STE(A)M IT

AN INTERDISCIPLINARY STEM APPROACH

STE(A)M IT INTEGRATED LEARNING SCENARIO

A drop of water makes a difference

Music, Arts, Citizenship

Natural Sciences, Mathematics

USE IT IN YOUR CLASSROOM

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STE(A)M IT INTEGRATED LEARNING SCENARIO

INTRODUCTION

In order to inspire students, see the added value of STEM subjects and careers, contributing the same way in tacking unfavourable perceptions and the overall lack of interest in Science, there is a need to reconsider the way STEM subjects are taught. For this purpose, there is a need for an integrated way of teaching. More specifically, there is a need to combine Science classes with other disciplines, ensuring that the integrated STE(A)M education will contextualize STEM teaching is such a way that it becomes more attractive for every student. Right now, there is no integrated STE(A)M education framework in Europe that will further enhance coherence in STEM education. It is essential to bring together partners from different countries, already working in STE(A)M education, policy, pedagogical innovation and professional development of teachers, educators and school leaders, and engage them in discussions, planning, implementing and the review of new practices. This will ensure that the topic is given new and more intense attention within each country. Therefore, the STE(A)M IT project will lead the way in the creation and testing of the 1st Integrated STE(A)M framework, aiming to strengthen the coherence in STEM education by defining collectively with MoEs and STEM teachers the integrated STE(A)M education framework. The focus group teachers that will create interdisciplinary and innovative teaching and learning scenarios, will be used to test the proposed framework of reference for integrated STE(A)M education.

The creation and implementation of the aforementioned framework is particularly important for students who do not link STEM subjects and their use with their everyday life, but most importantly with their future career paths. The teaching of each STEM subject individually often prevents students from linking those subjects, consequently missing out on a cohesive educational opportunity that might largely affect their study path choice and eventually career.

It is additionally important for teachers of Primary and Secondary schools to work together and fully exploit the benefits of the in-between them collaboration, while contributing to the creation of innovative and cross-disciplinary approaches to STE(A)M teaching in education, each adding their own insight, expertise and knowledge. This collaboration and continuous feedback aim to provide an opportunity for reflection and support a steady and much necessary change in formal education but also career consultancy. This way, schools will assume the additional role of mentorship supporting their students collectively.

A STE(A)M IT Integrated lesson plan is a teacher's detailed description of the course of instruction or "learning trajectory" for a lesson, a guide and a document that will be

continuously improved and updated. Each lesson needs to combine three subjects, two of the subjects must be STEM and the third subject can be either STEM or non-STEM. is about designing educational activities that facilitate deep learning to enhance 21st century skills such as critical thinking, collaboration, communication and creativity and divergent thinking. Designing a path based on methodologies such as Problem, Project and Challenged Based learning allow to incorporate problem-solving, inquiry and design based learning into the teaching activity taking care of real challenges in an authentic context, that of our world.

With this in mind, an integrated STEM approach will develop capable citizens who personally and professionally make informed decisions in their daily lives and have the power to follow STEM careers and guide innovation at any age.

Title

A drop of water makes a difference

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Summary

This learning scenario aims to raise awareness among students about the water scarcity problem in the world. After watching videos (Google Classroom platforms) and/or reading articles about it, they will debate about what they had learned from those videos/articles. The teacher will ask students to identify problems related to the misuse of water by society and particularly in their school. They will also build a survey to implement at school. The data collected will be organized into graphics to be displayed at the school's lobby. Students will be asked to build a water filtration device. Finally, they will also build a musical instrument using water, after discovering the ideal proportion of water to produce different sounds. This LS can be implemented in an online environment like Google Classroom.

Licenses

Subject (s)

Math, Music, Natural Sciences, Art, Citizenship

Real- life questions

- How can we prevent waste in our school community?

- How can we use everyday materials to collect water?

Aims of the lesson

- Understand and raise awareness about water scarcity and the misuse problem.
- Work towards possible ways of solving it within the school community.
- Demonstrate that the problem identified in this LS can be assessed in different subjects like math, music, and natural sciences.

