HOW TO USE AUGMENTED REALITY IN STEM EDUCATION

GUIDEBOOK

CONTENTS

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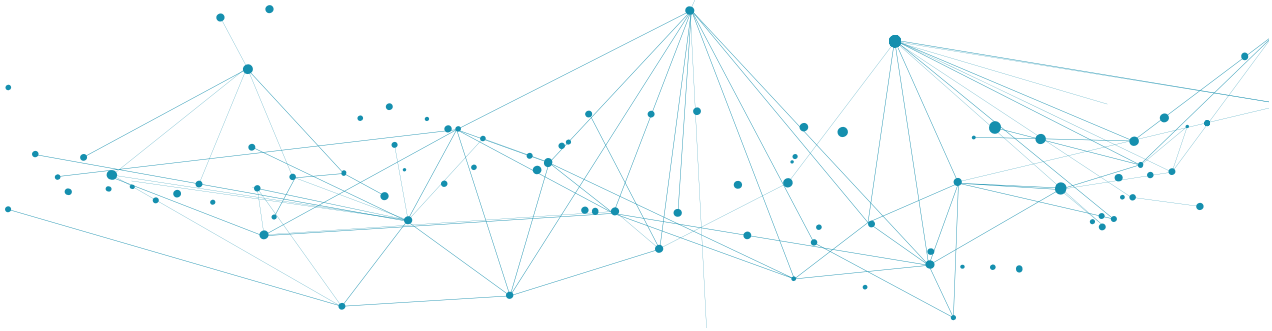
INTRODUCTION

Due to globalisation and fast-growing technology, the world undergoes a continuous, transformative change. Apart from that, the COVID-19 pandemic required new approaches on how to equip educational systems to face the challenges presented by the recent sudden shift to online and distance learning, including supporting teachers in the development of digital competences and safeguarding the inclusive nature of learning opportunities. It is inevitable that teaching strategies are rapidly digitized. By 2027, the market for educational technology is estimated to be worth $680.1 billion, expanding at a the anual pace of 17.9% (Global News Wire, 2020). And augmented reality the biggest trend in education, is leading the way. AR in education means transforming conventional classrooms in a variety of ways, from assisting students in acquiring knowledge more quickly to teaching them cooperation skills.

"Tell me and I'll forget, show me and I may remember, involve me and I will understand" - the proverb goes. This statement accurately captures the use of the AR in education. Students' capacity to retain what they have learnt is increased by the interactivity and engagement of what the AR solutions provide. Schools are creating programs and leveraging resources suc as AR-enabled workbooks, virtual maps, 3D colouring books, etc. in order to do this and enhance the educational experience. The AR in education gives pupils the chance to improve their knowledge of a variety of topics, including the STEM education.



A student who focuses on the course material will probably master the subject more quickly. Learning becomes more interesting with the use of the AR technology, which also facilitates concentration and speeds up learning. Innovative visualization and interaction technologies are a perfect fit in the constant effort to hold the students' attention. Greater visualization capabilities are compatible with the initiatives in higher learning and research allowing the AR to address the entire education ecosystem, from pre-kindergarten to postgraduate research. By bringing abstract topics to life, the AR makes learning engaging. This is particularly important in Science, Technologies, Engineering and Mathematics (STEM) education where there are a lot of abstract concepts to untangle and grasp.

The STEM underpins the 2030 Agenda for Sustainable Development, and the STEM education can provide learners with the knowledge, skills, attitudes and behaviour required for inclusive and sustainable societies. The 21st-century jobs require creative confidence, critical thinking and collaboration. Science, technology and innovation are also a crucial part of the Sustainable Development Goals (SDGs): addressing the impact of climate change, food security, healthcare, limited freshwater resources and biodiversity.

The project "Augmented Reality for STEM education" found the opportunity to apply the Augmented Reality (AR) technology as an educational tool for young people in Europe. Educational systems and schools play a central role in determining students' interest in the STEM subjects and in providing equal opportunities to access and benefit from quality STEM education. The main target group of the project are teachers who are interested in the new and innovative tools for education and engagement of youth, also the development of digital pedagogical competences, enabling them to deliver high-quality inclusive digital education. This guidebook is created with the purpose to help educators to build knowledge and skills to deliver modern, high-quality education in the STEm classrooms.

FEEDBACK

Within the project we have prepared not only the manual that you are currently reading but also 16 augmented reality learning materials as well 16 lesson plans that show how to best integrate our prepared materials into your STEM teaching. If you have feedback about any of the above mentioned materials, it will be much appreciated! Please use this button to fill out a feedback survey.

FEEDBACK

THE GUIDEBOOK HAS THE FOLLOWING STRUCTURE

Section 1

Explanation of the Augmented Reality and implementation of technology in the educational process. Technical possibilities and limitations of the AR technology. Supportive instructions to help addressing technical limitations, learning to incorporate and adapt digital elements in working with the STEM education students.

Section 2

Presentation of 15 best cases of use of the AR from around Europe. List of relevant tools and case studies on successful implementation and description of use of the Augmented Reality.

Section 3

Guidelines on how to successfully implement the AR in the educational process of the STEM and beyond it. Step by step instructions of the iSee app and comparison of different available tools and functionalities.

SECTION 1
EXPLANATION OF THE AR AND IMPLEMENTATION OF THE TECHNOLOGY IN THE EDUCATIONAL PROCESS

Section 1 of the manual deals with explanation of the AR technology and its implementation in the educational process.

This section consists of 3 separate units:

- **Unit 1:** Explanation of the AR and implementation of the technology in the educational process for the STEM subjects
- **Unit 2:** Technical possibilities and limitations of the AR technology
- **Unit 3:** Addressing technical limitations

The purpose of Section 1 is to provide the reader with solid understanding of what the AR is and how it can be used in the STEM education and how to envisage certain limitations and obstacles when using this technology and what needs to be taken into account to ensure smooth learning experience.

UNIT 1
EXPLANATION OF THE AR AND IMPLEMENTATION OF THE TECHNOLOGY IN THE EDUCATIONAL PROCESS FOR THE STEM SUBJECTS

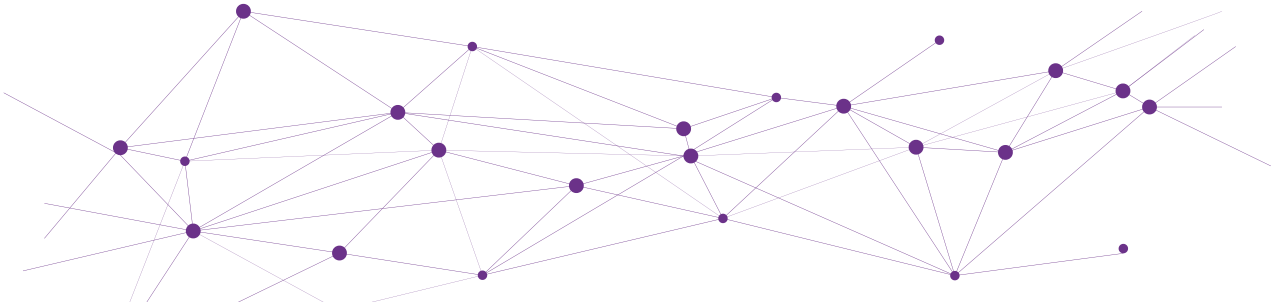
The Augmented Reality (AR) is a technology that modifies and enhances the real-life environment with 3D objects, music, sounds and other elements that stimulate the senses. To project these elements in the physical space, we need mobile devices such as tablets and mobile phones/smartphones. The use of the AR technology is growing very fast not only in the game industry, but also in education and teaching practice. In the classroom, lessons with the AR can be transformed into a remarkable experience, more interactive and enjoyable for the students. The AR App can increase the learners' engagement as it allows teachers to add gaming elements when teaching a subject and exemplify concepts by using virtual examples. The visual properties of the AR technology boost students' learning and expand their memory capacity. Humans tend to remember visual experiences for a longer time and this is something that the AR Apps offer to their users.

According to the Horizon Report, the AR is one of the emerging educational technologies with significant advances (Brown et al., 2020), and the studies complementary to this evolving technology are expected to increase in the coming years.

Another commonly used term nowadays is STEM which stands for Science, Technology, Engineering and Mathematics. It covers any subjects that fall within these categories.

The following are considered to be common STEM subjects:

- Biology
- Chemistry
- Civil engineering
- Computer science
- Technology
- Economics
- Electrical engineering
- Finance
- Information technology
- Mathematics
- Mechanical engineering
- Physics



The STEM topics demonstrate valuable transferable skills such as problem-solving, critical thinking, teamwork and cooperation. These skills can be utilized in various occupations. Employers appreciate the transferable skills gained through a STEM degree, offering positions within the STEM disciplines following graduation. There are more and more job prospects offered for the STEM alumni, considering the fast rate at which science and technology are evolving. A study titled Jobs of the Future by EDF Energy predicted that between 2016 and 2023, the rate of growth for professions associated with the STEM will double compared to any other occupation (Social Market Foundation, 2016). The Covid-19 pandemic underlined the necessity for innovative science and technology, which ensured new employment prospects. According to the literature review, the most common types of the AR Applications used in the STEM studies are inquiry-based simulators and problem-based simulators.

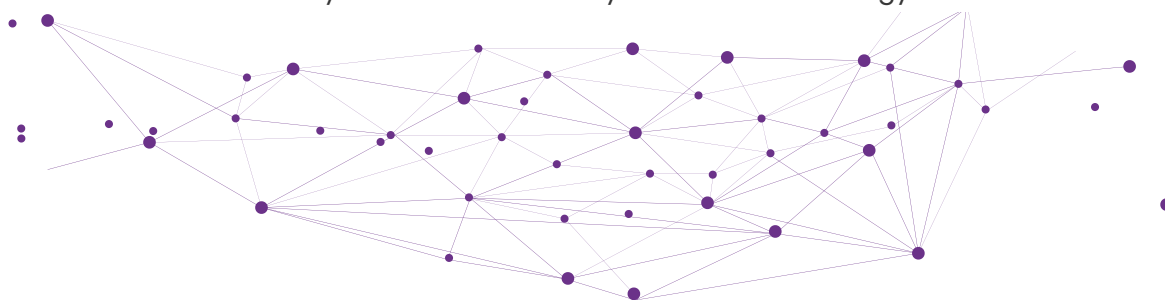
In Natural sciences, the most preferable is location-based AR while in Physics and Mathematics, the marker-based are extensively utilized (the difference between these two types is explained in Unit 2). Studies also showed that the marker-based AR was preferred compared to the location-based AR, as it is easier to use, easier to develo, and is commonly used in K-12 studies in the classrooms (M. Ibáñez & Delgado-kloos, 2018; Sırakaya & Sirakaya, 2020).

Both AR types mainly use handheld displays such as smartphones and tablets, since they allow users to move freely around, whether indoors or outdoors, compared to desktop/laptop displays (Dey et al., 2018). The most frequent digital features used in the AR Apps are video and animation.

In the study of Ajit et al. (2021), the advantages of the AR in the STEM subjects are grouped into four areas : 1) its contribution to learners, 2) achievement of learning outcomes, 3) the interaction of the AR and 4) other advantages. The application of the AR technology enhances learners' achievement (Cai et al., 2014; Chen & Liu, 2020; Echeverría et al., 2012; Fidan & Tuncel, 2019) and learning performance (Chang &Hwang, 2018; Georgiou & Kyza, 2018; Zhang et al., 2014). The AR supports the construction of knowledge (Chiang et al., 2014) and improves learners' understanding of the studied topic (Chiu et al., 2015; Fidan & Tuncel, 2019; Kamarainen et al., 2013). The virtual component enriches the learning experience and promotes the memorization of procedural knowledge among pupils (Cai et al., 2014).

Georgiou and Kyza (2018) reported that secondary students' performance substantially increased in a science field trip performed with the AR location-based approach. Nevertheless, in Conley et al., (2020), learning statistic via "MantarayAR" shows that the ones who benefit are only the students with the low previous knowledge of the studied topic. Former studies show that the mental imagery process differs among pupils (Palmiero et al., 2019). Students may enhance their skills and accomplish anticipated learning outcomes by training of spatial visualization and the use of the appropriate tools such as in the AR. Students will build positive mindsets (Cai et al., 2014; Sahin & Yilmaz, 2020), thereby boosting their interest (Chen & Liu, 2020) and motivation to learn (Chang & Hwang, 2018; M. B. Ibáñez et al., 2014, 2020). The AR enables learning by permitting learners to experiment effectively and easily (Akçayir et al., 2016). Learners also profit from direct feedback right after using the AR Technology to clarify concepts, as it promotes additional learning (T. C. Huang et al., 2016). Consequently, the application of the AR enhances learner fulfillment (Cai et al., 2014) and leads to positive feelings on the STEM subjects (T. C. Huang et al., 2016).

