STEM LABYRINTH

AS A METHOD FOR INCREASING THE LEVEL OF KNOWLEDGE
THROUGH PROBLEM SOLVING

Guidelines

for STEM Educators for
using STEM Labyrinth methodology

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

The project is financed by Erasmus+ KA2: 2020-1-PT01-KA201-078645

Contents

1. Introduction ... 3
   1.1 STEM Labyrinth - aim and objectives of the project ... 4
   1.2 Results of the STEM Labyrinth project ... 5
   1.3 The purpose of the guidelines ... 8
   1.4 Brief content of the guidelines ... 9
2. Executive Summary ... 10
   2.1 Summary of IO-3 ... 11
   2.2 Target groups and expected impact ... 11
   2.3 Partners who designed the problems and Guidelines ... 12
   2.4 Number and subject/topic/area of the problems ... 13
3. Methodology of the STEM Labyrinth App ... 19
   3.1 What is the purpose of the app? What are the core objectives of the Mobile App? ... 20
   3.2 What are the target users and their needs? ... 20
   3.3 How to approach the design of a problem? ... 20
4. How to use the STEM Labyrinth App ... 22
   4.1 What is the content of the Mobile app and how to access it ... 23
   4.2. How the *STEM Labyrinth* method and its Mobile App can be used in the teaching and learning process ... 34
   4.3. Ideas for finding/ exploiting/ adapting/ extending the content of the App according to the needs of students and teachers in approaching a topic ... 40
   4.4. How the teacher can create his/her own problem scenarios based on STEM Labyrinth Method and other resources according to their needs and the needs of the students ... 43
   4.5. Developing Lessons plans for particular topics by exploiting the Mobile App ... 48
   4.6. Analysis of different categories of problems in the Mobile app following description and approach of some examples from Mobile app ... 72
5. Pilot testing of the Mobile App ... 78
   5.1. Evaluation form of the STEM Labyrinth problems ... 79
   5.2. Evaluation form from the pilot testing with students ... 82
   5.3. Report of the pilot testing of the mobile app organized in partner schools ... 84
6. Assessment of the students' knowledge and skills using the Mobile App ... 86
   6.1 Assessment of students' learning in interdisciplinary STEM education ... 88

6.2 Mobile apps: mobile-assisted formative assessment 88
7. How the teacher can motivate and inspire the students to be problem solvers and creative thinkers 90
7.1 Introduction 91
7.2 Motivation 91
7.3 Students' Participation in the Learning Process 92
7.4 Mobile Apps in STEM Education to Maximize Student Engagement 93
8. Developing identities of STEM teachers at emerging STEM schools 94
8.1 What is a STEM school? 95
8.2 What a STEM teacher is and how to become a good one? 96
8.3 How STEM education helps students? 96
9. School principals and educational community in process of adapting Action plan for STEM education 99
10. State boards of education can create a supportive state policy framework as a key foundation to successful STEM education redesign 102
11. Developing bonds between the schools, community, and policymakers 104
References 107
Authors 111

1.Introduction

1.1 STEM Labyrinth - aim and objectives of the project

Nowadays, the world has been changing rapidly, and the knowledge and skills acquired today are not foreseen to be sufficient while preparing our students for life. It is emphasized that the 21st century skills, such as digital skills, critical thinking, cooperation, problem solving, innovative and analytical thinking, are more than required. Technology has been improving so rapidly that it is of great significance for students to adapt to these constant changes in technology. Individual competencies in STEM subjects (science, technology, engineering and mathematics) are getting more important for the occupations of the future which are based on high technology. Therefore, innovative approaches are much required in education.

As teachers, we need to be aware of the changes and the needs of today's students. We have noticed that these generations of students have low-attention disorders, just because they are born with the technology. They are used to getting to the information in just one click on their phones, tablets, and computers, so being in the classroom, being taught in a traditional way, by old textbooks, shows that the educational system is not efficient. According to the learning patterns and students' needs, this project intended to develop interactive materials that help students to develop problem-solving skills, i.e. the capacity of students to understand problems situated in novel and cross-curricular settings, to identify relevant information or constraints, to represent possible alternatives or solution paths, to develop solution strategies, and to solve problems and communicate the solutions.

Firstly, the project is aimed to develop the so-called "STEM skills" in students (Science, Technology, Engineering and Math), which can be considered basic skills and are, for this, the main focus of our project. Moreover, they are considered to be very challenging and not attractive to students, which is shown in the latest PISA tests. All the project's partner schools have identified a need to improve the quality of education in science, mathematics and technology, and have submitted a project aimed at developing a joint framework to support the involvement of pupils in learning.

One of the most important horizontal priorities we emphasize is the innovative practices in a digital era, according to the objectives of our project. In this strategic partnership we promote innovative methods and pedagogies in the direction of increasing the motivation of students. The smartphone app and Toolkit materials for promoting STEM provide the schools innovative practices for non-formal learning based on real-life problems, supporting ICT-based teaching, supporting teachers in acquiring or improving the use of ICT for learning, and promoting OER as priorities.

In particular, our project addresses the horizontal Erasmus+ priority - Supporting individuals in acquiring and developing basic skills and key competences - promoting a multidisciplinary and interdisciplinary approach, involving different disciplines (Physics, Computer Science, Mathematics, Science, Design), promoting learning based on real-life problems, hands-on learning and innovative approaches to teaching contexts of high technology, with particular emphasis on in high-tech physical environments. We are fostering critical thinking especially through problem solving in an environmental context.

The educational outcomes in traditional settings focus on how many answers a student knows. We want students to learn how to develop a critical stance with their work: inquiring, editing, thinking flexibly, and learning from problem solving. The critical attribute of intelligent human beings is not only having information but also knowing how to use it and take most advantage of it.

The project also promotes strengthening the profile of the teaching profession, dealing with complex classroom realities and adoption of new methods and tools that will also add up to acquisition of skills and competences of both students and teachers. The proposed activities also help develop transversal skills, such as digital skills and multilingualism: not only within the involved students, but also within every person who is directly involved in the implementation of the project. Besides the use and integration of ICTs in the process of teaching, using innovative pedagogical approaches help the learners to develop their transversal skills.

Most important objective of the project is certainly improving the quality of STEM education and helping students develop and apply a conceptual understanding of science, technology, engineering, and math. It's important for students of all ages to engage in this type of higher-order thinking in order to get prepared for their future education and career. By enabling interactive learning, apps can spark an interest in students for STEM-related careers at an early age.

1.2 Results of the STEM Labyrinth project

The rationale behind the project proposal was based on the question: How well prepared are young students to solve the problems that they will encounter in life beyond school, in order to fulfill their goals at work, as citizens and in further learning? For some of life's challenges, they need to draw on knowledge and skills learned in particular parts of the school curriculum – for example, to recognise and solve a mathematics related problem. Many real-life problems are less obviously linked to school knowledge in one particular subject, and often require students to deal with unfamiliar situations by thinking flexibly and creatively.

This project is concerned with problem solving of the second, more general variety. With the project we are introducing a new and innovative approach for the teachers in STEM education to follow and use as additional teaching material. We are developing an innovative STEM Labyrinth Method and designing Mobile Application, to create a transformative educational experience for high school students. The real-life problem scenarios are being deployed with the help of mobile applications that empower students for higher-order thinking. Students can really get to grips with the real-world based application of what they learn and become inspired to take their studies beyond the classroom. There is great potential in using mobile devices to transform how students learn by changing the traditional classroom to one that is more interactive and engaging. STEM learning is largely about designing creative solutions for real-world problems. When students learn within the context of authentic, problem-based STEM design, they can more clearly see the genuine impact of their learning.

The era of the fast moving technology needs to be brought into the classroom, and more teachers need to be aware of the patterns that these students need, in order to capture their attention and make them acquire skills and competences. Critical thinking and creativity can be learnt by the students in order for them to be ready to cope with the challenges of the society. The STEM Labyrinth project focuses on learning, teaching and using new technologies and being adequate about using digital competencies. Technology is playing a critical role in how curricula are being developed and implemented. This is reflected in a huge movement in many countries to create STEM (science, technology, engineering and mathematics) curricula to prepare students for lifelong learning and for the demands of the future.

The specific results of the project as intellectual outputs refer to development of several tangible results to be used by STEM teachers, teacher trainers, school managers, and mostly students. They are as following:

1. Toolkit promoting STEM Education

It provides core messages, materials, and communications strategies to help schools and policy makers overcome challenges and build strong support for STEM education initiatives. This Toolkit contains a range of implementation tools, from conducting analysis on STEM education policies and STEM teachers' practices in partner countries, to finding strategies to support the needs assessment when developing their own STEM programs. There is also implementation advice on how to choose a curriculum, design and adapt interactive lesson plans – including already prepared with our proposal. Designed to be free and friendly, this Toolkit is accessible to all students, teachers, and the educational community. The STEM activities require that mentors invite classes to make study visits and practical workshops to enable students to understand the various concrete applications of the topics they are working on, giving them an outlook for the future choice of university and work careers.

2. Mobile application STEM Labyrinth

This output refers to development of a Mobile App that would represent a virtual simulator of real-life problems asking learners to tackle a real-world problem and by doing that to gain knowledge through problem solving.

Many everyday situations and problems require not only pure science and mathematics knowledge in order to be solved, but also problem solving skills, high-order thinking strategies and creativity. Thus, the *STEM Labyrinth* app puts the students in the center of a real-life situation and it challenges them to begin solving problems and eventually reach the solution. Through providing help at several stages, the app intends to increase the motivation and the students' understanding of the problem. At different stages students are able to get additional hints in the form of pictures, animations, videos etc. that enable them to move forward in the "Labyrinth" and get out of it with a solved problem.

The *STEM Labyrinth* application consists of real life problems - everyday situations, which can be solved with relevant knowledge and skills in math and science, using technology. The *STEM Labyrinth* method involves giving clues and hints, hidden formulas, definitions and drawings, but not answers. The purpose of the application is not giving them answers, but making them think and learn at the same time. The core of it is learning the most common operations and relations and using them in their everyday life. The App provides clues and paths towards solving the defined problems and a step-to-step approach that grabs the attention of students and inspires them to get excited about STEM. Once a user downloads the app, he/she is able to choose between the different types of categories: Environmental problems, Health and medicine, Urban infrastructure, Economical solar energy, Access to clean water etc.

3. Guidelines for the STEM Labyrinth methodology of the application

The result refers to creation of Guidelines for using the Mobile App intended for teachers/educators/STEM administrators who will use this particular method of teaching in their classroom as curricular or extracurricular activity. It provides the aims and objectives of the Mobile Application, the STEM Labyrinth methodology of getting to the solution of all real-life problems in it, lesson plans and some useful links, resources and explanations on using different ICT and OER tools. These Guidelines elaborate all needed basic elements for formulating the methodology for problem solving and aim to create a bridge between theory and practice. Its main goal is to describe the STEM Labyrinth methodology used in the Mobile app and the main steps to be taken in order to prepare training courses and activities compatible with school education processes and requirements for STEM education, in addition on how to apply the methodology for activities developing bonds between the schools, community and policymakers.

4. Training course for the STEM Labyrinth method

The course design is structured as a 3-5 days training. It is addressed to teachers, teacher trainers and school managers.

The main learning outcomes include:

- ➔ Methodology understanding
- ➔ Understanding the operation of the APP and the guidelines for using it
- ➔ Learning how to make subjects like Mathematics, Chemistry, Physics, and Biology more approachable and interesting for the students, through STEM Labyrinth method, and how to motivate students for problem solving and creative thinking
- ➔ Development of learning plans (real-world problem scenarios) for school students

The objectives of the STEM Labyrinth project are to:

- empower youth and students to be problem solvers and innovative thinkers through science and technology
- enable and motivate students to learn STEM topics by immersing themselves in interactive apps
- implement new teaching methods and materials that will encourage STEM teaching
- conduct progressive series of curricula developments
- provide teacher training to better improve content delivery
- develop course plans and teacher training courses for STEM

1.3 The purpose of the guidelines

The Guidelines' main purpose is to provide better understanding of the STEM Labyrinth Methodology, which is used in the Mobile app, and to suggest activities compatible with school education processes and requirements for STEM education. Moreover, it is on how to apply the methodology for activities developing bonds between the schools, community and policymakers.

The element of innovation of this result is its relation to the previous result, and it emphasizes the skills and competences to be developed by using it.

This result brings the innovative STEM Labyrinth methodology closer to the teachers, STEM educators and relevant institutions.It will help any teacher (not necessarily teachers with STEM background) to utilize the Mobile application in the best possible way for the benefit of the students and his/her own.

These guidelines include directions as for:

(1) how the STEM Labyrinth method and Mobile Application can be used in the teaching process

(2) how the teacher can create his/her own lesson plan scenarios based on the STEM Labyrinth Method and other resources according to their needs and the needs of the students

(3) how the teacher can motivate and inspire the students to be problem solvers and creative thinkers

(4) school principals and policy makers to adapt Action plans for STEM education

(5) state boards of education to create a supportive state policy framework as a key foundation to successful STEM education redesign

1.4 Brief content of the guidelines

These Guidelines are structured in sections, all covering different contents for the STEM teachers who are motivated to use innovative approaches in their teaching through technology. The sections in these Guidelines appear as it follows:

Section 1. Introduction

Section 2. Executive Summary

Section 3. Methodology of STEM Labyrinth App

Section 4. How to use the STEM Labyrinth App

Section 4.1. What is the content of the Mobile app and how to access it

Section 4.2. How the STEM Labyrinth method and Mobile App can be used in the teaching and learning process

Section 4.3. Ideas for finding/ exploiting/ adapting/ extending the content of the App according to the needs of students and teachers in approaching a topic

Section 4.4. How the teacher can create his/her own problem scenarios based on STEM Labyrinth Method and other resources according to their needs and the needs of the students

Section 4.5. Developing Lessons plans for particular topics by exploiting the Mobile App

Section 4.6. Analysis for different categories of problems in the Mobile app following "step by step" description/approach of some examples from Mobile app

Section 5. Pilot testing of the Mobile App

Section 5.1. Evaluation form of the STEM Labyrinth problems

Section 5.2. Evaluation form from the pilot testing with students

Section 5.3. Report of the pilot testing of the mobile app organized in partner schools

Section 6. Assessment of the students' knowledge and skills using problem solving strategies and Mobile App

Section 7. How the teacher can motivate and inspire the students to be problem solvers and creative thinkers

Section 8. Developing identities of STEM teachers at emerging STEM schools

Section 9. School principals and educational community in process of adapting Action plan for STEM education

Section 10. State boards of education can create a supportive state policy framework as a key foundation to successful STEM education redesign

Section 11. Developing bonds between the schools, community, and policymakers

2. Executive Summary

2.1 Summary of IO-3

The contemporary facilitators of learning need to be aware of the changes and the needs of today's students. It is generally accepted that the present generations have different approach to studying and are exposed to everyday use of many technologies. In this context this project developed a Mobile Application that brings the process of studying closer to their pattern of acquiring knowledge and it is expected to help students understand the subject that they find most challenging in their learning process.

The Guidelines for STEM Educators is intended for teachers/educators/STEM administrators in primary and secondary schools who are willing to spice up their teaching. The mobile application with this particular method of teaching can be used in the STEM classroom, or as an extracurricular activity, depending on the type of school where it will be applied, the teachers' preferences, or the students' time and will to experiment. It provides a detailed explanation of what the STEM Labyrinth methodology represents, what is its core, how to approach the real-life problems through ready lesson plans, useful links, resources and explanations. These Guidelines elaborate all needed basic elements for formulating the methodology for problem solving and aims to facilitate the teacher's practice.

This Manual and its relation to the previous output emphasize the skills and competences to be developed among educators and learners by using it. It brings the innovative STEM Labyrinth methodology closer for use by teachers, STEM educators and relevant institutions.

2.2 Target groups and expected impact

As beneficiaries of this output, teachers, students, STEM educators, STEM associations, schools, Higher education community, State boards of education and education agencies; and policymakers are able to use this guidelines independently, by complements existing education programs with high-quality STEM education for all students and by that to fosters both the educational and economic health of the state and its regions.

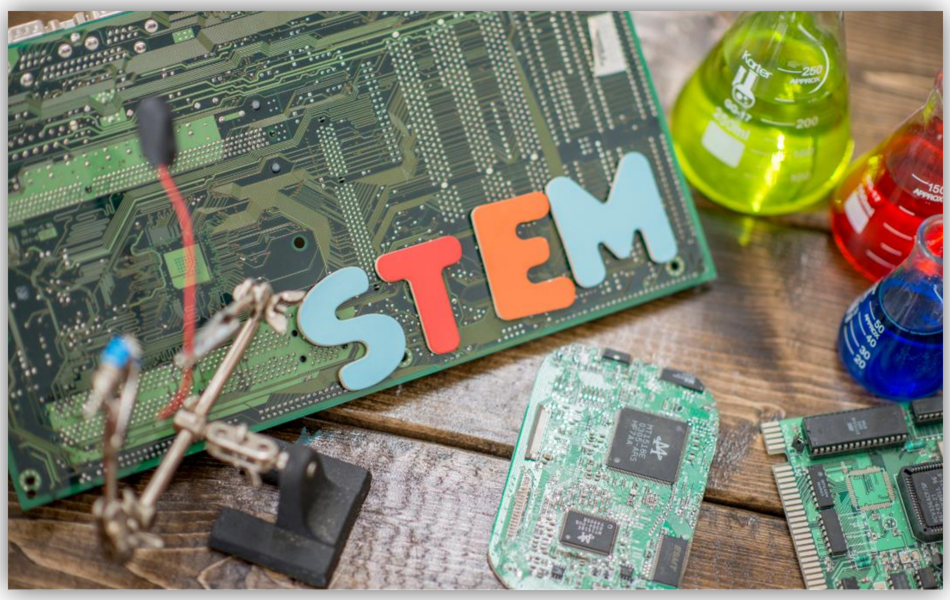
Teachers are meant to be direct beneficiaries, in using it to assist their students in achieving the objectives, and at the same time to develop an atmosphere for promoting critical thinking and innovation. With it, they have the opportunity to develop professionally and Implement innovative practices in education, stimulate interest in students towards a knowledge proposed by problem solving, with forms of learning on the job in real situations; develop skills of self-orientation and train students to have confidence in themselves, demonstrate initiative, flexibility and mental agility, willingness to change; raise awareness of students and staff for STEM education. Students benefit from hands-on, real world lessons and leadership opportunities, as well as exposure to STEM careers. The schools' benefit refers to curriculum support, cross-functional team building, and community involvement.

Moreover, the communities would benefit from the partnerships established among key stakeholders. Perhaps the most important consequence of students working on real problems is that they begin to develop empathy, a sense that there is something worth dedicating their efforts to outside of themselves. We need to grow a savvy, ethical workforce to solve looming issues.

2.3 Partners who designed the problems and Guidelines

The leader of this intellectual output, Association AMETA, had the main responsibility to coordinate the activities, establish communication, and delegate assignments to the other organizations included. They also have prepared evaluation forms to determine the extent to which the output is realized, and to define the disadvantages so that we could make improvements. This Guideline was developed to a great extent by the teachers/researchers who contributed with the contents in the STEM Labyrinth app, or with the design of the problems.

All the partners were involved in developing the materials of the Guidelines. Specific tasks were delegated according to the partners' expertise. Learnmera was responsible for design of the interface, non-schools partners were responsible for elaborating the methodology and syllabus of the Guidelines and for creating a supportive state policy framework as a key foundation to successful STEM education redesign. The partner schools provided materials on how the STEM Labyrinth method and the Mobile Application can be used in the teaching process and how the teacher can create his/her own lessons - plan scenarios based on STEM Labyrinth Method, and other resources according to their needs and the needs of the students by "step by step" description of some examples from the Mobile app.