Connection to STEM careers

- Product Designer (Natural Science): Create design concepts and drawings to determine the best product, present product ideas to relevant team members for brainstorming, suggest improvements to design and performance to product engineers.
- Mechanical & Civil Engineer (Natural Science): Assessing project requirements, measuring the performance of mechanical components, devices and engines, testing, evaluating, modifying, and re-testing products.
- Robotics Engineer (Natural Science, Music, Mathematics): Designing processes and prototypes to build machines, conduct research to determine the parameters of a robotic application, create prototypes and work on necessary components.
- Architect (Natural Science, Mathematics, Art): Preparing and presenting design proposals.
- Video Game Designer (Mathematics, Art): Game prototyping and level design.
- Sound Engineer (Music): Assist in synchronizing video and audio tracks, record, edit and mix audio tracks, test and improve sound quality.
- Brief explanations will be provided in order to understand how/which one of those are linked with each subject and competence.

Age of students

10-11 years old

Time

Preparation time: 8 hours discussing ideas, collecting materials and uploading materials on online platforms

Teaching time:

- non-STEM subject 1 - Citizenship - 1x50 min (Brainstorming, discussion, and research for materials)
- STEM Subject 1 - Natural Sciences - 2x50 min
- STEM Subject 2 - Mathematics - 2x50 min
- non-STEM subject 2 - Art - 1x50 min
- non-STEM subject 3 - Music - 2x50 min

Teaching resources (material & online tools)

Materials: Textbooks, magazines, newspapers

Online platoforms: Google Classroom, Microsoft Teams, videos, TED Talks, websites like Escola Virtual (https://www.escolavirtual.pt/) and Aula Digital (https://auladigital.leya.com/). In other countries teachers can use websites from local publishers and/or local organizations.

Other online tools include:

- http://board.net
- http://padlet.com
- http://classroomscreen.com
- https://bitpaper.io
- https://quizizz.com/admin
- https://www.microsoft.com/pt-pt/microsoft-365/microsoft-teams/download-app

Online video editing tools (this learning scenario was implemented online and an extensive list of materials can be found in Annex 2):

- An easy tool for automatic creation of videos based on uploading text: https://lumen5.com/
- A simple tool for writing your story and creating a video: http://textingstory.com
- An online tool for creating your interactive images, videos and virtual tours: https://www.thinglink.com
- An online tool for creating explanatory videos: https://www.mysimpleshow.com

21st century skills

This lesson plan will enhance among the students the following skills, defined as 21st century skills:

- Critical thinking (students will reflect on the topic of the learning scenario)
- Problem solving (finding solutions to problems)
- Communications (talking to others)
- Collaboration (working with others)
- Creativity/innovation (thinking outside the box)
- Information literacy (Understanding facts, figures, statistics, and data)
- Media literacy (Understanding the methods and outlets in which information is published)
- Information and communication technologies (ICT) literacy (Understanding the machines that make the Information Age possible)
- Flexibility and adaptability (deviating from plans as needed)

- Initiative and self-direction (starting projects, strategies, and plans on one's own)
- Social and cross-cultural interaction & meeting and networking with others for mutual benefit
- Productivity and accountability (maintaining efficiency and focusing on the problem)

Lesson Plan

The implementation of integrated STEM teaching and learning is facilitated by the use of specific pedagogical approaches (PBL, IBL, etc). In order to facilitate the research done by the teachers and the design of activities by teachers, a selection of such approaches is presented in Annex 1. Maintaining Annex 1 in the Learning Scenario and citing where necessary is mandatory.