Further studies revealed that the AR enables learners to envision theoretical ideas (Cai et al., 2014; Sahin & Yilmaz, 2020). Learners were capable of visualizing these abstract concepts (Chen & Liu, 2020) in the form of visual information (Chiang et al., 2014; Safadel & White, 2019), achieving more substantial learning and eventually improving academic success. Students also alleged that adding the AR to the STEM studies is exciting (Cai et al., 2014; Fidan & Tuncel, 2019; Huang et al., 2016). Interaction between the AR application initiates the learner's attention and learners gain more satisfaction from learning. Nevertheless, the exercise should be backed with a practical pedagogical approach to aid students throughout the learning process and prevent students from being preoccupied with their smart devices (Kamarainen et al., 2013). Moreover, the AR Technology successfully improves students' conceptual knowledge (Echeverría et al., 2012; Thees et al., 2020). Students were able to understand theoretical ideas more deeply and maintain the acquired knowledge to solve future problems in their STEM courses (Lin et al., 2013). The AR is benefitial to students' learning outcome by specifying abstract concepts (Fidan & Tuncel, 2019), increasing teamwork skills among fellow students (Kamarainen et al., 2013) and enhancing the class involvement (Georgiou & Kyza, 2018). The AR can additionally improve higher-order thinking skills and assist students with the more in-depth learning instead of shallow learning. Former reviews performed by Garzón and Acevedo (2019) and Akçayır and Akçayır (2017) have already detected that the successful outcomes might be attributed to the novelty effect of the recently launched technology to the learners.



Thus, further research is necessary to determine whether the novelty factor is going to substantially affect the retainment of the new skills over more extended periods. The AR increases the interactivity between teachers, learners and the environment (Kamarainen et al., 2013). Learners are more involved in communication with the teacher (Zhang et al., 2014), as the teacher has extra time to provide clarifications and work together with the pupils compared to the conventional classroom, which is more focused on memorizing information (Chang & Hwang, 2018). The AR facilitates student-centred learning (Kamarainen et al., 2013). Learners can freely explore knowledge related to a STEM subject (Chiang et al., 2014), as the AR provides customized assistance for the students centred learning (Chang & Hwang, 2018). In addition, learners can complete experiments on time with less supervision from the laboratory instructor compared to performance of conventional experiments (Akçayir et al., 2016).

An additional advantage of integrating the AR in the STEM topics is that students can easily use it. Students faced few difficulties in managing the AR Apps (Chiu et al., 2015) and could use the AR software within a short period of time (Cai et al., 2014).

Studies have shown that informal teaching/learning environments result in better learning outcomes than formal settings. Therefore teachers need to be ncouraged to integrate the AR technology in everyday classroom activities.

UNIT 2
TECHNICAL POSSIBILITIES AND LIMITATIONS OF THE AR TECHNOLOGY

From the technological point of view, the AR can be explained as a technology that allows users to engage with the virtual objects that overlay the view of the physical environment and this illusion is perceived from a camera of the device. Depending on the features included in the AR technology, there is a variety of modes where the AR functions. There are AR technologies supported by wearable devices (e.g. glasses, head-sets, helmets) and non-wearable devices (e.g. smartphones, tablets, TVs, projectors, PCs etc.) (Peddie, 2017). The latter group is characterized by higher accessibility from the end-user perspective due to the fact that devices such as smartphones and tablets are mainstream and multifunctional compared to, for instance, smart glasses compatible with one or two specialized softwares only.

Although the design of the AR solution itself is highly expensive, the rapid advancement of technology has resulted in lower cost and easier access to the ready-to-use solutions (software and hardware) to support user experience in various everyday life domains. For instance, the same smartphone connected to the Internet can be used to navigate in a shopping mall, to do shopping, including studying the objects and positioning them in the space without even leaving home and much more.

Before choosing an augmented reality app for the educational process, one has to understand its basic functionality. Two broad categories are usually considered: location-based apps and marker-based apps. However, one may come across two more sub-categories, namely, overlay and contour-based apps. Following this classification, it is possible to clarify that location-based, projection-based, overly based and contour-based apps are using the AR without using the markers approach. The differences between them are briefly discussed below.

Marker-based AR (also called Recognition-based AR) uses the camera to detect the object in the real environment by identifying specific markers (user-defined images) of the object to activate an augmentation experience. Markers are distinct patterns visually independent of the environment, either paper-based or physical objects. Based on the purpose of the specific marker-based AR, the augmentation triggers an object, text, video or animation appearing on the smartphone or tablet screen for further interaction. It usually requires an app to be processed, however, varieties of browser-based solutions also exist.

Location-based apps

The location-based AR apps work without markers. They detect the user's position with the help of a GPS, an accelerometer or a digital compass and overlay the augmented reality objects on top of real physical places. The most famous location-based app was Pokemon Go. These apps can send notifications to the user based on their location to provide them with the new AR content related to a given place. For example, an app could give recommendations about the best museums nearby and show directions how to get there.

Projection-based apps

The projection-based augmented reality transmits digital data in a static environment and focuses on presenting virtual 3D objects in the user's actual surroundings . Due to the placement of a tracking camera and a fixed projector in a particular location, the AR enables the user to move freely in those surroundings. By projecting artificial light onto actual flat surfaces, this technique primarily serves to produce illusions regarding the depth, position and orientation of an object.

Overlay-based apps

With the use of the augmented reality, an updated virtual image of an object is typically provided which differs from the original view that a person can see with a naked eye. With the option to show more pertinent information about the target object, an overlay AR offers several viewpoints of the original.

Contour-based apps

In essence, this technology uses specialized cameras to outline particular objects with lines for human eyes to see to make certain circumstances easier. For instance, it can be applied to automobile navigation systems to ensure safe operation under poor lighting conditions.

According to Edwards-Steward et al. (2016), other types of 'triggered' augmentation are the following:

Dynamic augmentation that stands for interactive augmentation with the option of object recognition, scaling and motion tracking;

Complex augmentation that uses dynamic view and pulls Internet information based on location data, markers or object recognition.

Other types of augmentation are characterized as:

Indirect augmentation which augments static view of the environment (meaning – a picture) by changing its distinct features, such as the colour of a wall or a sofa in the room;

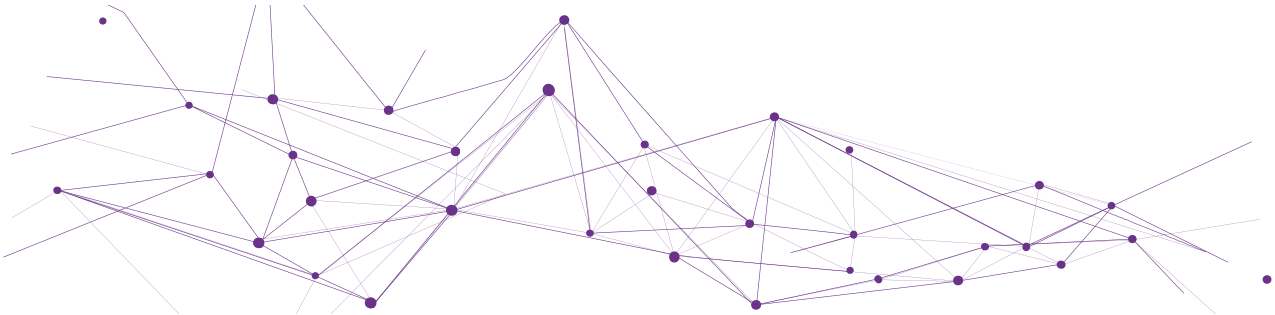
Non-specific digital augmentation transforms a dynamic view of the environment without transforming it, rather adding elements of interaction without any reference to the real-world background (Edwards-Steward et al., 2016).

The AR is still an innovative and therefore a dynamic field of study, consequently more complex and specialized technologies are being developed and newly categorized. For instance, there are cameras built for human eyes to perform outlining of specific objects (boundaries and lines) to help to navigate in complex environments (Outlining AR) or augmentation allowing to position, orient and measure the depth of the objects by determining the position of light on a surface (Projection AR).

UNIT 3
ADDRESSING TECHNICAL LIMITATIONS

The AR technical capabilities are diverse and have a great potential for application in pedagogy. Although the AR application in education is still innovative and is mainly researched in the context of higher and more specialized education, it has been scientifically proven that the AR application may improve the learning outcome, the collaboration between students and teachers, increase the engagement, enjoyment and motivation and help in visualizing abstract material (Akçayır, Akçayır, 2017; Maas, Huges, 2020). The mix of real and virtual environments and objects allows learners to experience phenomena that would otherwise be impossible in the real world, providing opportunities to develop certain abilities (Silva et al., 2016).

On the other hand, such immersive learning is often considered costly and requires special preparation of teachers, as the technological side of the AR is still a challenge. The first and the dominant requirement for applying the AR in learning is the availability and accessibility of the AR solutions, making sure that each learner is equipped with the necessary **hardware, software** and **support in using them**. Moreover, the available AR solutions may still demonstrate shortcomings in implementation and be challenging in exploitation.



From the **user perspective**, the most common limitations in applying the widespread AR solutions are linked to the following:

Hardware. Depending on the type of the AR and the area of application, a variety of devices are being designed and exploited for augmentation, such as smartphones, tablets, TVs, projectors, PCs, glasses, head-sets, helmets and other supporting accessories. Taking into consideration the innovativeness of the AR technology and accessibility requirement for quality education, currently, the hardware mostly used for the AR in education are smartphones, tablets and PCs equipped with processors, GPS, displays, cameras, microphones, speakers and other features required to support the AR in action.

Specialized AR glasses and lenses are being designed for the last decade and might be widely used for educational purposes in the coming years. Glasses and all kinds of lenses with the built-in camera, which are wearable as accessories, allow bigger comfort in using the AR, as they do not require holding and moving a device, thus hands can be used for other actions, such as “touching” or modifying features of the objects seen.

Camera. One of the most significant parts of the AR hardware is a built-in camera as a sensor that allows depiction of the real-life environment on the screen. More advanced AR technologies require more than one camera with several slightly different viewpoints, which allows producing extra dimensions of the objects’ depth.

Battery. Depending on the environment where the AR is to be used and the type of augmentation, there might be additional requirements for the AR hardware battery life. The AR learning activities are dynamic and require switching on and off the devices and AR software which makes them energy-consuming to a different extent. Battery-life is especially significant when augmentation is done outdoors (e.g. location-based augmentation) or moving of the screen is required (e.g. Dynamic or Complex augmentation with functions of observing objects from all sides by walking around with the AR device). It is recommended to get equipped with the relevant charger devices (including power banks) and keep the AR devices fully charged before learning activity, especially if learners are expected to use their own smartphones daily.

Connectivity. Augmentation highly depends on the **Internet connection**, meaning the most practical one – wireless connection. The AR can be practiced with the help of a local network to a router, via a safe Wi-Fi network (if augmentation is done in the controlled environment, e.g. indoors) or via a more further-reaching and ubiquitous mobile broadband network. In contrast to optimized social media platforms, the AR software with its 'heavy' contents may require a stable and fast Internet to function smoothly. A poor connection may cause incomplete or stuck images and objects appearing on the screen and cause frustration of the learners instead of interest or amazement. Accessibility of the Internet might also determine the access to data, for instance, if the augmentation contains open access data from the Internet.

Location-based AR softwares may require **GPS** to identify the surroundings or track the user's position. GPS may also require additional data sets such as maps, however, modern technologies equipped with the Internet can connect the user to Google Maps or any other available app. However, GPS can determine location with accuracy within several meters, therefore **Bluetooth** is introduced as another technology that may help to determine a more precise location – with accuracy to several centimeters.

Software. Each individual AR software has its own usage requirements and the most significant requirements depend on compatibility with:

Hardware. Part of the AR softwares might simply not work without specialized attributes – lenses, helmets, sensors, etc. Also, certain AR solutions might be compatible with smartphones, others might be adjusted to larger size screens, as customization is necessary to adjust the software interface for smaller size screens.

Operating system. The usage and spread of technology largely depend on the operating systems compatible with developed AR solutions. Certain AR apps might be downloaded and used on Android and iOS systems (dominant for smartphones), Microsoft Windows, macOS or Linux (dominant for general-purpose devices), or might be limited to only one operating system . Before incorporating AR into learning activities, one might check if the AR software will work on all devices planned.

