AR4STE(A)M

Using Gamification Strategies and Augmented Reality for Innovative STE(A)M Learning

IO3 - A6

Further Recommendations for Using Games Developed through the Use of AR for Innovative STE(A)M Learning

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Report on further recommendations for using games developed through the use of AR for innovative STE(A)M learning

This report represents the 6th phase of the seven total steps of the 3rd and last intellectual outputs (IO3) of the AR4STEAM project co-funded by the Erasmus+ program of the European Union.

In this report, thorough documentation of the final implementational stages of AR4STEAM is provided. Moreover, this report gives a guideline to real-life implementational approaches of AR-supported gamification in the form of innovative labs that can be practically integrated into today's STE(A)M classroom. Above and beyond documentation, this report provides recommendations for future use and a reflective building block for future optimized versions of such innovative educational streaks.

Each European partner (Belgium, Germany, Italy, Netherlands, & Turkey) have built and utilized the chosen AR application to develop innovative AR4STEAM laboratories. These labs facilitated for school students and teachers to indulge for the first time with the final coming together of the immersive gamified Augmented Reality (AR) learning experience. In this report, we go through the planning phases of the innovative labs and the different organizational steps involved in rearranging the AR app in the chosen STEAM subject that's being worked with within the lab sessions.

Each partner country exhaustively elaborates on their unique process of developing the innovative lab and conceiving the AR gamified apps. They also report on the lab's main goals and as the various logistics of their implementational approaches. Furthermore, they dive deep into the hurdles and challenges they've gone through throughout the different lab sessions, established through intermittent feedback loops between sessions. In that way, the learning outcomes were always monitored and supported. Beyond that, the partners also provide a prognostic elaboration on the future uses of such AR-supported gamification methodologies in education. And finally, potential exploitation opportunities of AR-supported gamification in educational contexts and the transferability of the different AR apps employed in the innovative labs to other STEAM subjects are further discussed.

Belgium

Partner: AEDE

1. STEAM-laboratories goals

Provide the full range of the objectives intended for the STEAM laboratories. Please include some brief information on the methodology used (e.g., how the AR laboratories have been organized, students' selection process, an overview of possible science scenarios to be reproduced and/or investigated through AR and GBL). Moreover, also include some information about the learning methodology (e.g., game-based learning) and innovative technologies (e.g., AR) used to highlight the benefit of acknowledging and fostering the link between science education and creativity.

The objective of the AR4STEAM laboratories is to implement the results achieved so far by the project in the practice of classroom work, where digital technology benefits students and contributes to secondary school teachers' professional development, including new forms of experimentation and use of innovative ICT technologies during their STE(A)M lessons.
Belgian education attaches great importance to innovation in Wallonia, the regional innovation strategy being a core component of the "Marshall Plan 4.0"(a budget of € 642m for the innovation component 2015-2019).
The proposal to participate in the innovative lab aroused great interest in the school. We invited all the students to participate.
We have collaborated to carry out this work with the Belgian section of the SHAPE school of the NATO military base, located near Mons.

2. Planning phase: in-depth info on the development of the AR-Lesson

Please, briefly provide information on when and how the augmented reality game has been conceived and created. Please, also include some information about the science subject - STE(A)M topic - chosen by each country and list the laboratory working phases students will follow in order to "give it life" through AR.

The spatial geometry of molecules or molecules in SPACE is based on the "Mirage" application designed by Marc Aurélien Chardine, professor of physical sciences at the Lycée Pierre Corneille in Rouen. The name of the application "Mirage" is the abbreviation for Method of Inclusion of Augmented Reality in Educational Management (Méthode d'Inclusion de la Réalité Augmentée dans la Gestion de l'Enseignement).

Preamble:

Video presentation of the ROSETTA MISSION: https://www.youtube.com/watch?v=r3HbauwhdTY

In 2021, we still have not discovered the origin of living molecules on Earth. The ROSINA measuring device determined the chemical composition of the comet's hair, while the Philae robot carried out chemical analyses of the particles on the comet. The results could help identify prebiotic molecules, providing new evidence that these molecules could have arrived on early Earth, creating conditions favourable to the emergence of life.

Lab Activity

Students (using actual ESA data) take on the role of European Space Agency (ESA) researchers:

They have just received the analysis reports of the chemical composition of comet Tchouri carried out by ROSETTA mission. Scientists worldwide are eager to hear their lab reports and find out what this comet is about.

Teacher's instructions:

1. Install the Mirage "Molecule Geometry" application on your smartphone;

2. Using this application, analyse each result received by Philae and record your research work in the ESA (European Space Agency) report;

3. For each molecule identified, you will win the molecular model to determine if an amino acid can be constructed with all of your results;

4. The press conference is scheduled for the end of the session.

Once a step is taken, the students "gain" extra atoms, and those who get enough can recompose the molecule!

Part 1: Analysis of the results & tasks

-Identification and geometry report of the molecules detected by Philae:
(Map number /Identified atoms/ Electronic structure of the atoms /Lewis notation of the molecule/ Name of the molecule & molecular formula/Geometric structure)
-Make hypotheses to explain the differences in geometry between each molecule concerning the Lewis representation;
- Validate your previous results by viewing cards n ° 7 to 10.

Part 2: Study and representation of the glycine molecule & tasks

Amino acids are building blocks of proteins and thus of every living organism on Earth.
-Is it possible to produce this amino acid from atoms of the comet molecules?
-Give a representation of this molecule using the same conventions as in part 1

Part 3: Preparation of the press conference

'ESA researchers' invite journalists to a press conference held at its headquarters in Shape on November 19, 2021.
- Share with colleagues a short report of the research

(Most of the data is accurate. However, this lesson project was produced as part of school work with some fictitious information)

3. Future use and implementation for extended subject fields

Please specify if there is a broader future potential for the developed game in further subjects other than the ones it's preliminarily intended for.