2.4 Number and subject/topic/area of the problems

ANNEX 1 *Doukas School* List of Problems

#	Level	Subjects, Sub-subjects, Ages, Level of Difficulty	Title	No of quest.
D01	easy	Information Technology#Algorithms#Programming#14-15	Let’s discover algorithms and programming languages	12
D02	easy	Math#Geometry#Algebra#Environment#Algorithms#14-15#16-17	From Brussels Airport to Brussels Square and vice versa	14
D03	medium	Math#Geometry#Algebra#Environment#Algorithms#14-15#16-17	Traveling to five European cities	7
D04	medium	Math#InformationTechnology#Geometry#Algebra#Environment#14-15#16-17	The A4 paper in our everyday life	11
D05	medium	Math#Geometry#Algebra#Environment#Algorithms#14-15#16-17	Circles and hexagons on digital and real surfaces	14
D06	medium	Math#Geometry#Algebra#Environment#Algorithms#14-15#16-17	Distribution of spectators in a concert hall following safe social distancing rule	11
D07	medium	Physics#Motion#Newtonlaws#Mechanics#16-17#18+	The motion of a cyclist	9
D08	easy	Physics#Motion#Newtonlaws#Astronomy#16-17	The scale of the astronaut	9
D09	medium	Physics#Motion#Newtonlaws#Astronomy#16-17	The fall of the parachutist’s	7
D10	easy	Physics#Motion#Algebra#Environment#14-15	Cheetahs - sprinters vs Antelopes - runners	7
D11	medium	Science#Math#Geometry#Algebra#Environment#14-15	Eratosthenes’ method for the Earth’s circumference	8
D12	easy	Science# Math#Geometry#Algebra#Environment#Astronomy#14-15	From the ancient “rope around the Earth” to the modern “orbit of the ISS”!	8
D13	medium	Science#Physics#Math#Geometry#Environment#Astronomy#14-15#16-17	Can we determine the 12 main planetary data for the Earth?	12
D14	easy	Information Technology#Algorithms#Programming#Motion#14-15	Exploring the code of a robot game	10
D15	easy	Math#Algebra#Proportions#Probability#Sustainability#14-15#16-17	The mean, the median and the mode of the salaries of two companies	10
D16	medium	Physics#Motion#Newtonlaws#Astronomy#16-17	Newton's cannonball	10
D17	medium	Physics#Motion#Newtonlaws#Astronomy#16-17#18+	The Tesla Roadster and its space passengers	8
D18	easy	Science#Physics#Geometry#Motion#Astronomy#14-15#16-17	How does the light travel? What are its properties?	9
D19	easy	Math#Geometry#Algebra#Trigonometry#14-15#16-17	Which shape has the largest area?	9
D20	medium	Science#Biology#Environment#Genetics#14-15#16-17#18+	What are some key facts about the human evolution?	8

ANNEX 2 *Agios Georgios Lyceum* List of Problems

#	Level	Subjects, Sub-subjects, Ages, Level of Difficulty	Title	No of quest.
G01	Hard	Math#NewtonLaws#Functions#16-17	The Determination of the Time of Murder	6
G02	Medium	Math#Geometry#14-15	How to Measure the Height of a Tree	7
G03	Easy	Math#Trigonometry#14-15	The Stage Lighting on the Actor's Face	6
G04	Hard	Math#Algebra#16-17	Using logarithms to measure the Richter scale	7
G05	Medium	Math#Algebra#16-17	Arithmetic Sequence to Figure out how to Build a Retaining wall	5
G06	Easy	Physics#Motion#14-15	Rate of Travel	6
G07	Medium	Physics#Newton laws#16-17	Weight In An Elevator	5
G08	Easy	Math#Algebra#16-17	Geometric Sequence in calculating virus cases of COVID-19	5
G09	Hard	Math#Geometry#Functions#16-17	Bridge design	7
G10	Hard	Physics#Newton laws#16-17	The gravity of a planet	7
G11	Hard	Physics#Motion#Newton laws#18+	Riding the Ferris Wheel	7
G12	Easy	Math#Proportions#14-15	Medical Math	6
G13	Easy	Math#Trigonometry#14-15	The Cruises	5
G14	Medium	Math#Algebra#14-15	Flower garden	7
G15	Medium	Physics#Mechanics#14-15	The physics of volleyball	5
G16	Medium	Math#Geometry#14-15	Oil Film Experiment	6
G17	Medium	Physics#Motion#16-17	Motion of a Motorboat	5
G18	Medium	Math#Geometry#16-17	Nuclear cooling tower	5
G19	Hard	Math#Geometry#16-17	Whispering Galleries	7
G20	Easy	Math#Functions#14-15	Sound Intensity	6

ANNEX 3 *Martna Prohikool* List of Problems

#	Level	Subjects, Sub-subjects, Ages, Level of Difficulty	Title	No of quest.
M01	easy	Physics#Motion#14-15	Knocking on radiators	5
M02	medium	Physics#Math#Mechanics#14-15	Swimming in the sea	5
M03	easy	Physics#Astronomy#14-15	Which are light sources	7
M04	medium	Physics#Math#Mechanics#14-15	Electric bike versus car	6
M05	medium	Physics#Geometry#14-15	Choosing glasses	7
M06	medium	Math#Geometry#14-15	Choosing suitcases	11
M07	hard	Math#Functions#16-17	Arch Bridge in Tartu	12
M08	medium	Math#Physics#Mechanics#14-15	The lawnmower	10
M09	easy	Math#Geometry#14-15	Ventilation pipe	6
M10	easy	Math#Physics#Mechanics#14-15	Driving along the river Danube	8
M11	medium	Chemistry#Organic compounds#16-17	Mercury in our food	8
M12	medium	Biology#Genetics#16-17	Adopted child	8
M13	medium	Chemistry#pH#16-17	Is it acidic, alkaline or neutral?	12
M14	easy	Science#Functions#14-15	Friend from another time zone	10
M15	hard	Biology#Organic compounds#18+	The secrets of enzymatic browning	8
M16	easy	Biology#Viruses#16-17	Biology of viruses: are viruses alive or dead?	14
M17	medium	Chemistry#Organic compounds#16-17	Iron in our body	12
M18	medium	Chemistry#Organic compounds#16-17	Science behind ice cream	12
M19	hard	Chemistry#Organic compounds#16-17	The secrets of caffeine	11
M20	medium	Science#Climate change#14-15	Arctic and Antarctic - Comparisons & Similarities	11

ANNEX 4 *AMETA* List of problems

#	Level	Subjects, Sub-subjects, Ages, Level of Difficulty	Title	No of quest.
A01	easy	Math#Algebra#14-15	Changing the salinity of seawater	8
A02	medium	Math#Algebra#14-15	The execution of a large research project	9
A03	hard	Math#Algebra#Functions#16-17	The window in the loft	11
A04	medium	Science#Climate change#Global warming#16-17	Red Alert: Climate Melt Down	9
A05	medium	Science#Environment#16-17	Rust Never Sleeps	10
A06	easy	Science#Renewable energy#18+	NET-ZERO BUSES	7
A07	easy	Math#Algebra#14-15	Sample Calculations for Dietary Analysis	14
A08	medium	Math#Geometry#Renewable energy#16-17	SOLAR PANELLING A HOUSE	10
A09	medium	Math#Trigonometry#16-17	Trigonometry in action	8
A10	hard	Math#Geometry#16-17	The Geometry That Honey Bees Are Using	12
A11	medium	Science#Renewable energy#16-17	Renewable energy	12
A12	easy	Math#Algebra#14-15	Saving for a new car	9
A13	medium	Math#Algebra#16-17	Personal finance plan	7
A14	easy	Physics#Motion#16-17	Calculate the distance	9
A15	hard	Physics#Kinetics#18+	Where should you trim the weight?	10
A16	medium	Physics#Kinetics#16-17	Wind power	13
A17	easy	Math#Environment#14-15	Cutting energy bills with energy efficiency	10
A18	medium	Math#Functions#16-17	Minimizing material usage	8
A19	easy	Math#Probability#18+	Find the probability	10
A20	medium	Biology#Bacterial transformation#16-17	Bacterial Transformation	7

ANNEX 5 *Enjoy Italy* List of problems

#	Level	Subjects, Sub-subjects, Ages, Level of Difficulty	Title	No of quest.
E01	medium	Science#Environment#Climate change#16-17	Sustainable Development Goal 13: Gas emissions	6
E02	easy	Science#Environment#14-15	How are icebergs formed? What is their dynamic?	7
E03	easy	Phyisics#Mechanics#Motion#14-15	Car acceleration from a standstill	4
E04	medium	Physics#Mechanics#Motion#Newton laws#16-17	Ball up	6
E05	medium	Physics#Mechanics#Newton laws#16-17	Bungee Jumping	5
E06	easy	Math#Geometry#14-15	Volume of a solid formed by cube and cylinder1	10
E07	easy	Physics#Motion#Newton laws#16-17	Francesco Totti “spoon” penalty	5
E08	easy	Physics#Environment#16-17	A skier on a frozen lake	7
E09	medium	Physics#Mechanics#Motion#Kinetics#Newton laws#16-17	Car collision	6
E10	easy	Math#Algebra#Probability#14-15	Probability with sets	6
E11	easy	Math#Geometry#14-15	Distance of the Horizon	7
E12	easy	Physics#Astronomy#Newton laws#16-17	The Hubble Space Telescope	11
E13	easy	Chemistry#Oxidation#16-17	Wine turning into vinegar	5
E14	easy	Physics#Motion#14-15	Hang time of a basketball player when jumping	12
E15	easy	Math#Probability#16-17	Probability to select a specific card from a deck of cards and of being dealt a royal flush in poker	7

ANNEX 6 *ATLME* List of problems

#	Level	Subjects, Sub-subjects, Ages, Level of Difficulty	Title	No of quest.
AT1	easy	Information Technology#Passwords#14-15	How to make a good password?	11
AT2	medium	Math#Algebra#Functions#16-17	Packaging optimization	7
AT3	easy	Chemistry#Atom#14-15	Constitution and mass of atom	7
AT4	medium	Physics#Newton laws#16-17	Effect of forces on speed	7
AT5	medium	Math#Algebra#Functions#16-17	Pavilion construction	6
AT6	easy	Physics#Sustainability#16-17	How electricity works	10
AT7	medium	Biology#Reproduction#Genetics#18+	Infertility	13
AT8	medium	Science#Climate change#16-17	Chemical transformations	8
AT9	easy	Information Technology#Programming#HTML#14-15	Do know HTML?	13
AT10	medium	Math#Geometry#14-15	Bom Jesus elevator	8
AT11	medium	Math#Algebra#Functions#16-17	Production and Cost Optimization	6
AT12	easy	Chemistry#Organic compounds#16-17	Training and identification of organic compounds in daily life	7
AT13	hard	Physics#Astronomy#Newton laws#16-17	How the force of gravity works on Earth and other planets.	8

3. Methodology of the STEM Labyrinth App

3.1 What is the purpose of the app? What are the core objectives of the Mobile App?

STEM learning is largely about designing creative solutions to real-world problems. When students learn within the context of authentic, problem-based STEM design, they can more clearly see the genuine impact of their learning. That kind of authenticity builds engagement, taking students from groans of “When will I ever use this?” to a genuine connection between skills and application. This output refers to the development of a Mobile App that represents a virtual simulator of real-life problems asking learners to tackle a real-world problem, and by doing that to gain knowledge through problem solving.

Many everyday situations and problems require problem solving skills, high-order thinking strategies and creativity. Thus, the STEM Labyrinth App puts the learners in a real-life situation and it encourages them to solve the problems and reach to the solution. Through providing help at several stages, the app intends to increase the motivation and the students’ understanding of the problem. At different stages students are able to get additional hints in the form of pictures, links, formulas, animations, videos, etc. that enable them to move forward in the “Labyrinth” and get out of it with a solved problem. The STEM Labyrinth application is composed of real life problems - everyday situations, which can be solved with relevant knowledge and skills in math and science, using technology. The method STEM Labyrinth involves giving clues and hints, hidden formulas, definitions and drawings, but not answers. The purpose of the application is not giving them answers, but making them think and learn at the same time. It is all about problem solving, decision making, and understanding causation. Allows for hands-on, interactive learning, fosters scientific thinking by placing students in a situation where they must form, test, and revise strategies — specifically, the strategies they develop to learn and master the rules of the game.

3.2 What are the target users and their needs?

The *STEM Labyrinth* Mobile App is expected to have impact over a wide audience; especially young people who need to have developed 21st century skills, such as digital skills, critical thinking, problem solving, innovative and analytical thinking for career and pathways in a fast moving world. Not only teachers and students, but also graduates, university students, and any interested individuals in any educational environment would benefit from the use of the Mobile App. It encourages curiosity and confidence, connects in-class experiences to real-world concepts, and prepares today’s students for the professions of the future. The Mobile app also help students to develop and apply a conceptual understanding of science, technology, engineering, and math by solving real-world problems and designing solutions to novel problems.

3.3 How to approach the design of a problem?

STEM Labyrinth App creates a transformative educational experience for students, by changing the traditional classroom to one that is more interactive, engaging and motivating. Students placed in the

"Labyrinth" following a path with given hints and asked questions, develop and demonstrate knowledge, skills, creativity, thinking strategies and constructiveness. The *STEM Labyrinth* application consists of real life problems, which follow a template defined and developed by the partnership, in accordance with the requirements of the application.

STEM problems are categorized into difficulty levels (easy, medium and difficult).

Criteria for STEM Labyrinth problems:

- ✓ Addresses a real-world problem
- ✓ Helps students apply math and science through authentic, project based or hands-on learning
- ✓ Includes the use of (or creation of) technology
- ✓ Involves students in using an engineering design process
- ✓ Engages students in working in collaborative teams
- ✓ Reinforces relevant math and science standards
- ✓ Allows the development of digital skills, problem solving skills, critical and analytical thinking, and innovative strategies of students.

4. How to use the STEM Labyrinth App

4.1 What is the content of the Mobile app and how to access it

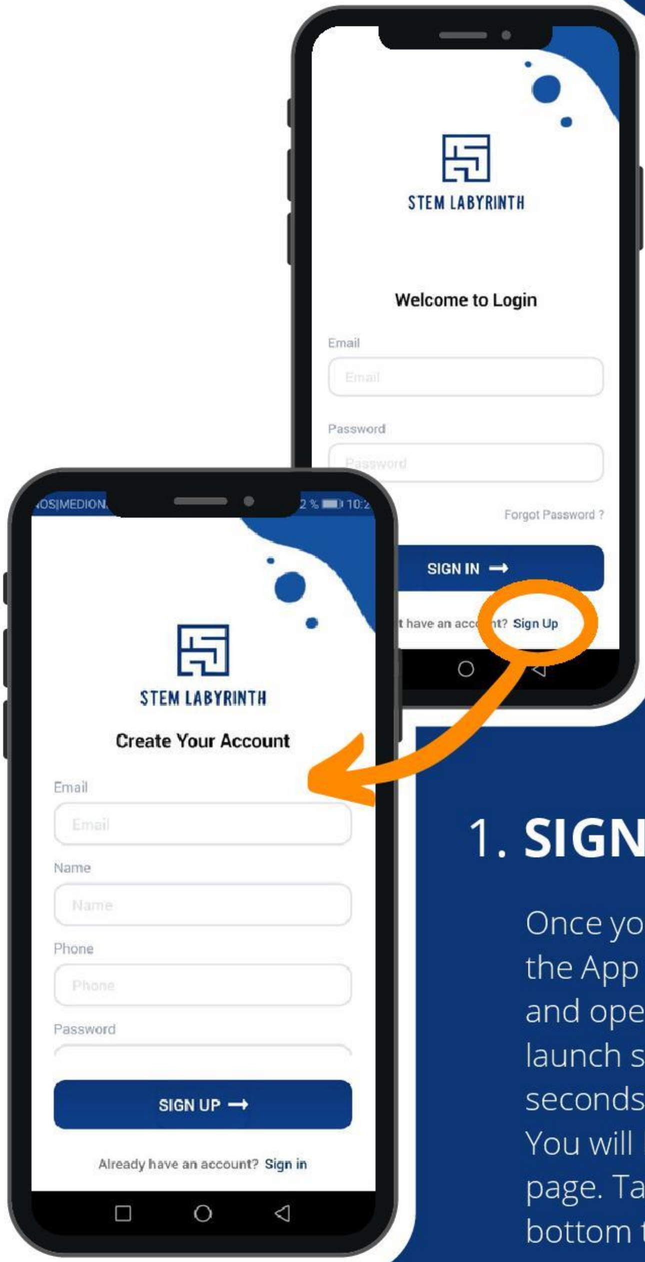
STEM LABYRINTH

APP
USER GUIDE

Welcome to the User Guide of the 'StemLabyrinth' App!

This App is a virtual simulator of real-life problems helping Students to gain knowledge through problem solving.
It will challenge them with the goal of them gaining problem solving skills for their future lives.
Through providing clues at certain stages, as well as a step-to-step approach, the app intends to increase motivation and the students' understanding of the problem.

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



1. **SIGN UP** & LOG IN

Once you have downloaded the App from your App Store and opened it, you will see the launch screen for a couple of seconds.
You will land on the Login page. Tap on 'Sign up' on the bottom to create your own account.