Name of activity	Procedure	Time
1st Lesson		
non-STEM Subject 1	**Citizenship**	50'
Brainstorming, discussion, and preparation for the next lesson	Students discuss with their teacher the following questions: • How do you use water at home? At school? • Give examples from your daily life: where do you think you are wasting water? • How can we stop wasting water? • Water: do we have enough? • Do you think there is enough water for everyone in the world? • Do you think water will end? Ask students to explore some information about water while using flipped classroom.	50'
Learning products	• Collect information online and offline. See Annex 2 for an extensive list of resources in Portuguese and English. • Students can save all the data to an online folder (Dropbox), or use Google Classroom.	
2nd and 3rd Lesson		
STEM Subject 1	**Natural Science**	

Name of activity	Procedure	Time
Watch, discuss and build	First session: After watching videos (annex 2) and/or reading articles, think about: Reducing consumption and waste, Reuse, Recycle and Use alternative sources. Resources used for this activity: 1. The Water Cycle – Khan Academy 2. Water Sense for Kids • Is water important for living beings? Why? • Does the Portuguese (replace with the respective country of the students) population consume too much water? • Do we consume a lot of water? • What can we do, in our daily lives, to reduce water consumption? • How can we ensure the sustainability of water? Students are asked to build a Mentimeter and a Mindmap. Students will work in groups (5 groups) of 4-5 students. Each group will build a Mentimeter and a Mindmap about one of the ideas presented before. Second session: In this activity, students are challenged to design and build a water filtration device using commonly available materials - following the same design process used by the engineers and scientists who developed the International Space Station Water Recovery System for NASA. First, they can watch this video. To meet this challenge, students use an interactive process as they build, test, and measure the performance of the filtration device. They also analyse the data collected and use this information to work toward an improved filtration design.	15’ 35’ 5’ 45’

Name of activity	Procedure	Time
	Students measure the effectiveness of their filtration device using pH test strips or other pH measurement methods. Students can also use the information on page 108 of this document.	
Learning products	1 - Mentimeter; Mindmap 2 - Water filtration device	
4th and 5th Lesson		
STEM Subject 2	Mathematics	
Water Statistics in your school	Read and write statistics about the misuse of water. Search for information in various websites, like: http://aquapath-project.eu/ Ask students to check their water footprint (http://aquapath-project.eu/calculator/calculator.html) Build and implement a survey (using QR codes, Mentimeter or Quizizz) to understand the reality in your school community. Watch videos about recircling water in ISS: https://www.youtube.com/watch?v=BCjH3k5gODI https://www.youtube.com/watch?v=cR_jQ4Is8t0	45’ 50’ 5’
Learning products	Survey Poster with graphic information about the collected data.	
6th Lesson		
non-STEM subject 1	**Art**	50’
Creative activity	**Create the 7 colours of the rainbow** Read and/or watch videos on how to create different colours from primary colours. For example: • https://www.youtube.com/watch?v=yBuDbMWlbac • https://trycolors.com/ • https://phet.colorado.edu/en/simulation/color-vision	10’

Name of activity	Procedure	Time
	• https://lmsev.escolavirtual.pt/playerteacher/resource/3056028/E?se=&seType=&coId=&area=search After watching the videos, students will work together in order to create a poster with the 7 colour sequence of the rainbow. Students may use crayons or gouache.	40’
Learning products	Poster	
7th and 8th Lesson		
non-STEM subject 3	**Music**	100’
Building musical water glasses	The teacher will ask the students to find out the proportion of water needed for each glass to produce a different sound. What you need: same-sized glasses, water, food colouring, and a wooden spoon. • Fill the glasses with different levels of water, then add the food colouring to further differentiate them. You can create a rainbow, reviewing the colours learned before in art class. When it’s finished take a wooden spoon and tap the glasses. • After that, the class can make their melodies to present to the school community. • Students can also use commonly available materials to imitate the sound of water.	50’ 50’
Learning products	• Musical water glasses • Group melody	
9th Lesson		
School’trip Hands-on Lab	Visit the Water Pavilion in Porto and/or participate in one Hands-on Lab (https://pavilhaodaagua.pt/participar/)	60’