The Mirage application, initially intended for the geometry of molecules, was subsequently extended to other subjects in chemistry and fields as varied as physics, mathematics, geography, and history. The Mirage Make evaluation module allows creating a series of multiple-choice questions or open questions and retrieving the results either live (with Internet connection) or to the end of the activity by scanning the participants' devices.

4. Challenges and benefits during implementation

Indicate whether there have been challenges for its implementation. If yes, please describe the difficulties encountered when applying the augmented reality game and how these have been or can be solved. Please, make a link with the national videos produced during the laboratories.

The school administration offered all its support in carrying out the activity.

We had to give up the application that we proposed in the first place (Crystallography) to respect the school program and the school curriculum. We collaborated well with the teachers, and by mutual agreement, we chose the new subject of the activity (The spatial geometry of the molecule).

The work of editing the video is currently in progress. Here, some snapshots of the team of teachers and students:

Has the level of curiosity and creativity of students increased? In what way was it possible to maintain the students' concentration and interest?

The students' interest was so great that it was impossible to limit the experiment to a certain number of participants.

Even if the classification of observations was made on the number agreed between the AR4STE(A)M partners in accordance with the Erasmus plus proposal, we had to admit the other students of the class to follow the application.

Could such a teaching/learning experience (AR STE(A)M laboratories) facilitate students to look for STE(A)M careers? Why and how?

It is indisputable that including AR and gamification in science and arts education significantly increases the curiosity and appetite of learners to pursue a career in science, research, or/and new technologies at the service of science. This is because of the truthfulness offered by AR, which links theory to the real world, not to mention the playful aspect which makes assimilating knowledge more pleasantly, ensuring a constant high rate of curiosity and discovery.

5. Learning outcomes

Describe which are the main learning outcomes that the innovative STEAM laboratories have achieved.

- **Become familiar with the AR APP**
- **Find, extract and organize scientific information**
- **Analyse, formulate a hypothesis**
- **Propose strategy, proposal, argument**
- **Communicate using concepts of adapted scientific vocabulary**
- **Formulate, present a synthesis or a conclusion in a coherent, complete and understandable way**
- **Be autonomous, show initiative**
- **Request relevant help**

6. Exploitation opportunities

Indicate if there are further possible extensions and exploitations of the current AR implementation.

The app is easy to be adapted for extension, according to educational and scientific interest.

7. Transferability to other STEAM topics

Indicate instructions to re-use the developed AR game for implementing a new lesson on STE(A)M changing its contents only. Moreover, highlight also the benefits of using AR and

GBL to also teach subjects other than STE(A)M (see www.cultapp.eu, in particular: http://cultapp.eu/compendium-of-augmented-reality-technologies/.)

According to the example provided by our project, it is quite easy to reuse this app for another lesson.

Starting from the knowledge already acquired, the content to be introduced can be done with the help of the discovery in the lab by the students, using AR, as in our example.

Sharing our experience on appropriate platforms could help teachers from different schools and subjects to reuse the app as it is or adapt it to their educational needs.

AEDE is pleased that The General Directorate of Steering and Educational Affairs (Regulatory Unit and European Unit) of Belgian education in Wallonia has already asked to share on its platform the example of the chemistry lesson we carried out at Shape school. https://fr.padlet.com/sabine_haot_cfwb/nd322fhzv67vclgs

Germany

Partner: DIPF

1. STEAM-laboratories goals

Provide the full range of the objectives intended for the STEAM laboratories. Please fill in the goals from the project proposal here and make it a fluent and pleasant to read text.
Please, also include some brief information on the methodology used (e.g., how the AR laboratories have been organized, students' selection process, an overview of possible science scenarios to be reproduced and/or investigated through AR and GBL). Moreover, also include some information about the learning methodology (e.g. game-based learning) and innovative technologies (e.g., AR) used to highlight the benefit of acknowledging and fostering the link between science education and creativity.

The main goal of the AR4STEAM laboratories is to implement the so far achieved body of work the project has already delivered with real school students. All in order to increase students' interest in STEAM subjects, develop their scientific sense, be able to make informed decisions about scientific applications, and above all to foster creative, collaborative learning environments for school teachers and students. The project is highly innovative as it extends the research area of computer-based assessment with stealth assessment methods (An approach to performance-based assessments that embeds assessments in digital games to measure how students are progressing toward targeted goals (a.k.a. Learning Analytics (LA)) to formative feedback formats for learners in STE(A)M education.
Each partner organization has contacted school teachers and students who were enthusiastic and welcoming to participate in the innovative laboratories. After the innovative lab proposal has been presented to the collaborating school teachers, the students who participated in the innovative laboratories have volunteered themselves to take part in the utilization of the AR-apps in different STEAM subjects supported with LA, badging systems, and further gamification strategies that promote student engagement. The German partners at DIPF institute have achieved the latter through collaborating with teachers and middle school students from Adorno Gymnasium in Frankfurt am Main.

2. Planning phase: in-depth info on the development of the AR-Lesson

Please, briefly provide information on when and how the augmented reality game has been conceived and created. Please, also include some information about the science subject - STE(A)M topic - chosen by each country and list the laboratory working phases students will follow in order to "give it life" through AR.