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

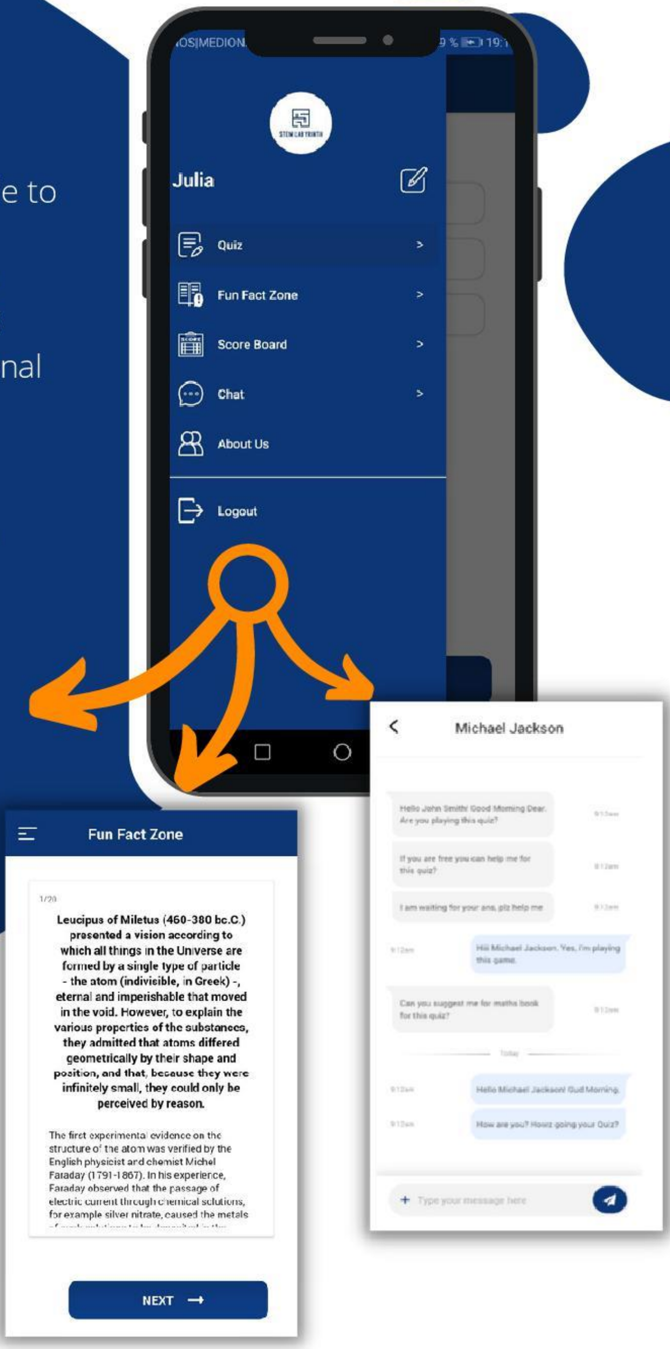
STEM LABYRINTH

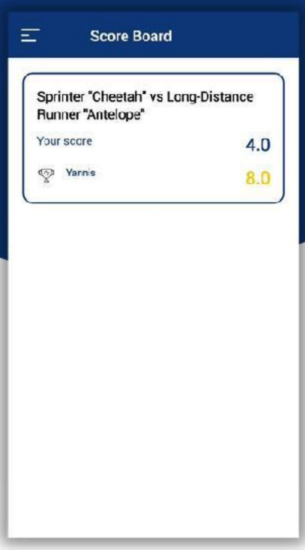
APP USER GUIDE

2. THE **MENU**

From here you will be able to access:

- The main **QUIZ** page
- scientific **FUN FACTS**
- insight on your personal **SCORES**
- a **CHAT** platform for students to discuss problems with fellow students

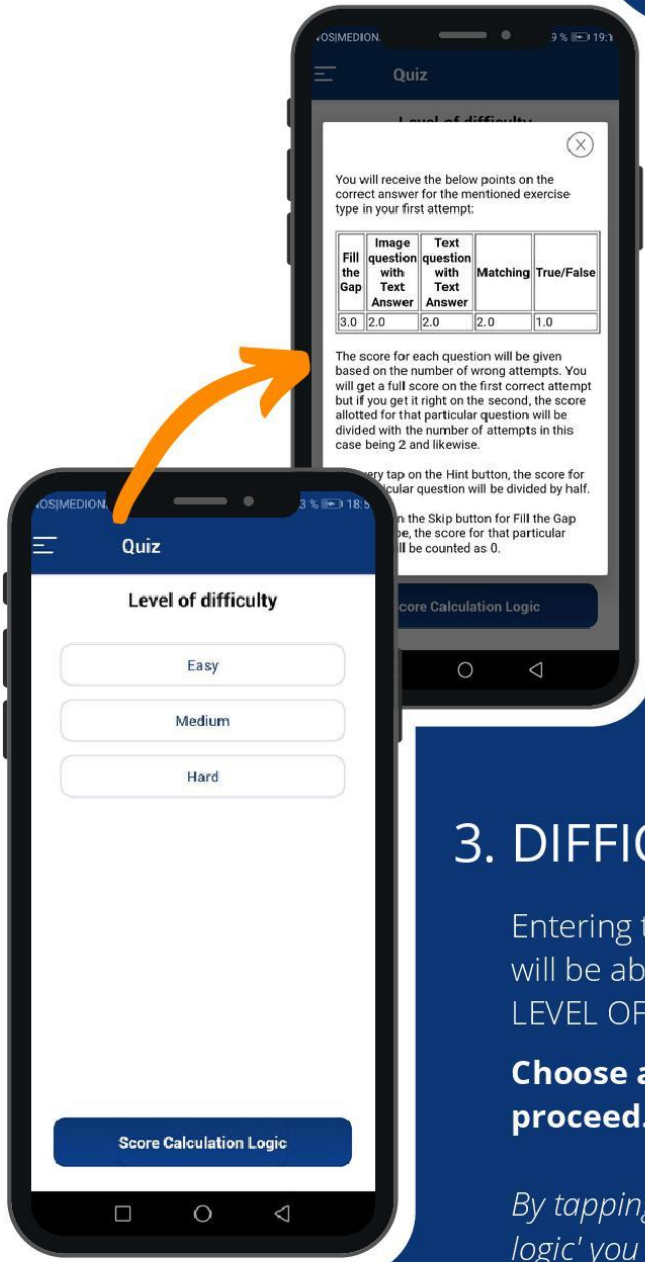




Co-funded by the Erasmus+ Programme of the European Union

STEM LABYRINTH

APP
USER GUIDE



3. DIFFICULTY LEVELS

Entering the Quiz Mode, you will be able to choose your LEVEL OF DIFFICULTY.

Choose and press NEXT to proceed.

By tapping 'score calculation logic' you can get insight on how the scoring algorythm is set up.

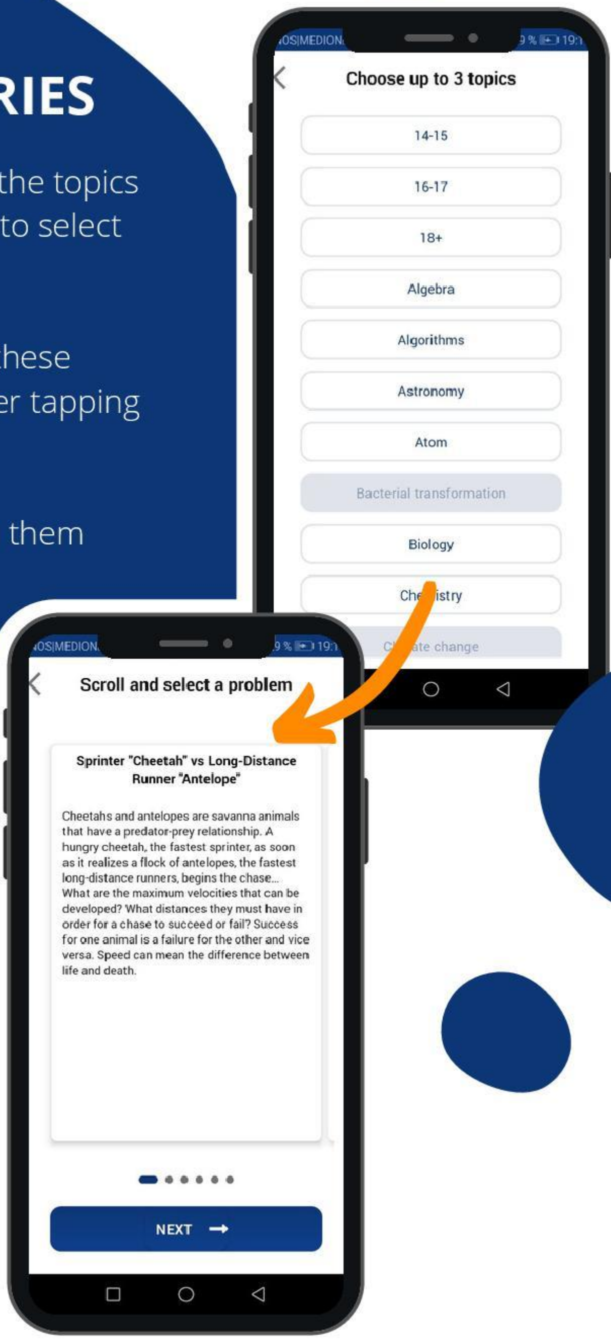
Co-funded by the Erasmus+ Programme of the European Union

4. THE **CATEGORIES**

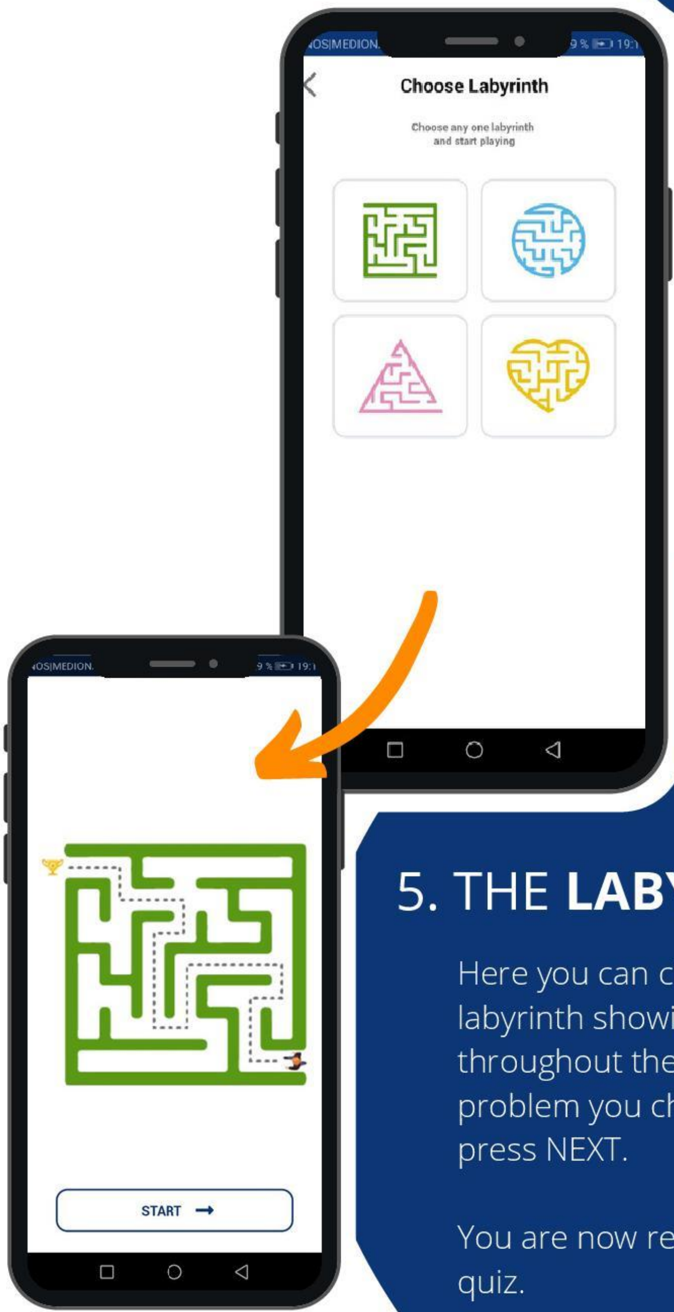
You will see a list of all the topics available. You are able to select up to 3 topics.

The quizzes matching these keywords will show after tapping NEXT.

You can swipe through them and read a short introduction to each of its topics. Select the quiz you want to take and press NEXT.



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



5. THE **LABYRINTH**

Here you can choose the layout of the labyrinth showing your progress throughout the process of solving the problem you chose. To continue press NEXT.

You are now ready to START your quiz.

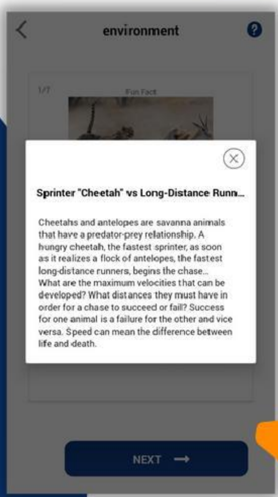
Co-funded by the
Erasmus+ Programme
of the European Union

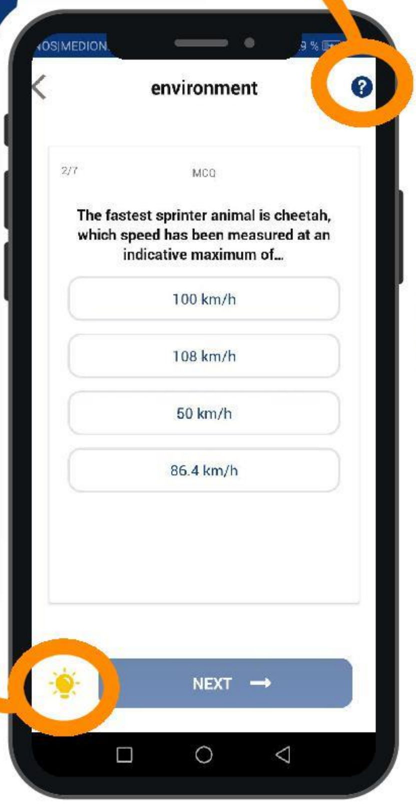
6. SUPPORT TOOLS

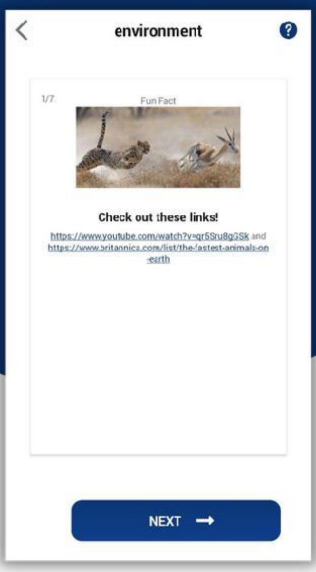
Click on this symbol to revisit the content of your chosen problem

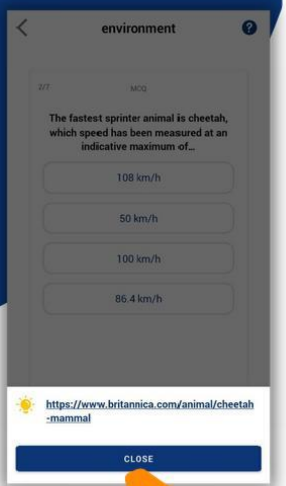
Click here to get a HINT that will help you finding the solution

Sometimes also a FUN FACT will appear throughout the quiz

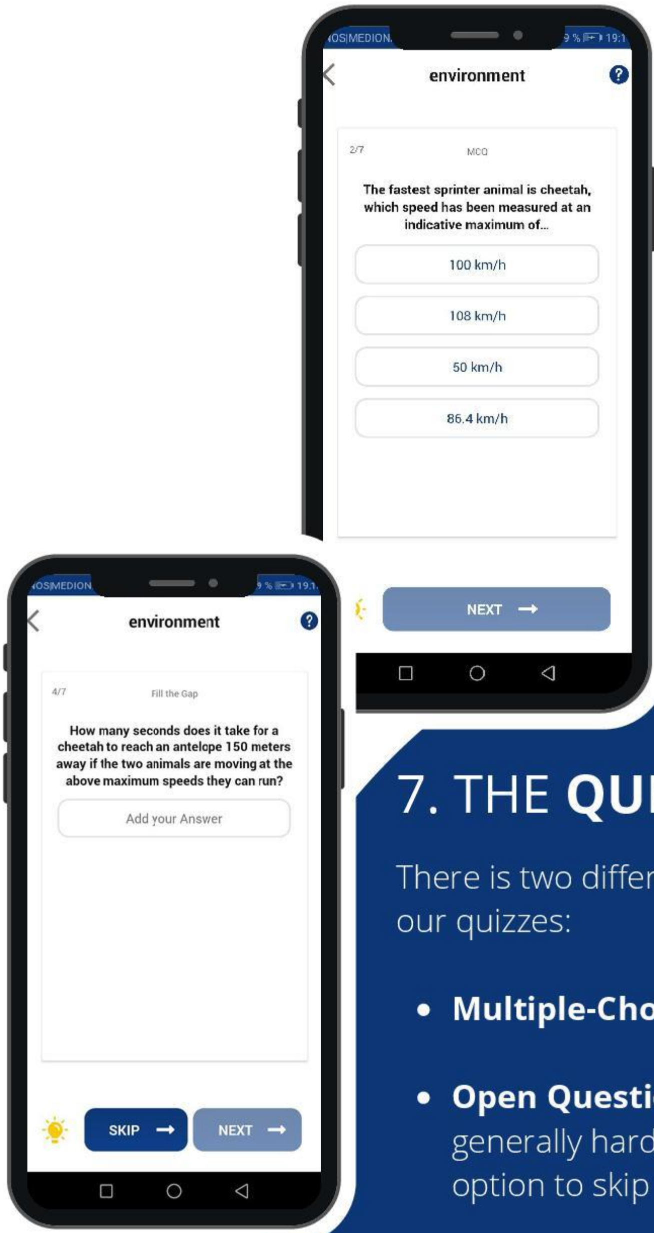








Co-funded by the
Erasmus+ Programme
of the European Union



7. THE **QUESTIONS**

There is two different types of questions in our quizzes:

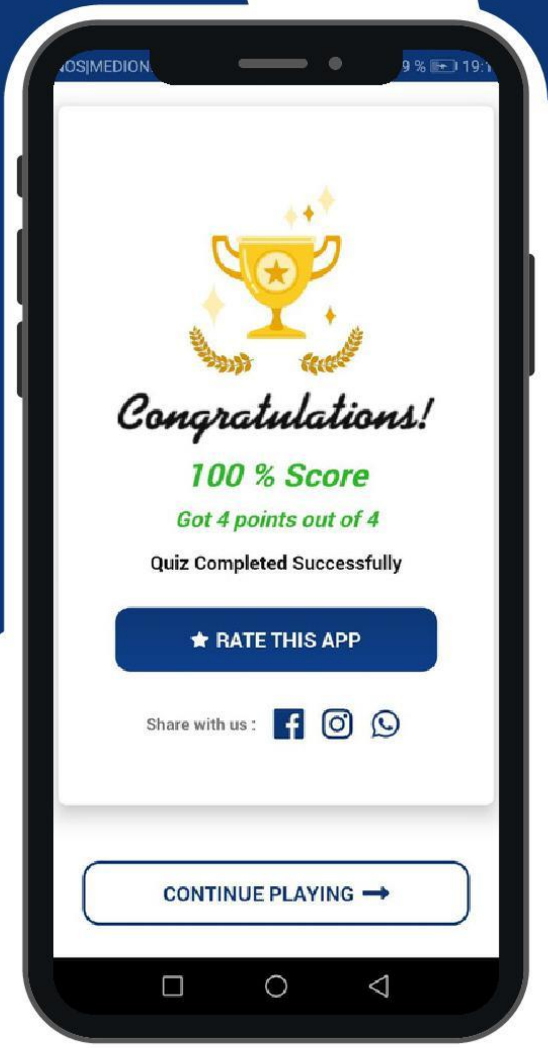
- **Multiple-Choice-Questions**
- **Open Questions** - as these are generally harder to answer, there is the option to skip them.

TIP: *Have a notebook at hand to keep track of your solutions, as sometimes you need them for further questions.*

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

8. FINAL STEPS

Once you have finished the quiz, you can view your score and students will also be able to share it with former students via social media.



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

STEM LABYRINTH

APP
USER GUIDE

HAPPY
LEARNING!

more info about the project:

@STEMlabyrinth

https://stemlabyrinth.com/

The project is financed by Erasmus+ KA2:
2020-1-PT01-KA201-078645

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

4.2. How the *STEM Labyrinth* method and its Mobile App can be used in the teaching and learning process

The modern information society has brought a constant and vast amount of information, in which it is becoming increasingly difficult to orientate. Abundance of information leads to fragmentation of knowledge. Therefore, the creation of a holistic view of knowledge becomes important. The integration of knowledge is an important issue both in terms of the specialization and explosive growth of knowledge and the social impact of rapidly evolving technology (Taba, 1962: 189). Specialized scientific knowledge, which ends in a profession, subject or discipline, is insufficient for the orientation of the individual in the complexity of the world from the point of view of education (Gustavsson, 2000: 80). Today, it is not enough to learn certain things; the ability to see developments and their alternatives, the ability to perceive and solve problems, the ability to make choices and make decisions becomes necessary.

According to J. Dewey, one of the founders of 20th century progressivism, real learning lies in the ability to solve problems related to real life (Krull, 2001: 379). The prerequisite for knowledge and education is considered to be human activity or, in other words, knowledge is inherently active (Gustavsson, 2000:18). For J. Dewey, learning was a collective process because all human experience is social, requiring communication and discussion (Hytönen, 1999: 19).
A student is an active participant in the learning process, who is capable of taking part in figuring out the purpose of their learning, studying independently or together, learning to evaluate and evaluate their peers, analyzing and managing their learning process. In planning and carrying out the training, knowledge and skills are used, among other things, in the real situation, research is carried out and links to non-school life in different fields, opportunities for learning and coping in different social relationships are created, methods of active learning are used.

It is becoming increasingly difficult to attract the attention of young learners using traditional learning methods. Social media and games due to their varied content and quick feedback are much more engaging than traditional learning.

A game-based learning method can be used as one of the ways to engage learners more effectively today. This will increase the student's interest in the content of a subject and learning activities, increase the learning motivation of each student, and provide quick feedback. Game-based learning is interchangeable and offers freedom of choice for both a teacher and a student, supports players' internal motivation, presents challenges, is engaging in visual design, compatible and comprehensive content.

