Using Mobile Augmented Reality Games to develop key competences through learning about sustainable development

Augmented Reality Toolkit

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INTRODUCTION

About the toolkit

As globalization continues to confront the European Union with new challenges, each citizen are expected to develop a wide range of skills to adapt flexibly to a rapidly changing and highly interconnected world. These skills emerge today as key to allow people develop good-quality jobs and fulfill their potential as confident, active citizens. Based on the European Commission's report (2016), early acquisition of these skills is the foundation for the development of higher, more complex skills that are needed to drive creativity and innovation. Education in its dual role, both social and economic, has a key role to play in ensuring that Europe's citizens acquire the skills needed to enable them to adapt. Implementing key competences in schools involves not only specifying them in curricula, but also developing structures, innovative teaching methods as well as proper ICT tools that are open to teachers and students. Given their cross-curricular nature, this involves a whole-school planning (Key competence Network in School Education- KeyCoNet, 2012). According to the same organization, the key themes in teaching Key Competences for the 21st century relate to creating meaningful education based on real problems and engagement, interdisciplinary environments that enhance learners' experiences through goal-directed, active, authentic and collaborative tasks.

Mobile Augmented Reality Games (MARG) are gaming environments that embed virtual, location-specific and contextual information into a physical site (Schrier, 2006, Kasapakis and Gavalas, 2015). These games require mobile or ubiquitous computing devices, such as hand-held computers or cellular phones, to enable game participants to access this virtual information. Instead of putting people in an artificial world, these games augment the physical world by embedding them with digital data, networking and communication abilities, and enhanced properties providing at the same time in-situ or inquiry-based learning experiences. Research on the use of MARG has shown potential benefits in fostering key competences such as collaboration, critical thinking, problem solving, social and civic competences as well as cultural awareness. However, there is a lack of an organized effort to sum up the potential benefits of these games and more importantly to incorporate them in the teaching practice as teachers' toolkit to foster students' key competences.

The Augmented Reality Toolkit presented in this document aims to provide educators with the necessary theoretical and technical knowledge to use MARG in their educational practice as means to develop students' key competences through learning about sustainable development. The Toolkit is structured as follows. First, the European Framework for key competences is presented as well as definitions for

digital and civic competences, which are the project's target competences. The second part of the toolkit presents the findings of the curriculum analysis conducted by the partner countries regarding how these competences are promoted through their school curricula under the subject of sustainable development. Then, an introduction to Augmented Reality (AR) and MARG is presented. Later, in the fourth part of the toolkit, a literature review regarding MARG good practices in education is presented. Finally, the document presents two educational platforms for the development of MARG.

1. Key competences for lifelong learning

Equipping children and young people with key competences which facilitate the application of knowledge to the fast-changing real-world contexts of the 21st century is a universal challenge faced by schools. In May 2018, the Council of the European Union adopted a Recommendation on key competences for lifelong learning. The Recommendation identifies eight key competences essential to citizens for personal fulfilment, a healthy and sustainable lifestyle, employability, active citizenship and social inclusion.

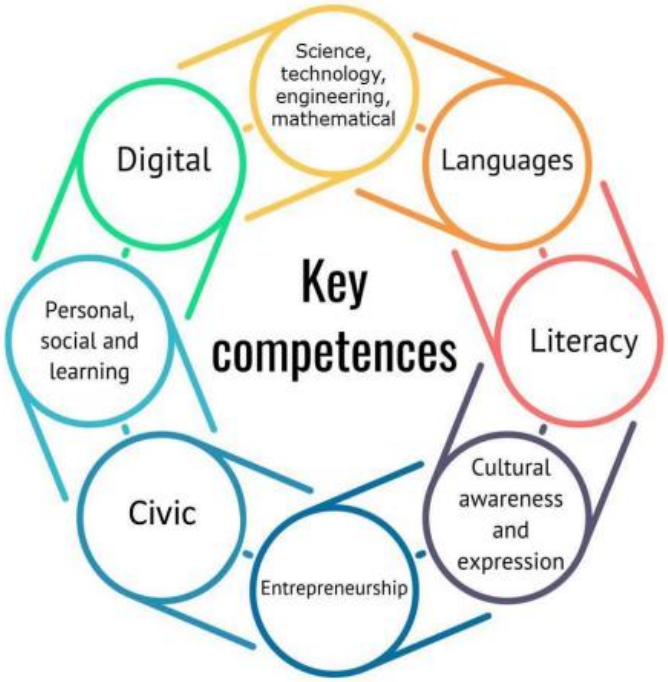


Figure 1: European Commission, 2018, Proposal for a COUNCIL RECOMMENDATION on Key Competences for Lifelong Learning https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018SC0014&from=EN

These eight key competences, which are also shown in Figure 1, are: **Literacy competence**, **Multilingual competence**, **Mathematical competence and competence in science, technology and engineering**, **Digital competence**, **Personal, social and learning to learn**

competence, **Civic competence**, **Entrepreneurship competence**, **Cultural awareness and expression competence**.

The key competences are a combination of knowledge, skills and attitudes (European Commision,2019).

- ***Knowledge*** *is composed of the concepts, facts and figures, ideas and theories which are already established, and support the understanding of a certain area or subject.*
- ***Skills*** *are defined as the ability to carry out processes and use the existing knowledge to achieve results.*
- ***Attitudes*** *describe the disposition and mindset to act or react to ideas, persons or situations.*

The key competences are developed throughout life, through formal, non-formal and informal learning in different environments, including family, school, workplace, neighborhood and other communities. All key competences are considered equally important and aspects essential to one domain will support competence development in another. For example, skills such as critical thinking, problem solving, teamwork, communication, creativity, negotiation, analytical and intercultural skills are embedded throughout the key competences.

1.1. Digital competences

Digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property related questions, problem solving and critical thinking. In order to help citizens improve their digital competences, European Commission has launched the Digital Competences Framework 2.0 (European Commission, 2016)

Essential knowledge, skills and attitudes related to this competence

- ***Knowledge***

Individuals should understand how digital technologies can support communication, creativity and innovation, and be aware of their opportunities, limitations, effects and risks. They should understand the general principles, mechanisms and logic underlying evolving digital technologies and know the basic function and use of different devices,

software, and networks. Individuals should take a critical approach to the validity, reliability and impact of information and data made available by digital means and be aware of the legal and ethical principles involved in engaging with digital technologies.

- ***Skills***

Individuals should be able to use digital technologies to support their active citizenship and social inclusion, collaboration with others, and creativity towards personal, social or commercial goals. Skills include the ability to use, access, filter, evaluate, create, program and share digital content. Individuals should be able to manage and protect information, content, data, and digital identities, as well as recognize and effectively engage with software, devices, artificial intelligence or robots.

- ***Attitudes***

Engagement with digital technologies and content requires a reflective and critical, yet curious, openminded and forward-looking attitude to their evolution. It also requires an ethical, safe and responsible approach to the use of these tools.

