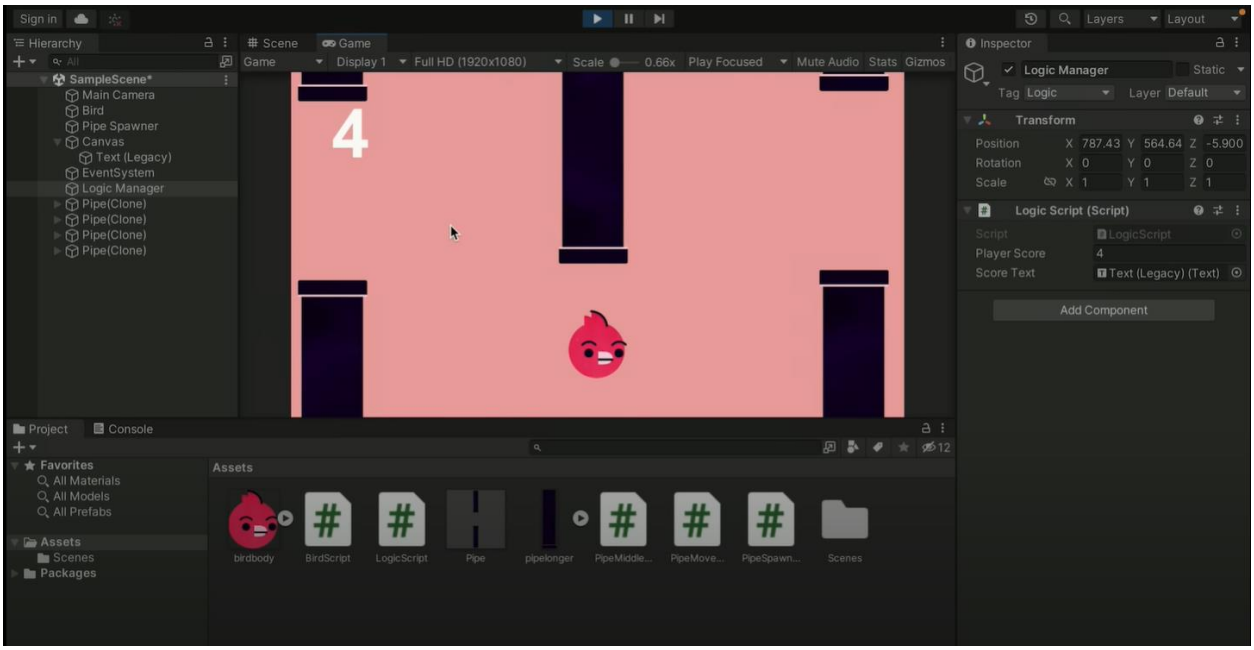

Figure 6.1 Screenshot of the Unity environment

Despite the current relatively small size of the VR market, Unity remains a solid option for VR development. It is known for its user-friendliness, extensive documentation, and strong compatibility with mobile devices. Furthermore, many developers affirm that Unity is easily optimized, ensuring high frame rates while efficiently utilizing processing resources. Consequently, Unity is particularly suitable for beginners or creators aiming at developing games primarily for low-powered devices, such as smartphones or all-in-one headsets such as the Oculus Quest. Unity’s physics engine, scripting capabilities and real time feedback makes the platform ideal for students to engage in learning experiences that promote critical thinking and problem-solving learning. At the same time, it facilitates the incorporation of game mechanics like rewards, leaderboards, and progression systems. Table 6.1 provides an overview of Unity’s functionality and characteristics.