AR-Mindpalace was conceived by German University students as a part of the Digital Education Hackathon Utrecht (DigiEduHack) 2020. The app itself is not subject-specific because it aims at improving student memory at any subject, all with the implementation of a memory-enhancing technique called the method of loci. As an app, it taps into two platforms, the AR platform, and the quiz platform. The quiz platform was made to be tailorable to any subject of interest where teachers can simply plug in the learning materials as they see suitable. As for the AR platform, it is also tailorable to various locations in which the learning process is planned to take place. For example, the demo app illustrates a scene in Frankfurt where quiz cards pop up at specific locations within the street (e.g., bus stop, taxi station, library entrance, etc.) just by directing the smartphone camera at that precoded quiz icon. By clicking on the quiz icon, the app opens the StudyCore quiz platform where questions are presented, and eventual gamification techniques (along with LA markers) like digital badges, point systems, and rankings are accessible. Also, another app was integrated as a part of the AR4STEAM labs called GeoGebra, which is specialized in visualizing physical phenomena with the help of mathematical measuring features.

The actual AR4STEAM innovative labs using AR-Mindpalace coupled with its extension in the StudyCore platform have been tailored for maths and physics tasks. In the first phases, the project team met with teachers and discussed which topics would be suitable for the innovative lab endeavour. In the next phase, the students took a tour along with the teachers and the AR4STEAM-team in the neighbouring park to their school and brainstormed holistically as to how would AR-Mindpalace potentially be implemented with the chosen subjects (maths & physics) in this rather familiar environment for the students. The following phase, the app testing phase, has begun, where the middle school students from Adorno Gymnasium tried out the augmented reality Geogebra-App in the park next to their school, and a maths and physics question-based parkour in the park was tested. Objects were scanned, volumes calculated, distances estimated and calculated.

3. Future use and implementation for extended subject fields

Please specify if there is a broader future potential for the developed game in further subjects other than the ones it's preliminarily intended for.

As mentioned before, the AR-Mindpalace app with its comprehensive StudyCore quiz platform essentially employs a memory-enhancing methodology, i.e., the Method of Loci. It being the latter renders this particular app generalizable for all subjects offered in a long-extending academic path. Mnemonics (memory enhancing techniques) can very much be facilitators for different types of learning pathways because learning always entails memorizing, and targeting this fundamental underlying cognitive process can be beneficial in multiple schools and University classrooms. Furthermore, in AR-Mindpalace, questions were presented in different forms; multiple-choice, single-

choice, fill-in-the-blanks, and answer-ordering. So for physics and math tasks, the question format varied, and in many cases, the answer needed multi-step calculations which a student needed to carry out complementary tools (calculator, or pen & paper) for the direct quiz platform and the AR media. For other subjects that require accurate knowledge retrieval, no extra tools are needed.

4. Challenges and benefits during implementation

Indicate whether there have been challenges for its implementation. If yes, please describe the difficulties encountered when applying the augmented reality game and how these have been or can be solved. Please, make a link with the national videos produced during the laboratories.

Has the level of curiosity and creativity of students increased? In what way was it possible to maintain the students' concentration and interest?

Could such a teaching/learning experience (AR STE(A)M laboratories) facilitate students to look for STE(A)M careers? Why and how?

Challenges: Although access to tablets and to the internet was feasibly granted to the school students, but some time was initially needed for them to grow accustomed to the app (Geogebra) user-interface and to the area (the park) where the AR4STEAM activity took place.

Benefits: The AR4STEAM activities enabled an innovative space for learning, cooperative teamwork, and a positive social atmosphere between teams of teachers, students, researchers, and developers. Furthermore, physically being all together on campus was good for the successful coordination and student engagement was visibly high. Thus students became more invested in the scientific topic at hand.

5. Learning outcomes

Describe which are the main learning outcomes that the innovative STEAM laboratories have achieved.

The students noticeably worked with materials beyond their usual comfort zones of day-to-day learning in school classrooms. They have shown good self-efficacy in dealing with the novel Information Communication Technology (ICT) and programming tasks.

One of the main structures of the AR4STEAM-lab was to establish a more self-guided and learner-centred environment. This indeed was quite visible after the students got used to the rhythm of the involved activities where they mostly have gone autonomously exploring the capacities of the app tasks at hand with their organically

organized teams. Undeniably, Feedback-loops between students, developers, teachers, and organizers were conducted intermittently throughout and between sessions.

The Innovative activities within the AR4STEAM-labs have also done an excellent job at engaging the students with the utilized STEAM subject, i.e., physics in Geogebra-app. As mentioned on several occasions, they were autonomously motivated to finish the task and to deliver accurate answers. One was capable of noticing how much the change of senary and the innovative app tasks was fun for the students, which is indicative of underlying engagement and motivational enhancement.

6. Exploitation opportunities

Indicate if there are further possible extensions and exploitations of the current AR implementation.

For example, the AR function of GeoGebra does not yet support the setting of fixed proportions, which is necessary for measuring/adapting the models to real-life structures. Moreover, the app for the course could actually be expanded with more gaming elements. For example, one could mark which/how many stations have already been successfully processed.

7. Transferability to other STEAM topics

Indicate instructions to re-use the developed AR game for implementing a new lesson on STE(A)M changing its contents only. Moreover, highlight also the benefits of using AR and GBL to also teach other STE(A)M subjects (see www.cultapp.eu, in particular: http://cultapp.eu/compendium-of-augmented-reality-technologies/*.)*

As previously elaborated, AR-Mindpalace is adjustable to almost all STEAM subjects, i.e., to all subjects that require memorization. Thereby a transferability here to any other STEAM subject should be very much smooth.