1.2. Civic competences

Civic competence is the ability to act as responsible citizens and to fully participate in civic and social life, based on understanding of social, economic, legal and political concepts and structures, as well as global developments and sustainability

Essential knowledge, skills and attitudes related to this competence

- ***Knowledge***

Citizenship competence is based on knowledge of basic concepts and phenomena relating to individuals, groups, work organizations, society, economy and culture. This involves an understanding of the European common values, as expressed in Article 2 of the Treaty on European Union and the Charter of Fundamental Rights of the European Union. It includes knowledge of contemporary events, as well as a critical understanding of the main developments in national, European and world history. In addition, it includes an awareness of the aims, values and policies of social and political movements, as well as of sustainable systems, in particular climate and demographic change at the global level and their underlying causes. Knowledge of European integration as well as an awareness of diversity and cultural identities in Europe and the world is essential. This includes an understanding of the multi-cultural and socioeconomic dimensions of European societies, and how national cultural identity contributes to the European identity.

- ***Skills***

Skills for citizenship competence relate to the ability to engage effectively with others in common or public interest, including the sustainable development of society. This

involves critical thinking and integrated problem-solving skills, as well as skills to develop arguments and constructive participation in community activities, as well as in decision-making at all levels, from local and national to the European and international level. This also involves the ability to access, have a critical understanding of, and interact with both traditional and new forms of media and understand the role and functions of media in democratic societies.

- ***Attitudes***

Respect for human rights as a basis for democracy lays the foundations for a responsible and constructive attitude. Constructive participation involves willingness to participate in democratic decision making at all levels and civic activities. It includes support for social and cultural diversity, gender equality and social cohesion, sustainable lifestyles, promotion of culture of peace and non-violence, a readiness to respect the privacy of others, and to take responsibility for the environment. Interest in political and socioeconomic developments, humanities and intercultural communication is needed to be prepared both to overcome prejudices and to compromise where necessary and to ensure social justice and fairness.

2. CURRICULUM ANALYSIS IN PARTNER COUNTRIES

Key competences have grown in prominence in European education systems in recent years and most European countries have made significant progress towards incorporating the key competences into national curricula and other frameworks (European Commission, 2019). Depending on their education systems and national curriculum goals, EU member states have developed unique approaches to key competences independently of the influence of the European framework, resulting in varying emphases. In some member states, there are national frameworks similar to the European Framework. In others, aspects of key competences have been added as a complement to parts of existing curricula. They are designed and organized in different ways depending on the prevailing ideas and priorities in each member state. These framings structure the ways in which key competences are implemented in national curricula and in schools.

UMARG project's main objective is to explore the potential of MARG use in educational settings, in order to promote students' digital and civic competences. In this context, educators will create playful learning experiences with MARG for their students, while students learn about sustainable development. In this chapter, we present a brief introduction in Sustainable Development Goals as adopted by UNSECO as well as how digital and civic competences are linked with sustainable development education. Furthermore, researchers and educators involved in the UMARG project, present their findings from the analysis on their national curricula regarding how digital and civic competences are promoted under the subject of sustainable development. The findings of the analysis will help educators gain an overall understanding on how sustainable development is promoted in the rest of the partner countries (Figure 2) and thus find common ground with their collaborating educators towards creating meaningful game experiences that promote their students' digital and civic competences.

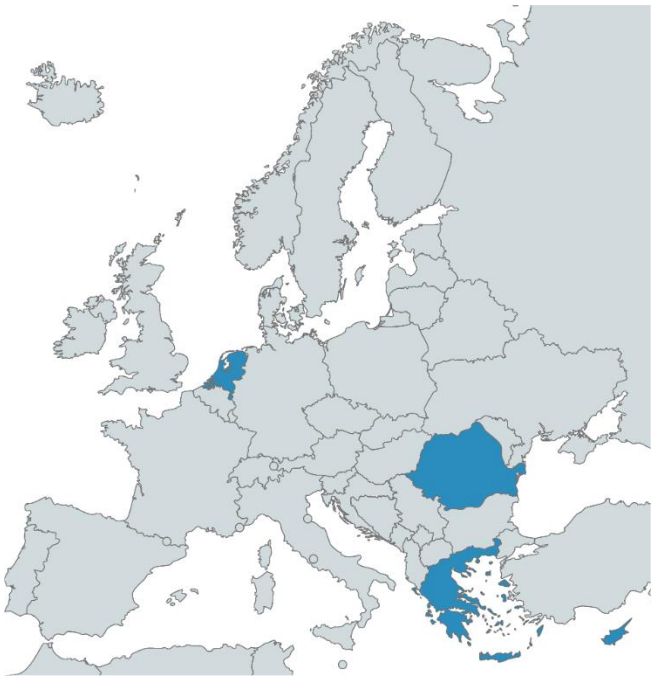


Figure 2 UMARG partner countries

2.1. Key competences in Education for Sustainable Development

As societies around the world struggle to keep pace with the progress of technology and globalization, they encounter many new challenges. These include increasing complexity and uncertainty; more individualization and social diversity; expanding economic and cultural uniformity; degradation of the ecosystem services upon which they depend; and greater vulnerability and exposure to natural and technological hazards. A rapidly proliferating amount of information is available to them. All these conditions require creative and self-organized action because the complexity of the situation surpasses basic problem-solving processes that go strictly according to plan. People must learn to understand the complex world in which they live. They need to be able to collaborate, speak up and act for positive change. We can call these people "sustainability citizens" (Wals, 2015; Wals and Lenglet, 2016).

There is general agreement that sustainability citizens need to have certain key competencies that allow them to engage constructively and responsibly with today's world. The sustainability skills represent what sustainability citizens particularly need to deal with today's complex challenges. According to UNESCO (2018) critical thinking, problem solving, collaboration, active citizenship, self-awareness and critical use of all forms of media are core sustainability skills that cut through several key competences (as described by the EU Key Competences Framework) and are essential to future citizens. Based on the above, it is easily understood that most of the core sustainability skills are directly linked with both civic and digital competences which are UMARG project's target competences.
In Table 1, we summarize UMARG project's target key competences and their skills.

Table 1: UMARG project's target key competences and their skills

Digital competencies	Civic competencies
information and data literacy	critical thinking
Communication and collaboration	active citizenship
problem solving	respect for differences

Education for Sustainable Development (ESD) is a key element of the 2030 Agenda for Sustainable Development. It is considered a driver for the achievements of all 17 Sustainable Development Goals (Figure 3).

Figure 3:Sustainable Development Goals by UNESCO

According to UNESCO (2018). ESD is holistic and transformational education that addresses learning content and outcomes, pedagogy and the learning environment. Thus, ESD does not only integrate contents such as climate change, poverty and sustainable consumption into the curriculum; it also creates interactive, learner-centered teaching and learning settings. What ESD requires is a shift from teaching to learning. It asks for an action-oriented, transformative pedagogy, which supports self-directed learning, participation and collaboration, problem-orientation, inter- and transdisciplinary and the linking of formal and informal learning. Only such pedagogical approaches make possible the development of the key competencies needed for promoting sustainable development.

In order to support educators, UNESCO has published an educational giude with learning objectives for each Sustainable Goal and developed an online resource bank with hundreds of pedagogical ideas for classroom activities and multimedia resources detailing how best to integrate ESD into teaching and learning, from early childhood care through secondary education.