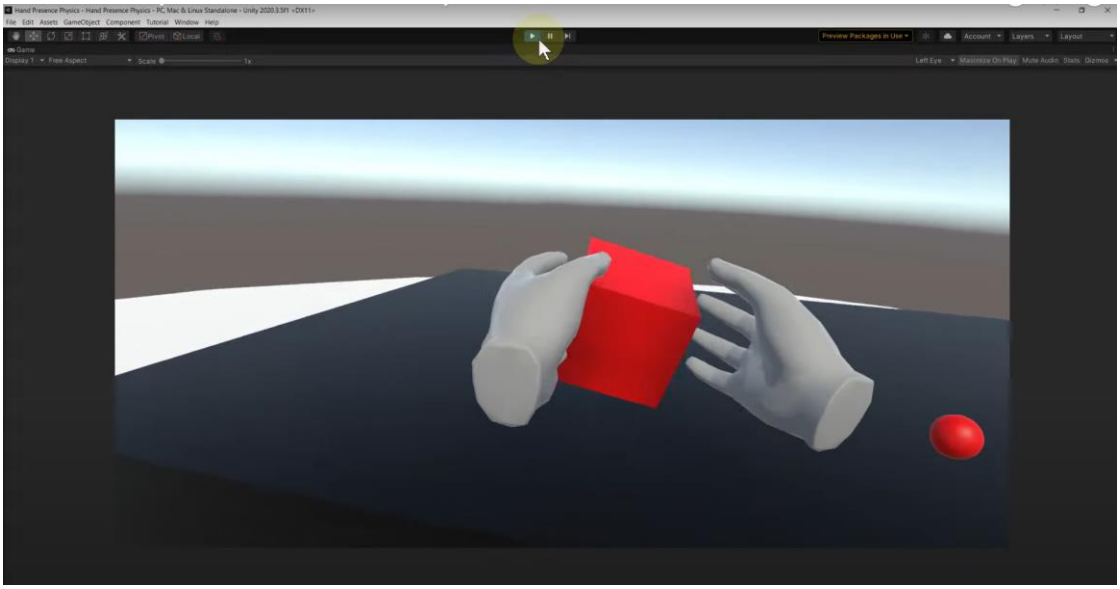

Figure 6.2 Screenshot of VR development using Unity

Table 6.1 Unity functionality and characteristics

Unity								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android, Windows, Mac.	Oculus Rift, HTC Vive, PlayStation VR, Microsoft HoloLens.	Free and paid versions	Independent	✓	Manually by the user	Mid	✓	Pathfinding and AI, Event System, Networking, Particle System, User Interface (UI) System, Timeline and Cinemachine, Real-Time Physics Simulation.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	✓	✓	✓	✓

Related links

Cost: Free for personal use and for students

Link: *https://unity.com/*

Tutorials: https://learn.unity.com/

YouTube:
https://www.youtube.com/watch?v=gB1F9G0JXOo&t=1772s&ab_channel=freeCodeCamp.org

Facebook: https://www.facebook.com/unity3d/

6.2 Unreal Engine

Unreal Engine is a complete suite of creation tools tailored for game development, architectural and automotive visualization, linear film and television content creation, broadcast and live event production, training and simulation, and various other real-time applications. Initially developed for PC first-person shooters, it has since been used in a variety of genres of both 2D and 3D games and has been adopted by a variety of industries, with a notable presence in the film and television industry.

Unreal Engine is available for free download and comes with everything needed for crafting and distributing successful multi-platform games and location-based entertainment across various genres. Offering complete access to the source code, a robust C++ API, and Blueprint visual scripting tools at your disposal, you can shape the development of your project to suit your preferences. This openness fosters the potential for self-directed learning among its users.