Hosting environment. Recent advancements have produced the options for AR hosting and using augmentations in either Native AR or Web AR. The first one requires a special app to be designed and later downloaded on the hardware device prior to using certain AR software. The second option allows discovering AR without apps, allowing it to work across all platforms, devices and operating systems using only a camera and a QR scanner. It allows to save time and focus on the content instead of technical procedures of accessing it. The purpose of the augmentation determines functionalities, therefore these aspects should be taken into consideration when thinking about the user experience – how fast and easy users can access the AR content and how convenient the usage is.

Access to data. AR data can be accessed in two ways. The first is browsing data stored in some database within the user software (and hardware). Another one is reaching data freely accessible on the Internet, for instance, by connecting to Wikipedia, Twitter or any other source, or offering the review of several selected sources at once. Such technology is used in the recognition of faces and places, and the contexts added via Internet sources. Also, the AR solution can direct to some closed data stored on the cloud to be accessible to specific people only.

Appropriate use of the device. The probability to detect the object decreases when the AR device is used inappropriately, for instance, the camera of the AR device detects only a part of the object, the object with its markers does not fit the allocated "frame" or the camera is being moved around too fast. Precise tracking across large environments is important to support pixel-accurate registration. It happens that only part of the larger object needs to be scanned for successful augmentation, therefore learning tasks should always contain specific instructions on what and how something should be registered by the AR solution.

Apart from technical opportunities and limitations, **the technology and skill** gap is another significant burden for AR application in the learning process. Depending on the complexity of technology in use, each learning programme should first assess the openness of teachers to new technology adaptation and ensure appropriate training to make them confident as AR users, promoters and positive learning experience providers to students. Knowledge assessment and training constitute the timely and adequate support for applying AR. Piloting activities are always recommended before launching AR as a method for educational purposes. There are several reasons for mindful preparation for AR technology use:

Skills gaps. Teachers who have never experienced AR in practice might be confused and scared of the new "unknown". Learning should start at the facilitators' side, starting from the basic explanations on how AR functions, what devices, softwares, support and environment is necessary, and what benefits AR provides to learners. Even installing and switching on the AR app is something that requires attention, so the teacher is able to further support the learners of various ages.

Malfunctioning. The use of AR solutions may even be problematic if the teacher or learner feel confident about the technology. Difficulties with logging in, content glitches, poor internet connection or slowly working devices might frustrate and demotivate learners. AR objects don't always anchor properly and devices function precisely as they should. Therefore teachersshould always test the proposed AR before using it for learning purposes and in case of malfunctioning – be ready to support learners or substitute learning activities.

The distraction of learners. When the usage of AR involves the technical design of the virtual objects performed by the learners or simply usage of deficient technological solutions, learners may spend too much time and effort on the technical implementation of the learning tasks. Also, cognitive overload might appear when focusing on the AR and the outside environment simultaneously (Maas, Hughes, 2020). In such cases, the attention of the learners might shift from the learning content and instructional goals. The problem of students' distraction is closely linked to the teachers' expertise in using AR as a learning tool, meaning that it can be both insufficient or too advanced, causing difficulties in understanding AR in students.

Lack of related content. As AR is still an innovation, the content for learning specific topics is somehow limited, especially taking into consideration a variety of languages. The lesson plans have to be either adjusted to what is already available on a market or created by the teachers themselves. The second option is knowledge- and time-consuming, but still possible, as there are several well-known AR Browsers offering the design of their own content by the teachers and education experts themselves. However, training still needs to be undertaken in order to design functioning AR content, as not every content is suitable for AR technology and not every learning activity is compatible with the augmentation. For instance, holding a device for augmentation is not always possible when physical activity is required.

SECTION 2
BEST CASE OF SUCCESSFUL IMPLEMENTATION AND USE OF AR

Section 1 has been dedicated to understanding the general components and technical aspects of AR and its possible role in STEm education and benefits that it can bring. All in all, despite some technical considerations that need to be taken into account, teachers should be encouraged to integrate AR technology in everyday classroom activities since it helps to render the learning experience more interactive and hands-on, and studies have shown that introduction of more non-formal education elements in formal education improves learning outcomes. However, it can be difficult to motivate teachers and educators to use AR without helping them to get familiarized with concrete examples of how AR can be used and incorporated in the curriculum because without that the technology remains too foreign and incomprehensible.

The purpose of section 2 is to do exactly that – showcase 15 best practice examples from around Europe of different ways and approaches of how AR can be used in the classroom in STEM subjects. This section offers a list of relevant, tried, and tested approaches starting from AR visualizations and different apps to lesson plans and scenarios developed in EU projects. This section is both meant to create a deeper understanding of how practically AR integration in STEM subjects in the classroom can look as well as to provide readers of the manual with a selection of valuable resources and materials that can be used in one's own teaching.

The cases are presented in templates that provide an overview of the name of the tool or project, STEM subject it can be relevant for, organization, country and year of implementation if relevant, level and type of education it can be used for, the target group, the purpose of the tool or initiative, method used, relevance, achieved results, strengths and weaknesses of the tool or initiative and links to sources of information.

TITLE

Virtuali Tee

SUBJECT WHERE IT CAN BE USED

Biology

ORGANIZATION, COUNTRY, AND YEAR OF IMPLEMENTATION

Golnno, Slovenia, 2019

LEVEL AND TYPE OF EDUCATION IT CAN BE USED FOR

- Primary education
- Non-formal education

TARGET GROUP

Children aged 7-12

PURPOSE

To provide an interactive and engaging way for children to learn about our body anatomy with AR implementation.

METHOD

A Virtuali Tee app installed on a smartphone, or a tablet (Apple or Android device) and a Virtuali Tee (a special T-shirt with a scannable icon on) are needed to perform the activity.

In the class, a few children wear special t-shirts. Then with an app on the smartphone or tablet children scan the icon on the shirts. A 3D graphic of body anatomy appears on the device. Additionally, if children tap on specific places on the screen, they are able to see different anatomy systems (e.g. only bones, only vessels etc.). The app also works in a selfie mode, so the child who is wearing the T-shirt can investigate his/her own body.

ACHIEVED RESULTS

A Virtuali Tee app installed on a smartphone, or a tablet (Apple or Android It is useful to engage pupils in learning about their own bodies with AR features. The learning is increased because of visual input and real-life context, besides the usual listening, reading, and writing activities.

It is appropriate for children of different ages with different levels of knowledge of the human's body. It can be used in different countries since it is translated in 11 languages including English.

RELEVANCE

The teacher can bring biology lessons to life with products that will engage, open up and bring the whole class together. This is high-quality product that enables high-quality tech time in the classroom. It is hard for pupils to understand abstract subjects if there is no real-life context.

The Virtuali-Tee is the way to learn about the human body anatomy directly on a child, which simple diagrams cannot deliver. It can be used directly by a teacher or in groups/individuals for student-driven learning.

STRENGTHS

The Virtuali-Tee enables the children to learn about human anatomy on a human body. Pupils can see what's happening beneath their skin. The lessons cover Digestive, Respiratory, Skeletal, Renal and Circulatory Systems.

AR/VR experiences allow students to dive inside with full 360° of freedom to look around and investigate or view their "own" heart beating live in AR using the Heart Rate tracker. Children also get new knowledge about AR technology and what can be done using new technologies.

WEAKNESSES

The main limitation is that the T-shirt with the scannable icon must be purchased. But with one T-shirt the whole class or even school can have the added value of using the app and some lessons are also available for free to download.

Also, the language can be an obstacle. The app is available in 11 languages and one of those languages is English. But the teacher might need to translate the texts themselves if the app is not available in the local language and the students do not have enough knowledge of English.

SOURCES OF INFORMATION

VIDEO

VIRTUALI TEE

VIDEO

TITLE

SKIN – Animated educational tool

SUBJECT WHERE IT CAN BE USED

Biology

ORGANIZATION, COUNTRY, AND YEAR OF IMPLEMENTATION

University of Ljubljana and Primary School Franc Rozman Stane in Ljubljani, Slovenia 2021, Authors: Celeste Sanja Smareglia, Jure Sulič; Tjaša Gašperlin, Tanja Hrkač, Helena Gabrijelčič Tomc; Urška Stankovič Elesini

LEVEL AND TYPE OF EDUCATION IT CAN BE USED FOR

- Primary education
- Formal education

PURPOSE

To make learning about skin attractive and ejoyable, both in school or at home.

TARGET GROUP

13-14 years old pupils. It can also be used with younger pupils or interested adults

METHOD

An app was created as part of a thesis at University of Ljubljana which contains 3D animation about human skin which was created based on the topics of the school curriculum of Biology for the 8th grade of primary school. The 3D animation presents the skin as an organ and shows its characteristics and the main processes that appear in it. It also contains fun facts, explanations, and real-life connections.

To open up the application and watch the 3D animation, you need to scan an AR poster with icons with your phone or tablet. The icons are placed on different parts of the skin and every icon leads you to the connected chapter of 3D animation. For better clarity, the material is divided into chapters, which makes it easier for students to revise the material and review the chosen topic. This application may be used at school and also at home to consolidate the knowledge pupils get at school. In the end, pupils have the option to solve the quiz and answer the survey about their learning experience.

RELEVANCE

It is an educational tool that fits formal education, where there is a shortage of use of innovative teaching methods and the AR technology as opposed to other informal or non-formal education.

ACHIEVED RESULTS

Results reached with the app were evaluated with the questionnaire for the teachers and the pupils. Pupils said they rather learn about skin with the use of the application because the 3D animation with the AR was attractive for them and they used it when preparing for their exams. The pupils enriched their learning at school, learned about innovative learning techniques using the AR and gained enthusiasm for learning. The teachers also agreed that the pupils were more motivated and interested in this type of learning.

STRENGTHS

Similar practice can be used in every school environment and every curriculum by preparing some 3D animation with the information from any topic and the AR connection.
Easily accessible as a tool since it requires a smart phone or a tablet that almost every student has. It increases interest in learning and the motivation of pupils by presenting an abstract subject in a very practical way.

WEAKNESSES

The biggest weakness is that since this example was created as part of a university thesis, the tool itself is accessible to limited public. However, this can serve as a case of inspiration of what is possible and what type of tools can be created in collaboration between schools and technical universities.

SOURCES OF INFORMATION

DOCUMENT

ANIMATION

TITLE

Moon Observing Project

SUBJECT WHERE IT CAN BE USED

Physics

LEVEL AND TYPE OF EDUCATION IT CAN BE USED FOR

- Secondary education
- Formal education

TARGET GROUP

10-15 year old pupils
Teachers' science classes

PURPOSE

Implementing the AR tools in learning about the phases of the moon, developing an understanding of the relative positions of the Sun, Moon and Earth, discussing when the Moon can be seen and why. Theoretical facts are supported with spatial representation with the AR tool for a more engaging and actively involving learning experience.

METHOD

The pupil's aim is to perform a moon observing project in a physics class. During 30-days they have to observe the moon at least once a day and write a diary with their observations – what is the shape of the moon and where in the sky it is located. First, in the school lesson, the project is presented to the pupils. The topic of the moon is displayed by using the AR tool – a freely available app SkyView Lite, which can be used by smartphone or tablet computer. SkyView Lite is a beautiful and intuitive stargazing app that uses your camera to precisely spot and identify celestial objects in the sky, day or night. With the app, you can scan across the sky, locate planets in our solar system, stars and constellations, discover distant galaxies and witness satellite fly-bys.

Pupils can see which objects are seen in the sky above the horizon and which are not seen at this time, the path of the planets and the detailed information about all of the objects presented. You can also search for a celestial object and the app will guide you to spot it. In the class, pupils search for the moon, locate it and observe its shape (in which cycle it is), the moon's orbit, when and where it comes on the horizon, etc. When they observe the moon at home and they do not have the possibility to go outside or the weather is cloudy therefore the moon cannot be seen, pupils can use the AR app which can help them to do their work regardless of the weather conditions. After the end of the project, pupils present their notes and results. Discussion will follow, why the students' findings and notes may differ.

RELEVANCE

It is the case of using an AR app in the school setting. It can be adaptable to the context of informal education in the form of some workshop or extracurricular activity. However, it can be used in a wide context to learn about space also with younger children.

ACHIEVED RESULTS

Pupils are engaged and learn through experience. Pupils enjoy the experience and dermonstrate plenty of new knowledge about the stars, the sky objects, planets, constellations and the moon from the Earth's perspective. They can see the concept of the horizon, what it means and why the moon cannot be seen every moment of the day.