	In other countries, students may choose to visit local museums/institutes/exhibitions related to this subject. For example: • Opificio delle Acque – Water Factory of Bologna, Italy https://www.canalidibologna.it/en/chiusa-di-casalecchio-di-reno.php • Teachers can also invite their students to a virtual tour to a museum related to water like the Waterworks Museum in Boston https://my.matterport.com/show/?m=oPAHhaFcUWh	

Assessment

Padlet, Water Footprint Calculator (http://aquapath-project.eu/calculator/calculator.html)

Initial assessment

QR code, Mentimeter, Mindmap, Quizizz

Formative evaluation

Kahoot

Final assessment

Google forms

Student feedback

Google forms

Teacher feedback

Because of the pandemic situation, the teachers decided to implement the learning scenario online, using online video conference tools to record all the activities and materials used and created by the students and teachers. The LS' timetable worked well for the online implementation. We used the Google Classroom to send reminders to the students, so they knew in advance what to expect from the next session of the project. This way, they could check the videos and the apps we wanted them to watch and understand. For the Natural Science' session and the Music' session, we planned to divide the class into groups and work from there. But, because everyone was at home, only one of students in each group was able to build the water filtration device and the music water glasses. The other elements of the group helped, by commenting online, their colleagues' work.

When it comes to the teaching outcomes, as a team of teachers we, once again, realized that working together brings out best practices. We built a better learning scenario for our students, because we worked on the same idea, but with different perspectives. Our collaborative work helped students realize that one real-life problem, can and must be addressed by different subjects, in order to create a better solution. As teachers we learned

from each other, built a better understanding of a real-life problem, and learnt how we can use the knowledge from each subject to solve it. Our job as teachers is to prepare students for life, and doing that in an interdisciplinary way, is a great way to learn more than one subject, with a very important meaning for their future. Through an integrated learning scenario, students are encouraged to develop 21st century skills, that will help them in their future career. To be able to do that, teachers are asked to work collaboratively, in order to create a learning scenario that will show students how important is to work together and how each subject is needed to help solve a problem. Eventually, and because any learning scenario or lesson is never really finalized and closed, it would be necessary to make some changes and updates to it. But that, shouldn't be a problem. It's always a way to improve. Students responded well to the learning scenario and quickly picked up on the tools used. Their knowledge in this matter on STEM careers was quite weak. However, with the teachers' help, whether through viewing videos or conversations between students and teachers, it was possible to improve their knowledge in this matter. Their enthusiasm grew, realizing how each subject can help address a real-life problem.

When it comes to the implementation due to pandemic situation, all the sessions were online, and for that we had to use a video conference room. In our case, we used Jitsi Meet, but it could be a different one. So, instead of working at school, the teachers and all the students were at home. For the Natural Sciences and Music sessions, the teachers had to deliver the necessary materials to students' homes. At this point, we would like to acknowledge parents' contribution and assistance. Lastly, when it comes to the time allocated, all activities that were initially planned were implemented. Due to the pandemic situation, we decided to send reminders to the students, using Google Classroom, so they knew the kind of work expected for each session.

Annexes

A thorough and complete list of all the materials used will be asked from all teachers. Those materials will be cited as Annexes and they can be further cited in the learning scenario.

Annex 1

PEDAGOGICAL TRENDS IN EDUCATION

Disclaimer: Information presented in this document has been previously partially published in the Scientix Newsletter "Pedagogical trends in education", May 2019: http://files.eun.org/scientix/scx3/newsletter/Scientix-Newsletter-May-19.pdf

Inquiry-based science education

IBSE adopts John Dewey's principle that education begins with curiosity (Savery, 2006), and makes students go through all the steps of scientific research: ask a question, develop a hypothesis, plan how to test this hypothesis, collect data, analyse the results and share it with peers (Pedaste et al. 2015). IBSE is ideal for science education, because it makes teaching more hands-on, and is perfect to learn how scientific research works. Students learn how to formulate questions answerable through experimentation. The teacher has both a facilitator role and an instructor role, making it an in-between method compared to full facilitation in problem-based, and instruction in project-based learning. However, the approach can be gradually made student-directed; students can start an IBSE project with a question provided by the teacher, and then can come up with their own questions to transfer what they learned for deeper learning.