2.2. Cyprus

In Cyprus, the implementation of sustainable development started officially in 2011 as an interdisciplinary lesson and not a separate lesson itself. The main purpose of the Sustainable Development Curriculum is to develop a sustainable school that promotes sustainability and adopts it in school life. In this curriculum, environmental issues beyond being considered natural phenomena are holistically and interrelated in the light of the social, economic, political, and ethical factors involved and affecting them. In this context, the thematic modules constitute a flexible learning tool, through which each school has the opportunity and ability to approach environmental and sustainability issues based on its own needs and aspirations. These issues transcend

the school curriculum, are systematical, interdisciplinary, and comprehensive from early childhood, and extend lifelong through the link between formal and non-formal education, beginning with the learner and his immediate local environment.

The specific purposes of the Sustainable Education curriculum are to shape active citizens so that they:

- will be environmentally aware and possess the necessary skills and will to become agents of change to solve them,
- will not passively respond to and adapt to the choices and requirements of the various centers of power,
- will intervene dynamically and democratically in the social events aimed at the changes required and the development of sustainable development conditions,
- will have visions, abilities, and values that will help them negotiate and individually and collectively design the social terms of sustainability

The Sustainable Development Curriculum is being taught in parallel with other subjects such as Language, Geography, History, Science in 5th and 6th grade in elementary schools of Cyprus. Some of the thematic units in the context of Sustainable Development Curriculum as well as the subskills related to civic and digital competences are summarized in Table 2. For the detailed report on the curriculum analysis from Cyprus, please check Annex.

Table 2: SCE Thematic units and Key competences in Cypriot national curricula

SDE Thematic Units	Key competences and skills
Offscourings, Urban Development Biodiversity, Forest, Energy, Poverty Desertification, Means of transport Production and Consumption Culture and Environment	Problem-solving, Critical thinking, Social responsibility Autonomy, Questioning, Reflection, Active Citizenship, Learning how to learn, Decision making, Respect for differences, Sustainable development thinking, Collaboration, Environmental awareness, Socio-economic systems knowledge, Values and democratic cultivation, Respect human rights

2.3. Greece

Greece places particular emphasis on achieving sustainable development and is strongly committed to the implementation of the 2030 Agenda for Sustainable

Development and its 17 Sustainable Development Goals (SDGs), as they provide an ambitious, visionary and transformative framework for a new, equitable and sustainable development path. In this context, the Hellenic Ministry of Education is promoting policies and measures at all education levels, for the integration of the basic principles of sustainable development, in line with the overall national education policy, and is implementing concrete interventions at all levels of education. For this reason, a new legislative framework for ESD has been designed, which integrates all related thematic areas (Environmental Education, Health Education and Cultural Issues) into a common sustainable whole-school approach, with the aim to provide schools with an overall unified framework equally applied for all sectors of education, under which any specific activity can be carried out in a concerted way.

The specific purposes of the Sustainable Education curriculum are to shape active citizens so that they understand and apply in their daily lives knowledge and processes related to:

- The basic human needs, such as the right of all people and societies to access natural resources for survival and quality of life, within the bearing capacity of the planet.
- Human rights and fundamental principles, which ensure access to participatory democracy.
- The interdependence / interaction between all forms of life, including the human, within the physical systems.
- The recognition that the production or consumption of a product or one service, in one part of the planet, depends on natural resources to other parts of the planet and that this creates dynamic opportunities but and losses of environmental, social and economic elements to other parts of the local - global chain.
- The ecological footprint regarding the amount of land and natural resources consumed by an individual, community or population as well as and their impact on the environment and especially on their depletion resources and pollution or contamination.
- The principle of prevention, specifically the knowledge of the consequences on the environment from human activities.

The Sustainable Development Curriculum is being taught in parallel with other subjects such as Language, Geography, History, Science in 5th and 6th grade in elementary schools of Greece. Some of the thematic units in the context of Sustainable Development Curriculum as well as the subskills related to civic and digital competences are summarized in Table 3. For the detailed report on the curriculum analysis from Greece, please check Annex.

Table 3: SCE Thematic units and Key competences in Greek national curricula

SDE Thematic Units	Key competences and skills
Water resources management Soil and subsoil quality Loss of Biodiversity Energy Issue Energy Footprint Environment and Social / Human Relationship Issues Natural Disasters / Environmental Crisis Management Local Environment Sustainable school and sustainable home Climate change	Problem-solving, Critical thinking, Social awareness, Reflection, Active Citizenship, Learning how to learn, Decision making, Respect for differences, Sustainable development thinking, Collaboration, Environmental awareness, Values and democratic cultivation, Respect human rights

2.4. The Netherlands

In the Netherlands, the implementation of sustainable development is embedded within different school subjects and not taught as a separate course. The main purpose of the Sustainable Development Curriculum is to promote sustainable thinking in future citizens. In this context, students are made aware of the way in which humanity uses the earth resources and the consequences thereof. They will look not only to the current state but also be made to think about sustainable solutions for the future and how their own usage impacts the planet. Also the subject of prosperity in relation to the use of resources is taught within Geography.

The workings and consequences of the Greenhouse-effect and the human impact thereof are taught both within Geography and Biology. This is also the case when it comes to recognizing ecosystems at different levels where students learn to give examples where the capacity of the natural environment is exceeded and recognizes environmental problems. Within Biology the subject of ecosystems is further developed with knowledge about biodiversity, characteristics of ecosystems and the role of biotic and abiotic factors such as soil and water. Biology also covers the subjects of dynamic equilibrium, food cycles and carbon cycles as ways in which species are dependent and influence each other.

The last subject contains within itself goals pertaining to sustainability is physics. Within physics student are taught about energy and different kinds of energy transition. This then helps them describe different kinds of energy-sources, like (fossil) fuels, waterpower, wind, solar energy and ways to make and store these kinds of energy. As well as the relation between the use energy and environmental problems and sustainable solutions. To aid in this they are taught to calculate the energy efficiency of different devises. Next to energy there is also the subject of heating and

combustion. Students will be able to relate (in)complete combustion with environmental effects like the greenhouse effect or air pollution by small particle.

Some of the thematic units in the context of Sustainable Development Curriculum as well as the subskills related to civic and digital competences are summarized in Table 4. For the detailed report on the curriculum analysis from Netherlands, please check Annex.

Table 4: SCE Thematic units and Key competences in Dutch national curricula

SDE Thematic Units	Key competences and skills
Earth resources management Environment and Social / Human Relationship Issues Loss of Biodiversity Energy Issue Energy Footprint Climate change	Information and data literacy, Computational thinking, Communication Technological literacy, Research and organization of information, Collaboration, Problem solving, Creativity, Critical thinking, Active citizenship, Research skill, Exchange ideas, Scientific point of view

2.5. Romania

In Romania, Sustainable Development is addressed transversally in the formal curriculum of pre-university education (starting with the 3rd grade), as well as in various extracurricular activities (especially within the national program Școala Altfel). The overall purpose of Sustainable Development in education is to turn children into active citizens that understand the complex implications of one's actions and choices, but also the role that each of them plays in shaping a sustainable future.