STRENGTHS

The engagement, relatability to real-life concepts, adaptability of the AR tool (can be applied at home or at school).

WEAKNESSES

The use of smartphones may be prohibited in schools, because they can be distracting for the pupils. The limitation is also the availability of the smart devices (in the school, larger number of smartphones may not be available). To avoid this issue pupils can work in groups.

SOURCES OF INFORMATION

EDUCATOR GUIDE

APPLICATION

TITLE

WWF Free Rivers: Discover Free-Flowing Rivers in the Augmented Reality

SUBJECT WHERE IT CAN BE USED

Biology, Geography or Environmental science

LEVEL AND TYPE OF EDUCATION IT CAN BE USED FOR

- Primary education
- Informal education

TARGET GROUP

Children aged 13-19

RELEVANCE

Kids can get a unique perspective of the global river ecosystems as they view them through this eye-catching AR app. Since students in most cases prefer learning from technologies, this app will be a great asset for lessons in Biology, Geography or Environmental science.

PURPOSE

WWF Free Rivers demonstrates just how important rivers are to the Earth. It also shows how human actions impact them. Through the interactive augmented reality and beautiful visuals, the app proves why we need to keep rivers healthy and flowing. The WWF's Free Rivers transforms your tabletop into natural landscapes, from the Himalayas to the African Sahara, allowing you to digitally manipulate entire ecosystems to better understand how water flow affects habitats.

METHOD

A smartphone or a tablet (Apple or Android device) with the installed WWF Free Rivers app is needed to perform the activity. You can access this app in both the Apple app store and Google play store and it is for free. The WWF Free Rivers is a great experience for children to learn about rivers. Once you open the app, allow it to load and then you will be prompted for permission to use the camera, tap OK. At the top of the screen, you will see a blue line loading, this shows that the app is loading and getting ready for use. Once this section is loaded, it is accessible and the children will be asked to point their cameras down towards a flat surface and move their device around. The river plane will appear, the children can move around the river plane and resize it so that they can see the whole plane from the camera on their device. The children are then guided through different parts of the river starting with the basin, they can focus in and see what is happening. They will also see different people that work along the river, such as the farmer and what happens if they build a dam in the wrong place.

ACHIEVED RESULTS

The WWF Free Rivers puts an entire landscape in your hands, on the table in fact. Through this immersive, augmented reality experience, students will discover the river that flows through the lives of people and wildlife and how their homes depend on those flows. Students can dam the river to see what happens and then try different options for sustainable development that keep the river healthy and flowing. Besides, students can collect stories of people and animals along the way and explore how a free-flowing river benefits people and wildlife.

Furthermore, they can learn about how dams affect the whole landscape and the people and wildlife that depend on the healthy, flowing river. Finally, they can simulate the rainy season to see how a healthy landscape adapts to the excess water.

STRENGTHS

The WWF Free Rivers' excellent narrator and clear visuals help kids to learn about free-flowing rivers and how dams can change the rivers and the ecosystems around them. Kids also learn about hydroelectric and other forms of power and how changing rivers affect ecosystems, food supplies, animals and human societies globally. While global river problems may seem like a major downer, the beauty of the WWF Free Rivers coupled with its narrator's hopeful tone and positive solutions keep this topic light enough for the kids to absorb the information without feeling hopeless. Plus, it is a beneficial use of the augmented reality that helps kids learn in a fresh way.

WEAKNESSES

The limitation is Minimum software requirements: iOS 11.3 or later; Android 8.0 and up, also the fact that the app is in English can be an issue for students and teachers with poor command of this language.

SOURCES OF INFORMATION

WWF FREE RIVERS

APPLICATION

TITLE

vLearn

SUBJECT WHERE IT CAN BE USED

Engineering

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

- Formal secondary education
- Informal education

TARGET GROUP

Students aged 13-19

PURPOSE

An interactive and engaging way for students to study machinery engineering.

METHOD

vLearn is the world's leading augmented reality learning app with an initial focus on providing an immersive learning experience. At vLearn, a new technological chapter connects the digital world with the reality and the future where technology paves the way for new learning experiences.

vLearn as a platform creates an environment that fosters working together to solve problems, prioritizes open communication and provides students with opportunities to both learn from and teach others.

The complex engineering learning process and heavy machinery allows the users to experience an immersive reality.

ACHIEVED RESULTS

Interactive learning and collaboration, as well as successful group work to engage in the environment that reinvigorates the classroom structure, strengthening an indispensable skill of critical thinking and problem solving. The students will be glad to get a more interactive approach to learning.

RELEVANCE

vLearn enables users to be completely engaged in learning by replicating the traditional learning environment with simulations having artificial objects over the real world providing an immersive experience. This AR provides information about automobiles, machinery and utility. Using this AR students can explore Tesla, motorcycle, IC engine, steam turbine, tube light and the operation of their internal parts.

STRENGTHS

Vlearn app would be very beneficial for engineering lessons, machine engineering in particular, since the inside parts of a car are well presented. VLearn app is very helpful in providing information about the mechanism of an electric car. This application gives proper visualization to the concept and students can easily learn the topics.

WEAKNESSES

As all the information is in English which may be an issue for students and teachers with poor command of the language. The music in the background can become quite distracting.

SOURCES OF INFORMATION

APPLICATION

TITLE

WWF Forests

SUBJECT WHERE IT CAN BE USED

Biology, Geography or Environmental science

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

- Primary education
- Informal education

TARGET GROUP

Children aged 13-19

PURPOSE

WWF Forests app takes you on an immersive tour of temperate forests through an augmented reality experience. Learn about healthy forests and why they matter to people and wildlife, witness some of the threats forests face and practice how to manage a forest sustainably. At the end of your journey, plant your own augmented reality forest, bringing the beauty of the forest inside to enjoy and share.

METHOD

The WWF Forest app allows teachers to bring the forest to their students and learn a lot about it on the way. Teachers can use the app on individual devices or have students gather around a larger screen tablet to view the AR-generated forest along with the bits of information hidden throughout. While the bits of information themselves are just short sentences on various aspects of the forest, they can generate discussion and introduce larger concepts. The app will allow people to immerse themselves in the forest and watch as animals react to their presence as if they are really out walking in nature. Tigers pace in the distance, monkeys leap into the trees, birds soar overhead and butterflies flit from flower to vine. People using the app may even get caught in a rain shower.

The app also ends with links to the WWF website, where students can explore these issues in greater detail. Pieces of information presented in the app can also be used to set students up for a larger project on the various aspects of the forest - its life cycle, human influences on the forest, hazards and preventing damage to the forest and its ecosystems. When students are ready to use the AR feature, make sure there is enough space available to get the most out of it!

Features:

- guided tours through temperate forests teeming with wildlife that respond to your presence;
- full immersion or tabletop modes allow you to experience the forest both above and below the canopy;
- playful interactive elements that incorporate both iPad's and iPhone's unique features;
- cool and unusual forest facts (who came first - a fern or a dinosaur?);
- photo and video captures to share your forest with friends and family.

ACHIEVED RESULTS

Considering the fact that students in most cases prefer learning from technologies, this app will be a great asset for lessons in Biology, Geography or Environmental science.

RELEVANCE

Nowadays, the problem of deforestation is becoming an increasingly prominent issue.There is a progressing need to protect and conserve vital and magnificent forests around the world to sustain the nature's diversity, benefit our climate and support human well-being. Humans have a deep and enduring connection to forests. From the air, we breathe to the food that sustains us, even the city dwellers depend on the forest ecosystems far from their urban skylines. Forests ensure the health of freshwater rivers and streams, produce food and medicine and are home to the vast majority of land-based life on our planet. Forests also absorb carbon emissions providing the most important nature-based solution to climate change.

STRENGTHS

Immersive experience design with interactive features, interesting educational facts, high-quality technology.

WEAKNESSES

A little slow at times, as sometimes the AR takes a while to work. Works only on iPhone and iPad.

SOURCES OF INFORMATION

VIDEO

APPLICATION

TITLE

AR Bee World

SUBJECT WHERE IT CAN BE USED

Biology

ORGANIZATION, COUNTRY, AND YEAR OF IMPLEMENTATION

Ministry of Agriculture, Forestry and Food of Slovenia
GoINNO Institute, Slovenia, 2017-2022

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

- Primary/other education
- Informal education

TARGET GROUP

Pupils aged 7-12 and primary school teachers

PURPOSE

An interactive and engaging way for pupils to learn about bees with the help of theAR projection.

METHOD

This app is part of the interactive Bee World – project led by the Ministry of Agriculture, Forestry and Food of Slovenia. It uses augmented reality in order to overlay videos and text across different sets of pictures located within the Bee World pavilion thereby enabling the users to inform themselves about the bees.

ACHIEVED RESULTS

Motivation for learning is increased, children enjoy taking photos with the bee. The engagement in learning lead to opening new questions and ideas by the learners.
The app was used with the primary school and the feedback from teachers was very positive, the participants were interested in using it in their classes.

RELEVANCE

It is useful to engage pupils and adults to learn about bees, because they are important for our life – without bees, a lot of plants would not survive and that would lead to the enormous damage of ecosystems of the planet and food production. This type of method and the use of the AR is adaptable to a variety of contexts: the animals from our yard, the insects, the pets, beekeeping, honey, relevance for ecosystem and food security, environmental issues, etc.

STRENGTHS

Practice is easy to implement and it offers a lot of fun for pupils and adults. It can be applied in a variety of contexts, as an addition to a learning lesson or just for fun, engaging and motivation.

STRENGTHS

The weakness lies in the fact this AR Bee lacks the learning content and learning facts. Therefore, this AR Bee can only be an addition to other educational content. Furthermore, this app is part of the interactive Bee World – project led by the Ministry of Agriculture, Forestry and Food of Slovenia. It uses the augmented reality in order to overlay videos and texts across different sets of pictures located within the Bee World pavilion thereby enabling the users to inform themselves about the bees. Please note that this app is specifically designed for the use with the Bee World pavilion.

SOURCES OF INFORMATION

AR BEE WORLD

DOCUMENT

BEE DAY

TITLE

Virtual Reality Education and Game Based Achievements in Classrooms - VEGA Project

SUBJECT WHERE IT CAN BE USED

Astronomy, Biology, Chemistry, Geography, Geometry, Maths, Natural Sciences, Physics, Technology

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

- Primary and secondary (upper and lower)
- Formal education

ORGANIZATION, COUNTRY AND YEAR OF IMPLEMENTATION

Smedsby-Böle skola, Teachergaming LLC, Centrum Edukacyjne EST, Dalvíkurskóli, SYNTHESIS Center for Research and Education, Blue Beehive,
Finland, Iceland, Poland, Spain, Cyprus,
December 2020 - November 2022

TARGET GROUP

The primary target group are teachers and their students at primary and secondary education level (11 to 18 years old).
Other target groups addressed are policy makers and researchers in the field of Game Based Learning.

PURPOSE

This initiative aims at promoting game-based learning and VR/AR technology in schools as a way to enhance the curriculum with motivating content for students. The project partners' ambition was to address several issues that hinder teachers from engaging in the new tech at school, in particular:

- to propose specific digital games and VR/AR apps, accessible and flexible enough to fit selected areas of the curriculum and to train a group of teachers;
- to develop exemplary scenarios on how to integrate them into different subjects of the curriculum;
- to pilot them at schools with teachers unfamiliar with such technology.

METHOD

During the first months of the project, the consortium performed desk research collecting the available VR/AR games for the STEM subjects. A repository was created with the results of this research. Next, the partnership developed a series of lesson plans for the STEAM subjects incorporating in their design various VR/AR tools such as Oculus Quest, Cardboard, VR/AR games and apps, as well as PC games. The consortium organized pilot tests of the lesson plans in schools in the partner countries.

ACHIEVED RESULTS

The material developed is uploaded on the project's website freely available for any teacher interested to use it in his/her classroom.

RELEVANCE

Partners identified a number of obstacles that hinder teachers from engaging in the new tech at school. The main problems are the following:
- teachers are not sure how to integrate games and apps into the instruction;
- it is hard to find games that fit the curriculum;
- it is not easy to find quality games and apps;
- the emphasis is on the standardized test scores;
- insufficient time to use the games and apps;
- lack of tech resources;
- unfamiliarity with the technology;
- costs;
- lack of administrative support.

The VEGA project aimed at addressing and creating concrete solutions to some of these obstacles.

STRENGTHS

The learning scenarios developed are aligned with the STEAM subjects and topics taught in the school curriculum. This eases their implementation by the teachers and increases the applicability of the materials. The teaching scenarios are available for free use by the general public.