The STEM Labyrinth method and the Mobile App offer students and teachers the opportunity to bring together knowledge and skills to solve problems through different situations in real life. Students must associate their theoretical knowledge acquired in the course of their studies with the skills they need in real life in order to resolve their tasks. In addition to everything, it is a game-based personalized learning opportunity that can be seen as an approach for which every learner is important. Learning opportunities are equal for all, regardless of learning skills or learning motivation. Students can choose between the problem tasks of different subjects based on the level of difficulty: easy, medium, difficult.

In summary, the benefits of using the STEM Labyrinth method and the Mobile App for a student as an active participant in the learning process can be described as following:

- **developing skills to solve real life problems;**

In everyday life, people have to solve problems in different forms, they can be either simpler or more complicated, more predictable or more unexpected. All problems need a solution and a process of resolution. The ability to solve problems is actually the ability to decide.

Examples of problems that need to be solved in the app:

[1]Mike has recently visited an optometrist. He was strongly recommended to start using glasses because his ability to see further objects had reduced. Inability to see further is also called short-sightedness or myopia.

[2]Kate and Laura are planning a trip to England. They know that it rains quite often in England and thereby must take an umbrella. Kate's umbrella is 70 cm long, Laura's 75 cm. Umbrellas cannot be closed. The girls are in the store to buy suitable suitcases, but they don't have their umbrellas with them in the store. They have a choice between three suitcases: A) black which dimensions are 55 cm x 40 cm x 20 cm; B) red which dimensions are 67 cm x 46 cm x 25 cm; C) blue which dimensions are 53 cm x 36 cm x 20 cm.

[3]Sarah is baking an apple pie and because of that she sliced some apples. After a while the slices turned brown. Sarah knows that this process is called enzymatic browning and it happens because of oxygen, an enzyme called polyphenol oxidase (PPO), which is found in apple cells in chloroplasts and polyphenols found in apples. Normally, the PPO and polyphenols in an apple never touch each other. That's why freshly cut apples aren't brown. But when you cut the apple you cause cell damage. And cell damage is what brings PPO and polyphenols together. Cutting or biting also exposes an apple's cells to air, which triggers the oxidation reaction that causes enzymatic browning.

[4]Helen lives in London UK, and her best friend Sarah lives in Toronto, Canada. Because of that, communicating between them is complicated. Why is it so? Both are speaking English and they mostly communicate via the Internet.

[5]The Arctic is the Earth region that lies between 66.5°N and the North Pole. The majority of the Arctic is composed of the Arctic Ocean along with straits and bays, and a drifting ice pack. The Arctic region's climate is very cold and harsh for most of the year due to the Earth's axial tilt. In the winter, the Arctic region has 24 hours of darkness, by contrast in the summer, the region receives 24 hours of sunlight because the Earth is tilted toward the sun. Because the Arctic is covered with snow and ice for much of the year, it also has high albedo or reflectivity and thus reflects solar radiation back into space. Antarctica is a cold and enchanting continent at the South Pole of the globe, which is covered in ice. This ice makes up 70% of the world's freshwater resources. It is the highest continent in the world.

- **relating the material learned to real-life situations;**

In the problem tasks found in the app, it is possible to solve/associate different situations based on the material learned in class.

Examples of tasks that can be found in the app:

[6]It was a night. Stars could be seen. Tom, Mike, and their friends stood outside and observed the celestial bodies in the sky. They had a telescope and smartphones in their pockets. They found out that both the Moon and the smartphone give light. Where do they get the light from?

[7]*The boys got a task to mow the lawn of a football pitch before the game starting at 19.00. Will they get the task done on time if they begin at 17.00?*

[8]*Many biologists say that viruses are not alive, because they don`t have all seven characteristics of life. In modern biology viruses are often considered to be in the gray area between living and dead. Think about viruses and characteristics of life and decide. Do you agree with biologists?*

[9]*Caffeine is a stimulant and the most commonly used drug in the world. Caffeine is found in coffee beans, tea leaves and even in cocoa. The average lethal dose of caffeine for a grown up person is considered to be about 0.2 g per kilogram body weight. The average cup of coffee contains about 100 mg of caffeine.*

- **integration of different subjects in tasks;**

Mathematics is one of the most important subjects which provides prerequisites for learning other subjects. The previously acquired knowledge in mathematics is needed when solving problems in chemistry, physics, biology, and geography. For example, chemistry mainly uses percentage calculation and calculations based on proportional dependence (calculations according to reaction equations) in calculation tasks, as well as presenting data in graphs and diagrams, which have already been discussed in mathematics.
The following math skills are used in physics: calculating percentages, expressing a variable, systems of equations, vectors, operations with powers, operations with fractions, etc.

Here you can see examples of tasks in the app:

[10]***Mathematics, geography, and physics** - The students are on a school trip to the Hungarian capital Budapest. On the last day they decide to take a boat trip along the river Danube to the town Visegrad, which is 50 km away. The average speed of the boat is 35 km/h, not considering the flow of the river. Note that the river is flowing at a speed of 6 km/h and Visegrad is the first stop after Budapest. Will the students be back at 5pm if they start their journey at 11am, visit a fortress, have a meal and spend a total of 3 hours in Visegrad? The boat will return at 15.50.*

[11]***Biology, chemistry** - Anemia occurs when you have decreased level of hemoglobin in your red blood cells. Hemoglobin is the protein, which is responsible for carrying oxygen to tissues. The most common type of anemia is iron deficiency anemia. It is caused by low iron levels in the body. To treat iron deficiency anemia, it is necessary to take food supplements, which contain iron salts.*

- **tasks of varying difficulty;**

Each student can choose a task according to their abilities or challenge themselves by solving a more difficult problem.

For example:

[12]***easy** - Tom and his friend Mike were swimming in the sea. They looked at the boat nearby and were curious how it could stay on the water.*

[13]***medium** - The most common cause of mercury (Hg) poisoning is from consuming too much Hg, which is linked to eating seafood. For example tuna fillet contains 0.39 milligrams mercury per*

kilogram. For an average human it is safe to consume 1.30 micrograms Hg per one kilogram of body weight. An average person weighs 72 kg.

[14]***hard**- Marcus had a walk on the arch bridge in the city of Tartu. He admired the bridge and was curious how tall were the highest and the shortest posts of the bridge. He found out on the Internet that the highest point of the bridge is 8 meters and the width of the river Emajõgi is approximately 90 meters. He also found out that there are 12 posts. Help Marcus find out how many times the highest post is higher than the shortest post.*

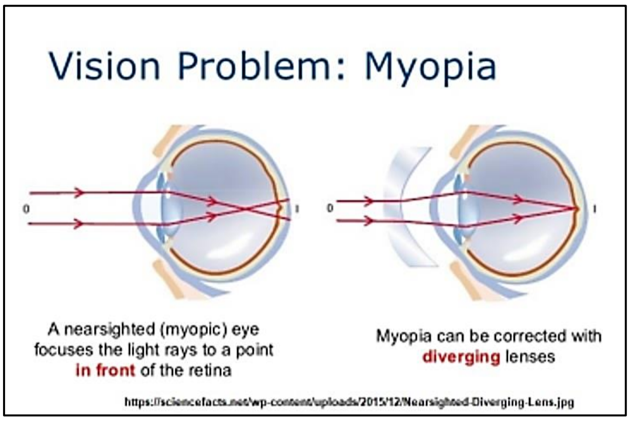
- **the ability to use the app on many sides - at school and at home, for study, but why not also for useful recreational furnishings - to repeat/consolidate different subjects;**

- **playful;**

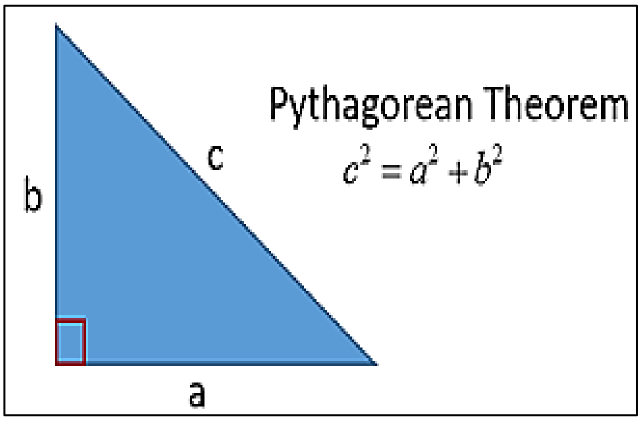
The app is built on the principle of a game. When you open the app, you can choose the level of difficulty and age of solving the problem. On the basis of a keyword, it is possible to find problems by field. When solving tasks, a playful maze is used to move from one question to another. In case of trouble, it is possible to use a hint. The assignments also contain fun facts that broaden the student's horizons.

Examples of funfacts:

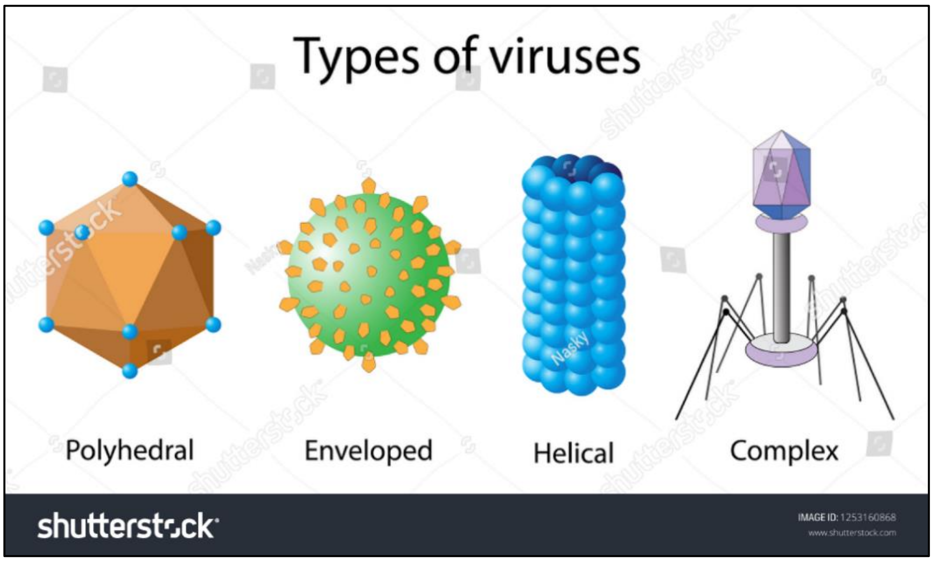
[15]



[16]



17

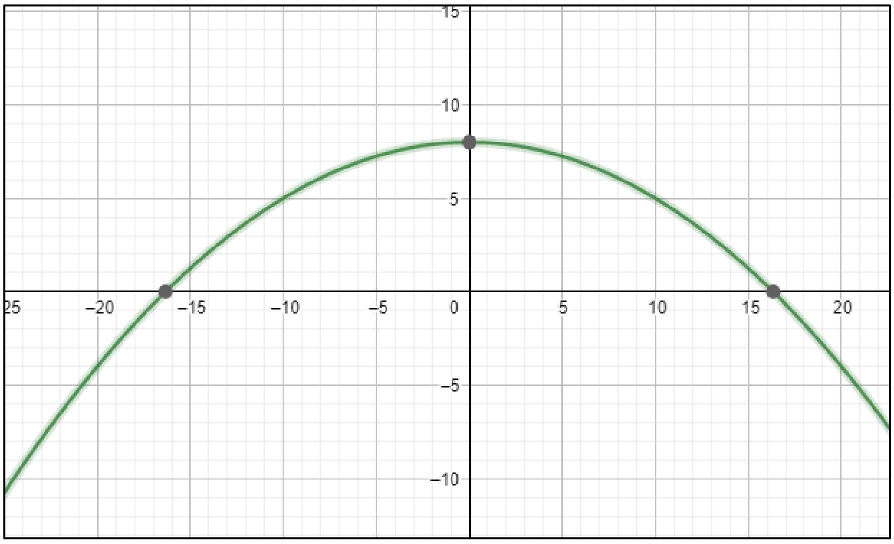


- **visualized;**

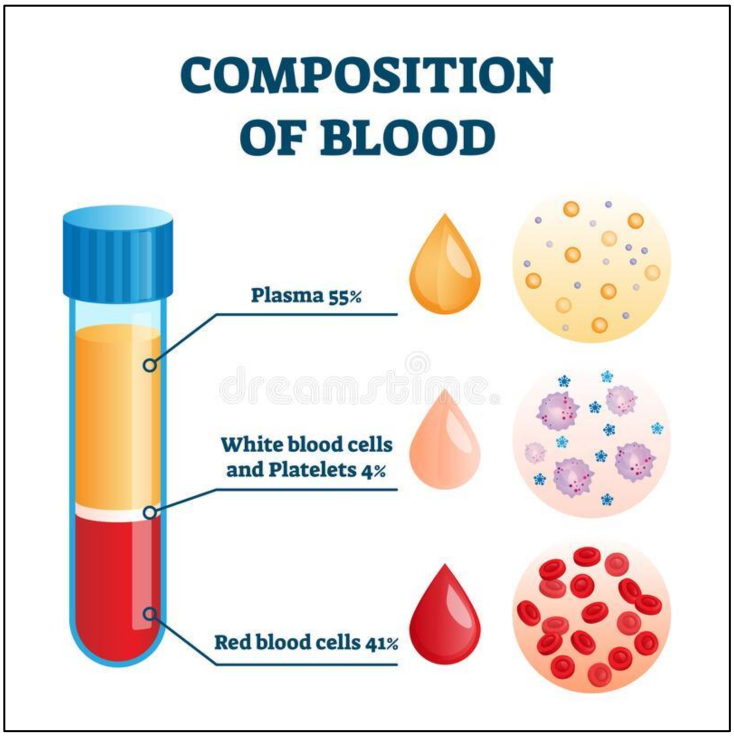
Various schemes have been used to illustrate the tasks, drawings that help explain the material. Added videos for viewing.

For example:

18



19



20

	Group A	Group B	Group AB	Group O
Red blood cell type	A	B	AB	O
Antibodies in plasma	Anti-B	Anti-A	None	Anti-A and Anti-B
Antigens in red blood cell	A antigen	B antigen	A and B antigens	None

- **quick feedback to the student and teacher.**

At the end of solving the task, the student and the teacher receive quick feedback in the form of percentage of correct answers.

It is also possible to go back to the beginning if you answer incorrectly three times, or to repeat the material of the current topic and then start solving the task again.

Learning in this way should be interesting for students, challenging, focused on real-life problems and providing a sense of security, so that nothing bad will happen even if the correct answer is not reached - in this case, one should simply analyze the mistakes, reflect on what has been learned, and solve the task again. After all, making a mistake is one of the best learning methods, it helps you learn with deep understanding through the analysis of your mistakes. Learning is the courage to be wrong, which in turn supports creativity, gives experience and courage to solve life's problems and the ability to find the necessary information and evaluate its correctness.

4.3. Ideas for finding/ exploiting/ adapting/ extending the content of the App according to the needs of students and teachers in approaching a topic

1. Finding content

The tasks in the app are divided as follows. Firstly, by the level of difficulty: *Easy, Medium, Hard.* The tasks in the app can be found by age: *14-15, 16-17, 18*. To find the tasks, you have to choose the subject you like / need from the following: *Biology, Chemistry, Information Technology, Mathematics, Science, Physics.* Subcategories have also been included within the subjects. For example, to find a problem for the Pythagorean theorem, the following options must be made: *Easy/Medium/Hard, 14-15, Math, Geometry*. Or, if you want to solve problems about Covid-19, you should search for the keywords *Biology - Viruses* after determining the difficulty level and age. A lot of problems are integrated between different subjects. For example: a problem titled *Swimming in the sea* has content in both *physics and math*.

All possible keywords you can use are collected into the following table:

SUBJECT	CATEGORY	AGE
Math	Geometry; Equations; Functions; Trigonometry; Proportions; Logarithms	14-15 16-17 18+
Science	Climate change; Global warming; Renewable energy; Environment; Sustainability	
Chemistry	pH; Atom; Organic compounds	
Physics	Mechanics; Kinetics; Motion; Newton laws; Astronomy	
Biology	Reproduction; Genetics	
Information Technology	Programming; HTML; Passwords; Algorithms	

2. Use of Content

The tasks in the app can be used to consolidate what has been learned in school lessons (see section 4.5) to show that what is learned in theory is useful in real-life situations.

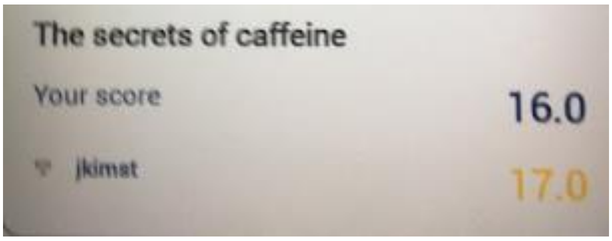
For example: In physics lessons the 8th graders learn about buoyancy. After the theory and the different types of experiments it is good to give to the students the tablets and let them solve the next problem: *Tom and his friend Mike were swimming in the sea (Physics, Math, Mechanics, 14-15). They looked at the boat nearby and were curious how it could stay on the water.* First questions: *Mike had heard that there is a certain force which keeps some bodies at the surface. What is it called?* and *What is density?* help students memorize the theory and next questions: *Tom cannot float on the water. He thinks that he is too heavy. What is the weight in kg that ensures that he stays on the water surface?*

He weighs 70 kg, the average density of the human body is 1100 kg/ m^3, the density of seawater is 1020 kg/ m^3. and there *was one person In the boat that boys saw. What is the maximum amount of people that the boat could carry? The volume of the boat is 2 m^3, the weight of the empty boat is 500 kg and the density of seawater is 1020kg/ m^3. Assume that each person weighs 75 kg,* let students practice their ability to calculate.

It is also possible to assign tasks in the app to students for homework. Since all the tasks also contain the necessary clues as well as interesting facts, why not give these tasks for independent study before learning a new topic.

For example, a problem titled *Choosing suitcases* (Medium, Math, Geometry, 14-15) starts with the Youtube video about Pythagorean Theorem https://youtu.be/gRf780Pce7o. After watching the video it is easy to understand the connection between legs and hypotenuse in the right triangle and find solutions for all questions in this problem like: *How long is the longest possible diagonal of a face in millimeters?* or *How long is the diagonal of the suitcase in centimeters?*

The app is built on the principle of a game, a student collects points for solved tasks, therefore it is possible to conduct an intra-class or inter-class competition. Results are given by problems. Each student can see his/her own result in comparison to the other user's results. See on the picture given below:



3. Content customization

All tasks in the app are free to use and modify so that all app users can make copies of tasks. All tasks given here in the app are free to print out or use them in presentations, books, etc.

It is possible to make corrections to the content of the copied tasks: add or remove questions, replace removed questions with the ones you have created, change the types of questions, for example, replace true / false by typing an answer instead. You can also make changes to answers of questions, change their options, add or remove them.

The problem called *Biology of viruses: are viruses alive or dead? Many biologists say that viruses are not alive, because they don`t have all seven characteristics of life. In modern biology viruses are often considered to be in the gray area between living and dead. Think about viruses and characteristics of life and decide what you think. Do you agree with biologists?* begins with this fun fact: *The word is from the Latin neuter vīrus referring to poison and other noxious liquids.* All of you are free to create your own problem based on this, by copying it and adding more interesting facts, if you have.

4. Content development

There are currently over 100 different problems in the app, most of them in Math and Physics. In order to further develop the content, a register of existing tasks should be kept in order to get an overview of which tasks in the field of STEM would be most needed. One way to further develop the content would be to translate all the tasks into different languages.

The course for STEM teachers is a good way for adding more problems into the app.

4.4. How the teacher can create his/her own problem scenarios based on STEM Labyrinth Method and other resources according to their needs and the needs of the students

The glossary in our every-day activities contains many words such as **time, length, height, area, speed, acceleration, weight, force, power**, **temperature, substance, light,** and many other words that are common to the scientific subjects (STEM). We can read, say, see, listen, watch, write these words in any form of our communication. We use these words very often. In everyday life, they have a wide range of meanings. In science, they have a specific meaning. Most of the **100 problems** using the STEM Labyrinth methodology, developed by the project partners, contain these words. These words are precisely related to our daily lives, but also related to the STEM concepts, and they are important for solving these problems.