Though the preoccupation with the matter of Sustainable Development is strong in the Romanian educational climate, it has not yet been granted the status of a discipline in the curriculum; in exchange, the issue of Sustainable Development is significantly present in the syllabus of other related subjects starting from the 3rd grade (8-9 years old): Civic Education (e.g. community actions to protect the green spaces near the school units, understanding the impact of the individuals on the climate and on the climate changes), Natural Sciences (e.g. identification of certain forms of pollution, identification of human destructive behaviours towards the environment, selective waste collection, greening), Geography (e.g. understanding the need to protect the living environment, participation in environmental conservation activities, asserting respect for natural and human diversity, understanding and appreciation of human diversity, through tolerance and respect for different value systems, proposing measures/solutions for the conservation and protection of the diversity of local, national, European and world heritage), Social Education (e.g. identification of existing minorities at local level, civic participation of minorities and/or immigrants, local intercultural relations, integration of a

disadvantaged minority, cultural diversity and interference, etc.), Technology (promotion of a healthy lifestyle, clean environment, influence on the individual/society; reuse of objects/products in new situations/contexts used; identification of ways to save resources and reuse waste), Biology (e.g. practising responsible behaviours in case of emergency, e.g. earthquakes, fires, accidents, etc., analysis of the action of some pathogens/polluting factors on the health status of the living creatures, including of the human being, self-assessment of eating behaviour), Physics (energy and renewable energies). The integration of these sustainable development topics into primary school subjects favours a comprehensive approach to learning that basically encourages the formation of responsible citizens from early childhood.

Some of the thematic units in the context of Sustainable Development Curriculum as well as the subskills related to civic and digital competences are summarized in Table 5.

Table 5: SCE Thematic units and Key competences in Romanian national curricula

SDE Thematic Units	Key competences and skills
environmental protection natural resource management biological and nature diversity in the local and global context production and consumption models rural and urban development civic responsibility, citizenship duties, human rights, health, cultural diversity.	critical thinking, active citizenship, respect for differences, information and data literacy, communication, collaboration,

3. INTRODUCTION TO AUGMENTED REALITY

Implementing key competences in schools involves not only specifying them in curricula, but also developing structures, innovative teaching methods as well as proper ICT tools that are open to teachers and students. Given their cross-curricular nature, this involves a whole-school planning. This procedure presents a number of challenges specifically in terms of learning environments. Based on the European Policy Network on the Implementation of Key Competences (2014), traditional classroom learning environments may not be the most appropriate context for the effective development of key competences. Instead, learners need 'innovative, non-traditional avenues and venues'. The key themes in teaching key competences for the 21st century relate to creating meaningful education based on real problems and engagement, interdisciplinary environments that enhance learners' experiences through goal-directed, active, authentic and collaborative tasks. Such activities can motivate learners more than traditional approaches, they provide a meaningful

environment where learners can be presented with real life problems, which they can attempt to solve through debate, experimentation, exploration and creativity and collaboration with other learners. Examples of such activities are more recently found in the use of contemporary technology applications, as for example, augmented reality.

Augmented Reality (AR) is an upcoming technology that could prove itself a useful tool for educators to create engaging learning experiences for students. The technology of AR is expected to play a dominant role in the way we learn in the next years and research findings from the use it in education have shown quite promising results. Furthermore, the increasing usage of mobile devices by young people puts mobile AR on the top rank of available open technologies that can be used for educational purposes. Although, there are numerous reports that consider virtual learning environments the next trend in teaching key competences, there seems to be a lack of initiatives that incorporate this technology in their toolkit. The basic reason for this is that AR is still in an advancing state and most educators are mainly not aware of it and in most cases not properly trained to use and implement it in their teaching practice.

The purpose of this chapter is to inform educators about what is considered as AR technology, its types and the available technologies to experience it as well as to define Mobile Augmented Reality Games (MARG) as mobile gaming environments that use AR.

3.1. What is Augmented Reality?

Augmented reality is the technology that expands our physical world, adding layers of digital information onto it. Unlike Virtual Reality (VR), AR does not create the whole artificial environments to replace real with a virtual one. AR appears in direct view of an existing environment and adds sounds, videos, graphics to it. A view of the physical real-world environment with superimposed computer-generated images, thus changing the perception of reality, is the AR.

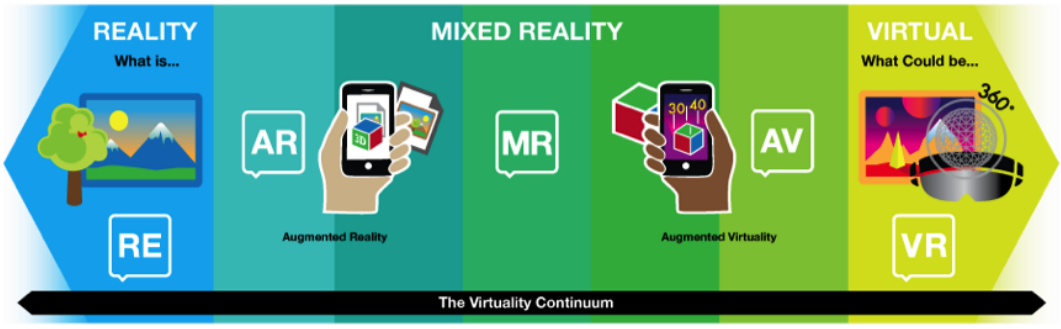


Figure 4: Virtuality continuum.
Retrieved from https://www.trekk.com/insights/augmented-or-virtual-how-do-you-your-reality,2019

The terms augmented reality (AR) and virtual reality (VR) are often used interchangeably in conversation, but they actually represent two completely different ways to experience information (Figure 5). Traditionally, AR is experienced with a mobile device or via a computer screen and webcam. Your camera "sees" a marker and the view you have through the window of your device is altered to reflect an enhanced version of the scene in front of you. Hence, "augmented" reality. Virtual reality, on the other hand, is the practice of tricking the mind into experiencing a completely alternative reality — one that is not really there. Today this is done with wearables like headsets or glasses).

3.2. Types of Augmented Reality

These technological elements are the only things that add-up into what is augmented reality term. The process of it is a complex of different technologies, and it can work through two basic approaches which are described below and examples of them are shown in Figure 6.

Image based AR: This technology is based on the usage of the camera to identify visual markers or objects. They can be 2D, QR codes or natural feature tracking markers (NFT), which shows an overlay when the marker is covered by the device's camera. The marker-based AR technology mostly depends on the camera to distinguish a marker from the real-world objects. When the marker is recognized by the device, it is immediately replaced by the digital information or virtual 3D graphics.

Location-Based AR: Opposite to what is augmented reality by recognition, location-based AR is mainly based on a GPS, digital compass, velocity meter, or accelerator to receive the data about the location and implement augmented reality visual based on the data that is collected. Smartphones are one of the best possible devices to use location-based AR apps since they have the needed functions and make it easy to leverage this type of technology, at the same time making it even more popular. If you are wondering if you ever met this kind of technology – you probably have. It is mostly used in such technologies as finding nearby services, location-centric mobile apps, and mapping directions.