As for Geogebra, it is a subject-specific app. It is an app dedicated primarily to a mathematical branch in science. This means the app is somewhat subject-specific and is created so that it serves mathematical exercises, either necessary for the understanding of physics, statistics, or pure math. However, since mathematics is a tool of physics, many physical questions can be modeled and visualized with GeoGebra. For instance, geometry also plays a role in other subjects and activities that can be developed in a related manner, for example, to art (https://www.geogebra.org/m/ygkys53d) or to biology (https://www.geogebra.org/m/V36bhpeS). In AR4STEAM we have also found a way to visualize biological processes in a tree (https://www.geogebra.org/m/mafnp4m7).

Indeed, not all possible contents in these subjects can be dealt with the help of GeoGebra. Still, there is a particular potential for interdisciplinary tasks that could be summarized in a larger holistic course.

Italy

Partner: ITT MARCO POLO

1. STEAM-laboratories goals

Provide the full range of the objectives intended for the STEAM-laboratories. Please, also include some brief information on the methodology used (e.g., how the AR laboratories have been organized, students' selection process, an overview of possible science scenarios to be reproduced and/or investigated through AR and GBL). Moreover, also include some information about the learning methodology (e.g. game-based learning) and innovative technologies (e.g., AR) used to highlight the benefit of acknowledging and fostering the link between science education and creativity.

Ars Chimica has been used to make students investigate and understand three fundamental topics:

- **The periodic table structure (Interpret and connect the system and characteristics of the periodic table to the electronic configuration of an element. Identify the position (group or period) of an element in the periodic table. Describe the trend of the main periodic properties: the properties of the elements decrease or increase along with the periods or groups on a regular basis. Identify the metal, semi-metal, and non-metal elements in the periodic table)**
- **chemical bonds (Relate the characteristics of the bonds to the properties of the elements. Predict the type and number of bonds that can be established between atoms. Describe how electronegativity makes it possible to predict the kind of bond that arises between the elements)**
- **chemical reactions (Identify a chemical reaction based on macroscopic clues. Represent chemical reactions by means of reaction equations. Describe the reactions of synthesis, decomposition, single-replacement, and double-replacement. Balance the chemical equations. Observe and describe the development of the reactions and the products obtained)**

The laboratory activities have been organized in dedicated sessions after school time. The students have been selected as a whole class to confront a homogeneous sample. They worked in groups and compared their results.
Each of the three activities was carried out with a learning by doing approach. The App plays the role of a facilitator since it creates images of non-visible stuff -helping the students to build virtual objects in their imagination- and shows the results of the action taken -allowing them to experiment with all possible outcomes, even the dangerous ones.

2. Planning phase: in-depth info on the development of the AR-Lesson

Please, briefly provide information on when and how the augmented reality game has been conceived and created. Please, also include some information about the science subject - STE(A)M topic - chosen by each country and list the laboratory working phases students will follow in order to "give it life" through AR.

Ars Chimica was developed in 2017. It has been conceived from a corporate brainstorming, as a part of the "ARSchoolnnovation" project, developed by the Italian company Lucana Sistemi Software House with the aim of using Augmented Reality as a simple technology to support the learning process of young students both at school and at home.
Ars Chimica enables learners of secondary schools to gain knowledge in chemistry. Once installed on their device, students have to use the app to frame one of the cards and observe the properties of the corresponding chemical element. The next step is to combine different cards and to study the chemical bonds and reactions. The last step is to make the reactions happen in the laboratory.

3. Future use and implementation for extended subject fields

Please specify if there is a broader future potential for the developed game in further subjects other than the ones it's preliminarily intended for.

The APP is easily transferable to a non-formal context, especially considering its already 'equipped' with game-based learning activities. Regardless of the context, it's a valuable tool to strengthen soft skills like problem-solving, information use, and self-awareness.

4. Challenges and benefits during implementation

Indicate whether there have been challenges for its implementation. If yes, please describe the difficulties encountered when applying the augmented reality game and how these have been or can be solved. Please, make a link with the national videos produced during the laboratories.

Has the level of curiosity and creativity of students increased? In what way was it possible to maintain the students' concentration and interest?

Could such a teaching/learning experience (AR STE(A)M laboratories) facilitate students to look for STE(A)M careers? Why and how?

Ars Chimica is a very user-friendly tool; there were no problems in its presentation nor in use by the students. On the contrary, giving a straightforward approach to a challenging subject helps the students to stay focused on the concepts. In contrast the

gaming side helps in stimulating their curiosity and catching their attention. Once discovered that chemistry - and more generally STEM subjects - is less unreachable than expected, more young people will take into consideration STEM careers.

5. Learning outcomes

Describe which are the main learning outcomes that the innovative STEAM laboratories have achieved.

With the support of the Augmented Reality APP, using cards A and B and framing them, students can view the reagent molecules, and then by combining the cards, they will find the products of the reaction obtained. They can experience all the different chemical reactions, thus highlighting the formation and breaking of the bonds present within the compounds. Through the APP, pupils can then practice balancing chemical equations and test themselves with a verification quiz by levels (basic, intermediate, advanced).

6. Exploitation opportunities

Indicate if there are further possible extensions and exploitations of the current AR implementation.

At the moment, Lucana Sistemi S.r.l. has developed an augmented reality software aimed to teach not only chemistry but also STE(A)M subjects like maths, science, geography, art to students between 8 and 13 years old.

7. Transferability to other STEAM topics

Indicate instructions to re-use the developed AR game for implementing a new lesson on STE(A)M changing its contents only. Moreover, highlight also the benefits of using AR and GBL to also teach subjects other from STE(A)M (see www.cultapp.eu, *in particular:* http://cultapp.eu/compendium-of-augmented-reality-technologies/*.)*

The combined use of the app and the cards create a flexible framework, where students of different ages and competence levels can easily be guided to discover basic concepts in chemistry. Additional lessons can be organized by simply addressing different data stored in the database.