From the above words, we will select the following **two basic groups**, with particularly frequent reference to the problems, constituting the cognitive base of STEM approaches. We create a table with the meanings of words in every-day life and their scientific correspondence, so we can observe similarities, differences and conflicts.

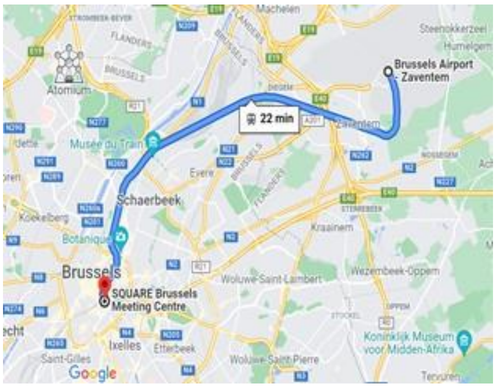
The **first group** is related to spatial concepts or quantities: ***length, width, height, depth, distance, displacement, perimeter, circumference, area, volume***.

These concepts dominate our daily life in many forms. These include the length of a car, the height of a mountain, the depth of a lake, the length and width of a screen. The distance in kilometers, the distance from a planet, the circumference of a circle, the area of a room or a lake, or the volume of a bottle (with their meters, their square meters and liters or cubic centimeters). Velocity and acceleration are derived from length and time (they we will not be mentioned here, but in the problems in the following section). The meanings of the above quantities are shown in the following table (definitions from www.dictionary.com & scienceworld.wolfram.com/physics).

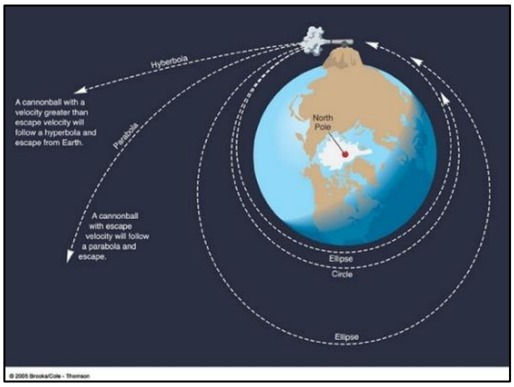
Word	Every-day life meaning	Scientific definition
length	- the longest extent of anything as measured from end to end - the measure of the greatest dimension of a plane or solid figure	- the straight-line distance between two points along an object
width	- extent from side to side; breadth; wideness - a piece of the full wideness, as of cloth	- the horizontal distance from side to side
height	- distance upward from a given level to a fixed point - considerable or great altitude or elevation	- the vertical length of an object from top to bottom
depth	- a dimension taken through an object or body of material, usually downward from an upper surface, horizontally inward from an outer surface	- the extent, measurement, or dimension downward, backward, or inward
distance	- the extent or amount of space between two points, lines, etc. - a linear extent of space	- the extent, measurement, or dimension downward, backward, or inward
displacement	- the act of displacing - the state of being displaced or the amount or degree to which something is displaced	- a vector, or the magnitude of a vector, that points from an initial position to a subsequent position (Physics)
perimeter	- the border or outer boundary of a two-dimensional figure. - the length of such a boundary	- the sum of the lengths of the segments that form the sides of a polygon or the total length of any closed curve
circumference	- the outer boundary, especially of a circular area; perimeter - the length of such a boundary	- the boundary line of a circle - the boundary line of a figure, area, or object

area	- any particular extent of space or surface - a geographical region;	- a measurement of the size of a surface (expressed in square units)
volume	- the amount of space, measured in cubic units, that an object or substance occupies. - a mass or quantity, especially a large quantity, of something:	- the amount of space occupied by a three-dimensional object or region of space (expressed in cubic units) - a measure of the loudness or intensity of a sound.

We notice that we do not have significant inconsistencies between scientific meanings and the meanings of our daily life. Surely, the scientific definitions are more clearly defined.



www.google.com/maps/place/Bruxelles



isaacnewtonresearchanaloira.weebly.com/inventions.html

The **second group** is related to the concepts of ***mass, weight, force, energy and power***, which dominate our lives, having today a more dynamic presence.

The concept of mass, is confused with the weight of a person or a food. The concept of energy, that especially nowadays has multiple and varied significances, also appears every moment in our life, e.g. in all food packaging, with "Nutrition Labeling" it is mandatory to refer the kJoules/calories). Energy and power are also related to every form of consumption or production, to household appliances, to cars, to mobile phones, to the measure of radiation of a transmitter (e.g. a television station with a power transmission) etc. Power also characterises humans!

Word	Every-day life meaning	Scientific definition
mass	- a body of coherent matter, usually of indefinite shape and often of considerable size - a collection of incoherent particles, parts, or objects regarded as forming one body	- a measure of the amount of matter contained in or constituting a physical body. In classical mechanics, the mass of an object is related to the force required to accelerate it
weight	- the amount or quantity of heaviness or mass; amount a thing weighs - a system of units for expressing heaviness or mass:	- the force with which an object near the Earth or another celestial body is attracted toward the center of the body by gravity
force	- physical power or strength possessed by a living being - strength or power exerted upon an object; physical coercion; violence	- any of various factors that cause a body to change its speed, direction, or shape (force is a vector quantity, having both magnitude and direction)
energy	- the capacity for vigorous activity; available power - the ability to act, lead others, effect, etc., forcefully	- the capacity or power to do work, such as the capacity to move an object (of a given mass) by the application of force (exists in a variety of

		forms, e.g. electrical, thermal, mechanical, etc, and can be transformed from one form to another
power	- ability to do or act; capability of doing or accomplishing something - political or national strength	- the source of energy used to operate a machine or other system - the rate at which work is done, or energy expended, per unit time - the number of times a number or expression is multiplied by itself, as shown by an exponent (Maths)

We notice, for instance, that the everyday life meanings of mass-weight and energy-power have inconsistencies with the scientific ones (e.g. force is physical power *whereas* power is the ability to act forcefully!)

We can identify many interesting problems related to our daily life, based on the above initial ideas, the previous and next chapters of these Guidelines, all the materials produced by the project, and searches in the literature. These problems can be included into the school curriculum and designed as STEM problems, with the methodology described in the previous sections. Mainly each problem can be divided into sub-problems, by asking questions with different types, in a gamification approach.

The three Partner Schools from the consortium (Martna-Pohikool, Agios-Georgios and Doukas School) developed **60 problems that contain about 500 Questions and "Fun-Facts"** for all the STEM Subjects and their combinations (see ANNEX 1). **The total problems are 100** with the contribution of the "non-School" partners. An indicative list of such problems either real or hypothetical (e.g. thought experiments), which teachers and researchers developed in a creative way, is given in the following table. You can navigate to these problems using the STEM app by giving the corresponding ***Level, Subjects, Sub-subjects and Ages***.

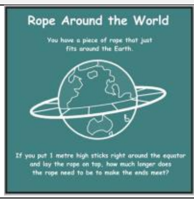
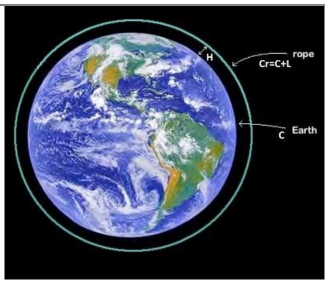
Examples of 15 problems from the 100 of the STEM Labyrinth Mobile App

#	Level	Subjects, Sub-subjects, Ages	Title	No of Quest.
D14	easy	Algorithms#Programming, 14-15	Exploring the code of a robot game	10
M12	medium	Biology#Genetics, 16-17	Adopted chilld	8
M16	easy	Biology#Viruses, 16-17	Biology of viruses: are viruses alive or dead?	14
M19	hard	Chemistry#Organic compounds, 16-17	The secrets of caffeine	11
M11	medium	Chemistry#Organic compounds, 16-17	Mercury in our food	8
M13	medium	Chemistry#pH, 16-17	Is it acidic, alkaline or neutral?	12
D15	easy	Math#Algebra#Proportions, 14-15#16-17	The mean, the median and the mode of the salaries of two companies	10

G08	easy	Math#Algebra, 16-17	Geometric Sequence in calculating virus cases of COVID-19	5
G20	easy	Math#Functions, 14-15	Sound Intensity	6
D03	medium	Math#Geometry#Algebra, 14-15#16-17	Traveling to five European cities	7
D06	medium	Math#Geometry#Algebra, 14-15#16-17	Distribution of spectators in a concert hall following safe social distancing rule	11
G02	medium	Math#Geometry, 14-15	How to Measure the Height of a Tree	7
G16	medium	Math#Geometry, 14-15	Oil Film Experiment	6
G19	hard	Math#Geometry, 16-17	Whispering Galleries	7
G12	easy	Math#Proportions, 14-15	Medical Math	6
G13	easy	Math#Trigonometry, 14-15	The Cruises	5
D10	easy	Physics#Algebra#Environment, 14-15	Cheetahs - sprinters vs Antelopes - runners	7
M03	easy	Physics#Astronomy, 14-15	Which are light sourses	7
M05	medium	Physics#Geometry, 14-15	Choosing glasses	7
M04	medium	Physics#Math#Mechanics, 14-15	Electric bike versus car	6
G15	medium	Physics#Mechanics, 14-15	The physics of volleyball	5
G06	easy	Physics#Motion, 14-15	Rate of Travel	6
D08	easy	Physics#Motion, 16-17	The scale of the astronaut	9
D16	medium	Physics#Motion, 16-17	Newton's cannonball	10
D07	medium	Physics#Motion, 16-17#18+	The motion of a cyclist	9
D17	medium	Physics#Motion, 16-17#18+	The Tesla Roadster and its space passengers	8
G10	hard	Physics#Newton laws, 16-17	The gravity of a planet	7
D11	medium	Science#Geometry#Algebra, 14-15	Eratosthenes' method for the Earth's circumference	8
M20	medium	Science#Climate change, 14-15	Arctic and Antarctic - Comparisons & Similarities	11
M14	easy	Science#Functions, 14-15	Friend from another time zone	10

An example of a problem is presented at the next page. We can categorize these problems and their questions in different types. These categories will be described at the next section.

Sample STEM Labyrinth Problem

Problem Tittle	From the ancient "rope around the Earth" to the modern "orbit of the ISS"!		
Difficulty level, Topics, Ages	Easy, Science-Math-Geometry-Algebra-Astronomy, 14-15		
Problem Description	There are two different problems, an ancient and a modern, with common concepts. We are looking for sizes related to circular orbits around the circumference of the Earth, whether they are very close to it, e.g. at one meter away (such as the "rope around the Earth") or they are far, e.g. at 400 kilometers (such as the orbit of the ISS)!		
Question Type	**Question** (Sub-problem)	**Hint** (help)	**Answer(s)** (correct the 1st)
Fun Fact	Read the details about the ancient problem of "rope around the Earth" that first appeared in W. Whiston's "The Elements of Euclid" 1702, posed by Euclid 2,300 years ago! https://mathimages.swarthmore.edu/index.php/Rope_around_the_Earth Study the "Conundrum 17" problem: https://www.abc.net.au/science/surfingscientist/pdf/conundrum17.pdf		
True/ False	The perimeter of a circle (circumference) is $2\pi R$	R is the radius of the circle	True
Multiple Choice	Suppose a rope was tied taut around the Earth's equator. It would have the same circumference as the Earth (C=40,075 km). By how much would the rope have to be lengthened so that, if made to hover, it would be one meter (H=1 m) off the ground at all points around the Earth? How meters is this lengthening (L) of the length of the rope (Cr=C+L)? 	*Earth's circumference:* C=2*π*R (R: Earth's radius) *Lengthened rope:* Cr=C+L=2*π*(R+H) =2*π*R+2*π*H =C+2*π*H, *therefore:* C+L=C+2*π*H => L=...	• 6.28 m • 6.28 km • 40,078 m • 40,076 km
Fill the gap	Suppose that a super-drone travels, without stopping, around the equatorial circumference, which is 40,075 km, with a constant velocity of 150 km/h. How many days will be required, approximately, to travel around the circumference? Give a 2-digit number, rounded to the nearest integer:	The circumference is divided by the velocity to find the total hours, and the hours are converted to days	11
Fun Fact	What is the International Space Station (ISS)? It is a large spacecraft in orbit around Earth. It serves as a unique science laboratory, where crews of astronauts and cosmonauts live. Several nations worked together to build and use the space station. https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-the-iss-58.html		
Fill the gap	The ISS orbits Earth at an average altitude of approximately 250 miles (A=~400 km). How many kilometers is the circumference-orbit of the ISS, around the equatorial circumference, if the equatorial radius is 6378 km? Give a 5-digit number, rounded to the nearest integer.	Circumference: 2*π*Ra Ra: sum of the earth radius + A (400) km	42566
Fill the gap	If ISS travels at a speed of 28,800 km/h, how minutes does it take, for the weightless laboratory, to make a complete circuit of Earth, without taking into account the rotation of the earth? Give a 2-digit number, rounded to the nearest integer/decade?	42,566 km divided by 28,800 km/h gives the hours, so convert the hours to minutes	89
Fun Fact	"Where is the International Space Station?" Astronauts working and living on the ISS experience 16 sunrises and sunsets each day. A tracker developed by ESA, shows where the Space Station is. https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station/Where_is_the_International_Space_Station		

4.5. Developing Lessons plans for particular topics by exploiting the Mobile App

Each STEM Labyrinth Lesson Plan (or Learning Plan - LP) contains the following seven fields:

1. **STEM subjects and topics** (related to ages and level of difficulty
2. **Objectives** (related to competences/skills and subjects' concepts)
3. **Methodology** (related to material and needed resources)
4. **Implementation & STEM Labyrinth Problems** (related to specific activities and)
5. **Evaluation & Assessment**
6. **Real-World Application**
7. **Assignments**

The most important decision for the development of a Lesson Plan using the STEM Labyrinth problems of the Mobile App is the effective matching of

- the objectives related to the **STEM subjects, STEM curriculum and Student Ages**, with
- the existing **Problems uploaded to the Mobile App**.

Of course, it is also possible to develop a Lesson Plan with the **STEM Labyrinth Methodology**, creating a **new problem,** based on real-word problems, using different categories of problems and different categories of questions (see next section). In that case there are two options for the designing - create/uploading - delivering of your problems to:

- the **STEM Labyrinth Mobile App**, using the platform that was created by the partners of the project, or
- another existing **Online Gamified Platform for Quizzes** (e.g. Quizizz, Kahoot, Mentimeter).

The "**Implementation**" field, with the systematic description of the activities, is the core of the Lesson, and there are *three main approaches for the creation of sequence of activities*.

In the *1st approach the Teacher choose specific problems from the Mobile App*. An example with the following objectives are:

- to apply knowledge about motion in different situations;
- to use the 2 main quantities *length-time* and the 4 related quantities *distance-circumstance/perimeter-velocity-acceleration;*
- to apply physical & mathematical formulas for the measurement of the previous quantities.

The three problems of real-life and one hypothetical (thought experiment) are:

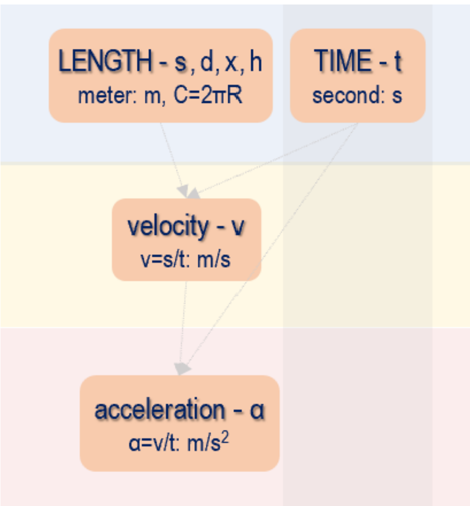
1-2: measurement of circular orbits around the circumference of the Earth, whether they are very close to it (a "rope" at 1 meter) or they are far (such as the orbit of the ISS),

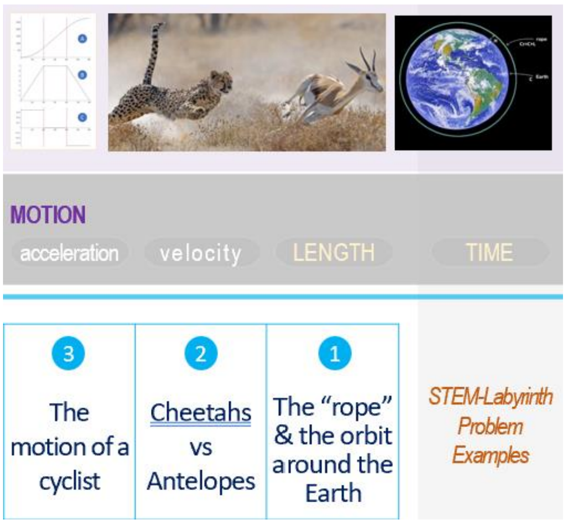
3: experiment with the "fastest sprinter" Cheetah trying to reach the fastest "long-distance runner" Antelopes, 4: movement of a bicycle that starts accelerating, moves at a constant velocity and finally decelerates to stop.

In this case, the *8 Main Activities of the Lesson Plan* "***Moving on the surface or around the Earth***" are:

1. Discussion: What are the common and the different concepts about motion in the above videos? What are the differences between distance and position, about moment, minute and time?
2. ***Play with the App: D12-Problem "From the "rope around the Earth" to the "orbit of the ISS"*** (doc file)
3. Discussion: How quickly our position can change? We can divide distance by time, but we can also divide time by distance? What's the difference? What we decided?
4. ***Play with the App: D10-Problem "Cheetahs vs Antelopes"*** (doc file)
5. Discussion: What distances they must have in order for a chase to succeed or fail? Success for one animal is a failure for the other and vice versa. Speed can mean the difference between life and death.
6. Presentation: What are the safety reminders to keep cyclists safe?
7. ***Play with the App: D07-Problem "The motion of a cyclist"*** (doc file)
8. Discussion: What are the maximum permitted speed for bicycles? What are the speed of satellites? How fast can the speed change? What does this mean? What is the acceleration of satellites?

The activities 2, 4 and 7 are the three Problems of the Mobile App. According to the following diagram, there is a sequence, based on progressive engagement of STEM concepts (something like a path from one concept/quantity to another, with increasing difficult level).





In the *2nd approach the Teacher asks his students to search, find and select suitable problems from the Mobile App*. An example of experiment about Pythagorean theorem with the following objectives are:

- to apply investigative learning methods to solve a problem,
- to use the Pythagorean theorem in real life situations to find solution.

The *5+ "Main Activities" of the Lesson Plan* "***Pythagorean Theorem***" are:

1. The Teacher pairs up the students. 2. The Teacher introduces the activity and the work principle of the STEM Labyrinth app. 3. The Teacher writes on a blackboard or shows with the projector possible problems related to the Pythagorean theorem. 4. Students: - familiarize themselves with the STEM Labyrinth App - find suitable problems for Pythagorean Theorem. Two different problems per pair - solve the problems separately - compare with peer the results they have got - pairs introduce their results to the classmates. 5. The Teacher makes a leaderboard of the three best results taken by using the STEM Labyrinth App *** *For the faster pairs teacher gives extra exercises from* IXL-Geometry

In the *3rd approach the Teacher implements the STEM Labyrinth methodology without using a specific problem from the Mobile App*. An example the students will investigate how to minimize the time needed for a lifebuoy starting from a specific point on the perimeter of a pool to reach a particular point in the pool, with the following objectives are:

- to apply students' knowledge of uniform linear motion in a novel situation
- to learn how to find an optimal solution by solving a minimization problem.