Figure 5: Examples of Image based AR and Location based AR. Images retrieved from https://thinkmobiles.com/blog/what-is-augmented-reality/

3.3. Augmented Reality devices

Augmented Reality can be experienced through a wide variety of devices. These are:

- Computers with cameras
- Mobiles devices (smartphones, PDAs, tablets)
- Head mounted displays (HMD)
- AR glasses

3.4. Mobile Augmented Reality Games

Mobile Augmented Reality Games (MARG) are gaming environments that embed virtual, location-specific and contextual information into a physical site. These games require mobile or ubiquitous computing devices, such as handheld computers or cellular phones, to enable game participants to access this virtual information. Instead of putting people in an artificial world, these games augment the physical world by embedding them with digital data, networking and communication abilities.

Research on the educational value of MARG in education have shown quite promising results. The advantages of educational MARG can be found in their capability to be played both in formal as well as in informal educational settings, allow the collaboration of multiple players, provide real-context learning situations that can boost players' critical thinking and maximize learning outcomes.

4. GOOD PRACTICES FOR EDUCATIONAL MARG

Mobile augmented reality (MAR) has emerged as a mainstream technology to provide novel visualization and interaction opportunities across application domains. The primary advantage of MAR is its ability to bridge the real world with virtual worlds by bringing virtual elements onto a real-world view, and by adapting the experience according to the user's location and other context parameters. Research has shown (Laine, 2018) that MAR possesses a multitude of affordances in the field of education. These affordances can be amplified in educational MAR games (EMARGs) due to the motivational value and the fun factor provided by intriguing game elements. MARG are particularly well-suited for educational applications in informal contexts, such as museums, parks, and streets, where the learning experience can be adapted to match the location and other contextual information connected to the learner.

To explore if and how AR and especially MARG are promoted in partner countries, researchers have collected a number of case studies that took place in their national educational context. The results showed that although AR was frequently used in teaching and learning, it was limited by the use of certain AR applications or AR devices

(i.e. AR glasses). There were only a few MARG found, which emphasizes the project's rationale and the need for an organized effort to sum up the potential benefits of these games and more importantly to incorporate them in the teaching practice as teachers' toolkit to acquire and foster key competences.

In this chapter, we present a number of good practices of educational MARG from international context as well as one representative case study from each of the partners' national context. Through this presentation, educators will have the opportunity to explore how MARG were used in each educational setting (formal/informal) as well as to discover different game scenarios, devices and platforms that were used in these cases.

4.1. International case studies

EcoMOBILE

Figure 7: EcoMOBILE project in action, Retrieved from http://positive6.com/ecomobile-takes-the-tech-outside/, 2020

Positioned in the context of situated learning theory, the EcoMOBILE project (Kamarainen et al, 2013) combined an AR experience with use of environmental probeware during a field trip to a local pond environment. Activities combining these two technologies were designed to address ecosystem science learning goals for middle school students, and aid in their understanding and interpretation of water quality measurements. The intervention was conducted with five classes of sixth graders from a northeastern school district as a pilot study for the larger EcoMOBILE project, and included pre-field trip training, a field trip to a local pond environment (Figure 7), and post-field trip discussions in the classroom.

During the field experience, students used mobile wireless devices with **FreshAiR platform**, an augmented reality application, to navigate the pond environment and to observe virtual media and information overlaid on the physical pond. This AR experience was combined with probeware, in that students collected water quality measurements at designated AR hotspots during the experience. Teachers reported that the combined technologies promoted student interaction with the pond and with classmates in a format that was student-centered rather than teacher-directed. Teachers also reported that students demonstrated deeper understanding of the principles of water quality measurement than was typical on prior field trips without these technologies and that students had expanded opportunities to engage in activities that resemble scientific practice.

Environmental Detectives

Environmental Detectives was the first AR game created by the MIT Step Lab (Klopfer & Squire, 2007) and the MITAR tool (now known as **Taleblazer**). It was targeted at high school and university students. In this game students played the role of environmental engineers who were enlisted by the University president to investigate the spill of the toxin, a carcinogenic degreasing agent, commonly found in machine shops, cafeterias, and hospitals. The goal of the game was to locate the source of the spill, identify the responsible party, design a remediation plan, and brief the president of the University on any health and legal risks so that he will be prepared for a meeting with the EPA – all within two hours. At the end of the game, students made a five-minute presentation to their peers outlining their theory behind the spill.

The spread of the toxin was simulated on a location-aware Pocket PC (Figure 8), which functioned as a tool which students could use to investigate the toxic spill. Each Pocket PC was equipped with a GPS device, which allowed players to sample chemical concentrations in the groundwater depending on their location. Players were given three reusable drilling apparatuses which they could use to drill for water samples. After drilling for a sample, players waited three minutes for the sample to return, meaning that students could only take three samples at a time, and were forced to develop sampling strategies in order to optimize the amount of ground that they could cover in limited time. Environmental Detectives contained a multimedia database of resources which students could use to learn more about the chemical, where it was found on campus, the health risks associated with exposure to the toxin, how it flowed through ground water, relevant EPA regulations, remediation strategies for cleaning up the toxin, and the political and economic consequences of EPA violations on campus. Students accessed these resources by obtaining interviews from virtual university faculty and staff who were spread across campus at locations roughly corresponding with actual operations.

Figure 8: Pocket-PC in Environmental Detectives, Retrieved from http://web.mit.edu/mitstep/ar/ed.html ,2020

Feedback from the students participating in this trial showed that they enjoyed the combination of real and virtual worlds, as well as the interplay between primary and secondary information. Students were particularly intrigued by the virtual characters and were excited to see game play linked to character interactions.

Mad City Mystery

Mad City Mystery was a murder mystery game created by Wisconsin Field Lab (Squire & Jan, 2007) and set in around Lake Mendota Madison. Students were assigned the investigation of an untimely death caused by a murder, suicide, or the combination of several interacting toxic chemicals that were commonly found in the region. The goal of the game was to investigate whether augmented reality games on handhelds could be used to engage students in scientific thinking (particularly argumentation), how game structures affected students' thinking, the impact of role playing on learning, and the role of the physical environment in shaping learning. The game was designed with **ARISGAMES**. It was played through smartphones and contained a multimedia database of resources which students could access by obtaining interviews from virtual university characters in order to collect evidence that could lead to the solution of the mystery.

Results showed that MARG games hold potential for engaging students in meaningful scientific argumentation. Through game play, players were required to develop narrative accounts of scientific phenomena, a process that required them to develop and argue scientific explanations. We argue that specific game features scaffolded this thinking process, creating supports for student thinking non-existent in most inquiry-based learning environments.

4.2. Case studies in partner countries

Cyprus

Young Archaeologists

This study investigated the contribution of a location-based AR inquiry-learning environment in developing 3rd grade students' historical empathy and conceptual understanding. Fifty-three 3rd grade students, in two groups, visited an archaeological site with the support of an AR learning environment on mobile tablet devices. The pedagogical design of the field trip consisted of three activities: (a) A classroom-based activity prior to the field trip, (b) the outdoor field trip activity and (c) a post-field trip, classroom-based activity.