WEAKNESSES

One of the biggest challenges of the project for the teachers was to familiarize themselves with the VR/AR equipment. They had to devote time to learn the proposed apps and games to guide their students during the pilot testing of the learning scenarios. The partners organized personal training for the teachers in their countries who would participate in the pilot testing. This helped them to understand better the functionalities of the VR/AR games and apps they were going to apply during their lessons.

SOURCES OF INFORMATION

WEBSITE

SCENARIOS

TITLE

Use gamification strategies and augmented reality for the innovative STE(A)M learning

SUBJECT WHERE IT CAN BE USED

STEM education in general

ORGANIZATION, COUNTRY, AND YEAR OF IMPLEMENTATION

DIPF I Leibniz Institute for Research and Information in Education, AEDE, Effebi Association, Hearthands Solutions, ITT Marco Polo, Niekée/ Agora
Belgium, Germany, Greece, Italy, Netherlands and Turkey
December 2019 – May 2022

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

- Upper secondary
- Formal education

TARGET GROUP

The primary target group are teachers and their students in upper secondary education level. Other target groups addressed are policy makers and researchers in the field of Game Based Learning.

PURPOSE

The purpose of the project is to address the primary difficulty of effectively teaching STE(A)M subjects, which is that students lack motivation and interest in such subjects and the difficulty teachers face in explaining and clarifying complex topics. Teachers need appropriate training and mentoring and more practice implementing the game-based and AR methods. The project addresses these issues by providing a repository of the AR tools and best practices with the AR tools for the STE(A)M subjects. Furthermore, the teachers interested in the topic can enroll in the online course and improve their knowledge in applying the game-based and AR technologies in STE(A)M subjects.

METHOD

The first Intellectual Output of this project was a Compendium of gamification strategies based on the Augmented Reality for the STE(A)M learning in a digital format. The consortium collected 16 learning practices in 6 EU countries (Belgium, Germany, Greece, Italy, Netherlands and Turkey). Next, the partners developed an online teacher training program. The aim of the course is to familiarize teachers with the gamification strategies, game-based learning techniques and Augmented Reality (AR) technologies to make STEAM learning even more innovative and engaging for the students.

The partnership also developed the platform, the Cult-app platform for the AR4STE(A)M. This platform is an AR-project facilitator that allowes teachers to create their own AR project reaping the benefits of the common methodology for blended or classroom-based teaching. The last Output was the Further Recommendations Report which includes best practices for using the games for the innovative STE(A)M learning through the AR.

ACHIEVED RESULTS

The material developed is uploaded on the project's website, available for free to any teacher interested to learn more about the topic of the AR strategies and game-based learning.

RELEVANCE

The partnership performed 50 interviews with teachers in the Netherlands, Germany, Belgium, Italy and Turkey to identify the training needs and challenges they face concerning the Augmented Reality technologies, gamified and game-based learning strategies in teaching the STE(A)M subjects. According to the results of the interviews, the main obstacles in effectively teaching the STE(A)M subjects are the students' lack of motivation and interest in such subjects and the difficulty that teachers face in explaining and clarifying complex topics, especially in Physics and Maths.

As far as the economic resources are concerned, all teachers admitted a minimal budget allocated to support teachers in using new and advanced technologies. At the same time, the materials provided for experimentation are rather insufficient. In addition, teachers mentioned that they are inexperienced in using the AR tools in the classroom when teaching the STE(A)M subjects.

The issues mentioned above cause difficulties in applying such strategies in the classrooms. Appropriate training and mentoring and spending more time implementing the game-based and AR methods constitute the teachers' primary needs.

STRENGTHS

The project offers an engaging training based on the ICT (Information & Communication Technologies) that fosters the teachers' capacity to teach the STE(A)M effectively. Both the Compendium of gamification strategies based on the Augmented reality for the STEAM learning and the Online Teacher Training Program are available online for free use.

WEAKNESSES

The material developed targets teachers and students in upper secondary education level. It is quite advanced and it takes time for the teachers to familiarize themselves with the proposed tools.

SOURCES OF INFORMATION

ABOUT STE(A)M

STE(A)M RESULTS

STRATEGIES

PROGRAM

TITLE

Augmented and Virtual Reality in Education

SUBJECT WHERE IT CAN BE USED

Science, Technology, Mathematics, Geography

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

- Upper secondary
- Formal education

TARGET GROUP

The target group are teachers and their students at upper secondary education level.

ORGANIZATION, COUNTRY AND YEAR OF IMPLEMENTATION

Ekpedeftiki Shareholder Ltd, Pedro de Axular Cooperativa, IMS private school, Instituto Comprensivo Panicale-Piegaro-Paciano,
Greece, Spain, Cyprus, Italy
December 2017 – May 2019

PURPOSE

The schools participating in this project were looking for the methods and tools to:
1. Engage and support students, including underachievers, in better understanding of the STEM subjects, trigger their motivation, attention, critical thinking and knowledge;
2. Improve the students' digital literacy;
3. Improve the students' communication skills.

METHOD

The project was implemented for the secondary school students using tablets (IOS, Android, Windows). The Virtual Reality (VR) tools and 3D printing were an exceptional didactic approach to inspire students in the teaching of science in the classroom, in the science lab and during the educational visits. The approach was successfully applied in Science, Technology, Mathematics, Art, Literature, Photography and Geography courses. The aim of the approach was to trigger motivation, increase the attention, boost critical thinking and improve the knowledge of the Secondary school students.

ACHIEVED RESULTS

The teachers designed, exchanged and applied educational scenarios using tablets, 360 cameras and mobile phones. The existing educational AR and VR applications were also used. Additionally, new educational material was designed using proper software and 3D printers.

RELEVANCE

The project developed learning scenarios for the STE(A)M subjects at the upper secondary level of education.

STRENGTHS

The material developed has been tested in schools and it is linked to the school curriculum.

WEAKNESSES

The material developed can be accessed only through the e-twinning platform.

SOURCES OF INFORMATION

FACEBOOK

TWINSPACE

TITLE

Augmented Reality for Environmental Education

SUBJECT WHERE IT CAN BE USED

Environmental Science

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

Lower secondary and secondary education

TARGET GROUP

The main target group of this project are youth workers and educators interested in the new and innovative tools for the youth education and engagement, as well as pupils aged 12-16.

ORGANIZATION, COUNTRY AND YEAR OF IMPLEMENTATION

Social Innovation Center, Mittetulundusühing Involved,
VšĮ Inovacijų biuras,
Latvia, Estonia, Lithuania
January 2020- April 2021

PURPOSE

With the purpose of tackling the challenge of finding new education methods attractive for young people, the project partners created an educational tool with the Augmented Reality application that focuses on the environmental education. Taking into consideration the interactive digital nature of the Augmented Reality, this tool can be used to motivate young people to learn more about the challenges and possible futures regarding the environment and the change of habits needed in order to attain a more nature-friendly society.

METHOD

The Project partners chose environmental education topics and created scan cards/posters which were used together with the already existing and developed AR applications iSee, creating not only informative reading material but also complementary interactive educational content with images and videos that give additional insight for each of the chosen topics. This educational tool is available for printing out and use in the classrooms as well as in digital format online free of charge, therefore youth workers and educators who are interested in the innovative tools are able to access and use it within their informal education programs and activities.

ACHIEVED RESULTS

The iSee app and educational scan cards/posters are available for free use by the general public.

RELEVANCE

The project Augmented Reality for Environmental Education is the inspiration for the AR4STEM project and AR4STEM builds on the concept and approach created in the previous project and develops it further.

STRENGTHS

This project provides teachers and youth workers with the engaging, interactive materials to modernize the education process and increase youth participation and interest in environmental education.

WEAKNESSES

The main challenges were the creation of the digital solutions and overcoming technical limitations in order to create the best visual materials that are sufficiently engaging for the target audience.

SOURCES OF INFORMATION

ABOUT PROJECT

POSTERS

APPLICATION

TITLE

Augmented Reality for Science Education

SUBJECT WHERE IT CAN BE USED

Biology

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

Formal primary and secondary education

TARGET GROUP

Schools, teachers, students, teacher educators, researchers and developers of educational technology

ORGANIZATION, COUNTRY AND YEAR OF IMPLEMENTATION

VIA E-Learning and Media (Coordinator), VIA University College, Skolen I Midten, Supercomputing Centre of Galicia, Oslo and Akershus University College of Applied Sciences, Centro Público Integrado O Cruce, The University of Manchester
Denmark, United Kingdom, Spain, Norway
2014 - 2017

PURPOSE

The project produced the materials to facilitate the students' learning and engagement and also built models of how teachers can use the technology and increase the students' engagement.

METHOD

The project investigated three different implementations of the AR in the science education:

1. Teacher using the existing AR resources in their teaching process;
2. Teachers as the producers of the AR resources for their own teaching process;
3. Students as the producers of the AR Resources.

An example of the developed materials: "Lost in the Woods" and "On Fire", both suitable for the curriculum for the Early-years foundation: 7-11 (key stage 2) students. "Lost in the Woods" focuses on having students use the AR for exploring and communicating scientific phenomena. In this case, scientific phenomena that relate to the living plant. The students must use different AR-based models to explore how the plant handles different challenges such as transportation of water, photosynthesis, capture of carbon dioxide and so forth. Subsequently, the students must be able to give a scientific explanation by using the selected AR-based models.

ACHIEVED RESULTS

The project contributed to the development and implementation of the innovative science education process and enhanced the quality of the science teaching and learning. It also strengthened the students' motivation and positively changed their attitude towards science education. The project also developed a student-centred approach to science education facilitating the inquiry-based teaching, collaboration and active learning. Last but not least, it strengthened the technology-enhanced teaching and learning in the ways that make sense to students and teachers.

RELEVANCE

This project addresses the need to develop and take on the new approaches to teaching and learning and to use the new technologies to support and facilitate modern education process, especially when it comes to the STEM education. The science subjects pose problems or obstacles for a large number of students in European schools. School science subjects are considered "hard" and require high levels of abstraction. As a result, there is a decline in the young Europeans' interest in the science subjects, both during their education and as career opportunities.Inquiry-oriented approaches are recommended to make the learning of science more like the practice of science.

This project addresses the above concerns by contributing to developing and implementing the innovative science education in order to enhance the quality of science teaching/learning and students' attitudes and motivation. The basic rationale of this project is that science education can be strengthened through the use of the Augmented Reality, because the AR makes possible active, collaborative learning and interaction with and visualisation of central science knowledge. The AR can support an inquiry-based approach to science education with a high level of the student involvement. Furthermore, the AR offers the potential of facilitating situated learning in "real world situations", where powerful augmented content is anchored in reality and delivered via mobile and other devices. In addition, the technology offers visualisation of invisible or complex processes.

STRENGTHS

The development of the materials was based on the needs analysis concerning the potential of use of the AR in science teaching and education.

WEAKNESSES

Through the course of the project, managing the technical mode of delivery has been problematic. This is not symptomatic of all technology, rather of the innovative technology that has yet to find maturity and stability in a fast-moving space. It is worth considering that involvement with the new technologies will always hold risks as well as more obvious benefits. While it is difficult to pre-empt all potential issues, effective planning and provision of alternative solutions can potentially gauge technical success.

SOURCES OF INFORMATION

ABOUT PROJECT

ERASMUS +

AR-SCI PROJECT

ANALYSIS

TITLE

Enlivened Laboratories within the STEM Education

SUBJECT WHERE IT CAN BE USED

Science, Technology, Mathematics

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

Lower and upper secondary school

TARGET GROUP

The main target group of this project are educators and 12-18 year-old students.

ORGANIZATION, COUNTRY AND YEAR OF IMPLEMENTATION

Cyprus, Greece, Finland, Portugal, Estonia
September 2017 – June 2020

PURPOSE

The project aimed at the engagement of the students who may not be interested in the STEM related studies/careers and increase the interest of those who already displayed interest and, in general, to improve the students' performance in the courses related to the STEM education.

Enlivened Laboratories for Science, Technology, Education and Mathematics (EL-STEM) seeked to practically contribute towards meeting the 2020 EU target of reducing the number of underachievers in the STEM education to below 13% and motivating a bigger proportion of the young Europeans to exhibit interest in the STEM and to undertake scientific and technical studies and careers (EU Council, 2006).

This practical contribution was to be achieved by integrating the Augmented Reality (AR), or more generally, the Mixed Reality (MR), within secondary STEM education, to make the subjects more accessible and attractive for all children and particularly those at special risk of exclusion from scientific studies and/or careers.