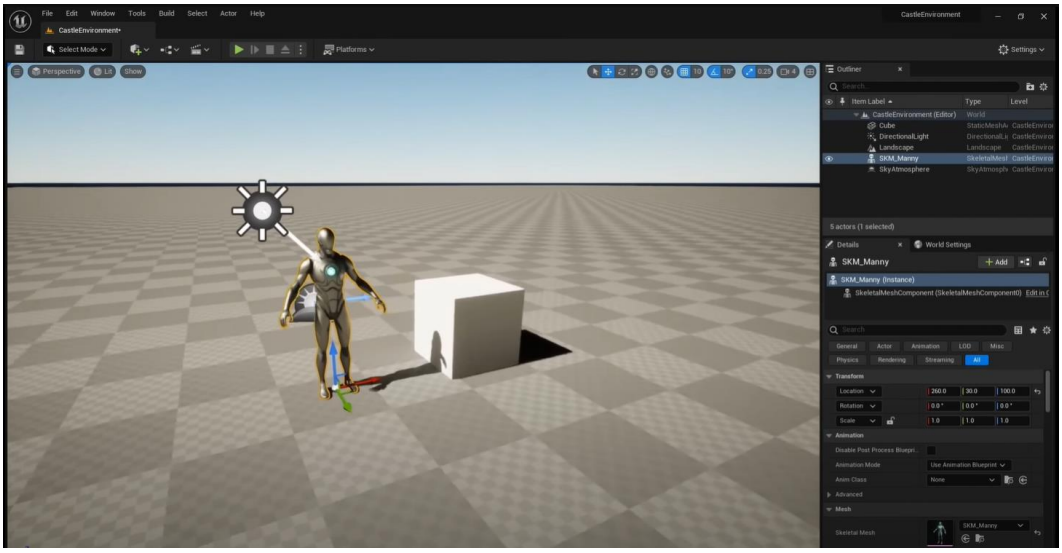

Figure 6.3 Screenshot of the Unreal Engine environment

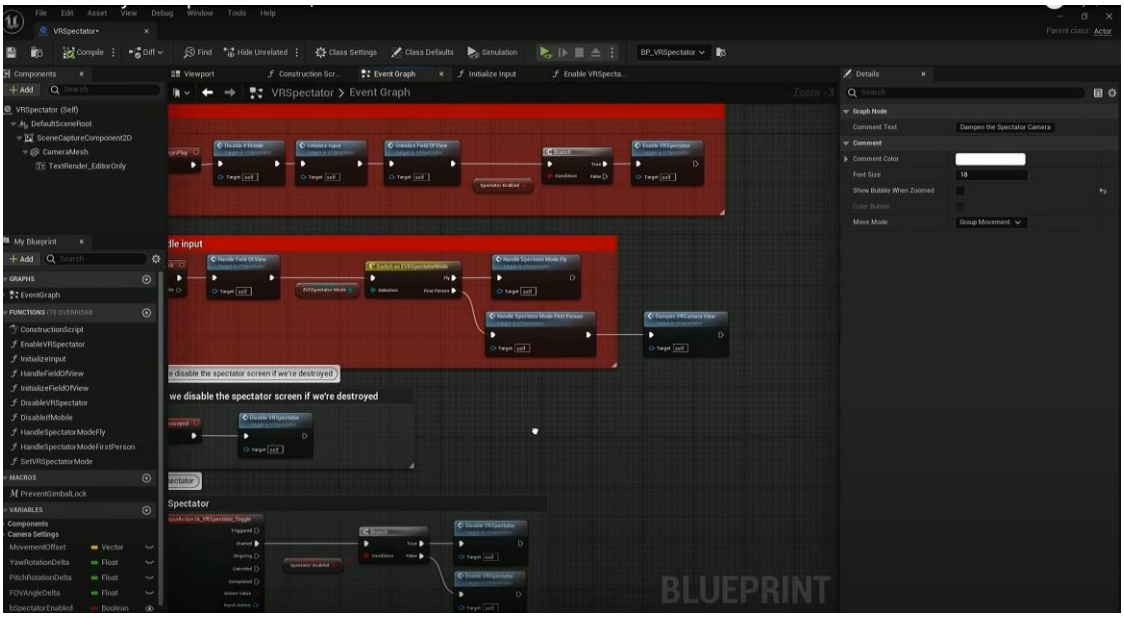

Figure 6.4 Unreal Engine's Blueprint

Unlike Unity, Unreal Engine stands out as an optimal choice for proficient developers aiming to craft VR games utilizing cutting-edge graphics technology. With exceptional support for a range of VR, AR, and MR platforms/tools, this engine opens up exciting possibilities for incorporating innovative features into future games.