In this case, the *6 Main Activities of the Lesson Plan* "***Lifebuoy saves lives when needed***" are:

Development activities (preparation for practice): 1. Students are divided into groups and asked to formulate thoughts and arguments to make a layout plan 2. Carry out appropriate calculations 3. Decide the procedure that will lead them to the optimal solution sought (for example experimentation) *Practicing activities (guided practice -> free practice):* 4. Students carry out their plan 5. Teacher supervises activity 6. Students work on handout(s) and draw conclusion(s)

Final, the most important materials and resources needed for applying a well-documented Lesson Plan using the STEM Labyrinth App are the following:

- good internet connection
- whiteboard and/or interactive board and/or flipchart
- tablets (one Android tablet per two or three students) with the STEM Labyrinth App installed
- IO3 Guidelines (this document)

- IO4 Learning Modules
- the STEM Labyrinth App with the uploaded Problems

The 3 Schools of the Project (Martna-Pohikool, Agios-Georgios and Doukas School) developed **6 Lesson-Learning Plans** for all the STEM Subjects and their combinations, using some of the problems of the Mobile App (see ANNEX 2). Next you can find the template of the STEM Labyrinth Lesson-Learning Plans, and the Table of "*Short Descriptions of the 6 STEM Labyrinth Lesson-Learning Plans*".

Short Descriptions of the 6 STEM Labyrinth Lesson-Learning Plans

Problem 1	**Swimming of bodies**
Content Areas	Physics, Maths, Technology
Duration of Lesson	2x 45 min
Target grades, Age	8 grade, 14-15
Brief description of the lesson	In the lesson: 1. Conditions of swimming, floating and sinking are introduced. 2. Experiments about gravity and buoyancy are conducted in pairs using a simulator. 3. Problems about swimming bodies are solved by applying a STEM Labyrinth method using an app.
General objectives	- to apply a scientific method to solve a problem - to develops a skill of reading and understanding scientific texts - to get an insight into physics connections with technology - to develop literacy related to science and technology, creativity and systematic thinking
Particular objectives	- to know the following terms: gravity, buoyancy, density, swimming, floating, sinking - to know the formulas for calculating buoyancy and gravity - to conduct experiments using a simulator - to measure, collect and analyse data

Problem 2	**Pythagorean Theorem**
Content Areas	Geometry
Duration of Lesson	45 min
Target grades, Age	9th grade, 15-16
Brief description of the lesson	In the lesson: 1. The short animation about Pythagorean theorem is watched. 2. Exercises about Pythagorean theorem are solved by applying a STEM Labyrinth method using an app.
General objectives	- to apply investigative learning methods to solve a problem; - to use Pythagorean theorem in real life situations to find solution.
Particular objectives	- to know about relations between legs and hypotenuse in a right triangle:

	- to know the formula for calculating measurement of legs and hypotenuse of the right triangle

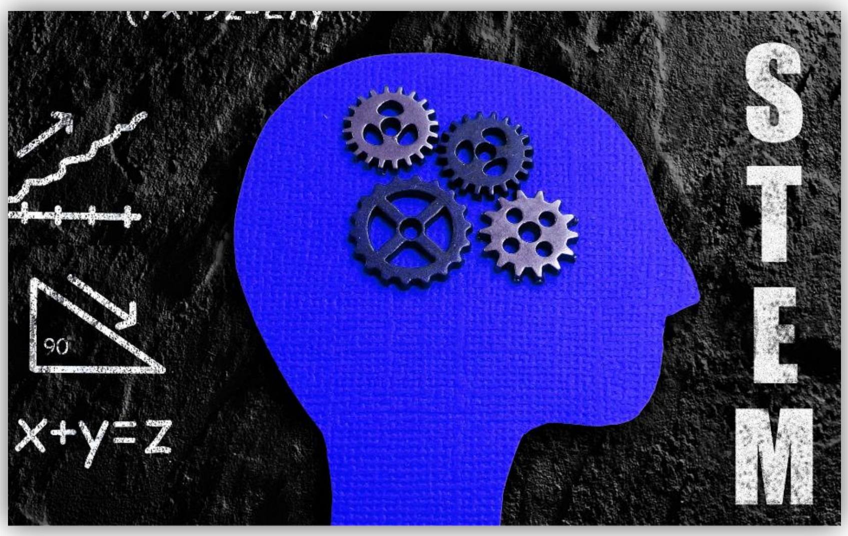
Problem 3	Lifebuoy saves lives when needed
Content Areas	Physics, Mathematics, Technology
Duration of Lesson	90΄
Target grades, Age	16-17
Brief description of the lesson	We will investigate how to minimize the time needed for a lifebuoy starting from a specific point on the perimeter of a pool to reach a particular point in the pool.
General objectives	- to apply students' knowledge of uniform linear motion in a novel situation - to learn how to find an optimal solution by solving a minimization problem.
Particular objectives	- to train the students in the use of interactive applets, for computational approaches to the problem.

Problem 4	Estimating the size of a molecule using an oil film
Content Areas	Chemistry, Physics, Mathematics
Duration of Lesson	90΄
Target grades, Age	14-15
Brief description of the lesson	We will investigate through an experiment how oil mixes with water and how an oil spill develops and to measure the size of an oil molecule. The activity is closely related to the pollution of the sea.
General objectives	- to measure the size of the oil molecule with simple materials: olive oil, water, small volumetric container, eyedropper, ruler, fine powder/lycopodium powder (dried pollen), large dry tray, calculator.
Particular objectives	- to synthesize knowledge and skills from many fields: physics, chemistry, mathematics, and environmental studies to study a realistic problem (pollution from oil spills).

Problem 5	Moving on the surface or around the Earth
Content Areas	Physics, Mathematics, Mechanics, Environment
Duration of Lesson	2 * 45 min
Target grades, Age	9th - 10th grade, ages: 15-16
Brief description of the lesson	We discover three real-world examples and one hypothetical, posing questions about distances velocities, accelerations, safety and how speed can mean the difference between life and death. 1. orbits around the circumference of the Earth, whether they are very close to it (a "rope" at 1 meter) or they are far (such as the orbit of the ISS),

	2. experiment with the "fastest sprinter" Cheetah vs the fastest "long-distance runner" Antelopes, 3. movement of a bicycle.
General objectives	- using of interactive applets and gamification for problem solving - applying knowledge about motion in different situations
Particular objectives	- using the 2 main quantities length-time and the 4 related quantities distance-perimeter-velocity-acceleration - applying physical & mathematical formulas for the measurement of the previous quantities

Problem 6	**From the free fall to the orbit of the satellites**
Content Areas	Physics, Mathematics, Technology
Duration of Lesson	2 * 45 min
Target grades, Age	10th - 11th grade, Ages: 16-17+
Brief description of the lesson	We discover the main features of the gravity with two real-world examples and one hypothetical, posing questions about velocities, distances, masses, forces and the orbits: 1. study the fall of a parachutist, 2. experiment with the Newton's cannonball, 3. launch of the Tesla Roadster for escaping out of Earth's gravitational grip.
General objectives	- to use of interactive applets and gamification for problem solving - to apply knowledge about motion and force
Particular objectives	- to use the 3 main quantities *length-time-mass* and the 4 related quantities *velocity-acceleration-weight-force* - to apply physical & mathematical formulas for the measurement of the previous quantities



ANNEX 7

STEM Labyrinth
LESSON PLAN 1

1. OVERVIEW	
Lesson Topic	Swimming of bodies
Content Areas	Pressure of bodies
Duration of the Lesson	2x 45 min
Target grades / Age	8 grade/ 14-15
Brief description of the lesson	In the lesson: 1. Conditions of swimming, floating and sinking are introduced. 2. Experiments about gravity and buoyancy are conducted in pairs using a simulator. 3. Problems about swimming bodies are solved by applying a labyrinth method using an app.
2. LEARNING OBJECTIVES	
General objectives	Students: • can apply a scientific method to solve a problem. • has an overview of terms in physics and can use them; • develops a skill of reading and understanding scientific texts; • gets an insight into physics connections with technology. • develops literacy related to science and technology, creativity and systematic thinking.
Particular objectives	Students: • knows the following terms: gravity, buoyancy, density, swimming, floating, sinking; • knows the formulas for calculating buoyancy and gravity; • conducts experiments using a simulator; • measures, collects and analyses data; • solves problems.
21st century skills gained	• critical thinking and problem solving; • creativity; • communication and cooperation; • management and use of information; • using ICT.
3. METHODOLOGY	
Teaching methods	• slideshow • video • cooperative learning;
Teaching techniques	• discussion • problem solving, • conducting experiments.
Prerequisites	Student • knows units of mass, gravity, buoyancy, density and the constant of gravity; • can conduct experiments using a simulator; • can calculate a mass of a body, values of buoyancy and gravity; • can read instructions and follow them;

	• solves problems using the labyrinth method.
Materials	• video; • simulator; https://phet.colorado.edu/sims/html/density/latest/density_en.html • computer with internet connection, projector; • worksheet on paper or online; • computers for students; • MobileApp Stem Labyrinth; • writing implements.
Resources used by the teacher	• Google Docs • GoogleSlides • Youtube • Transum • simulator; https://phet.colorado.edu/sims/html/density/latest/density_en.html
Resources for the students	• Google Docs • simulator of experiments in physics; https://phet.colorado.edu/sims/html/density/latest/density_en.html • MobileApp

4. IMPLEMENTATION (organization of the lesson)

Introduction/ Motivation (20 min)

- Greetings, introduction of the content and aims of the lesson.
- Introductory video;
- Discussion on the video watched. Students find examples of swimming bodies from the real world.
- The teacher draws a map onto a blackboard or a screen.

Main Activity (50 min)

1. The teacher divides students into pairs using Transum;
2. The teacher introduces the steps of the activity and gives each pair a worksheet.
3. Students:
    - Familiarize themselves with the worksheet, the teacher explains what to do.
    - do the first three exercises about theory. The teacher helps if needed.
    - open the simulator on the internet.
    - conduct experiments, fill the tables with data, perform calculations.The teacher helps if needed.
    - introduce the results of experiments they conducted and results of discussions.
    - solve example exercises on worksheets.
4. Teacher concludes the topic shortly.

Reflection/Closing Activity (20 min)

- Students solve the task about swimming of bodies in the app made using the labyrinth method.
- The teacher concludes the lesson and introduces homework.

5. EVALUATION / ASSESSMENT

	• real world problem solving skill;

Assessment Type: (what is measuring, assessing)	• cooperation and communication; • critical thinking; • creativity.
6. Real-world application	
Students find examples of swimming bodies from the real world. They take photos of these and use them to illustrate exercises which they make themselves.	
7. Assignment	
Homework: Students make an exercise about swimming bodies using Google Docs. It should consist of two parts: a sheet with a problem and a sheet with an answer including a full solution.	
8. Extension	

Author: Järvi Kimst

Annex 7.1 Worksheet

Name: .... **Date: ....**

Swimming, floating, sinking

1) Name swimming conditions:

Body swims if …

1)...

2)...

3)...

2) Fill in the gaps.

	Swimming	Floating	Sinking
The body is in liquid…	....	....	....
Compare densities of the body and the liquid (> = <)	ρ_b...... ρ_l	ρ_b ...... ρ_l	ρ_b ......ρ_l
Compare the buoyancy and the gravity of the body	F_b ...... F_g	F_b ...... F_g	F_b ....F_g

(> = <)

3) Compare swimming and floating.
Similarities: ………………………………………………………………………………………
Differences: ………………………………………………………………………………………

4) Open the website https://phet.colorado.edu/sims/html/density/latest/density_en.html

Task 1

Turn on intro. Select the two-block model from the right corner. Then choose wood and brick as materials. Set the weight of both bodies to 4kg.

Mark in table:
- How much gravity applies to a wooden block on the ground? Calculate.
- Place the wooden block in the water. What do you notice?
- What is the buoyancy of the wooden block in the water? Calculate.
- Mark in the table whether the body is swimming, floating or sinking.
- How much gravity applies to a brick on the ground? Calculate.
- Put the brick in the water, what do you notice?
- How much buoyancy applies to the brick in the water? Calculate.
- Mark in the table whether the body is swimming, floating or sinking.

wood:	Volume	Gravity	Buoyancy	Does the body swim, float or sink?
on the ground				
in the water				

brick:	Volume	Gravity	Buoyancy	Does the body swim, float or sink?
on the ground				
in the water				

Discuss why a wooden block has a bigger buoyancy in the water than a brick.
……………………………………………………………………………………………
……………………………………………………………………………………………

Task 2

Now set the same bodies to equal volume.
Mark in table:
- the mass of both bodies on the ground.
- gravity applying to both bodies.
- place the bodies in the water. What do you notice?

- ....
- buoyancy applying to both bodies.
- find out how much the body masses seem lighter in the water.

	Mass	Gravity	Buoyancy	The body mass in the water
wood				
brick				

Discuss why bodies seem to be lighter in water? When justifying, use the terms gravity and buoyancy.

....
....

5) Mark in the formula of buoyancy the following symbols and their units.

$F_b = \rho_l g V$

	Name of the symbol	Symbol of the unit	Name of the unit
F_b			
ρ_l			
g			
V			

How much of the buoyancy force is applied to a wooden block with a volume of 10 m3 when sinked completely in water? The density of water is 1000 kg / m3.

Granite stone with a volume of 500 cm3 is placed entirely in the water. How much extra force must be applied to it so that it does not sin. The density of water is 1000 kg / m3, the density of granite is 2600 kg / m3.

Used materials:

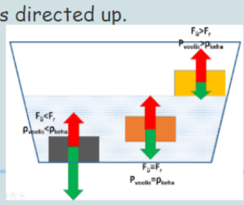
- http://opiq.ee
- Pixabay.com

Annex 7.2 Presentation

Conditions of swimming body

2022

The bodies in the water are affected by two forces - the gravity affecting the body, which is directed down, and the buoyancy of the fluid that is directed up.



FLOAT SWIM SINK

Buoyancy is equal to gravity

Buoyancy is less than gravity

Characteristics of swimming:

1. The body is partially fluid. (Output fluid mass = body mass)
2. If the gravity is less than the buoyancy, **Fg < Fb**, the body will rise to the surface. The body rises out of the water so that buoyancy and gravity affecting the part of the body underneath water become equal, as a result the body swims. **Fg = Fb**
3. The average density of the body is less than the density of the liquid.

$\rho_b < \rho_l$

Characteristics of floating:

1. The body is fully in the liquid.
2. The body's buoyant force is equal to the body's gravitational force. **Fb = Fg**
3. The average density of the body is equal to the density of the liquid. $\rho_b = \rho_l$

Characteristics of sinking:

1. The body is fully in the liquid.
2. The body's buoyant force is less than the body's gravitational force. **Fg > Fb**
3. The average density of the body is higher than the density of fluid.

$\rho_b > \rho_l$

Whether the body sinks, swims or floats depends on the density of the body and the liquid.

- According to the Archimedes principle, the buoyancy depends on the density of the liquid and the volume of the body:

$$F_b = \rho_l g\, V.$$

- We can analogously express the gravitational force of the body $F_g = m_b g$ through its density ρ_b and volume **V** using the formula

$$F_g = \rho_b g\, V.$$

Used literature and photographs

- Pärtel, E., Loide R-K. (2018). Physics Form 8. Tallinn: Koolibri
- Pixabay. com

Thanks for the attention!

ANNEX 8

STEM Labyrinth
LESSON PLAN 2

1. OVERVIEW	
Lesson Topic	Pythagorean Theorem
Content Areas	Geometry
Duration of Lesson	45 min
Target grades/ Age	9^{th} grade/ 15-16
Brief description of the lesson	In the lesson: 1. The short animation about Pythagorean theorem is watched 2. Exercises about Pythagorean theorem are solved by applying a labyrinth method using an app.
2. LEARNING OBJECTIVES	
General objectives	Student: • can apply investigative learning methods to solve a problem; • uses Pythagorean theorem in real life situations to find solution.
Particular objectives	Student • knows about relations between legs and hypotenuse in a right triangle: • knows the formula for calculating measurement of legs and hypotenuse of the right triangle • solves problems.
21st century skills gained	• critical thinking and problem solving; • managing and using information; • using ICT.
3. METHODOLOGY	
Teaching methods	• cooperative learning; • peer teaching.
Teaching techniques	• discussion; • problem solving,
Prerequisites	Student • knows units of distance; • can calculate squares and square roots; • can find dimensions of legs and hypotenuse in a right triangle; • can read and follow given instructions.
Materials	• a video - https://www.youtube.com/watch?v=elr2w5jrFbQ; • a computer with internet connection, a projector; • tablets for students
Resources used by the teacher	• Google Classroom • Youtube • Classroomscreen. com •
Resources for the students	• Google Classroom • STEM Labyrinth app
4. IMPLEMENTATION (organization of the lesson)	
Introduction/ Motivation (10 min)	

- Greeting, introduction of the topic and the aims of the lesson.
- Introductory video.
- Discussion based on the watched video. Students find examples from their daily lives.

Main Activity (30 min)

1. The teacher pairs up the students by using Classroomscreen.
2. The teacher introduces the activity and the work principle of the STEM Labyrinth app.
3. The teacher writes on a blackboard or shows with the projector all possible problems related to the Pythagorean theorem.
4. Students:
   * familiarize themselves with the STEM Labyrinth App
   * find suitable problems for Pythagorean Theorem . Two different problems per pair
   *solve the problems separately
   *compare with peer the results they have got
   *pairs introduce their results to the classmates.
5. Teacher makes a leaderboard of the three best results by using the STEM Labyrinth App

*** For the faster pairs teacher gives extra exercises from https://www.ixl.com/math/geometry/pythagorean-theorem

Reflection/Closing Activity (5 min)

- The students give feedback of the learning process with the STEM Labyrinth App
- The teacher concludes the lesson.