Figure 9: The "Young Archaeologists" interactive navigation map, (Efstathiou et al. 2017)

The classroom activity prior to the field trip focused on the Palaeolithic era. During the field trip students used the inquiry-learning environment "Young Archaeologists" specifically designed by their teacher using the **TraceReaders** (Georgiou & Kyza, 2013) location-based AR learning platform. The multimedia data were activated at each of five hotspots using the tablet's integrated GPS system and supported by Google Maps navigation. A virtual archaeologist in the "Young Archaeologists" learning environment (LE), presented in the form of videos at each hotspot, provided information and prompted students to reflect and connect the data with the archaeological site, thus seeking to bridge the distance between the present and the historical past. During the third phase, students answered a questionnaire about their trip and discussed their results with their classmates.

Greece

Save Elli, Save the environment

The purpose of the game "Save Elli! Save the Environment" was that students of the last three grades of primary school to explore the environmental problems of the island of Santorini, adopt positive attitudes toward environmental issues on the island, propose solutions for improving the quality of life and the development of their land, and finally develop ways and skills of intervention in their immediate social environment to address the problems of the wider environment.

Figure 10: Examples of game screens, (Koutromanos et al.2018)

For this purpose, five locations with real environmental issues were selected. Those locations were either within walking distance of school or provided clear visual contact from the point the game was taking place. The scenario of the game asked students, in groups of five, to save a small sea turtle, Elli, from a wicked scientist whose purpose was to destroy the environment of Santorini. At the time of her abduction, Elli left five clues at the above five locations of the island to guide the students to the scientist's laboratory. Those five clues composed the five-digit code that, at the end of the game, released Elli from the lab of the bad scientist. Each of the five locations was augmented with two kinds of digital material, which appeared automatically when the students

entered the geographical boundaries of the selected area: (a) the ecological problem ,enhanced with digital information (image, video, or website) and (b) a multiple choice question related to the environmental problem. To earn the clue of each area, students had to collect and process information from the digital material and from the physical environment through a worksheet so as to answer correctly the question that followed. By answering the questions correctly, students could discover the secret code that released Elli and successfully complete game. The game was designed with **ARIGAMES platform** and was played on tablets (iOS operating system). Examples of game screens are shown in Figure 10.

Each group of students, upon its return to school the next day, completed the worksheet by proposing solutions to limit or address the environmental problem of each location they visited. Finally, all groups discussed together their experiences regarding the environmental problems they identified, and through various activities (e.g., collage, posters), they suggested specific actions for the implementation of the solutions they proposed.

The Netherlands

Frequency 1550

The Frequency 1550 AR game was developed by the Waag Society - a Dutch ICT research foundation working in the social and cultural domain- to help pupils in their first year of secondary education playfully acquire historical knowledge of medieval Amsterdam. The pupils were introduced to the game, the tasks, the tools to be used and the objective of the game: To gain citizenship in the city of Amsterdam via attainment of the required 366 points or 'days of citizenship' which represent the medieval year-and-a-day rule that required residence within the Amsterdam city walls for that period of time to earn civil rights. Groups of four or five pupils were formed, and the pupils were randomly assigned the identity of a beggar or a merchant who have different rights and a different status (i.e. order) in the game. The part about earning citizenship was the main storyline or the backstory. With the help of the Internet, smart phones, videophones and GPS technology, Amsterdam became a medieval playground (Figure 11).

As soon as the GPS data showed a group reached a particular location, three video assignments in addition to the introductory video were automatically sent from the server in The Waag to the videophone. For each area, there were three similar types of assignments: an orientation assignment, an imagination assignment and a symbolic assignment. Each assignment consisted of three parts and was concluded with a final multiple choice or open-ended question which often required the students to combine their knowledge to find the answer.

Figure 11: Map of medieval Amsterdam in the gameplay, (Huizenga et al. 2007)

Romania

A location-based AR game was designed by Advanced Technology Systems (Romania). The main objective of this game was to investigate to what extent the usage of a location-based AR game could increase the engagement, as well as the learning outcome related to a technical topic (i.e. the core objective of the course).

The 18 participants of the case study (Söbke et al, 2019) were enrolled in a course on management of urban water, which was a part of the master programme Environmental Engineering at Bauhaus-University Weimar offered as distance education with some on-site workshops. As a part of the first on-site workshop in Weimar, the students experienced a customized scenario using a location-based AR game, allowing the students to explore both touristic Points of Interests (POIs), as well as information related to water management. The game was developed with PlayVisit platform and worked on the principle of a scavenger hunt: it lead the students to the next POI by continuously indicating the current distance. Specific, customized information were displayed for each of the POIs, and questions were integrated in the location-based experience to allow checking the students' knowledge, to establish a competition and to capture students' interest. The scenario contained a total of 16 POIs, 6 of which were exclusively of a touristic nature. The differentiation between technical and touristic POIs was based on the subject of the related question (Table 1). For example, the Kirms Krakow House, a touristic location, served as a setting for a question on the role of water in epidemics and therefore was considered a technical POI. Each POI was associated with one multiple choice question that had to be answered. Each questions was preceded by an introductory text, and the answer was followed by an explanatory text.

The participants were divided into groups, using three different paths (set in the personalization of the game play) to avoid a joint tour in a single large group. Each group consisted of three participants, each of whom was asked to perform one of three tasks: (1) operating the mobile app, (2) coordination and documentation of the city tour, and (3) ensuring road safety for the group. Two outcomes were requested to encourage students to participate in the activity: The achieved score in PlayVisit and the handwritten completion of a protocol form in which, for each POI visited, the name of the POI, its key information from the students' point of view, as well as further remarks regarding the POI had to be entered. The tour was expected to last 70 min, and all groups had to return within 90 min. At the end there was a combined debriefing and feedback session of 15 min, where the winning group determined by the highest point score in PlayVisit, was rewarded with a small prize.

5. PLATFORMS FOR CREATING YOUR OWN MARG

The current popularity of mobile AR applications is reflected in a great variety of platforms on which mobile AR games and other applications can be created. However, most of these platforms are targeted to developers and people familiar with coding. Table 6. summarizes 26 of such platforms with their names, target mobile platforms, availability of SDKs, methods of AR target tracking, and license information.

