STE(A)M IT

AN INTERDISCIPLINARY STEM APPROACH

## STE(A)M IT INTEGRATED LEARNING SCENARIO

# Graphene – miraculous 21st Century Material

English language, Chemistry

Physics, Technology (ICT)

Co-funded by the Erasmus+ Programme of the European Union

USE IT IN YOUR CLASSROOM

Funded by the European Union's ERASMUS+ programme, grant agreement 612845-EPP-1-2019-1- BE-EPPKA3-PI-FORWARD), and coordinated by European Schoolnet (EUN - the network of 32 European Ministries of Education), in partnership with Istituto Nazionale di Documentazione, Innovazione e Ricerca Educativa (INDIRE), Università Telematica degli Studi IUL, Ministry Of Science And Education Of The Republic Of Croatia, Ministério da Educação – Direção-Geral da Educação (DGE) and University Of Cyprus,the STE(A)M IT project is about creating and testing a conceptual framework of reference for integrated STE(A)M education, with a particular focus on the contextualization of STEM teaching, especially through industry-education cooperation. The creation of this learning scenario has been made possible thanks to the project's focus group of teachers who co-designed and tested the STE(A)M learning scenarios that will contribute to the overall STE(A)M framework. The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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# STE(A)M IT INTEGRATED LESSON PLAN TEMPLATE

# 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

**Graphene - miraculous 21st Century Material**

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## Summary

Throughout history, every time period has been marked by some material. In this lesson, students will learn about graphene - a material that is rightly called miraculous 21st Century Material.

Graphene is a material with many excellent properties - it is the only material in 2 dimensions, with a thickness of only one atom. It is made of carbon atoms that are extremely tightly bonded, which makes graphene more solid and stable even than diamond, but at the same time very flexible so it can be bent and shaped as desired. In addition, it is a good conductor of heat and electricity and transmits light. All of this points to how graphene really is the material of the future.

In this lesson, students will learn about the chemical and physical properties of graphene and using ICT tools will draw a single layer of graphene which they will produce using the 3D printer. At the end of the lesson, they will be introduced to the ideas of using graphene in everyday life in the future (e.g. wearable flexible electronics that can be used in healthcare, security, sports or fashion).

## Licenses

## Subject (s)

- **STEM Subject 1 - Chemistry**
- **STEM Subject 2 - Physics**
- **STEM Subject 3 – Informatics (ICT)**
- **non-STEM Subject 1 – English language**

## Real- life questions

- While implementing this learning scenario, we aspire to make students familiar with the material of graphene, in order to introduce this material as miraculous 2D material
- Students will be introduced with graphite and it's use in everyday life (pencils, lubricants)
- As students will be familiar with chemical structure of graphite, they will be able to answer how does a pencil leave its mark on a paper and why does it conduct electricity
- Students will be able to answer what is a touch screen made of

## Aims of the lesson

**By the end of the lesson, students should be able to:**

**Chemistry**

- explain the structure of graphite
- relate the properties of graphite to its structure
- explain the use of graphite in their daily lives

**Physics**

- do a simple circuit with graphite
- explain why graphite conducts electricity and heat

**Informatics (ICT)**

- use appropriate software for creating 3D model of molecules
- design and print 3D models

**English language**

- translate an interview from the mother tongue to English

## Connection to STEM careers

- Material science and engineering – by learning about graphene as a ''Miraculous 2D material of the future'' students will be able to understand how materials can be used in technology development and how engineers implement those materials in gadgets that we use in everyday life.

- 3D printing engineering – by printing their own graphene model, students will be introduced in basics of 3D printing that can be used in further career development.

## Age of students

**13-14**

## Time

**Preparation time:**

- 4 hours to discuss with colleagues and define activities
- 2 hours for each teacher to prepare materials for lessons

**Teaching time:**

- **Brainstorming and discussion** – 45 min
- **STEM Subject 1 -** Chemistry – 45 min
- **STEM Subject 2 -** Physics - 45 min
- **STEM Subject 3 –** ICT – 180 min + 90 min
- **non-STEM Subject 1 –** English language – 90 min

**Materials:**

- Elements of a simple circuit (4.5 V battery, light bulb, switch, conductors, graphite from a pencil)
- Glass jar, hot water and few different materials (plastic, wood, metal, graphite)
- Tablets or PCs with the Internet connection
- 3D printer with filament (or molecule models parts, modelling clay)
- Mobile phone with camera for an interview filming

**Online tools:**

- Microsoft Office 365 tools (Word, PowerPoint, OneDrive, Sway, Forms)
- Video – Structure of graphite (https://www.youtube.com/watch?v=SXmVnHgwOZs); Time: 1.21 - 2.17
- Video for Croatia students – Structure of graphite (https://edutorij.e-skole.hr/share/proxy/alfresco-noauth/edutorij/api/proxy-guest/7b5e1fe5-86e2-4142-af6c-5197c4a08148/kemija-8/m02/j01/index.html); Time: 0.30 - 1.25
- Video – Invention Of Pencil (https://www.youtube.com/watch?v=mKxIWzkQ2EI)
- Avogadro online tool - https://avogadro.cc/