METHOD

Inspired by emerging technologies of the IoT (Internet of Things) and AR (Augmented Reality), the project connected the physical and/or the remote laboratory to the digital world and turned it into an "Enlivened Laboratory". The project explored various digital solutions to "immerse" students within the STEM laboratories while implementing experiments and managed to attract students to the STEM related studies through intense hands-on experiences, where they participated, transformed and augmented what they were implementing. The Enlivened Laboratories STEM approach was supported both at school and at home through the involvement of the appropriate online tools offering the opportunity to experiment with simulated remote laboratories. This project provides a pedagogical framework for developing an inquiry-based STEM learning approach which can be used in designing the instructional processes and materials for the use of the mixed reality and augmented reality in learning and in assessing the outcomes of this learning process. For the last decade, the inquiry-based learning has been considered one the key methods in the STEM learning.).

ACHIEVED RESULTS

The Project outputs included the AR/MR educational scenarios expressed in the Lesson Plans (LPs) and implemented the use of technologies that explored the utilisation of the AR/MR Remote and Local Laboratories. The project created a comprehensive teaching and learning framework for providing teachers with the innovative digital tools to enrich their laboratory-based courses in order to not only attract the students' attention towards the STEM education but also to achieve better performance in the STEM related subjects. The EL-STEM developed, pilot tested and implemented an innovative in-service teacher training program that offered the EU secondary school STEM teachers high-quality professional development on how to effectively embed the AR into the instruction.

The program provided an innovative Methodological Framework and related AR/MR Learning Resources that equipped teachers with a wealth of practical experiences and IBSE methods that can help foster children's learning and motivation towards STEM-related studies and careers.

RELEVANCE

Cross-national studies of the student achievement (e.g. TIMSS, PISA) indicate lack of scientific competence for a considerable proportion of students. For example, about 50% of the EU countries that participated in the PISA 2015 had significantly lower than average performance in the basic science and mathematics skills, while only 2 countries (Estonia, Finland) were included within the top-10 rated countries globally, with the scores lower than 13% (OECD average concerning share of low achievers).

In addition to the students' low achievement in sciences, there is a well-documented evidence of declining interest in the key STEM topics and/or careers for the EU students and internationally). Low student performance and decline in interest are of concern, since skills in the STEM are among the key competencies that all individuals need in a knowledge-based society for employment, inclusion, subsequent learning, personal fulfilment and development.

Furthermore, this particular project differs from the other AR STEM projects, since it is not just providing informative educational materials that have some AR elements in them, but also takes a very central idea of the STEM studies, the practical experiments in a lab, and connects the physical laboratory to the digital world thereby providing immersive experiences to students through intense hands-on experiences.

STRENGTHS

The Enlivened Laboratories are an innovative method to promote collaboration and exploratory learning and provide students with the hands-on learning activities that allow them to apply technology, science, math and engineering skills as they enjoy the 21st century learning experience. Laboratories are being given a central and distinctive role within the STEM education while experiments constitute a critical part of the STEM related courses and promote better understandingof the taughttheories among students.There are several potential benefits to adapting laboratories, including (a) attraction of the students' interest and (b) provision of multiple opportunities for theacquisition of practicalknowledge. The project recognizes the need for employing a combination of different types of laboratories during different phases of an educational process and highlights the potential of remote, virtual and augmented reality labs on the enhancement of the educational process, especiallywithin the e-learningand blended learning environments.

STRENGTHS

The transferability of these methods has been only tested within the countries of the consortium, hence further application of these methods beyond the consortium is to be further determined.

SOURCES OF INFORMATION

ABOUT ELSTEM

ERASMUS +

TITLE

Augmented Reality Education Module - Development and implementation of the innovative ICT-based educational tool in the STEM orientated school subjects

SUBJECT WHERE IT CAN BE USED

STEM education in general

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

Formal secondary education

TARGET GROUP

Secondary school pupils and teachers

ORGANIZATION, COUNTRY AND YEAR OF IMPLEMENTATION

North Macedonia, Croatia, Bulgaria
November 2018 – October 2021

PURPOSE

The main aim of the project is development and use of a new software solution - an innovative ICT based educational tool (Augmented Reality - AR learning module) to connect students with the STEM fields as a non-traditional approach beyond the limits of the classic classroom. Nowadays, students in secondary schools are not interested enough in Science, Technology, Engineering and Mathematics (STEM).

At the same time, the STEM orientated school subjects help the students to develop the skills needed to succeed in the global labour market, especially taking into account that scientific and technological innovations are becoming increasingly important as students face the benefits and challenges of globalization and knowledge-based economy.

METHOD

During the project, a Strategic action plan for transnational cooperation in the field of educational development with the help of the new innovative educational tools was created. The new ICT based educational tool was built by using the Augmented Reality. Activities to increase the teacher's computer literacy and competences and skills to use the AR learning module and OER were carried out. Also, a Q&A database with the STEM related questions and answers was established. The main aim of the innovative educational software is to generate the Augmented Reality symbols on the predefined locations (with x, y, z coordinates) in the towns of Kochani, Pazardzik and Ludbreg. Those symbols can be seen through cameras from any mobile device that has an Android based operating system. On those devices, the application software will be installed which will allow interaction with the AR symbols – by clicking on the question and four possible answers (one correct and three false), they will appear on the screen of the mobile device. In case of the correct answer, students will receive points. Results can be seen on the web platform.

ACHIEVED RESULTS

A new innovative educational tool (AR educational module) that can be used in education was developed. A manual for implementation of the AR educational module in the STEM orientated school subjects was created. The teacher's network was established by using the eTwinning module as the main pre-request for further partnership and cooperation in the increase of the teacher's skills and competences by exchanging good practices. A strategic action plan for transnational cooperation among different socioeconomic organisations in the field of education was created.

RELEVANCE

This practice is interesting as it applies the use of the AR and OER to the outside-of-the-classroom environment, hence the pupils can engage in the educational activities in the urban environment familiar to them. Software can be used by anyone who will install it on an Android device, will fill Q&A database and will create x, y, z coordinates where symbols will appear (this can be done for each location on Earth without limits). However, the interested parties outside the project partners will need to ensure the rent of a domain and dedicated server where the application will be placed for use.

WEAKNESSES

The biggest strength of the application is also its biggest limitation - this app is designed to be used in a more spacious environment than a classroom, hence it is not suitable for in-classroom learning.

STRENGTHS

Pupils can engage in educational activities in the urban environment familiar to them making the experience even more interactive, engaging and enjoyable - their hometowns or cities become their extended classroom.

SOURCES OF INFORMATION

ERASMUS +

WEBSITE

BROCHURE

TITLE

ARSTEAMapp - Fostering Scientific Vocations through Augmented Reality about European Cultural Heritage

SUBJECT WHERE IT CAN BE USED

Science, Technology, Engineering, Mathematics

ORGANIZATION, COUNTRY AND YEAR OF IMPLEMENTATION

Turkey, Romania, Portugal, and Spain 2022 - ongoing

LEVEL AND TYPE OF EDUCATION WHERE IT CAN BE USED

Formal secondary education

TARGET GROUP

12–16 year old pupils

PURPOSE

The purpose is to develop an augmented reality educational app to explicitly reflect on the connections between the STEAM disciplines through the analysis of the relevant European cultural heritage (i.e. sculpture and buildings).

The project aims to:

- Enable the adoption of the integrated STEM approach through explicit connection between emblematic buildings of the European cultural heritage and the contribution of the STEAM disciplines to their design and construction through the development and application of the AR based on the STEAM;

- Facilitate the teachers' enactment of the integrated STEAM approach through the AR resources due to the development of a constructivist-based pedagogical model. Thus, the pedagogical design of the tools created, app and guidelines will be carried out based on the educational curricula of different countries of the participating partners.

METHOD

As an example of the intended app, students would scan the façade of a cathedral using tablets or smartphones. They will learn about the aspects related to science (type of rock used), technology (tools used for its construction), engineering (successes and failures of its design), mathematics (structure) and art (historical context in which the cathedral is designed and built through a virtual tour). Students will also understand the social and cultural importance of the cathedral while making explicit connections between the STEAM disciplines content.

ACHIEVED RESULTS

The project is still underway but it plans to create an educational tool that allows students to work the disciplines of science, technology, engineering and integrated mathematics through the Art, using elements of the European Cultural Heritage. This application will be based on the Augmented Reality so that the user (students and teachers), from the scan of an image or a 3D model of an element of the European Cultural Heritage can: learn about its history and the people who participated in its design and construction; discover the science, mathematics and technological development that made its construction possible; know the used engineering design. For each element of the Heritage (architectural work or sculpture) selected, an educational scenario will be created: after scanning a specific characteristic of the element with a QR code, the app will activate a reproduction of the monument in the Augmented Reality from which the user will be able to work the STEAM disciplines. The project will also provide a pedagogical guide on the STEAM and cross-curricular implementation.

RELEVANCE

The ARSTEAMapp addresses the challenges of improving the teaching of the STEAM disciplines in the 12–16 age group by designing an innovative way to establish connections between these disciplines in a meaningful and viable way within the educational context.

STRENGTHS

The project explicitly reflects the connections between the STEAM disciplines through the analysis of the relevant European cultural heritage (i.e. sculpture and buildings) helping pupils to engage with the STEM education through real life world around them and understand how the STEM subjects come together in tangible examples in the world they live in. The project's uniqueness is in its cross-curricular approach.

WEAKNESSES

The project is still underway therefore weaknesses are to be further determined.

SOURCES OF INFORMATION

ABOUT ARSTEAM

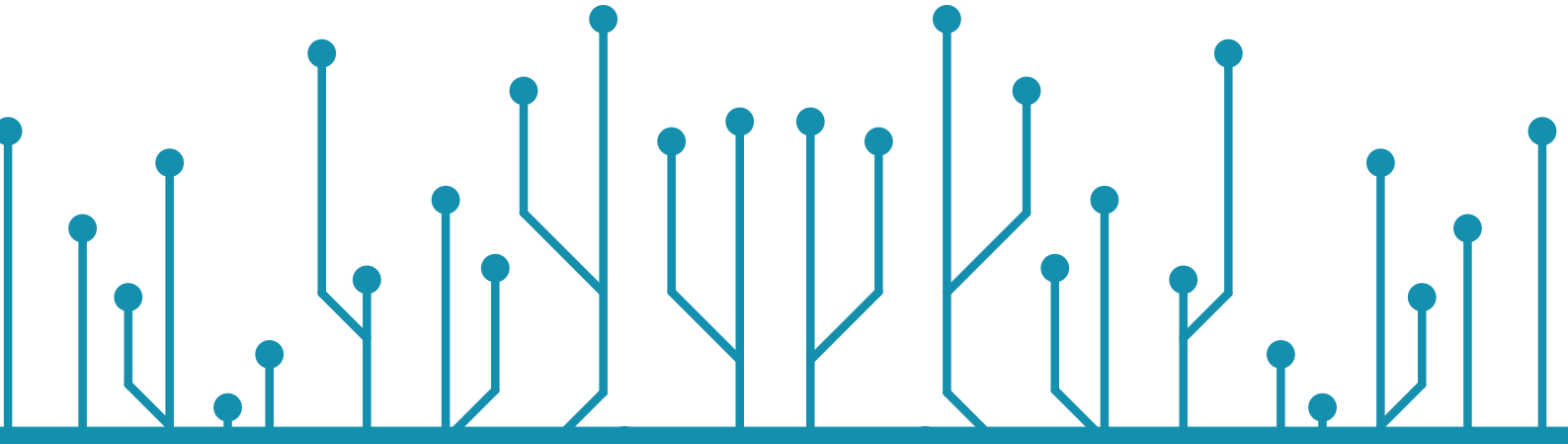
SECTION 3
COMPARISON OF THE AR TOOLS FOR TEACHERS

Digital technologies are becoming a more integral element of many children's and parents' school experiences, whether they are used to facilitate learning, assess the learning outcomes or communicate with parents and guardians.

Similarly, the augmented reality in education is getting increasingly prevalent. In fact, the AR offers a chance to see and learn from dynamic models and simulations and therefore fits in well in formal education, since it helps students to see in front of their own eyes how theories unravel and how concepts work in practice (Alnajdi et al., 2020). The AR technology is steadily conquering a prominent position within the educational process, since it can provide interactive and engaging learning materials, encourages learner focused teaching and is a helpful tool with the inquiry based learning.