Table 6: Mobile AR platforms. (Laine, 2018)

Name	Client Type	SDK	Target Tracking	License
ALVAR	Android, iOS, Windows, Linux, Mac	Y (C++, Unity)	Fiducial, image, point cloud	Commercial
ANDAR	Android	Y (Java)	Fiducial, image	Open source
ARCore	Android	Y (Java, C#, C++, Unity, Unreal)	Sensor, object	Commercial (free)
ARIS	iOS	N	Fiducial, image	Open source
ARKit	iOS	Y (Objective-C, Swift, Unity, Unreal)	Sensor, face	Commercial (free)
ARToolkit	Android, iOS, Mac, Linux	Y (C/C++, Java, Unity)	Fiducial, image	Open source
Augment	Android, iOS, web browser	Y (Java, Objective-C, Swift, JavaScript)	Fiducial, sensor	Commercial
Aurasma	Android, iOS	Y	Image	Commercial (free)
Blibbar	Android, iOS	Y (JavaScript)	Image	Commercial (free)
CraftAR	Android, iOS	Y (Java, Objective-C, JavaScript, C#, Unity)	Image	Commercial (free)
DroidAR	Android	Y (Java)	Fiducial, sensor, location	Open source
EasyAR	Android, iOS, Windows, Mac	Y (C/C++, Java, Swift, Objective-C, C#, Unity)	Image, object	Commercial (free)
EON Reality	Android, iOS, smart glasses	Y (C++)	Fiducial, image	Commercial
Hoppala Augmentation	Android, iOS	N	Image, location, object	n/a
Infinity AR	Android, iOS, wearables	n/a	Image	Commercial
Kudan AR SDK	Android, iOS, Windows, Mac	Y (Java, C#, Objective-C, Unity)	Image, object	Commercial (free)
Layar	Android, iOS, Blackberry	Y (Java, Objective-C)	Image	Commercial
Maxst AR SDK	Android, iOS, Windows, Mac	Y (C#, Unity)	Fiducial, image, sensor	Commercial (free)
NyARToolkit	Android, iOS, Mac, Linux, Windows	Y (C/C++, Java, C#, ActionScript, Unity)	Fiducial, image	Open source
Rajawali	Android	Y (Java)	Fiducial, image	Open source
Rox AR SDK	Android, iOS, Windows, Linux	Y (C, C#, Unity)	Object, image	Commercial (free)
ViewAR	Android, iOS, Windows, web browser	Y (HTML, JavaScript, CSS)	Image, object	Commercial
Void AR	Android, iOS, Windows, Mac	Y (C#, Unity)	Image	Commercial (free)
Vuforia SDK	Android, iOS, Windows	Y (C#, JavaScript, C++, Java, Unity)	Fiducial, image, object	Commercial (free)
Wikitude	iOS, Android, smart glasses	Y (Java, Javascript, Objective-C, Unity)	Location, object	Commercial
Xzimg	Android, iOS, Windows, web browser	Y (C#, Unity)	Fiducial, face	Commercial (free)

Given the fact that coding is not the field of expertise for the majority of educators, this chapter aims to provide educational community with a list of available and easy to use platforms for creating educational MARG as well as analytical description and user guidelines for the two most popular platforms (Taleblazer and ARISGAMES). Table 7 summarizes the results from the research on the available tools as they appeared both in partners' national and international context.

Table 7: Platforms for creating educational MARG

Name	Client Type	Cost	Website
Taleblazer	Android, iOS	Free	http://taleblazer.org/
ARIS GAMES	iOS	Free	https://fielddaylab.org/make/aris/
Actionbound	Android, iOS	Yes	https://en.actionbound.com/
PlayVisit	Android, iOS	Yes	https://www.playvisit.com/
FreshAir	Android, iOS	Free	Currently not accessible

5.1. Taleblazer

5.1.1. About Taleblazer

Taleblazer is an Augemented Reality (AR) software platform developed by MIT STEP lab. Taleblazer allows users to play and make their own l*ocation-based* mobile games.

5.1.2. Features

Playing games Requirements
• Taleblazer games can be played on most GPS-enabled Android (v. 4.0 or higher) and iOS (v. 6.0 or higher) smartphones. • Google maps API must be bundled with OS. • Mobiles must be equipped with enabled GPS technology. • At least 50MB of storage to cache available • Once the game is downloaded, user does not need an internet connection to play.
Creating games
• Taleblaze editor is browser-based, with no local installation required. It uses visual blocks-based scripting language (helps user to create rich interactivity and to avoid syntax errors). • Users create accounts (project can be saved to the cloud and user can have instant access to it from any computer attached to the Internet)
Featured games
• Visit an officially partnered TaleBlazer Place to play a professionally developed TaleBlazer game. The Home Screen on our TaleBlazer Mobile application showcases the TaleBlazer Place in the immediate vicinity and allows players to see nearby games at the touch of a button.

Use of Taleblazer	
For Organisations:	zoos, nature centres, historic locations, museums etc
For Teachers:	Schools and Universities
For Researchers:	Engage users in activities or learning as well as help them to conduct large scale simulated environmental measurements and analysing data.

5.1.3. User instructions

Main Idea
Players move around real space while the GPS of the device allows them to interact with “nearby” virtual objects in the TaleBlazer game.
Game Designer
• Specifies one or more *regions* (real world location where the game takes place) • Adds *agents* (representing items, characters or whatever) to the region • The designer can also specify traits (variables) displayed as a list and actions displayed as a row of buttons on the agent dashboard (as well as name, description and image)
Player
• When the player’s location comes close enough to the agent’s location, the player is said to *bump* into the agent. • When bumping an agent, the agent dashboard comes up by default, displaying the agent’s name, description and image.
Software Components
• An online game *Editor* (create/edit/save games) • A game *Repository* server (store the games) • A multi-player server (maintains a shared game universe for multi-player games) • Installed mobile application (to play the game / iOS and Android)
Editor Software
• Game organization and game control panel (modify name, image, description of the game) • Save or Create a New Game
Tabs
• World: all the setting relevant to the entire game world - **Mobile Tabs**-the game designer specifies visible to the user i.e.: o Game {*name, image, description, game code, Leave Game button}*, o World {*dashboard, name, description, image, traits, actions}*, o Map {*current location, bump agents}*, o Player{*dashboard, name, description, image, player-specific traits and actions}*, o Clue Code {*to interact with an agent anytime, anywhere}*, o Heads Up {*compass and GPS readings to show nearby agents as markers overlaid onto the video camera display}*, o Inventory {*the contents of player’s inventory}*, o History {*list of agents previously encountered}*,

    - Log {*all previous actions of user*},
    - Settings {*debugging functionality*}
  - **Multi-player Vs Single player** (under development)
    - Requires internet access (data plan or Wifi signal)
    - Player experience a share game world
    - Pass object to each other
    - Chat with others
    - Accomplish goals together
  - **Introduction** (a mini tutorial set by the game designer to orient the player to the game when the game starts)
  - Mobile settings
    - Choose key pad
    - Tap to bump option
  - Bump settings (control how hard or easy it is for a player to *bump into* an *agent*)
  - Scenarios (multiple choice questions that the player answers at the beginning of the game i.e. 'Easy or Hard' or 'Short or Long' or 'Start at Main Entrance or Start at Side Entrance'.
  - Actions (Actions are buttons like text, Video, Built-in, Script which can be changed by name, type, content and visibility)
  - Traits (variable that the game designer can specify for agents, roles, teams, and the World itself).
  - Scripts
- Map (a specific location in the real world where the game will take place)
  - Custom map (a picture format map .jpg or .png displayed on the background during game play instead of the Google Map to allow game without internet connection)
  - Multiple regions (can be used to define different physical locations in which to play the game)
  - Indoor regions (part of the game can be played indoors. GPS is turned off and player can just bump into agents by tapping them without moving in the area)
- Agents (created by game designer who gives them name, description, image, icon and visibility)
  - Settings
    - Clue Codes (instead of at a coordinate in a specific region)
    - Password protection (to protect the dashboard for using the traits and actions on the agent)
  - Excluded agents (inert and inaccessible by the player)
  - Bumping agents – It can be happen in one of five ways:
    - GPS proximity