IBSE does not only tap into creativity, problem-solving, and critical and analytical thinking. It also sets the stage for learning about how to collect and interpret data (become science and data-literate), and how to do this ethically and reliably. All these are skills of the 21st century, where data is abundantly available in every part of life.

As mentioned in the recent European Schoolnet publication, while inquiry-based science education (IBSE) has been already around in STEM education for decades, there is still much room for improvement in teachers' development and continued dissemination of innovative pedagogical approaches. To highlight the impact of IBSE, its challenges, and the initiatives

addressing these, we published the "Teacher Training and IBSE Practice in Europe, A European Schoolnet overview".

Research shows that IBSE results in greater interest in Science, and motivation for STEM careers. Another important observation from the publication is that the benefits of IBSE are long-term and maintained, in contrast to the short-term acquisitions of traditional pedagogies that also come with less inclusion of both genders, and less interest in STEM.

One challenge is teacher support: teachers report that they receive little support in implementing IBSE in their classroom. Another challenge to IBSE is standard assessment: PISA tests, as well as end-of-secondary-education exams, are still more focused on recall and repeated-drill exercises, deterring the use of more diverse pedagogies. In order to better integrate inquiry-based methods in school curricula, standardized tests also need to evolve along with traditional pedagogies.

Problem, project and challenge-based learning

Problem-based learning (PBL) is a student-centred multi-disciplinary method that was initially adopted in medical education as a means to put multiple topics in context (Newman, 2003) PBL aims to make students good problem-solvers in the real world: for instance, to put knowledge from multiple disciplines into use, and be able to work with others productively. After all, real-world problems are hardly ever solvable by one single discipline and one single person.

A PBL activity consists of working on an open-ended, even ill-defined question, with no solution provided by the teacher. Students need to work collaboratively and devise a solution to the problem by themselves. The key component is that it is student-centred; students are more motivated when they are responsible for the solution to the problem, and when the whole process rests with them (Savery, 2006). Decades of research has established that although students who went through PBL do not necessarily score better on standardized exams, they are definitely better problem-solvers (Strobel & van Barneveld, 2009).

Project-based learning also involves collaborative learning and finding a solution to a problem. However, the process and the end product are more specified from the beginning. Students work on a project for an extended period of time, a project that will produce a solution to a complex question or solve a complicated problem. The role of the teacher is more active here because multiple obstacles are typically encountered in the production of something like a rocket, or a space habitat, and these obstacles mark the moments for the teacher to instruct specific topics.

Finally, with **challenge-based learning (CBL)** (Johnson et al. 2009), students are again asked to develop a solution to a problem. However, they are only provided with a "big idea", a societal problem that they need to address with a challenge of their choosing (e.g. disinterest in mathematics, low upturn in elections). While the use of technology can be considered optional in other trends, technology needs to be incorporated in every step in CBL. Similar to project-based learning, there is an end product, although this product is determined in the process, not at the beginning. The focus is on the use of ICT in the collection of data and sharing the results.

Design thinking

If IBSE recreates scientific methodology in the classroom, **design thinking (DT)** does the same for design and prototype production. DT helps students develop the skill to identify problems and needs in the society, and entrepreneurship. DT can be implemented within problem or project-based learning; the difference is that the problem is identified by students, and the end product is a prototype to solve the problem. The product is tested and refined in multiple iterations. Students go through a cycle of steps: (1) empathize; (2) define; (3) ideate; (4) prototype; (5) test.