Huerta et al. (2019) claims that the AR could raise technical education standards and be preferred over conventional approaches, since it has increased success in boosting the learners' competence, abilities and engagement. The authors clarified that in the STEM education, theories are a source of fundamental information that supports problem-based learning, but often are challenging to grasp because they are too abstract for the learner's mind, therefore the AR is a very fitting tool to tackle this challenge, as it allows to concretize and visualize processes and reactions otherwise hard to demonstrate.

A teacher or educational process facilitator must be educated about the AR and be aware of the potential changes it may pose during lessons in the classroom. Hence, Section 3 consists of 4 Units that have the purpose to provide step by step instructions and comparison of different tools, functionalities and features available for teachers, so that they know what they can use to create their own examples and successfully implement the AR in the educational process of the STEM. Unit 1 focuses on different aspects to be taken into account while selecting proper AR tool for educational process. It is followed by Unit 2 dedicated to the financial terms of the AR app use. Unit 3 describes in detail how to use the Isee app. Finally, this section ends with the selection of the STEM related AR apps.



UNIT 1
HOW TO SELECT THE BEST MATCHING AR TOOL FOR THE EDUCATIONAL PROCESS?

In the present digitized world, the augmented reality is an excellent approach to engage interactively with pupils, however, selection and planning of the educational process must be performed carefully. Although there are still numerous disparities, technology, software and mobile devices have actually become part of every young person's life, regardless of location, community or social or economic status. Because of this, the AR apps are accessible and efficient on a worldwide scale. Several actions must be taken in order to build the appropriate AR related educational process within the class.

Pay attention to the pupils' needs in a specific subject. Fundamental prerequisites for the AR include having a thorough understanding of the pupils' needs, their motivations and the way of learning. Pupils' needs must be the primary focus. Whenever possible, engage pupils already in the brainstorming and design phases to understand the specifics of their learning pattern and the most attractive forms to engage with them. Whenever possible, present a selection of the AR tools, discuss and make joint selection of the AR to be used in a specific subject.

Educational goals. The goals of an application of the specific AR app in the educational process (e.g. within a lesson plan) must be clearly stated. A method to assess the efficacy of the AR application must be suggested whenever possible and it must be determined whether the AR application can be utilized to achieve the desired aim at full or in part. One of the most difficult aspects of the AR application is the selection of proper activities to achieve educational goals. The AR content must be entertaining, interactive and with the engaging multimedia components. The AR learning activities must be designed in a way that at least fundamentals can be performed by any pupil in the class.

At the same time, tasks must be customized and modified whenever possible to fit the ability levels of different pupils. Then again, it is expected that each activity that comes after will require more work from the child and will be increasingly challenging to their knowledge and abilities. Practically speaking, it refers to stepping up the complexity of any task.

Selection of the proper AR app based on functionality. Since functionality, features and even costs of different apps vary, proper selection is one of the keys to success. Make sure which function or feature best fits the educational goal you would like to achieve.

Testing before implementing. Whenever possible, a specific AR app must be reviewed by the educational process experts or already tested by another group of pupils. This would help to understand the applicability and appropriateness of the specific educational AR tool. If such options are not possible, testing with a smaller group or on your own can be the option before introducing the app. In general, the teacher has to be well prepared on the functionality of the specific app before introducing it to the class.

Usability - usability is defined by the ISO (International Standard Organisation) as "the extent to which specified users can utilize a product to achieve specific goals with quality, effectiveness and satisfaction in a specific context of usage" (Lewis, 2018). The key usability indicators are task match, ease of learning and ease of use. The effort required to utilize a technology until the user has fully grasped and mastered it is referred to as the ease of learning. The task match refers to how effectively the system's information and features satisfy the user's needs (Elfaki et al., 2013).

Teamwork level. The AR can be designed to work on an individual level but also in small groups, teams. Decide whether teamwork is an important part of the educational process within a subject and design educational goals keeping in mind the level of the required team work.

Costs. As previously described, there are several types of the AR related costs or the AR can be free for use. Depending on the subject, level of difficulty, educational aim to be achieved and internal school policies related to the costs and privacy of the pupils data, selection must be made keeping all of these aspects in mind. If educational purposes can be achieved with the basic functions and free versions, it is always recommended to go for the tools available for general use. However, if the educational aim can be achieved only by the use of the paid options, the aspects of the costs must be evaluated versus possible learning outcomes and respective efficiency ratio of such application.

Evaluating or projecting (possible) learning outcomes. When evaluating possible learning outcomes, one needs to assess the following elements as a result of the AR application in the educational process:

- **Level of the engagement and interest** – make your own scale to observe general interest and follow up different stages of the AR use to perform a specific task;

- **Supportive learning environment** – assess whether an interactive learning environment improves the educational process and encourage students to practice and master new abilities;

- **Content understanding** – is the AR app supportive to get better understanding of the topics difficult to visualize and understand, e.g. physics, maths, chemistry subjects as examples;

- **Memory** – does an interactive content contribute to better memorization of the specific subject.

In summary - the AR offers educators the chance to assist pupils in understanding difficult ideas. Teachers can improve learning experiences in the classroom, impart new knowledge, stimulate students' minds and pique their interest in pursuing new academic pursuits by utilizing the interaction and experimentation that the AR technology provides. However, to get the best results, a teacher must invest time and select the most appropriate tool among a variety of apps available in the market.

UNIT 2
FREE, ''FREEMIUM'', PAID AND ''PAYMIUM'' VERSIONS OF THE AR TOOLS

Understanding how and whether the new educational applications comply with the school's data and student privacy regulations is an important aspect to consider before choosing any app, including the AR related. Finding educational apps that meet the teacher's needs and offer the security required to protect the personal information of the teachers and kids using them may often be challenging, given the vast number of educational apps currently accessible and the new ones appearing every day. Data privacy policies related to the pupils must be agreed with the school management, hence, implementation of the AR related apps depends on the data policy of the school. The next step is to identify whether the chosen app is a free, ''freemimum'' or paid version.

Free version – When just starting to explore the AR apps, the first ones to consider are the free versions. These apps are most likely not going to have extensive functionality or may be less visually attractive compared to the freemiums or paid versions but it is a fantastic resource for anyone just getting into the augmented reality.

Freemium - The freemium (a combination of free and premium) has emerged over the past ten years as the preferred format in the app development sector. With this approach, consumers can choose to access more advanced services for a monthly price while still receiving the basic functions for free. They are free for download and offer the so-called optional in-app purchases. Freemium apps are accessible to all users, regardless of whether or not they choose to spend on the optional functions to enhance or customize the experience.

Types of in-app purchases

- **Consumable.** To advance in an app, users can buy a variety of consumables, such as extra lives or jewels in a game. Consumable in-app purchases can be repurchased after they have been used up.

- **Non-consumable.** Within an app, users can buy premium, non-consumable features. Non-consumables, like extra filters in the photo software, are bought once and have no expiration date.

- **Automatic subscription renewals.** Users can buy access to services or frequently updated material, such as monthly cloud storage access or a weekly subscription. Until they choose to cancel, users are continually charged.

- **Non-renewable subscriptions.** Users can buy season passes for streaming material or access to services or content for a set period of time. Users must renew this type of subscription each time because it does not renew itself.

Paymium - in this hybrid of the premium and freemium models, users pay to download the app and then have the opportunity to make in-app payments for a more in-depth access to features, content or services. Pay-for-use apps provide premium content, functionality and design in addition to cutting-edge features that enhance the user experience. Similar to paid apps, users may give more thought whether the app is well worth if it costs money to get it.

When deciding whether to have freemium, paymium and paid versions while selecting the AR apps, equity must be a priority in educational environments, particularly when decisions are being made about the use of technology for teaching and learning. Software in educational settings must not have tiers of offerings where users who can afford to pay have access to a better version with more features and tools. This applies to both teaching and learning software as well as to parent - teacher communication software. Hence, freemium models must be considered in the educational process only if that promotes equal access to the educational process, namely, free part of features of the freemium app. Alternatively, if the paid version is used, it must be provided by the school or any third party support to guarantee equal access to the paid features to all pupils in the class.

The implementation of the universally usable tools by school boards and regional education bodies (e.g. municipal educational councils) must be prioritized in order to end the two-tier access for students and families made popular by freemium software. This may entail purchasing licenses for commercial software that has undergone thorough scrutiny and assessment to see how well it supports student learning.

It is crucial to realize that, all things considered, freemium software is not genuinely a free software. The supplier is gaining useful information from users as a result of the data collection. It was previously stated that data protection policy must be well considered while integrating any app collecting private information. Through the app, the software supplier gains access to the parent and child directly for marketing purposes.

One of the recent examples where popular Freemimum had a risk of manipulative effect on the children is Prodigy. Non for profit organisation FairPlay raised the question of the true aim of the specific app, discussed in their article:

ARTICLE

Examples and risks like the ones raised by FairPlay have to be well considered by the teacher when introducing specific apps.

Paid version – in the paid version, users (pupils) make a single payment to download software and access all of its features. No hidden fees or in-app purchases are present. Users who choose a one-time payment for the entire experience are drawn to this business model. Successful paid apps are frequently positioned as premium experiences through exceptional design, functionality and marketing, since the fee to download can make the consumers assess the app's value more carefully.

UNIT 3
ISEE APP AND ITS FUNCTIONALITY: STEP-BY-STEP GUIDE

The general idea of the product is to support scanning of the AR objects to have 2D interactive features in order to raise interest in the AR technologies in an attractive and gamified way. The whole atmosphere of the iSee App (hereinafter referred to as the app) is meant to encourage the User to discover and enjoy the possibilities provided by the AR in a variety of environments and to stimulate its applicability within the educational process.

Technical guidance

The User can easily install a mobile app on an Android or iOS device using the corresponding standard procedure. The app is available in both the Apple AppStore and Google PlayMarket.

Upon obtaining the app in the corresponding app store and clicking the "install" button, the mobile app must get installed onto the User's mobile device and appear amongst the list of the installed applications.

The User must be able to easily start the app immediately on his/her device.

When the App is opened

When the app is opened it should show the screen, which uses the camera of the phone. The User must allow the app to use the camera. Once the permission is given, the app is ready for use.

The User selects an object to scan

On the main screen, the User is presented with the possibility to scan the object. The object can appear on different locations. See the example below.

When the User selects the scan object, it connects with the media extracted from the selected source. The result is shown on the screen as an Augmented Reality object.

The User selects the new object to scan

The User is presented with the possibility to scan several objects.

After the User selected the first object and connected with the selected media source, it is possible to select the next object. The User must simply direct the camera to the new object and the markers will extract new media files linked to the new object from the selected source(s). The result is shown on the screen as the Augmented Reality object. The User can also come back to previous objects. The User can switch between several objects. See the image below.

Another option is to start a completely new scan by returning to the “Back to Scan” function. This function can be also used, if the User wanted to exit from the App, but decided to stay in the app and make a new scan.

UNIT 4
SELECTION OF 10 STEM ORIENTED AR TOOLS FOR TEACHERS

As discussed before, the AR tools can greatly facilitate the process of the STEM teaching since they allow learners to visualize and specify abstract concepts and theories in the form of visual information, achieving more in-depth learning, improved conceptual knowledge and eventually improved learning outcomes.

Unit 3 provides a selection of 10 specific AR tools that can be used in the STEM education in the classroom. The following 10 tools are presented by subject in which they can best be used - mathematics and geometry, physics and chemistry, astronomy, biology and information technology. Some of these apps can be used for more than one subject and if so, this is indicated in the template. The very first app to be presented can be used for a variety of the STEM subjects as it is an AR depository of knowledge covering a wide range of topics.

TITLE OF THE AR APP

JigSpace

LINK TO DOWNLOAD

APPLICATION

BEST MATCHING SUBJECTS

STEM

BASIC DESCRIPTION

JigSpace is an app for the iOS, Mac and Windows that uses the augmented reality (AR) to explore machines, inventions, space, how-to topics and more. Simply launch the app, select the desired 3D model (called a Jig) and point the camera at the table or the floor. JigSpace will load the object right there, giving students the opportunity to move around the object and inspect it more closely. Arrows on the side of the screen allow students to progress through the Jig, cycling through different animations and brief explanatory text. The animations often take the form of a 3D exploded diagram. Teachers can use JigSpace to introduce or explain different concepts, such as tectonic plates, how a battery works, the scale of the solar system, the structure of the human brain and others.

MATHEMATICS AND GEOMETRY

The AR tools can facilitate the process of implementing educational materials that engage students, fuel their interest and improve the learning outcomes, since the apps have the ability to help to comprehend complex mathematical and geometrical concepts through visualization and interactive 3D models. Furthermore, the AR apps can virtually guide the students through the steps required in to arrive at the correct solution of a calculation by the use of animation. 3D modelling is especially useful when learning geometrical shapes and forms.