With its extensive range of possibilities and support for both scripting for coders and non-coders, Unreal distinguishes itself as an excellent option for promoting inquiry-based learning. Students can manipulate variables, observe outcomes, and draw conclusions from their self-directed experiments. Coding with C++ enables a deeper development and simulation of complex scientific phenomena, empowering learners to refine their problem-solving skills. The main attributes of Unreal are included on Table 6.2.

Figure 6.5 Screenshot of VR development using Unreal Engine (Unreal Fest, 2022)

Table 6.2 Summary of characteristics Unreal

Unreal								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android,Mac, Windows.	Meta Quest and RIFT, lenovo Mirage S3, HTC Vive, Pico, Scorm, Igloo.	Free and paid versions	Independent	✓	Manually by the user	Mid	✓	Pathfinding and AI behavior trees, Event System, Networking, Particle System, User Interface (UI) System, Blueprints, Real-Time Physics Simulation.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	✓	✓	✓	✓

Related links

Cost: Free for personal use and for students

Link: *https://www.unrealengine.com/en-US/*

Tutorials: https://docs.unrealengine.com/4.27/en-US/Resources/

YouTube: https://www.youtube.com/watch?v=k-zMkzmdugI&ab_channel=UnrealSensei

Facebook: https://www.facebook.com/UnrealEngine/

6.3 EMERGO

The Open University of the Netherlands developed EMERGO (Effectieve Methode voor Ervaringsgericht Onderwijs / Effective method for experience-oriented education) as a dedicated design method and development toolkit for designing, developing, implementing, and evaluating scenario-based serious games aimed at acquiring complex professional skills.

At present, the EMERGO authoring platform comprises over 30 adaptable components, facilitating efficient and flexible game production. Over the past decade, more than 40 serious games spanning diverse domains and educational contexts have been created using EMERGO, with additional projects currently in progress.

The integration of research and development has played a pivotal role in the ongoing advancement of EMERGO. The absence of research can lead to game development lacking a foundation of evidence, innovation, and fresh ideas. Similarly, a dearth of concrete development can create a divide between research and its practical application in education. Since 2020, the Faculty of Learning Sciences has collaborated with the Department of Educational Production (ECO) to design game-based learning programs.

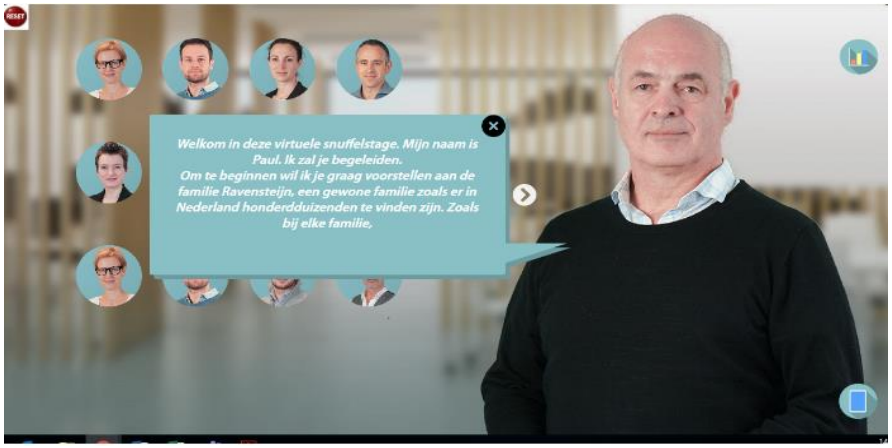

Figure 6.6 Screenshot of EMERGO

Cost: EMERGO is OpenSource and free of charge

Example article about an implemented EMERGO game: *https://bera-journals.onlinelibrary.wiley.com/doi/full/10.1111/bjet.12960*

Link: *https://www.ou.nl/en/emergo*

YouTube: https://www.youtube.com/watch?v=QgLv1Ju-UxQ&ab_channel=VersnellingsplanOnderwijsinnovatiemetICT

Note: Due to limited access to the information from Emergo we haven't included a comparison table here but added this engine as an additional possibility for consideration in future developments, since its a very interesting software to consider exploring further.