At the moment, Arsbook for Chemistry is mainly thought to be applied in upper secondary and iVET education but turns out to fit perfectly also into 'DADA' educational learning environments, since the use of technological devices like tablets, smartphones and game-based learning applications is considered a meaningful

contribution to the development of several 'soft skills' such as self-awareness, effective communication, as well as decision making and creative thinking.
The APP can be purchased through the company website, and it is potentially available in every Italian city and easily used in schools, museums, and even private families.

Netherlands

Partner: Agora Niekée - SOML

1. STEAM-laboratories goals

Provide the full range of the objectives intended for the STEAM-laboratories. Please, also include some brief information on the methodology used (e.g., how the AR laboratories have been organized, students' selection process, an overview of possible science scenarios to be reproduced and/or investigated through AR and GBL). Moreover, also include some information about the learning methodology (e.g. game-based learning) and innovative technologies (e.g., AR) used to highlight the benefit of acknowledging and fostering the link between science education and creativity.

The objective of the AR4STEAM laboratories is to implement the results achieved so far by the project in the practice of classroom work, where digital technology benefits students and contributes to secondary school teachers' professional development, including new forms of experimentation and use of innovative ICT technologies during their STE(A)M lessons.

2. Planning phase: in-depth info on the development of the AR-Lesson

Please, briefly provide information on when and how the augmented reality game has been conceived and created. Please, also include some information about the science subject - STE(A)M topic - chosen by each country and list the laboratory working phases students will follow in order to "give it life" through AR.

The goal of the AR4STEAM laboratories is to implement the results of the project in the classroom by cross-curricular collaboration between the subjects of Computer Science and STEAM. Computer Science Students and STEAM teachers will develop Augmented Reality solutions to explain (complex) STEAM-related subject items in and/or outside of the classroom.
Students are free to use different platforms to develop their solutions. Depending on the question, they make their decision on the platform. These platforms are supported by experts of Unity in combination with Vuforia or Wikitude. Basic solutions can be built with CoSpaces.
Students work by using the Design Thinking method. This method has five different phases to follow in the development process.

- **The first phase is the understanding/empathize phase, where the students learn to understand the situation of the teacher and students in STEAM-related subjects.**
- **The second phase is about defining the problem.**

- **The third phase is to generate ideas on how to use Augmented Reality in a specific STEAM-related situation to explain a STEAM topic.**
- **The fourth phase is to build a prototype after selecting the best fitting idea.**
- **The fifth and last phase is to test the application. This can be done in the STEAM classroom.**

There are different roles of teachers and students. The teacher has the role of the product owner of the problem. The students are members of the development team and work as a scrum team. That means they have different kinds of meetings and use artefacts to update each other about the process and their progress. Figure 1 visuals the combination of Design Thinking and Scrum. Here the development cycle has been done in two Scrum cycles. The second Design Thinking cycle in green is the next iteration to mature the app.

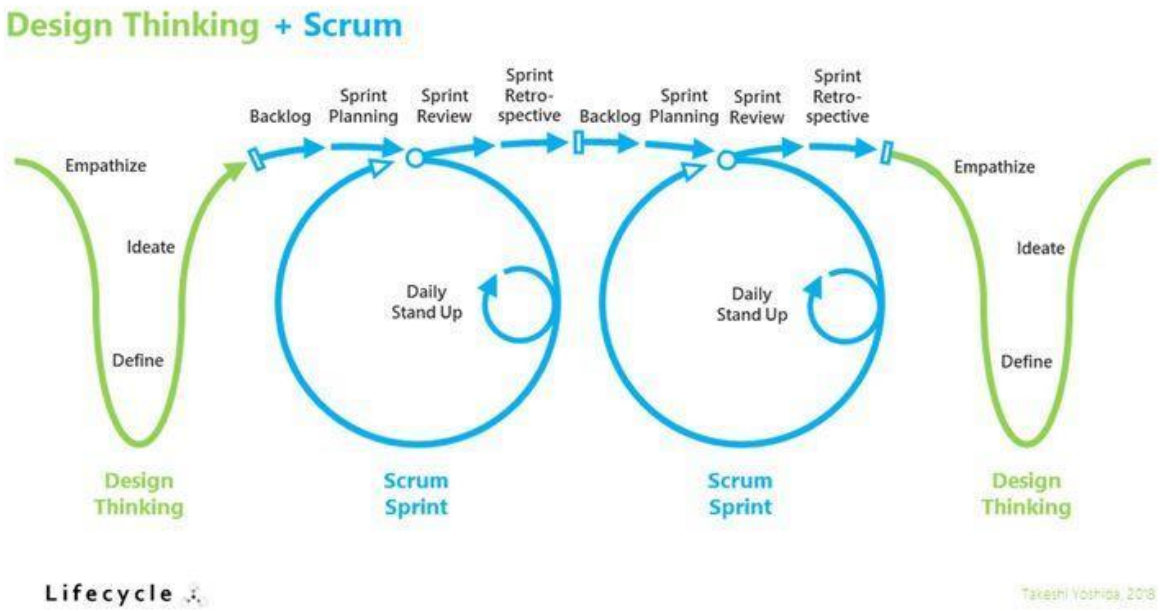

Figure 1: Design Thinking + Scrum cycle

The Agora school implemented the development in the curriculum of Computer Science. An extra dimension is that students are not situated at the same school location. The students are in four different schools and learn in a hybrid lessons plan.