5. EVALUATION / ASSESSMENT	
Assessment Type: (what is measuring, assessing)	• Problem solving skill • Cooperation and interaction • Critical thinking skill
Evaluation tools (instruments)	• Grading model
6. Real-world application	
The students solve real-world problems	
7. Assignment	
Oral feedback	
8. Extras	

Author: Kairi Mustjatse

ANNEX 9

STEM Labyrinth
LESSON PLAN 3

1. OVERVIEW	
Lesson Topic	**Lifebuoy saves lives when needed**
Content Areas	Physics, Mathematics, IT
Duration of Lesson	90΄
Target grades/ Age	16-17
Brief description of the lesson	We will investigate how to minimize the time needed for a lifebuoy starting from a specific point on the perimeter of a pool to reach a particular point in the pool.
2. LEARNING OBJECTIVES	
General objectives	To enable students to apply their knowledge of uniform linear motion in a novel situation. To learn how to find an optimal solution by solving a minimization problem.
Particular objectives	To train the students in the use of interactive applets, for computational approaches to the problem.
21st century skills gained	Computational methods as an integral mathematical tool and the use of interactive applets to facilitate computation. 21st century skills: • Critical thinking • Collaboration • Curiosity and inquiry • Problem-solving • Imagination
3. METHODOLOGY	
Teaching methods	• Teacher 1 (EC1): Teacher of Physics - Teaching of uniform linear motion and/or uniformly accelerated motion – Classroom • Teacher 2 (EC2): Teacher of Mathematics - Teaching optimization problems – Classroom • Teacher 3 (EC3): Teacher of Mathematics or IT teacher - Teaching how to transform a problem to an interactive applet and how to approach the solution with computational methods – IT Lab The coordinator may be the Teacher of Mathematics Teaching methods: • The Discussion Method • Cooperative learning • Student-centred Approach to Learning
Teaching techniques	Discussion, problem solving, experimentation, mathematical and computational calculations
Prerequisites	Students are taught the calculation of distance and time in uniform linear motion
Materials	Whiteboard/interactive board/flipchart, STEM Labyrinth Mobile App, student handout(s), calculator

<table>
<tr><td>Resources used by the teacher</td><td>Whiteboard/interactive board/flipchart, computer with suitable software, videos, handouts, laboratory, STEM Labyrinth Mobile App</td></tr>
<tr><td>Resources for the students</td><td>Physics/Chemistry/Mathematics teachers, handouts, graph paper, calculator, STEM Labyrinth Mobile App</td></tr>
<tr><td colspan="2">4. IMPLEMENTATION (organization of the lesson)</td></tr>
<tr><td colspan="2">Introduction/ Motivation (10 min)</td></tr>
<tr><td colspan="2">Activities of the teacher(s)and students (creation of interest, reference to real value issues, relation to background experiences etc.)
- Discussion of issue (minimizing time of intervention to save lives)
- Discussion of background knowledge
- Discussion of main activity.</td></tr>
<tr><td colspan="2">Main Activity (30 min)</td></tr>
<tr><td colspan="2">Development activities (preparation for practice)
- Students are divided into groups and asked to formulate thoughts and arguments to make
- a layout plan
- Carry out appropriate calculations
- Decide the procedure that will lead them to the optimal solution sought (for example experimentation)
Practicing activities (guided practice ->free practice)
- Students carry out their plan
- Teacher supervises activity
- Students work on handout(s) and draw conclusion(s)</td></tr>
<tr><td colspan="2">Reflection/Closing Activity (5 min)</td></tr>
<tr><td colspan="2">Activities of the teacher(s)and students
- Students submit results to the teacher
- Teacher summarizes results and guides students to draw final conclusion</td></tr>
<tr><td colspan="2">5. EVALUATION / ASSESSMENT</td></tr>
<tr><td>Assessment Type: (what is measuring, assessing)</td><td>- Teacher assesses design skills and group-work skills during activity
- Teacher assesses critical thinking and mathematical and computational skills through handout
- Teacher assesses the students' knowledge through the Stem Labyrinth Application
*Pre-Activity, Activity-Embedded, Post-Activity Assessment</td></tr>
<tr><td>Evaluation tools (instruments)</td><td>Activity handout(s) (formative assessment), STEM Labyrinth Mobile App after concluding the activity after concluding the activity</td></tr>
<tr><td colspan="2">6. Real-world application</td></tr>
<tr><td colspan="2">- where it can be applied
- design questions to put the students in real – life situations (the Least Action Principle in Physics can be discussed as a generalization)
- invite guest speakers
- real world research</td></tr>
<tr><td colspan="2">7. Assignment</td></tr>
<tr><td colspan="2">Study behavior of light as an extension
Ask students to consider other cases of minimization/maximization
Report back to the class</td></tr>
</table>

Author: Agios Georgios Lyceum

ANNEX 10 STEM Labyrinth

LESSON PLAN 4

1. OVERVIEW	
Lesson Topic	**Estimating the size of a molecule using an oil film**
Content Areas	Chemistry, Physics, Mathematics
Duration of Lesson	90΄
Target grades/ Age	14-15
Brief description of the lesson	We will investigate through an experiment how oil mixes with water and how an oil spill develops and to measure the size of an oil molecule. The activity is closely related to the pollution of the sea.
2. LEARNING OBJECTIVES	
General objectives	The purpose of the activity is to measure the size of the oil molecule with simple materials: olive oil, water, small volumetric container, eyedropper, ruler, fine powder/lycopodium powder (dried pollen), large dry tray, calculator.
Particular objectives	The activity enables students to synthesize knowledge and skills from many fields: physics, chemistry, mathematics, and environmental studies to study a realistic problem (pollution from oil spills).
21st century skills gained	The atomic and/or molecular structure of matter (otherwise kinetic theory of matter) is one of the basic concepts of science at all levels. Knowledge of the size of atoms/molecules is important and necessary for a better understanding of the importance of atomic theory. 21st century skills: • Creativity and Critical thinking • Collaboration • Curiosity and inquiry • Problem-solving • Perseverance
3. METHODOLOGY	
Teaching methods	• Teacher 1 (EC1): Teacher of Physics - Teaching of the Atomic Theory of Matter - Classroom Teacher 2 (EC2): Teacher of Chemistry - Teaching oil-water interaction - Shape of oil molecule Teacher 3 (EC3): Teacher of Mathematics - Teaching geometric volumes - processing of algebraic formulas - proportions. The coordinator may be the Teacher of Physics. Teaching methods: • Cooperative learning • Student-centred Approach
Teaching techniques	Discussion, problem solving, experimentation, mathematical and computational calculations
Prerequisites	Kinetic/atomic theory of matter, basic behavior of oil on water, shape of oil molecule, simple algebraic manipulation

Materials	Whiteboard/interactive board/flipchart, STEM Labyrinth Mobile App, student handout(s), laboratory with suitable equipment (large shallow tray, clean water, olive oil, fine powder/lycopodium powder, dropper, ruler, means of disposing used water)
Resources used by the teacher	Whiteboard/interactive board/flipchart, computer with suitable software, videos, handouts, laboratory, STEM Labyrinth Mobile App
Resources for the students	Physics/Chemistry/Mathematics teachers, handouts, laboratory, STEM Labyrinth Mobile App
4. IMPLEMENTATION (organization of the lesson)	
Introduction/ Motivation (10 min)	
Activities of the teacher(s)and students (creation of interest, reference to real value issues, relation to background experiences etc.) - Discussion of issue (oil spillages / sea pollution) - Discussion of background knowledge - Discussion of main activity.	
Main Activity (30 min)	
Development activities (preparation for practice) - Demonstration of equipment and discussion of procedure - Safety precautions - Discussion of mathematical procedures Practicing activities (guided practice ->free practice) - Students carry out their plan - Teacher supervises activity - Students work on handout(s) and draw conclusion(s)	
Reflection/Closing Activity (5 min)	
Activities of the teacher(s)and students - Students submit results to the teacher - Teacher summarizes results and guides students to draw final conclusion	
5. EVALUATION / ASSESSMENT	
Assessment Type: (what is measuring, assessing)	- Teacher assesses design skills and group-work skills during activity - Teacher assesses critical thinking and mathematical skills through handout - Teacher assesses the students' knowledge through the Stem Labyrinth Application *Pre-Activity, Activity-Embedded, Post-Activity Assessment
Evaluation tools (instruments)	Activity handout(s) (formative assessment), *STEM Labyrinth* Mobile App after concluding the activity after concluding the activity
6. Real-world application	
- where it can be applied - design questions to put the students in real – life situations - invite guest speakers - real world research	
7. Assignment	
Study a specific oil spillage in the sea near Cyprus, and how the authorities dealt with it. Report the results of the study to the class.	

Author: Agios Georgios Lyceum

ANNEX 11

STEM Labyrinth

LESSON PLAN 5

1. OVERVIEW	
Lesson Topic	**Moving on the surface or around the Earth**
Content Areas	Physics, Mathematics, Mechanics, Environment
Duration of Lesson	2 * 45 min
Target grades/ Age	9th - 10th grade, ages: 15-16
Brief description of the lesson	We discover the main features of motion, the distance, the velocity, the acceleration and the time with three real-world examples and one hypothetical: 1. study of the sizes related to circular orbits around the circumference of the Earth, whether they are very close to it (a "rope" at 1 meter) or they are far (such as the orbit of the ISS), 2. experiment with the "fastest sprinter" Cheetah trying to reach the fastest "long-distance runner" Antelopes, 3. observation of the movement of a bicycle that starts moving, accelerates, moves at a constant velocity and finally decelerates to stop. The questions for these real journeys on the surface and around the Earth are about distances velocities, accelerations and safety. Speed can mean the difference between life and death.
2. LEARNING OBJECTIVES	
General objectives	• using of interactive applets and gamification for problem solving • applying knowledge about motion in different situations
Particular objectives	• using the 2 main quantities length-time and the 4 related quantities *distance-perimeter-velocity-acceleration* • applying physical & mathematical formulas for the measurement of the previous quantities
21st century skills gained	• using and processing information • critical thinking and problem solving • curiosity and inquiry • collaboration
3. METHODOLOGY	
Teaching methods	• collaborative learning • gamification
Teaching techniques	• brainstorming • experimentation • problem solving
Prerequisites	• can read and follow given instructions • can calculate powers and roots • can use the basic formulas of: *distance-perimeter-velocity-acceleration*
Materials	• good internet connection • whiteboard and/or interactive board and/or flipchart • tablets (one tablet per two students) • STEM Labyrinth App installed in the tablets
Resources used by the teacher	• IO3 Guidelines • IO4 Learning Modules

<table>
<tr><td></td><td>

- STEM Labyrinth App
- Doukas School Problems 12, 10 and 07

(given at the Implementation Section)</td></tr>
<tr><td>Resources for the students</td><td>

- YouTube and relates links
- STEM Labyrinth App
- Web-based Apps

(links are given at the Implementation Section)</td></tr>
<tr><td colspan="2">4. IMPLEMENTATION (organization of the lesson)</td></tr>
<tr><td colspan="2">Introduction/ Motivation (15 min)</td></tr>
<tr><td colspan="2">

- Introduction of the topic and the aims of the lesson

Two introductory videos:

- Springboks Antelopes vs Cheetahs - Wild Africa
- Where is the International Space Station?</td></tr>
<tr><td colspan="2">Main Activity (2*30 min)</td></tr>
<tr><td colspan="2">

1. Discussion: What are the common and the different concepts about motion in the above videos? What are the differences between distance and position, about moment, minute and time?
2. ***Play with the App: D12-Problem "From the "rope around the Earth" to the "orbit of the ISS"*** (doc file)
3. Discussion: How quickly our position can change? We can divide distance by time, but we can also divide time by distance? What's the difference? What we decided?
4. ***Play with the App: D10-Problem "Cheetahs vs Antelopes"*** (doc file)
5. Discussion: What distances they must have in order for a chase to succeed or fail? Success for one animal is a failure for the other and vice versa. Speed can mean the difference between life and death.
6. Presentation: What are the safety reminders to keep cyclists safe?
7. ***Play with the App: D07-Problem "The motion of a cyclist"*** (doc file)
8. Discussion: What are the maximum permitted speed for bicycles? What are the speed of satellites? How fast can the speed change? What does this mean? What is the acceleration of satellites?
   Note: All the needed physical & mathematical formulas for the measurement of the quantities are given to the ANNEX 11.1</td></tr>
<tr><td colspan="2">Reflection/Closing Activity (15 min)</td></tr>
<tr><td colspan="2">

- The students submit results from the apps to the teacher
- The students give feedback of the learning process with the STEM Labyrinth App
- The teacher or the students summarizes results and the teacher guides students to draw final conclusions</td></tr>
<tr><td colspan="2">5. EVALUATION / ASSESSMENT</td></tr>
<tr><td>Assessment Type: (what is measuring, assessing)</td><td>

- Score assessment from the STEM Labyrinth App (indicative)
- Qualitative assessment of students' participation in the discussion and answering of teacher's questions
- Qualitative assessment of students' collaboration during the activities</td></tr>
</table>

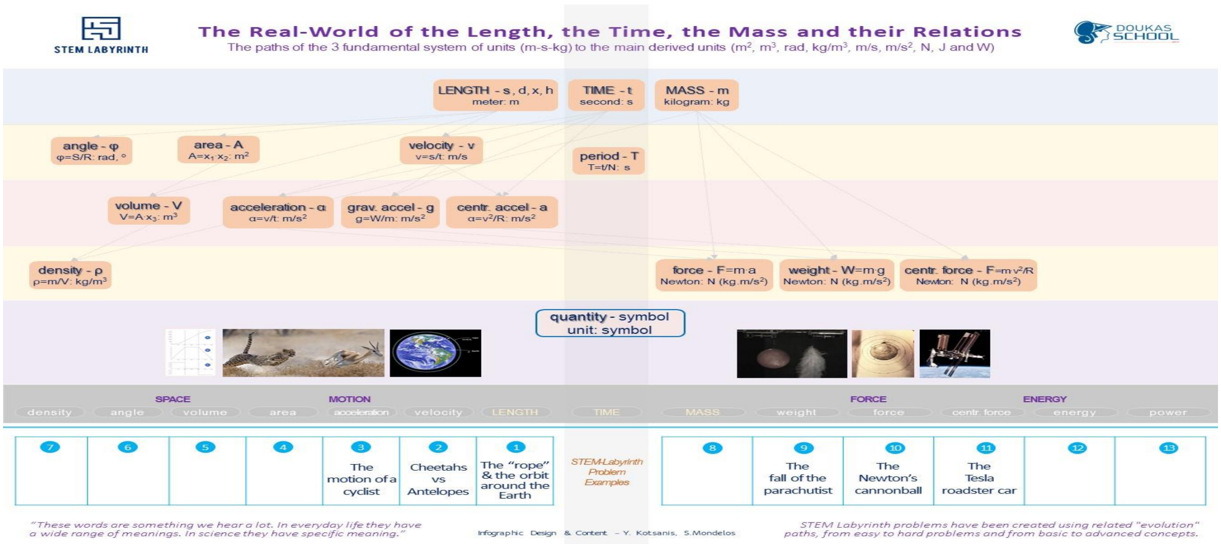
Evaluation tools (instruments)	● Scoring measurement of the *STEM Labyrinth* App (optional)

6. Real-world application
● design questions to put the students in similar or other real-life situations (the questions can also be asked by the students) ● real world research of similar cases

7. Assignment
● experimentation with the links of the "Fun Facts" of the 3 problems: The ancient problem of “rope around the Earth” https://mathimages.swarthmore.edu/index.php/Rope_around_the_Earth, https://www.abc.net.au/science/surfingscientist/pdf/conundrum17.pdf Cheetahs and antelopes are savanna animals that have a predator-prey relationship https://www.britannica.com/list/the-fastest-animals-on-earth, Springboks Antelopes vs Cheetahs | Wild Africa | BBC Earth, https://www.britannica.com/animal/cheetah-mammal, https://www.britannica.com/animal/pronghorn European laws and safety about the bicycle https://en.wikipedia.org/wiki/Electric_bicycle_laws, https://caask.ca/about-caa/advocacy-safety/bike-safety The story and the STEAM behind my bike, https://drive.google.com/file/d/1tyXJiyDt_oRywHeM3F96_WbTl43w4_fQ What is the International Space Station? https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-the-iss-58.html. Where is the International Space Station? https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station/Where_is_the_International_Space_Station

Author: Yannis Kotsanis, Spyros Mondelos

ANNEX 11.1 *The Infographic of* "The Real-World of the Length, the Time, the Mass and their Relations" (Google Drive Link)



ANNEX 12 STEM Labyrinth

LESSON PLAN 6

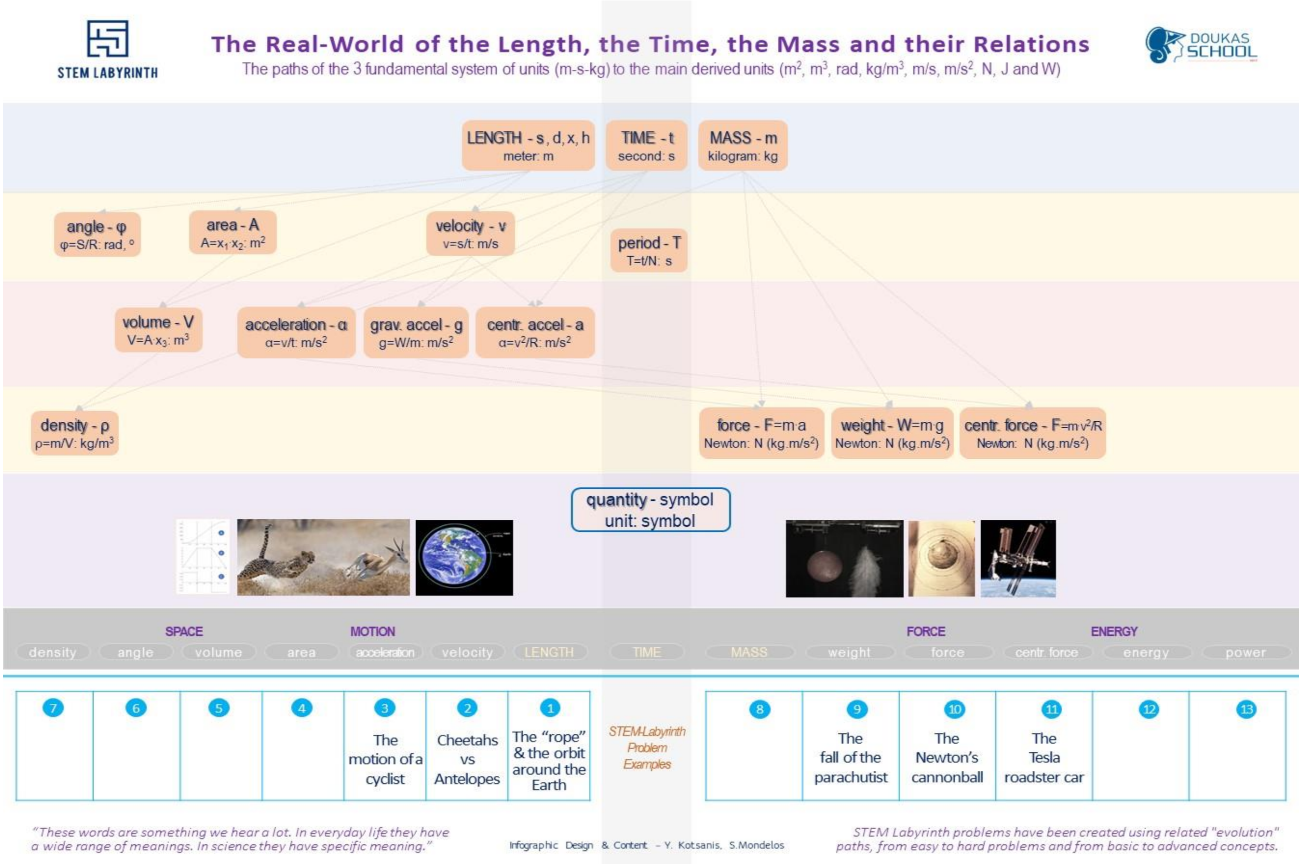
1. OVERVIEW	
Lesson Topic	**From the free fall to the orbit of the satellites**
Content Areas	Physics, Mathematics, Technology
Duration of Lesson	2 * 45 min
Target grades/ Age	10th - 11th grade, ages: 16-17+
Brief description of the lesson	We discover the main features of the gravity with two real-world examples and one hypothetical: 1. study the fall of a parachutist (parachute jumper) with or without air resistance, with or without the use of a parachute, 2. experiment with the Newton's cannonball 3. launch of the Tesla Roadster for escaping out of Earth's gravitational grip. The main questions for these real journeys are about velocities, distances, masses, forces and the orbits.
2. LEARNING OBJECTIVES	
General objectives	• using interactive applets and gamification for problem solving • applying knowledge about motion and force
Particular objectives	• using the 32 main quantities *length-time-mass* and the 4 related quantities *velocity-acceleration-weight-force* • applying physical & mathematical formulas for the measurement of the previous quantities
21st century skills gained	• using and processing information • critical thinking and problem solving • curiosity and inquiry • collaboration
3. METHODOLOGY	
Teaching methods	• collaborative learning • gamification
Teaching techniques	• brainstorming • experimentation • problem solving
Prerequisites	• can read and follow given instructions • can calculate powers and roots • can use the basic formulas of: *velocity-acceleration-weight-force*
Materials	• good internet connection • whiteboard and/or interactive board and/or flipchart • tablets (one tablet per two students) • STEM Labyrinth App installed in the tablets
Resources used by the teacher	• IO3 Guidelines • IO4 Learning Modules • *STEM Labyrinth* App • Doukas School Problems 09, 16 and 17 *(given at the Implementation Section)*

Resources for the students	● YouTube and relates links ● *STEM Labyrinth* App ● Web-based Apps *(links are given at the Implementation Section)*
4. IMPLEMENTATION (organization of the lesson)	
Introduction/ Motivation (15 min)	
- Introduction of the topic and the aims of the lesson *Two introductory experiments*: - Classroom experiment and discussion: Throwing two different paper sheets - Watching "The astronaut's experiment with a hammer and a feather" https://www.youtube.com/watch?v=ZVfhztmK9zI	
Main Activity (2*30 min)	
1. Discussion: What can cause the fall and delay or accelerate the fall? 2. Watching the video: "Bowling ball and feathers falling in vacuum" (NASA world's biggest vacuum chamber) https://www.youtube.com/watch?v=E43-CfukEgs 3. ***Play with the App: D09-Problem "The fall of the parachutist"*** (doc file) 4. Discussion: The free fall and the horizontal shot 5. ***Play with the App: D16-Problem "The Newton's cannonball"*** (doc file) 6. Discussion: From free fall to the law of universal gravitation 7. ***Play with the App: D17-Problem "The Tesla roadster car"*** (doc file) 8. Discussion: The speed of satellites. Depends on what? *9. Note: All the needed physical & mathematical formulas for the measurement of the quantities are given to the ANNEX 12.1*	
Reflection/Closing Activity (15 min)	
● The students submit results from the apps to the teacher ● The students give feedback of the learning process with the *STEM Labyrinth* App ● The teacher or the students summarizes results and the teacher guides students to draw final conclusions	
5. EVALUATION / ASSESSMENT	
Assessment Type: (what is measuring, assessing)	● Score assessment from the STEM Labyrinth App (indicative) ● Qualitative assessment of students' participation in the discussion and answering of teacher's questions ● Qualitative assessment of students' collaboration during the activities
Evaluation tools (instruments)	● Scoring measurement of the *STEM Labyrinth* App (optional)
6. Real-world application	
● design questions to put the students in similar or other real-life situations (the questions can also be asked by the students) ● real world research of similar cases	
7. Assignment	
● experimentation with the links of the "Fun Facts" of the 3 problems:	

- The experiment of Newton's cannonball: https://en.wikipedia.org/wiki/Newtons_cannonball
- Play with the interactive simulation “Newton’s Cannon” https://physics.weber.edu/schroeder/software/NewtonsCannon.html
- Useful information about the orbital velocity of satellites and planets: https://en.wikipedia.org/wiki/Orbital_speed and the escape speed from Earth's surface: https://en.wikipedia.org/wiki/Escape_velocity and how to calculate orbital velocity: https://enochko.com/blog/newtons-cannonball-and-orbital-velocity
- The story of lauching the the Tesla Roadster https://where-is-tesla-roadster.space and where is now live... https://where-is-tesla-roadster.space/live

Author: **Yannis Kotsanis, Spyros Mondelos**

ANNEX 12.1 *The Infographic of* "The Real-World of the Length, the Time, the Mass and their Relations" (Google Drive Link)



4.6. Analysis of different categories of problems in the Mobile app following description and approach of some examples from Mobile app

The general categories of problems, such as Content Areas (subjects and topics), target grades, ages and level of difficulties, and the 6 types of questions, have been presented in the previous sections. Here, we can present all the ***categories***, general and specific, in the following two tables. The first is about the ***problems*** and the second is about the ***questions***.