6.4 GameMaker

GameMaker is a comprehensive development tool for creating 2D games. It is utilized by indie developers, professional studios, and educators globally. GameMaker Studio 2 is the latest product of the cross-platform game engines crafted by YoYo Games, which they have been developing since 2007. It was released in 2017 and has been updated since its launch.

GameMaker provides a platform for designing cross-platform and multi-genre video games utilizing a tailored drag-and-drop visual programming language, as well as a scripting language called Game Maker Language (GML). GML allows the creation of more sophisticated games that cannot be constructed solely through visual programming tools. Originally, GameMaker was conceived to enable novice computer programmers to create computer games with minimal programming experience through these actions. However, modern versions of the software also strive to cater to advanced developers, thus bestowing GameMaker with a strong sense of inclusivity for its users.

While GameMaker Studio 2's (GMS2) 3D development features may be somewhat limited, YoYo Games does not market it as an advanced 3D tool. Conversely, the 2D game development community greatly favors GMS2 due to its exceptional 2D capabilities, which are comparable to those of Unity and Unreal, along with its robust and user-friendly development environment. Moreover, GMS2 operates in pixels, rather than units, which facilitates the creation of pixel games (a trendy game style at present).

Game maker is well suited for problem-based learning scenarios. Students can be presented with challenges that require specific knowledge to devise solutions. GameMaker's features for programming, level design and asset management allow for creative challenges and solutions to be incorporated into any interactive experience. Table 6.3 concentrates the basic information of Game maker's functionality and characteristics.