3. Future use and implementation for extended subject fields

Please specify if there is a broader future potential for the developed game in further subjects other than the ones it's preliminarily intended for.

The potential for the developed game is to collaborate between subjects so that students learn in a more natural way about a topic in different subjects. Because the development is taking place in various schools of Agora, Augmented Reality apps can be shared between the schools. Students can also use other app developments to continue updating and optimizing the app and adding new features.
The implementation of the app development in the classroom needs different pedagogical and didactical competencies of the teacher. Students also need different competencies next to the ICT-related competencies such as communication, collaboration, critical thinking, and creativity. Implementing this way of learning means students are owners and co-creators of their learning process and competence development.

4. Challenges and benefits during implementation

Indicate whether there have been challenges for its implementation. If yes, please describe the difficulties encountered when applying the augmented reality game and how these have been or can be solved. Please, make a link with the national videos produced during the laboratories.

Has the level of curiosity and creativity of students increased? In what way was it possible to maintain the students' concentration and interest?

Could such a teaching/learning experience (AR STE(A)M laboratories) facilitate students to look for STE(A)M careers? Why and how?

Because the app development entails students and teachers coming up with new ideas for implementing AR in STEAM classes, it is only natural for students to be uncertain at the beginning as to which area they could choose for their app development attempt. But because these students are comfortable with that initial uncertainty due to the free-choice educational methodology implemented in Agora's schools, they were indeed equipped with a set of skills that helps them find their way through the labs as they go. Interestingly, students seem to be self-motivated to go through the whole innovative lab experience. They are invested enough to frequent feedback on how to optimize different aspects that come to their attention throughout the implementation sessions. Moreover, students can communicate their ideas of what they'd like to learn in groups.

5. Learning outcomes

Describe which are the main learning outcomes that the innovative STEAM laboratories have achieved.

Due to the freestyle the students and teachers are using to try and tackle a product development of an AR-game for a STEAM class, they are learning how to learn independently while getting the chance to implement their newly gained computer

science knowledge as they develop the AR-app. Beyond that, the students are gaining practical experience in developing curricular material for a potentially younger cohort of students that are interested in such provided learning materials.

6. Exploitation opportunities

Indicate if there are further possible extensions and exploitations of the current AR implementation.

This particular version of AR4STEAM innovative lab experience is not dependant on one app over the other and therefore the exploitation possibilities go as far as the different student and teacher collaborations go. In other words, the AR environments developed are limitless in potential and future refinement. And above all, the apps can tackle all kinds of STEAM subjects without any particular app-bound restrictions.

7. Transferability to other STEAM topics

Indicate instructions to re-use the developed AR game for implementing a new lesson on STE(A)M changing its contents only. Moreover, highlight also the benefits of using AR and GBL to also teach subjects other than STE(A)M (see www.cultapp.eu, in particular: http://cultapp.eu/compendium-of-augmented-reality-technologies/.)

All STEAM subjects can be involved in this free-choice AR-game learning experience. This is due to the fact that the apps are created by interested teachers and curious students based on their own inclinations towards a particular subject like science methodology, chemistry, biology, physics, math, and art. Furthermore, platforms like Cospaces Edu enable a wide variety of customized AR & VR apps to be deployed for educational purposes that teachers and students can develop with little or no background in programming, which in itself is a learning experience in product development while using the above-illustrated Design Thinking and Scrum cycle map. These types of skills are not only deficient in academia but can also represent a bridging connection between academia, entrepreneurship, and industry.

Turkey

Partner: Samandira

1. STEAM-laboratories goals

*Provide the full range of the objectives intended for the STEAM-laboratories. Please, also include some brief information on the **methodology** used (e.g., how the AR laboratories have been organized, students' selection process, an overview of possible science scenarios to be reproduced and/or investigated through AR and GBL). Moreover, also include some information about the learning methodology (e.g. game-based learning) and innovative technologies (e.g., AR) used to highlight the benefit of acknowledging and fostering the link between science education and creativity.*

Augmented reality is an approach that can be used for things that cannot be visited, seen, reached, and the results of which cannot be predicted, allowing students to present many objects, practices, and experiments in which they cannot gain first-hand experience or materialize. In order to attract the attention of the new generation, the concept of Augmented Reality comes to the fore in education in terms of providing advantages over traditional methods and technologies and responding to the search for effective ways and environments to support and enrich education.

Using digital facilitation to make learning more attractive and engaging for students, however, can be established. The young generation is more than ever exposed to technological media that compete for their attention. Many times these media distract from productive tasks like learning. Therefore, tackling these issues in education with methods of the same level of digital immersion can potentially engage young students and encourage them to pursue promising careers in science, technology, engineering, art, and mathematics (STEAM). Here, it is the role of projects like AR4STEAM supported by the European Commission to raise awareness of the importance of choosing STE(A)M studies to pursue successful careers.
AR4STEAM's primary goal is to enhance current teaching methodologies and make learning more engaging and enjoyable with the help of augmented reality (AR). It also provides school teachers and educational institutions with the tools and learning analytics supported gamification strategies for effective integration of AR in today's classroom while also giving feedback mechanisms for teaching support.

2. Planning phase: in-depth info on the development of the AR-Lesson

Please, briefly provide information on when and how the augmented reality game has been conceived and created. Please, also include some information about the science subject - STE(A)M topic - chosen by each country and list the laboratory working phases students will follow in order to "give it life" through AR.