Blended-learning and the flipped classroom

In a classroom where all students are facing the instructor, each moment there will be students drifting from the topic, even if for thinking deeper about a specific point in the lecture. It is challenging to have the undivided attention of the whole classroom because each student has a different way of learning and a different pace. With online content, students can learn the material at home at their own pace. In turn, the teacher can use the classroom to engage students in debates, projects and group assignments. Blended-learning and flipped classroom are instructional strategies that help students learn in their own pace, and deepen their learning with making the most of classroom hours. Although these concepts are used interchangeably, they are slightly different: while blended learning complements online learning with class instruction and support, the flipped classroom requires students to learn the material before coming to class and do assignments and projects during class hours.

Content and Language Integrated Learning (CLIL)

Content and language integrated learning (CLIL) is a well-positioned pedagogical approach that emphasises on the integration of foreign language and thematic content within the context of all school subjects. CLIL is a pedagogical approach that allows to teachers and

students use a foreign language as the medium of instruction in non-linguistic subjects, allowing this way the practice and improvement of both the second language and the immersion to subjects that may vary from science subjects to humanities. According to Cenoz et al. (2013) "*the European Commission and the Council of Europe have funded many initiatives in support of CLIL because it responded to a need in Europe for enhancing second-language (L2) education and bilingualism that was well-received*" and research further supports that CLIL is applied successfully in task-based pedagogies. In addition, when it comes specifically to the application of CLIL in the science classroom there are specific advantages including enabling learners to learn a school subject that exists in their curriculum using the respective second language they are learning, provide authentic learning settings while using the resources available at their school and support learners' cognitive skills by equally supporting language practice and the teaching of science context.

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Annex 2

Websites

- 10 facts about wasting water
- Watersense for kids
- Protect water campaign
- State of the environment portal, Portugal
- Natural Resources Defense Council
- European Commission – Water Infographics

- ICT for water
- NRDC - Natural Resources Defense Council
- Trycolours (online color mixing tool)
- The Natural Resources Defense Council
- Broad collection of interactive simulations for science and maths:
- Broad collection of diverse learning apps
- STEM Learning
- Virtual tour to the Waterworks Museum
- Aquapath Project

Videos

- STEMonstrations: Water Filtration
- Aquastory
- The water global crisis-Ecosisters (A crise mundial da água – Ecosisters)
- The urban water circle (Ciclo urbano da água)
- How the water gets in our homes (Como é produzida a água que chega às nossas torneiras)
- The fantastic world of water (A água é um mundo fantástico)
- Importance of water
- How to mix colours with Play Doh (comment mélanger les couleurs en pâte à modeler play doh)
- Colour mixing with Play Doh
- Colour overlay with felt tip pens (Marcadores sobreposição de cores)
- There is science here - Water xylophone (Aqui Há Ciência - Xilofone de água)
- The water cycle
- Color Vision
- Top 10 water saving tips
- WATER our most precious resource
- Are we running out of clean water?
- Water Recycling on the ISS
- NASA: How To Recycle Water in Space

Relevant resources in Portuguese (account on Escola Virtual is required)

- Water saving measures (Medidas de poupança de água)
- Water functions in the living beings (Funções da água nos seres vivos)
- Importance of water composition for health (Importância da composição da água para a saúde)
- What are the main water properties? (Quais são as principais propriedades da água?)
- Earth water distribution (Distribuição da água na terra)
- Water in living beings (Água nos seres vivos)
- Measures for water sustainability (Medidas para a sustentabilidade da água)
- Water consumption in Portugal (Consumo de água em Portugal)
- Water pollution and contamination, and its consequences (Poluição e contaminação das águas e suas consequências)
- Water treatment plants (Estações de tratamento de água)
- Types of water (Tipos de água)
- https://auladigital.leya.com/catalogs/index.html#product_catalogs/38de3e76-46af-46f2-9f64-0010f8a15908/entries/241013f4-0704-4890-a6ab-93a01c5b5827/viewer/3bd55a07-ab18-499f-9896-9362c43e8a3a/11?closeall=true
- https://lmsev.escolavirtual.pt/playerteacher/resource/3056028/E?se=&seType=&coId=&area=search
- https://waterfootprint.org/media/downloads/WFN_presentation_schools.pdf