- Ma icon tap
- Heads Up tab
- Inventory tab
- Clue Code

- Actions
- Traits
- Scripts

- Roles (The game designer can configure a single role for a game, in which case all players experience the same game, or the game designer can configure multiple roles)
  - Actions
  - Traits
  - Scripts
- Scripting
- How to play a game
  - Name the game
  - Save Game
  - My Games (Saved games)
  - Download and Play

DISADVANTAGES

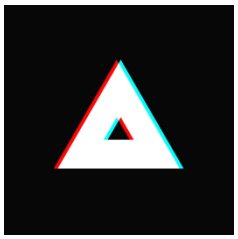
- Location-based building platform only
- Not functional for indoor locations (Indoor location do not have access to a valid GPS signal)
- Outdoor locations can have weak or poor GPS signals, particularly near tall buildings, open areas of water, and in sparsely populated areas
- Even under best case conditions, GPS positioning is only accurate to about 3 meters.
- Need to keep in mind pedestrian accessibility/safety, etc.

Useful links:

- A getting started guide and curriculum http://taleblazer.org/files/curriculum/TaleBlazer_Curriculum.pdf
- Documentation: http://www.taleblazer.org/files/docs/TaleBlazerDocumentation.pdf
- Introduction to the Taleblazer Editor: http://www.taleblazer.org/files/docs/TaleBlazerTutorial1.pdf

5.2. ARISGAMES

5.2.1. About ARISGAMES



ARISGAMES is an Augemented Reality (AR) software platform developed by Field Day Lab from Wisconsin University. ARISGAMES allows users to play and make their own location-based mobile games and stories.

5.2.2. Features

Playing games Requirements
• ARISGAMES games can be played on iOS (v. 8.0 or higher) iPhone, iPad or iPod touch. • Mobiles must be equipped with enabled GPS technology. • At least 50MB of storage to cache available • Internet connection needed to play the game
Creating games
• ARISGAMES editor is browser-based, with no local installation required. For an even greater customized game ARISjs, a javascript API, can be utilized. • Users create accounts (project can be saved to the cloud and user can have instant access to it from any computer attached to the Internet)
Featured games
• Within the app the most popular games of the day/week/month can be found. On the site of fielddaylab (https://fielddaylab.org/make/aris/) two games are highlighted: 1.Dilemma 1944 which takes students back to they high school in Vancouver during WWII making students face the question wether to enlist a month before D-day. 2. Teachers who gave their class ARIS as a new way to present their research on African countries as seen through an individual.

Use of ARISGAMES	
For Organizations:	zoos, nature centers, historic locations, museums etc

For Teachers:	Schools and Universities
For Researchers:	Engage users in activities or learning as well as help them to conduct large scale simulated environmental measurements and analyzing data.

5.2.3. User instructions

Main Idea
Players move around real space while the GPS or camera of the device allows them to interact with “nearby” virtual objects in the ARIS game.
Game Designer
The basic conceptual model for ARIS authoring involves **objects**, **triggers**, and **scenes**. ▪ Media content = **objects** ▪ How a player accesses content = **triggers** ▪ Organizational units for triggers = **scenes** **Triggers** can be GPS locations, QR-codes, Locks (something a player needs to do in the game, no physical world needed), a timer or a beacon (also location based but instead of GPS it could be a bluetooth beacon).
Player
• Depending on the trigger the object is shown when the player is close to the location (GPS or beacon), scans a code (QR-code), enough time has elapsed (timer) or inputs a code (Locks). • The default page to open for a player is dependent on which tab is placed first by the editor. If it is a QR-code based game the scanner would be placed default, if its location based a map would be shown. The menu offers the possibility to switch between different modes allowing for different triggers within a game. • Quests will help navigate players through the different triggers and objects of the game.
Software Components
1. Client (app) - to play games and collect data 2. Editor - to make ARIS experiences. 3. Server - Games live on a database in the cloud. The client and editor read from and write to it. Upside - No need to install games or go through the app store. Downside - you need an internet connection to play.
Editor Software

- Game organization and game control panel (modify name, image, description of the game)
- Save or Create a New Game

Tabs

Scenes (here you can order game objects)

- Conversations
- Plaques
- Player attributes/items
- Web pages
- Events
- Game object factories

Locations (add location triggers to objects)

- Conversations
- Plaques
- Player attributes/items
- Web pages
- Events
- Scenes

Quests (add an extra dimension to the game by adding a quest)

- New quest
- New Category
- New compound quest

Conversations (Add a new conversation)

- New Conversation

Media (Add images, video's, gifs)

- Upload media

AR Targets (Upload images to act as AR targets)

- Upload AR Targets

The Notebook (Deactivated but still visible in the editor)

Game (here you can adjust the settings and look of the game)

- Settings
- Tabs (the order and options of the menu as seen by players)
- Groups
- Tags
- Sharing (add multiple editors)

DISADVANTAGES
• Only for IOs devises • Internet connection required • Outdoor locations can have weak or poor GPS signals, particularly near tall buildings, open areas of water, and in sparsely populated areas • Even under best case conditions, GPS positioning is only accurate to about 3 meters. • There are a lot of options which makes it a very rich but also overwhelming gaming environment to edit.

Useful links:

- A getting started guide and curriculum https://fielddaylab.wisc.edu/courses/aris
- Documentation: http://manual.arisgames.org/
- Introduction to the Taleblazer Editor: https://arisgames.org/editor/#login

5.3. Taleblazer vs ARISGAMES

COMPARISON

Function AR software	Browser-based editor	DO	LB	Overhead/ Live-view	Archive	YouTube Embed	Roles	Dynamic Triggers	Assess	Data Collect	D2D	QR	3D	SN
ARIS	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N
TaleBlazer	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	N	N

6. CONCLUSION

The Augmented Reality Toolkit presented in this document aimed to provide educators with the necessary theoretical and technical knowledge to use MARG in their educational practice as means to develop students' key competences through learning about sustainable development. Equally important with the design of augmented reality games is supporting teachers develop "participatory" relationships with the materials that enable effective modification, learning, and use. It becomes then important to provide teachers with related training and professional development, which will enable them to construct pedagogical knowledge and develop related skills that would enable them to implement augmented reality games in their practices.

Also important is to provide pre-service teachers with opportunities to explore augmented reality games as learners and to design lesson plans that implement these games through professional development training. Teacher training and professional development courses could be an asset for teachers as they would instruct them on best practice when implementing augmented reality games into their lessons. Based on findings from the literature about the use of augmented reality games, especially for the purpose of supporting the development of 21st century skills, it becomes clear that they hold great promise and potential. We hope that this report will provide the basis for conversations between teachers, curriculum developers, designers, and scientists about the potential of augmented reality games in promoting goals related to both sustainable development and the development of 21st century skills.

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