The application we will do is to draw and run the electrical-electronic circuits in an augmented reality application prepared with unity. In the application, the materials will be placed on the screen by the student, cable connections will be made, and the circuit will work. Points will be awarded at each stage of the application. With the application, students will learn how to build a circuit in a fun way. Students' interest and motivation in the lesson will increase.

3. Future use and implementation for extended subject fields

Please specify if there is a broader future potential for the developed game in further subjects other than the ones it's preliminarily intended for.

The application we will make is designed for electrical-electronic lessons. But it can also be applied to all STEAM domains.

4. Challenges and benefits during implementation

Indicate whether there have been challenges for its implementation. If yes, please describe the difficulties encountered when applying the augmented reality game and how these have been or can be solved. Please, make a link with the national videos produced during the laboratories.

Has the level of curiosity and creativity of students increased? In what way was it possible to maintain the students' concentration and interest?

Could such a teaching/learning experience (AR STE(A)M laboratories) facilitate students to look for STE(A)M careers? Why and how?

The main challenge students face is the first encounter with the AR-app phase. They usually need some time to grow accustomed to the particular app technicalities and the unique user interface at hand. Some students had issues in running the app on their phones. However, the students learned how to work in groups with reality augmenting apps on electrical electronics. Also, Students have shown significant engagement, creativity, and enthusiasm towards the out-of-routine nature of the innovative lab tasks. These engaging factors can potentially develop into long-term investments for STEAM-related academic careers.

5. Learning outcomes

Describe which are the main learning outcomes that the innovative STEAM laboratories have achieved.

Students learn to work in groups on a dynamic electronics task. And indeed, they learn about electricity and different physical phenomena, all with the help of engaging AR and game elements. The students can be the centre of their own learning experience without necessarily resorting to traditional theoretical material. The learning experience within the lab sessions reinforced exploratory independent learning that realistically prepares school students for future academic careers that entail immense situations where these skills are needed.

6. Exploitation opportunities

Indicate if there are further possible extensions and exploitations of the current AR implementation.

The AR-app is specialized for the understanding of electrical circuits and related subjects in physics. So due to this targeted specialization, the app is, for these specific lab tasks, limited in its reproducibility in other domains. However, similar technical topics should also be illustratable within the app. Furthermore, the app was developed by the Samandira team, and therefore optimizations and usability potentials regarding different STEAM subjects, game elements, and badging systems are always an option. That, also given the continuously developing motivational and engaging features within gaming industries.

7. Transferability to other STEAM topics

Indicate instructions to re-use the developed AR game for implementing a new lesson on STE(A)M changing its contents only. Moreover, highlight also the benefits of using AR and GBL to also teach subjects other from STE(A)M (see www.cultapp.eu, in particular: http://cultapp.eu/compendium-of-augmented-reality-technologies/.)

The use of augmented reality in Physics, Chemistry, Biology, Geography, History, and many other courses increases students' commitment to the school, their interest in the course, and their level of success, as well as supporting emotional intelligence gains such as success, self-confidence, and creativity. The content of our application, which was developed for this purpose, can be changed and used in courses other than steam and steam.

Closing Remarks

School students and teachers' perspectives about the innovative AR4STEAM laboratories in the different EU countries were captured through short evaluation surveys conducted at the closing session of the innovative labs. To get an insight on students and teachers reports on their own experience, please click on the following link for a summarised visual report:

1. Overview on the evaluation questionnaires

In the framework of the "Project result 3 – Innovative STE(A)M laboratories" foreseen by the AR4STE(A)M project, two different evaluation questionnaires have been distributed to teachers and learners from the five educational institutions of the Consortium: DIPF, IIT Marco Polo, Agora Roermond, SATOM and AEDE. The surveys have been submitted in the partner countries national languages (for Germany, Italy, Netherlands, Turkey) and in English (for Belgium).

The main goals of the questionnaires are:

1. To measure the level of satisfaction of teachers and learners in participating in the STE(A)M laboratories;
2. To understand whether these collaborative activities contributed to increasing students' level of interest in science education;
3. To check whether teachers' and learners' soft skills and digital competences have been improved;
4. To evaluate if and in which way the STE(A)M laboratories have effectively brought an added value to develop students' motivation while increasing their performance;
5. To measure to what extent the STE(A)M laboratories have been a valuable support for teachers in order to develop curricula through innovative and effective teaching approaches;
6. To know whether teachers and learners are interested in replicating the experience;
7. To highlight the tasks in which students and teachers were particularly successful.

In this document, the data related to the final evaluation questionnaires for teachers and learners are reported and analysed. All partners have involved survey's targets through the online tool Lime-Survey, except for the Italian partner IIT Marco Polo who

distributed paper-based questionnaires and has collected and reported all data in an Excel Spreadsheet.

The following analysis will be based on a total of 54 surveys, 16 from teachers and 38 from learners. These numbers only account for surveys that were completed fully or at least in their most part. However, the total number of surveys collected among teachers were 26 whereas the ones received from students were 56, for a total of 82.

The answers to both questionnaires were collected during the period: October 2021 - February 2022.

2. Teachers' questionnaires' analysis

The total number of questions to be answered by the teachers was 32 mainly of natural sciences, mathematics and ICT.

The types of questions required different kinds of answers. The majority of them asked respondents to rate their answers on a scale from 1 (Strongly disagreed/ Not improved) to 5 (Strongly agreed/Improved). In some cases, open questions asked interviewees to provide a short answer motivating their opinions and impressions or maybe clarifying the answer to previous close-ended questions.

In general, except for very few cases, the overall perception of the usefulness and impact of the workshops realized has been positive, in fact the majority of teachers have felt rewarded by their efforts and commitment towards the laboratory experience and they believe that the collaborative experience has been a very valuable support for the project implementation.