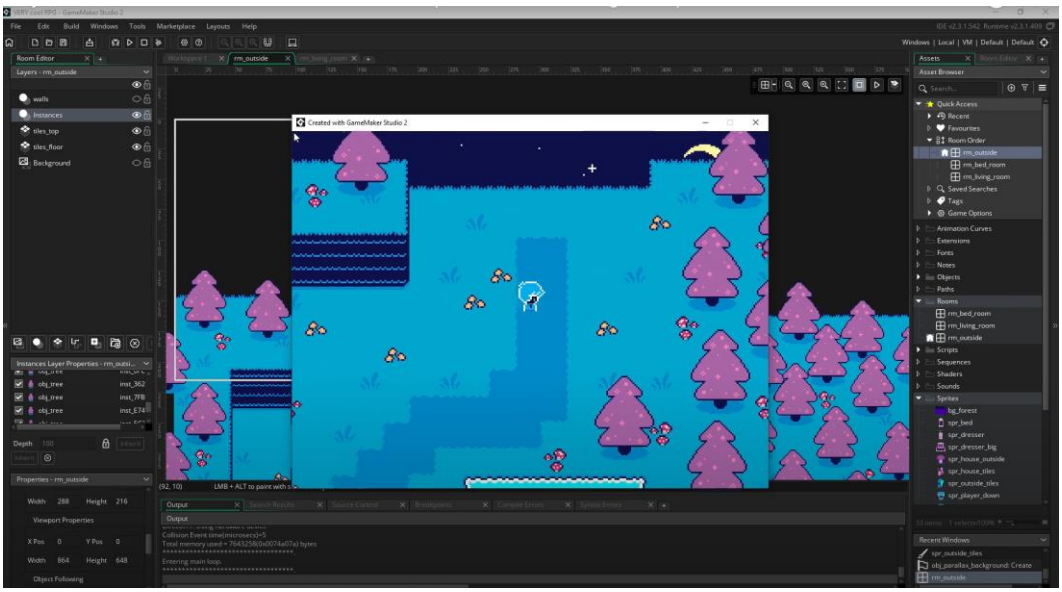

Figure 6.7 GameMaker Studio 2's authoring environment

Table 6.3 Game maker functionality and characteristics

Game Maker								
Platforms	**Supported VR devices**	**Cost**	**Domain**	**Collaboration**	**Gamification Elements**	**Ease of use**	**Content Library**	**Additional Interactive features**
iOS, Android,Mac, Windows, Web.	Over a third party extension: Oculus Rift, HTC vive.	Trial and Paid	Independent	✓	Manually by the user	High	✓	GML (GameMaker Language), collision detection, particle system, physics engine, timeline system.
Supported elements								
3D models	**Text**	**Image**	**Sound**	**Video**	**360 Video**	**Links**	**Template scenes**	**Advanced scripting capabilities**
✓	✓	✓	✓	✓	Third party extension	✓	---	✓

Related links

Cost: Free for personal use and students

Link: https://gamemaker.io/en

Tutorials: https://gamemaker.io/en/tutorials

YouTube: https://www.youtube.com/watch?v=nBCDzE9MDbk&ab_channel=ShaunSpalding

Facebook: https://www.facebook.com/GameMakerEngine/

6.5 Discussion

When it comes to game engines, two industry standards stand out today: Unity and Unreal. Each has its own strengths and capabilities. The latest updates in Unreal Engine 5 have significantly enhanced its 3D capabilities, making it a leader in incorporating advanced 3D graphics and offering ease of use for 3D artists. Meanwhile, Unity continues to maintain its dominance in the realm of 2D games. EMERGO serves as an example of an academic approach to methodologies and tools that are effective for serious games.

For user-friendly experiences and to engage younger users in development topics, GameMaker is a recommended platform. Its design allows for an easy start without the need for coding, promoting systematic thinking and introducing basic concepts that serve as a foundation for progressing to more advanced scripting tools.

It's important to emphasize that the effective implementation of inclusive learning, inquiry-based learning, problem-based learning, and gamification depends on game design, integration into the curriculum, and guidance from educators. While these game engines are powerful tools, they are essentially blank canvases that come to life through the content we create. However, in most major applications today, Unity or Unreal are the standards due to their extensive customization

options and versatility for developing various types of applications. It's worth noting that both Unity and Unreal require a higher level of coding knowledge compared to a tool like GameMaker, which may be more accessible for younger users starting out. Table 6.4 provides a comparison of the previously mentioned game engines.

Table 6.4 Comparison of game engines

Game engines		Unity	Unreal	Game maker
Platforms	Android	✓	✓	✓
	iOS	✓	✓	✓
	Windows	✓	✓	✓
	MacOS	✓	✓	✓
	Web	---	✓	✓
Cost		Free & Paid	Free & Paid	Trial and paid
Domain		Independent	Independent	Independent
Ease of use		Mid	Mid	High
Interactive features		Pathfinding and AI, Event System, Networking, Particle System, User Interface (UI) System, Timeline and Cinemachine, Real-Time Physics Simulation.	Pathfinding and AI behavior trees, Event System, Networking, Particle System, User Interface (UI) System, Blueprints, Real-Time Physics Simulation.	GML (GameMaker Language), collision detection, particle system, physics engine, timeline system.
upported elemen	Text	✓	✓	✓
	Image	✓	✓	✓
	Sound	✓	✓	✓
	Video	✓	✓	✓
	360 Video	✓	✓	Third party extension
	Links	✓	✓	✓
	Templates	✓	✓	---
Advanced scripting		✓	✓	✓
Collaboration		✓	✓	✓
Interactivity		✓	✓	✓
Gamification Elements		Manually by the user	Manually by the user	Manually by the user

7 Appendices

8 References

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