- Google translate tool - https://translate.google.hr/

## 21st century skills

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

- Critical thinking – thinking of how to use graphite and graphene in everyday life
- Problem solving – making experiments on physical properties of graphite and graphene
- Creativity – making graphene molecule in Avogadro
- Initiative – making their own presentation about graphene
- Innovation – thinking on how to use graphene in new innovations
- Productivity – making the model of graphene by 3D printing
- Communication and collaboration – during the final group presentation
- Computational thinking and digital literacy – breaking down complex problems into smaller parts and working towards their solution with the use of online tools

## 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** | |
| **Brainstorming and discussion** | Topic: From the ''lead'' in pencils to graphene | 45' |
| **Discussion and preparation for the next lesson** | Teacher and students start their discussion on graphite - what do we know about graphite and how do we use it on everyday life? As most of the students will refer to the ''lead'' in pencils, we can discuss why graphite leaves the trace on paper and on what does the trace colour depends on.<br>• Video – Invention Of Pencil | |
| | **2nd Lesson** | |
| **STEM Subject 1** | **Chemistry** | 45' |

| Name of activity | Procedure | Time |
|---|---|---|
| Introduction to the topic, class discussion based on video and group formation | In the Chemistry lesson, students will be introduced to the structure of graphite.<br>After the conversation, students will conclude that the graphite is made of carbon. Also, they will conclude that graphite is more similar in structure to metals than non-metals. Using pictures draw by pen and watching the structure of graphite, students will be able to explain why the pen leaves a mark. The reason is that the weak bonding between the layers of graphite is broken. The pen leaves a darker trace as more connections between layers of graphite are broken. Then the focus will be on studying of layer of graphite known as graphene. Graphene has a two-dimensional crystal structure in which the carbon atoms are laid flat. Each layer is made of hexagonal rings. In each layer of graphite there are delocalized electrons that make graphite the conductor of an electric current.<br>• Video – Structure of graphite (Time: 1.21 - 2.17)<br>• Video for Croatia students – Structure of graphite (Time: 0.30 - 1.25)<br>After watching the videos, students will be grouped and they will study the use of graphene by information found in Internet. They will present their results in 1-minute speech using the form of Sway or some other online tool. | |
| Learning products | Written reports by students about preliminary findings | |
| 3rd Lesson | | |
| STEM Subject 2 | **Physics** | 45’ |
| Learning products | In Physics, students will learn about physical properties of graphite.<br><br>1st experiment – electrical conductivity of graphite | |

| Name of activity | Procedure | Time |
|---|---|---|
| | Students will create a simple circuit with battery, light bulb, conductors and switch. They will then connect a graphite wand to the circuit and notice that electricity is flowing through it. Students relate the conductivity property of graphite to its structure that they learned about in chemistry (nonbonded electron).<br><br>2nd experiment – heat conductivity of graphite<br>Students will immerse few different materials (for example plastic, metal, wood) and a graphite in a hot water. They will then observe which materials are good heat conductors and which are not. | |
| **4th Lesson** | | |
| **STEM Subject 3** | **Informatics (ICT)** | 180’ |
| **Preparing the 3D models** | 1° 3D modelling of graphene molecules and a layer<br>During the Informatics lesson students will be introduced to the Avogadro application specialized for creating 3D printable molecular models. While creating 3D of the graphene molecule and graphene layer they will explore ways of storing results in appropriate file format suitable for 3D modelling programs. Also, they will be introduced with the idea of using modelling and simulation while acquiring new knowledge and how it could be beneficial.<br><br>2° Preparing for 3D printing and 3D printing<br>Students will explore a software for 3D printing and recognize the suitable file format for 3D printing software connected to the 3D printer. While working in groups students will explore the process of 3D printing, create and prepare their own (god) file for 3D printing. After creating successful gcode file, every group will print their own graphene layer which will be used later in their final lesson and chemistry lesson. | 90’<br><br>90’ |

| Name of activity | Procedure | Time |
|---|---|---|
| | While working on this assignment student will recognize and study the interdisciplinary application of computational thinking by analysing and solving selected problems in different areas of learning. | |
| **Learning products** | • Files with code<br>• Finalized products | |
| | **5th Lesson** | |
| **STEM Subject 3** | **Informatics (ICT)** | 90’ |
| **Non-STEM Subject 1** | **English language** | 90’ |
| **Preparing presentation; groupwork and videos** | Students are preparing final group presentation of a max. 3 minutes, in a form of a TED talk’s, TeachMeet or they can use any other online tool. The aim of the presentation is to explain why graphene is the ‘’Miraculous 21st Century Material’’.<br><br>Student will be interviewed (on their mother tongue) about their experience in interdisciplinary learning approach. After that, students will translate their answers on English and make the subtitles for a video of an interview. | |
| **Learning products** | • Class presentation<br>• Interview transcripts and notes | |

## Initial assessment

During the first lesson initial information about graphene and its application in real life will be gathered (survey or discussion).