TITLE OF THE AR APP

Photomath

LINK TO DOWNLOAD

APPLICATION

BEST MATCHING SUBJECTS

Mathematics, Geometry

BASIC DESCRIPTION

Photomath is a mobile app which utilizes the phone's camera to recognize mathematical equations and to display a step-by-step solution directly on the screen. The application is based on the advanced text recognition technology and a math solver algorithm; it is free on the Google Android and iOS. Photomath will recognize the text on a photo, then choose the appropriate math techniques to solve the problem. Photomath covers a wide range of math topics, therefore it is suitable for pupils from the second grade to the senior year. It covers elementary maths, algebra, geometry, calculus, trigonometry, statistics.

TITLE OF THE AR APP

Arloon Geometry

LINK TO DOWNLOAD

APPLICATION

BEST MATCHING SUBJECTS

Geometry

BASIC DESCRIPTION

This app features 3D models with the Augmented Reality for most geometric shapes. Students can view different geometric shapes from different angles, rotating them and unfolding the sides into flat figures for a robust understanding of their composition. Content to study includes regular polyhedral, prisms, bodies of revolution and pyramids. Arloon Geometry also includes the definitions and characteristics that differentiate shapes, procedural content such as geometric formula and exercises to practice the material. Arloon Geometry helps to develop spatial imagination applicable in real world problem solving. Arloon Geometry can serve as an assessment tool as well as a supplement to the classroom lessons.

PHYSICS AND CHEMISTRY

The AR apps allow for a more interactive learning which is especially important when trying to grasp complex concepts of chemistry and physics - concepts that cannot be observed with the naked eye but that are all around us in our everyday physical environment. By combining the AR elements, videos and animation, teachers can assist students in their scientific explorations and help students to gain deeper knowledge and understanding of complex elements such as acids and oxides, atoms and molecules and physical principles such as gravity or speed. In addition, learners can complete experiments with less supervision from the laboratory instructor compared to performing conventional experiments.

TITLE OF THE AR APP

Atom Visualiser for ARCore

LINK TO DOWNLOAD

APPLICATION

BEST MATCHING SUBJECTS

Physics, Chemistry

BASIC DESCRIPTION

This app enables students to visualize and explore atomic models in the Augmented Reality. Functionality allows to move and position floating representations of any atoms on the periodic table to view them from various angles. Although the electron orbital model is the default, you can also use the more precise but less useful electron cloud model.

TITLE OF THE AR APP

Merge Cube

LINK TO DOWNLOAD

APPLICATION

APPLICATION

BEST MATCHING SUBJECTS

Chemistry, Physics, Biology

BASIC DESCRIPTION

The Merge Cube lets students hold digital 3D objects enabling an entirely new way to learn and interact with the digital world. Students can explore a galaxy in the palm of their hand, hold fossils and ancient artifacts, explore a DNA molecule, investigate the Earth's core, dissect a virtual frog, hold and share their own 3D creations and much more. Merge EDU apps are free, however, additional content and features require a subscription.

TITLE OF THE AR APP

Galileo: AR Physics

LINK TO DOWNLOAD

APPLICATION

BEST MATCHING SUBJECTS

Physics

BASIC DESCRIPTION

Galileo: the AR Physics is an Augmented Reality app that students can use to get a better understanding of physics. The app lets the users place experiments and animated 3D models on a table and understand them. Apart from this, the app also consists of the articles that cover topics like mechanics and nuclear physics. To make these easily understandable, the app also consists of images, animations, 3D models and equations.

ASTRONOMY

Similarly, as with the processes linked to chemistry and physics, the very fascinating world of astronomy is hard to observe in an in-class environment since it requires hi-tech, expensive equipment usually not found in an average school. The AR models allow for the augmented views of the celestial bodies and encourage students' inquiries using spatial visual elements. The technology allows the creation of spectacular AR environments that support inquiry-based learning.

TITLE OF THE AR APP

Big Bang AR

LINK TO DOWNLOAD

APPLICATION

APPLICATION

BASIC DESCRIPTION

The Big Bang AR allows students to go 13.8 billion years back in time and discover how space, time and the visible universe came to be. Students can see the universe shape in the palm of their hand and witness the formation of the very first stars, our solar system and the Earth.

BEST MATCHING SUBJECTS

Astronomy

BIOLOGY

The AR tools provide an immersive format for students to learn and explore the earth's organisms and processes linked to them. The AR visualisations help greatly with concretising the subjects which in return improves knowledge retention since students learn better when they can relate biological processes to their own environment in the exciting and entertaining ways.

TITLE OF THE AR APP

Froggipedia

LINK TO DOWNLOAD

APPLICATION

BEST MATCHING SUBJECTS

Biology

BASIC DESCRIPTION

Froggipedia is a realistic and graphically sophisticated frog anatomy app that allows students to explore the frog life cycle and anatomy and go through a guided dissection. The app is split into three parts. The Life Cycle section starts off with a frog egg and the slider allows students to explore the different stages of the frog's development, from the egg to the tadpole to the froglet to the frog. Students can see all stages of development in realistic detail and they can zoom and rotate the creature at each stage.

TITLE OF THE AR APP

Plantale

LINK TO DOWNLOAD

APPLICATION

BEST MATCHING SUBJECTS

Biology

BASIC DESCRIPTION

In the Plantale, students have the opportunity to explore a sunflower plant's life cycle and reproductive cycle in the augmented reality (AR). Four different options within the app allow students to examine the plant and step through the stages of growth, from planting the seed to reproducing to withering and dying. Animations, labels, informative text and interactive elements help students to see what happens in the plant, from the outside in, during all of these stages. The app covers internal anatomy and gives students a good look at the outside of the plant during every stage from seed onward. Topics such as room temperature, pH, and how much to water the plant are addressed, briefly. Students can also plant their own sunflower in the AR and then return to that spot over the next several days to watch it grow, watering and fertilizing it to keep it healthy.

INFORMATION TECHNOLOGY

The AR can also be a very helpful tool to introduce pupils to the complex world of coding, since the AR and VR elements are incredibly entertaining and eye-catching and can help to engage the students with Information Technology and its possibilities.

TITLE OF THE AR APP

CoSpaces Edu

LINK TO DOWNLOAD

APPLICATION

APPLICATION

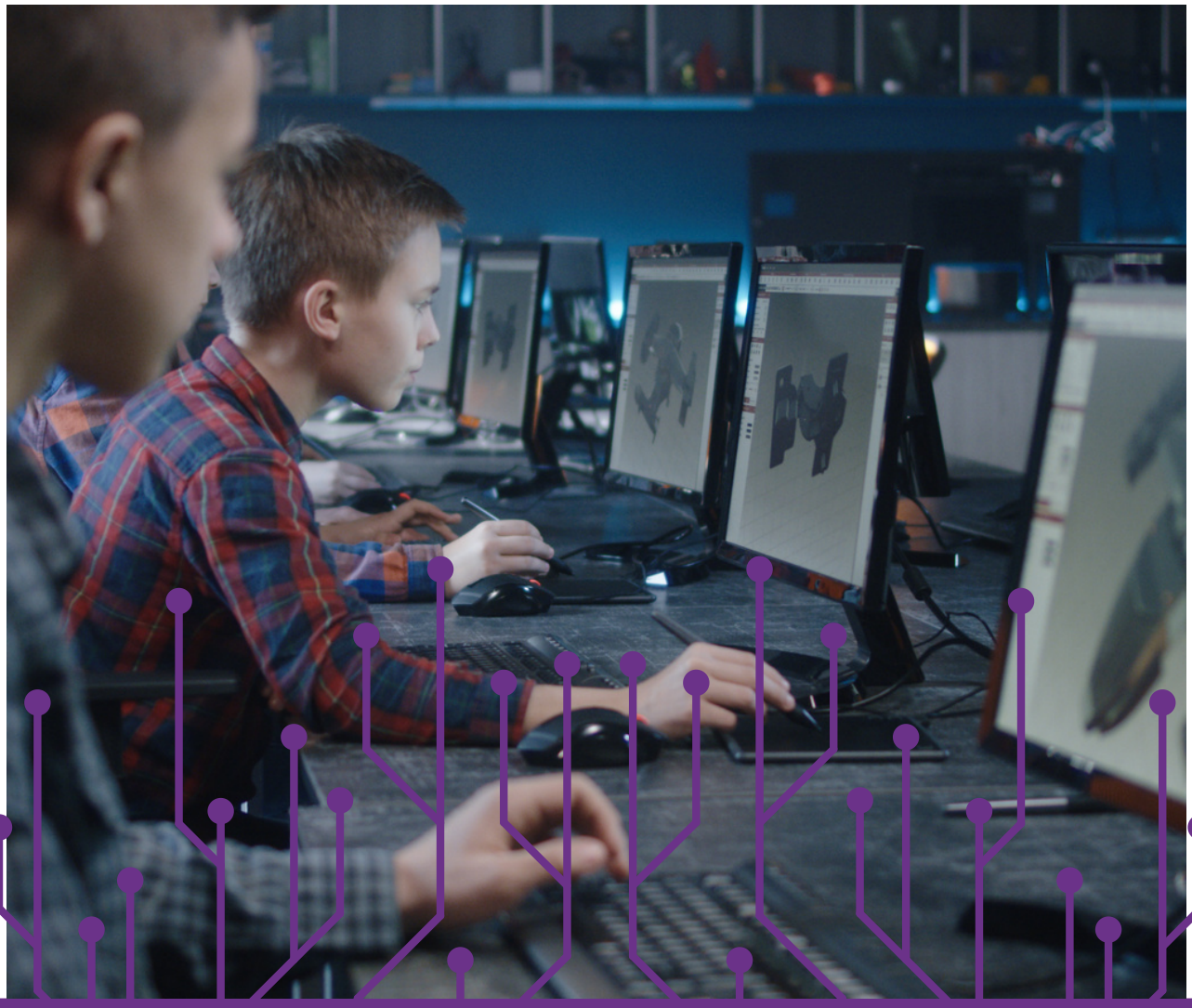
APPLICATION

BASIC DESCRIPTION

The CoSpaces Edu is a 3D creation web and app-based classroom tool that allows students to create in the 3D augmented and virtual reality environments. Finished creations can then be viewed in the VR with a mobile device using the app. The CoSpaces Edu is an entryway into the VR and AR creation and coding. Students create the scene's code with built-in CoBlocks that feature a drag-and-drop, Lego-style coding interface that Scratch popularized.

BEST MATCHING SUBJECTS

Information Technology



CONCLUSION

Due to digitalization, nowadays, an increasing number of professions require greater technical, entrepreneurial, social and civic competencies. Digitalization has an impact on how people live, connect, learn and work and as a result many jobs and industries will change. Some jobs will disappear, others will be replaced and new jobs will be created. Therefore investing in digital skills is crucial since they can help a person to connect with the employment market. Consequently, in order to fulfill the demands of digital technology, the educational system must adjust to this reality by providing new modes of learning and more adaptable training and educational models. Furthermore, as society, we will need to adapt our talents to reflect changes in the workplace. The discrepancy between the knowledge produced by the educational system and the skills required by businesses and people is growing. To get over these constraints, not only digital upskilling but also the STEM education needs to be prioritized, along with the growth of the STEM workplace competencies. Future workers are expected to spend more than twice as much time as workers do now on the jobs requiring science, maths and critical thinking. Future occupations will also strongly rely on the "21st century skills" such as problem solving, cooperation, creativity, cultural awareness and critical thinking. When implemented effectively, the STEM education supports the acquisition of the 21st century skills.

The AR4STEM project aims to increase the young pupils interest and understanding of the value of choosing the STEM education in order to pursue successful STEM professions. The project specifically intends to encourage secondary schools to incorporate game-based learning and immersive technologies into their curricula. A guidebook that will assist instructors in incorporating cutting-edge ICT into their STEM lectures is one of the goals of the project. This handbook is specifically intended for the educators who are working to promote the use of gamification and augmented reality in the STEM teaching. With the help of enthusiastic teachers who encourage students to actively engage in the STEM courses and activities, the use of the AR and gamification techniques in the STEM teaching methodologies can empower students to follow a career path connected to the STEM studies. This guidebook encourages educators to become fully immersed in the AR platforms and applications for more engaging and effective learning experiences for the pupils. It exemplifies how immersive technology and game-based learning can be incorporated into the STEM teaching for more engagement. This manual is designed in a practical way to enable easy consultation by teachers and educators. We hope this motivates both educators and pupils to explore the marvelous and fascinating world of both the STEM and the AR!

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