Moreover, in line with the overall positive perception of the impact of the laboratories on teacher's abilities, the majority of them think that the experience - valuable support for delivering science lessons - made them grow from a personal and professional point of view. In addition, they would recommend a similar experience to their colleagues. The one aspect that was mostly appreciated by teachers during the implementation of the workshops was the teamwork environment that both teachers and students were able to create. Many of them appreciated the use of Augmented Reality technologies as teaching tools in STE(A)M subjects and others underlined the benefits of the interdisciplinary approach of the workshops. Students' ambition and performance have ben increased as well. In this regard, the skill that was perceived as the most improved was "creativity".

The last questions of the survey aimed at investigating which were the main challenges of the laboratory experience and looked for further suggestions to improve the Activity results.

As far as the challenges are concerned, the main listed are:

- Dealing with technology, computer tools and connection issues;
- Find learning content that works well for AR;
- Create a motivating scenario while keeping the objective on the subject/ Create meaningful paths for a curricular didactic continuity of the discipline;
- Lack of time in the development of laboratories (short time for the implementation of the complicated tasks);

- Overcoming the natural resistance to approaching new teaching methods (VR) of which involved teachers' have little knowledge and applying these methods into teaching practice;
- Making the work done and educational innovation known and recognized by the educational institution;
- Managing a large number of students with apps installed on a few devices;
- Difficulty at involving the class at the same time and find suitable experiences for children;
- Difficulty in creating usernames and passwords with students
- Finding augmented reality programs online that can be used in STE(A)M;

3. Students' questionnaires' analysis

The total number of questions to be answered by the students was 38 whose gender is 17 female, 19 male and 2 diverse, have an age range that spans from 12 to 17.

As in the teachers' survey case, the types of questions required different kinds of answers. The majority of them asked respondents to rate their answers on a scale from 1 (Strongly disagreed/ Not improved) to 5 (Strongly agreed/Improved). Other questions required a Yes/no answer. In some cases, open questions required interviewees to provide a short answer motivating their opinions and impressions or maybe clarifying the answer to previous close-ended questions.

In general, except for very few cases, the overall perception of the usefulness of the workshops implemented has been positive and the feedback by the students have been constructive. As a matter of fact, the great majority of responses show a high level of agreement among the participants to the laboratory. In coherence with this statement, a high percentage of learners also confirmed to be very happy about the laboratory collaborative experience.

As for the impact of this experience on student's future possible careers, the STE(A)M lab has pushed a great majority of them to concretely consider pursuing a professional career path in the science sector, which is one of the main objectives of the AR4STE(A)M project.

Moreover, in line with the overall positive perception of the impact of the laboratories on students' abilities, the majority of them showed interest in sharing and replicating the lab experience with other schoolmates. Some students wrote they enjoyed the interactivity and the hands-on aspect of the laboratory, others highlighted that the activities were original and fun and that working with a team and not alone was very exciting. In line with these opinions, the following comments:*" It was an overall great experience: it taught me things I will not forget and it helped us (my teammates and I) develop our cooperative skills, whilst still remaining entertaining"; "[…] it is an interesting activity and I think that doing it with classmates is important to improve relationships. I am not that good in working in a team, but I found myself at ease in doing this project with my classmates. [Moreover, the laboratory] also allowed to fully understand concepts of science that are difficult to grasp through books."* deserve to be mentioned.

As far as the challenges are concerned, the main listed are:

Time management

- "It takes a long time before you have a result because we have to make it ourselves and not everyone has this experience"
- "It was not easy issue to prepare an app with Unity, time was not enough. We are students, we don't have that much time"

Teamwork

- "Being able to get along with the group based on different ideas"

Using technology:

- "The application we used was hard to find on the app store (I suggest just sending a link to students next time). The app was confusing to use at first"
- "The app works on mobile and tablets but the devices heated up"
- "Results were often deleted, which of course is a shame when you're already done (but it could also have been because of the internet)".

Technical problems:

- "If something went wrong and the indications (meters) get wrong, having to do everything all over again"
- "In the beginning, working with Geogebra was relatively difficult for me, but over time you learn and understand more"
- "It was a bit disturbing that you couldn't set the scale"
- "Every now and then the whole figure shifts, which means that you have to reset almost everything"
- "The figure that is used often does not fit into the environment, or it does not match the objects to be measured"
- "The same tasks were often tried again and again, although they had already been tested"

Lack of guidelines and updated materials

4. Conclusions

An overall analysis of the survey's results shows that the number of positive feedbacks expressed by teachers is considerably higher than the student's responses. The following table (**Table 1**) collects the total number answers to the closed questions of both teachers' and students' surveys.

If we consider the most positive rates that could be given to the questions, i.e., 5/5 (strongly agree/improved) and 4/5 (agree/improved), the percentage of students' that chose these two degrees of agreement is equal to 63%, the percentage of teachers' one was equal to 82%.

On the other hand, when considering the most negative rates, i.e., 1/5 (strongly disagree/not improved) and 2/5 (disagree/not improved), the answers collected among students and teachers were very different: whereas only 2% of teachers selected such

options, an important 18% of all students shared a negative opinion on some aspects of the laboratory experience.

	Teachers' answers	% Teachers' answers	Students' answers	% Students' answers
Strongly agree / improved	142	42%	321	36%
Agree / improved	135	40%	245	27%
Neutral	51	15%	167	19%
Disagree/ not improved	7	2%	83	9%
Strongly disagree/ not improved	1	0%	79	9%

Table 1: Overall survey's data – teachers and students answers

Annex_Evaluation Report