## Formative evaluation

During every subject lesson, several formative assessments will take place in a form of a survey, rubrics or quizzes with the purpose of gathering information about learning outcomes adaption.

## Final assessment

Final group presentations will be organised in the form of the TeachMeet or some other tool (for example 3 minute per group). Final assessment will be carried out by students according to the rubrics prepared by teachers.

## Student feedback

Each student will be interviewed about the methods supplied during the teaching process (digital tools, problem and project-based learning, IBL, using of a 3D printer, group work, collaboration, active learning etc.).

## Teacher feedback

When it comes to the teaching outcomes and overall teamwork, during the implementation of the learning scenario, students tried several experiments during the physics class that proved to be suitable and carried out very successfully. This allowed students to conclude that graphite is a good conductor of electricity and understand and further link several concepts from their science subjects. Also, during the experiment, students got the idea to check if gold jewellery is a good conductor of electricity. A special challenge was the production of graphene models using 3D printers. The students, with the help of the teacher, created a graphene structure in the Avogadro program and then used it as a blueprint for a 3D printer.
Students created their personal observations during physical and chemical experiments. In an appropriate molecule modeling program, they created their own model of the graphene molecule (file) and adapted it for printing on a 3D printer. The most successful works were printed on a 3D printer.
The real-life questions we just tried to answer are related to the development of technology. Thus, students, studying the physical and chemical properties of graphene, can answer what are touch – screen or solar panels made of. Also, they will be able to conclude about the structure of graphene through simpler questions such as why the pen leaves a mark on paper. By learning about graphene through different school subjects, we have brought the topic closer to our students in an understandable way. If we had covered the topic through each subject independently, it would have been much more difficult for us teachers to explain and bring this rather complex topic closer to the students. Through cooperation, we encouraged each other to think creatively and to devise the best forms of teaching for each of the individual subjects we teach. You could say that this way of teaching is a win-win situation because it is great for both students and teachers.
When it comes to the time allocated and overall challenges faced for teachers and students, the biggest challenge for teachers was to devise a way to conduct teaching in the new conditions caused by the COVID-19 epidemic. For example, students were not allowed to share work materials during the experiment, and we only worked with a certain group of students. The implementation took place in September 2020 and the time allocated was sufficient, but the constraints concern mainly the overall number of students involved in each activity and in some occasions difficulty in collaborating with each other. The selected activities mentioned in the learning scenario were implemented or modified with respect to

the situation caused by the COVID - 19 pandemic. Thus, the students made interesting presentations about graphene in Croatian or English language instead of the final group presentation in the form of TED talk`s

We had to adapt our teaching scenario in a way to protect the health of all participants. While planning and carrying out the chemical and physics experiments, we strictly made sure that the students did not share working materials and that they worked in groups of students who were usually together in the classroom every day. A special challenge was the realisation of IT lessons, since informatics is elective subject where every group has students from different classes. Lessons were performed in smaller groups of students. Such organisation slightly prolonged the realization of the scenario. Due to the special working conditions, we carried out some activities through the online environment: cooperation and communication with students regarding the project activities, preparation and presentation of digital students' contents on the topic of graphene and finally collection of their feedback. First of all, the students enjoyed the realization of the project. This project was realized with seventh grade students learning chemical and physical laws for the first time. Still, a few of the best moments need to be highlighted. First, during a Chemistry class, the teacher came up with the idea that it is best way to explain to students what graphene is, if she takes stick tape, sticks it to a piece of graphite, and what is left on stick tape is graphene. Second, during Physics class, students examined the electrical conductivity of graphite. After that, the students concluded that graphite, but also metals, conduct electricity. Then one student came up with the idea to check if her gold earring was conducting electricity. She was all happy when she saw the light bulb glow. Third, however, the students were most enthusiastic when they realized that the 3D printer was making a graphene molecule model according to their design from the Avogadro program. Students were only given guidance through a video lesson on how to use the Avogadro program that served as a blueprint for making a graphene molecule model in a 3D printer. Also, through a survey in Forms, we collected information on the evaluation of the project itself and student impressions.

In addition to the usual consents that parents have signed for the participation of their children in the project, we received feedback via online communication that they are satisfied with the implementation of this project. Probably some of them also worked with their children on a project assignment. Students feedback was collected through questionnaires using the Forms application and open communication in the classroom and online chats/post via virtual classrooms.

# 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**

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*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*

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### 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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