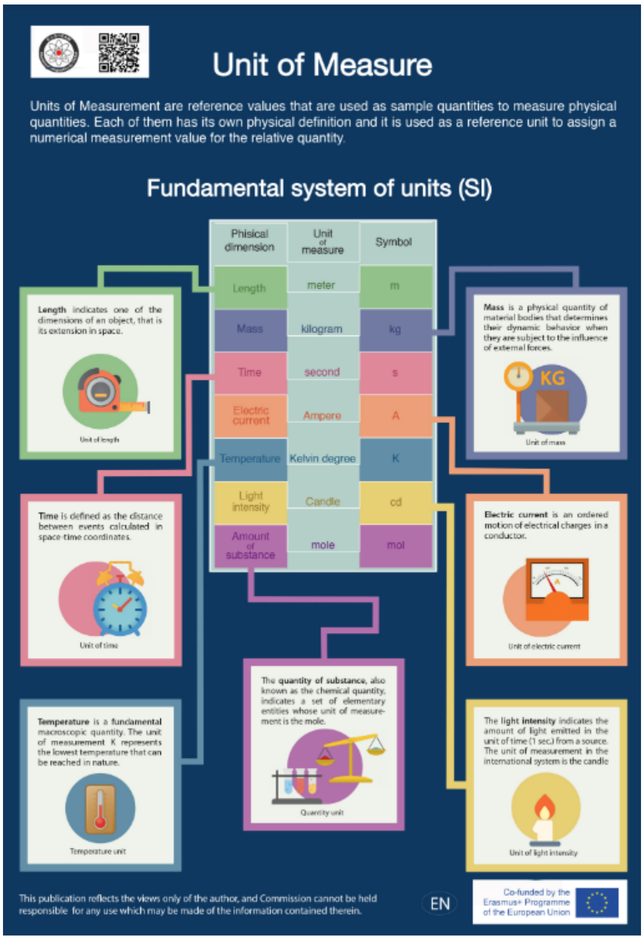
Categories of Problems

Difficulty Levels	easy, medium, hard
Subjects	Math, Science, Chemistry, Physics, Biology, Information Technology
Topics (Sub-Subjects)	Geometry, Algebra, Functions, Trigonometry, Proportions, Probability, Climate change, Global warming, Renewable energy, Environment, Sustainability, pH, Atom, Organic compounds, Oxidation, Mechanics, Kinetics, Motion, Newton laws, Astronomy, Reproduction, Genetics, Bacterial transformation, Viruses, Programming, HTML, Passwords, Algorithms
Ages	14-15, 16-17, 18+
S/T/E/M	
Type	real-life, thought (experiment) simple, complicated, complex, chaotic (D. Snowden) ill-defined, well-defined
Science's quantities (units)	length (meter), mass (kilogram), time (second), electric current (ampere), thermodynamic temperature (kelvin), amount of substance (mole), luminous intensity (candela), area, volume, angle, speed, acceleration, density, force weight, energy, power

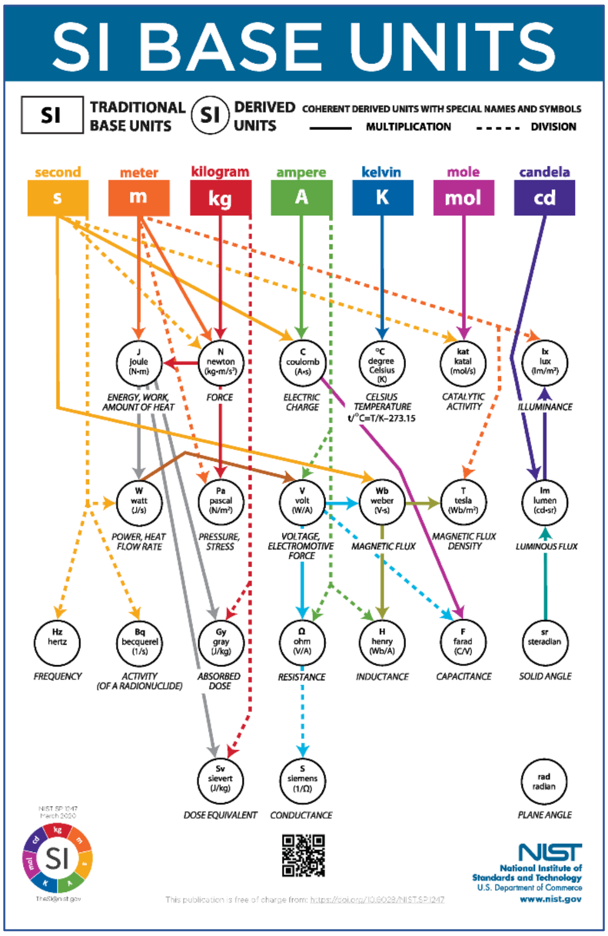
There are many studies and references about the types of a problem. An example is the 4 types of problems: *simple, complicated, complex, chaotic* (proposed by Snowden). For our purposes we focus only on *scientific problems* that can be either *real-life problems* or *thought problems/experiments*. One approach to deal with this kind of problems, related to STEM curriculum, is to begin with the main concepts or quantities (and their units) of a problem. The *seven fundamental quantities of our world* and their derivatives are presented at the following pictures:

SI Base Units			
Base quantity		**Base unit**	
Name	**Typical symbol**	**Name**	**Symbol**
time	t	second	s
length	l, x, r, etc.	meter	m
mass	m	kilogram	kg
electric current	I, i	ampere	A
thermodynamic temperature	T	kelvin	K
amount of substance	n	mole	mol
luminous intensity	I_v	candela	cd

Source: NIST Special Publication 330:2019, Table 2.



Source: https://steam-edu.eu/infographics

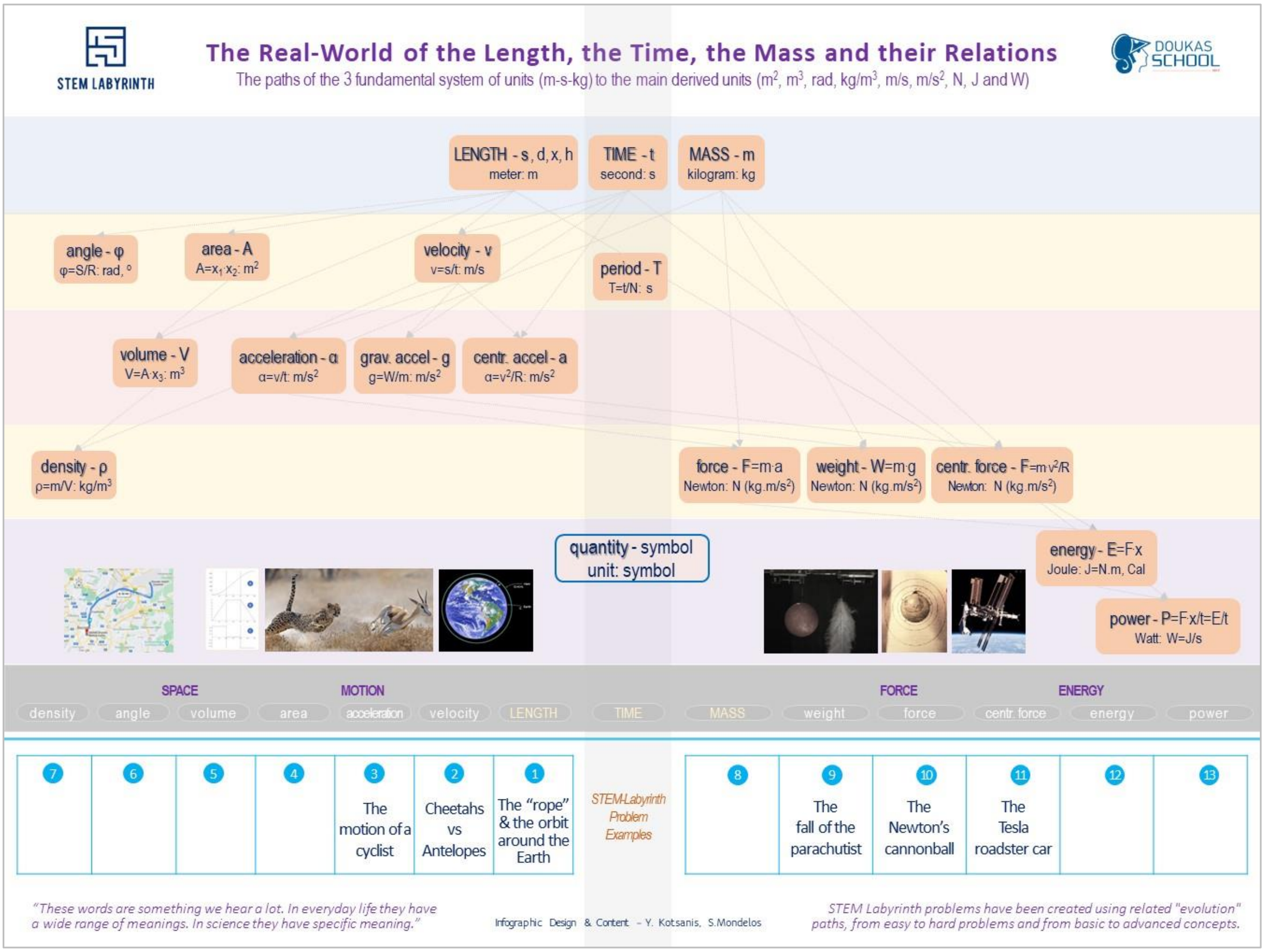


Source: https://www.nist.gov/pml/owm/metric-si/si-units

A fairly large percentage of the 100 problems of the STEM Labyrinth, is related with these fundamental quantities of time, length and mass, and many of their derivatives. Thus, we constructed the infographic:

“**The Real-World of the Length, the Time, the Mass and their Relations**”, containing the paths of the three fundamental system of units (m-s-kg) and their main derived units (m^2, m^3, rad, m/s, m/s^2, kg/m^3, N, J and W). This infographic has two main purposes:

1. to show all the **connections and formulas** between time, length and mass, and the most important of their derivatives, and
2. to help us following **paths for designing and selecting** related problems.



We presented the example of the Lesson Plan “*Moving on the surface or around the Earth*” (section 4.5 and ANNEX 11/12.1) that is based on the following three problems:

- D12: “From the “rope around the Earth” to the “orbit of the ISS” (doc file),
- D10: “Cheetahs vs Antelopes” (doc file),
- D07: “The motion of a cyclist” (doc file).

A similar example is presented at the ANNEX 2 at the Lesson Plan "*From the free fall to the orbit of the satellites*" that is based on the following three problems:

- D09: Problem "The fall of the parachutist" (doc file),
- D16: Problem "The Newton's cannonball" (doc file),
- D17: "The Tesla roadster car" (doc file).

Categories of Questions

Type	1. MCQ (Multi Choice Question) 2. TRUE/FALSE 3. MC-Image (Multi Choice with Image question) 4. Matching (with text question and text answers) 5. Fill the Gap (number) 6. Fun Fact
Content of questions	1. analyzing diagram 2. applying technique(s) 3. applying theory 4. applying rules 5. calculating formula(s) 6. calculating units 7. case study 8. checking the results (the physical meaning) 9. choosing the right formulas 10. coding-programming 11. combining the right formulas 12. create an artifact (document, spreadsheet, diagram, picture, etc.) 13. explore an artifact (document, visualized object, application, etc.) 14. following algorithms 15. open question (as a "fun fact" for brainstorming) 16. play a game 17. solving a sub-problem 18. study a reference (link, data, etc) 19. using experiments

	20. using simulations 21. watching a video
Formulas/Functions	logical, statistical, financial, trigonometry, engineering

The *STEM Labyrinth* app has six different **types** of questions (as analysed in previous sections).

We can also categorize the questions from their **content**. We found more than 20 different types of questions. Indicative examples from the questions and the "fun-facts" included to the 100 problems are at the following table:

Content Categories of the Questions as sub-problems

analyzing diagrams	Can you match which graph A, B, and C is related to distance, velocity, acceleration/deceleration and time?
applying rules	The A4 printing and office paper has height - width (mm/inches) and the ratio of height – width (measure with a ruler the height and the width of the two sides of the paper in cm or inch).
applying theorem	The light is an entity that can be described as either… particle/wave or ray/wave or ray/particle or heat/wave
calculating formula	If the mass of the cyclist along with his bicycle is m = 60 Kg what is the resultant force (Newton) exerted on him to accelerate (use the acceleration of the bicycle from the previous question)?
calculating formulas	The International Space Station orbits Earth at an average altitude of approximately 250 miles (A=~400 km). How many kilometers is the circumference-orbit of the ISS, around the equatorial circumference, if the equatorial radius is 6378 km?
calculating units	In our example, since the two animals are 150 meters apart, the antelope seems to be able to escape! How many meters will the cheetah finally be able to approach her in these first 20 seconds at maximum velocity, which it will then stop?
checking the results	The two companies have five different categories of employees (General Director, Managers, Professionals, Technicians, and Service Workers), the same number of employees (100), and the distribution of their salaries are presented in the table. What is the total of the monthly salaries for the two companies? The same or different or there is not clear data for the answer.
choosing the right formulas	Which of the following has firstly determined for the calculation of the Earth's "weight"?
coding-programming	When the robot receives a "start game" message, (this is an event driven structure), a forever loop is starting, that checks if the mouse clicks the button of the game. Then…
coding-programming	Can you write a program that calculate all the above numbers for any rectangle A * B?
create an artifact	It would be useful to create a table-worksheet (on paper or digital) of air-line (flight) distances for these five cities in all pairs (using e.g. Google Sheets or MS Excel, from a site e.g. https://www.distance.to). The table could be like the Image (but in air-line distances).
explore an artifact	Currently, Tesla is located more than 360 kms from Earth and 280 million km from Mars, going at an approximately speed of 6-7 km/s (with the same approximately speed of the "Cannonball" problem). LIVE ORBIT: https://where-is-tesla-roadster.space/live
explore an artifact	Infographic: The story and the STEAM behind my bike https://drive.google.com/file/d/1tyXJiyDt_oRywHeM3F96_WbTl43w4_fQ/view?usp=sharing

following algorithms	Algorithms are step by step instructions used to solve a problem. What does the diagram represent?
open	Can you think of and explain how you found the answer? Can you generate your solution? Can you find an arithmetic expression for the calculation of this problem?
play a game	Play the game "Chat noire". Can you keep the cat from running off the game field? Play the game 10 times. Place the obstacles next to the cat. How many times did you win? You probably won very few times! www.gamedesign.jp/sp/cat (if the link doesn't work, you can use another browser e.g. Google Chrome, or change settings on security level of your browser).
solving a sub-problem	Five different teams are working together in different cities in Europe. They want to travel to the other cities. These cities are: Paris, Amsterdam, Vienna, Budapest and Bucharest. How many pairs of neighboring countries do we have?
solving a sub-problem	Two parachutists with the same weight, fall at the same time and from the exact same height and open their parachutes at the same time, the first falls from a no moving helicopter and the second falls from a moving plane. Who will land first?
study a reference (link)	https://www.britannica.com/list/the-fastest-animals-on-earth and Springboks Antelopes vs Cheetahs | Wild Africa | BBC Earth
using simulations	Experiment with the interactive simulation "Newton's Cannon" (that it is based on a thought experiment and illustration from the Isaac Newton's book): https://physics.weber.edu/schroeder/software/NewtonsCannon.html
watching a video	Bowling ball and feathers falling in vacuum (NASA world's biggest vacuum chamber) https://www.youtube.com/watch?v=E43-CfukEgs

5. Pilot testing of the Mobile App

5.1. Evaluation form of the STEM Labyrinth problems

ANNEX 13 PEER EVALUATION FORM FOR STEM LABYRINTH PROBLEMS

Organisation: ___________________________________

Code: ___________________________________

Problem Title: ___________________________________

I Underline the answer:

- **Technical specifications:**

Contains Keywords: *yes / no*

Given the Difficulty Level: *yes / no*

Is it difficulty level appropriate? *yes / no*

What age is the problem appropriate for: 14, 15, 16, 17, 18

Involves only questions type provided by template: *yes / no*

Question answers are clearly given according to the template: *yes / no*

Hints are given as only a text or an image: *yes / no*

II Tick the box of the extent to which you agree about the following statements:

- **Usefulness:**

1. It has a clear purpose and aims

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

2. It contains reliable data.

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

3. Allows the development of problem-solving skills, digital skills, creativity, critical or analytical thinking strategies and constructiveness.

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

4. Helps students apply math and science through authentic, project based or hands-on learning

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

5. It can be used in the school environment (during classes or as an extracurricular activity)

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

- **Legibility and Design of the problem:**

6. It has a clear readability and it is easy to follow the hints

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

7. The type of questions are chosen appropriately

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

8. There is good hierarchy/organization of questions and relevant hints

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

9. Graphics-images are good quality, not distracting and consistent.

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

10. Includes the use of (or creation of) technology.

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

11. Involves students in using an engineering design process

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

12. Engages students in working in collaborative teams

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

- **Content:**

13. The content of the problem addresses a real-life problem

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

14. The problem depicts a **creative approach** of explaining the idea suggested by the title

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

15. The problem depicts an **innovative approach** of explaining the idea suggested by the title

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

16. The problem provides a framework for developing and enhancing skills and competencies in the context of STEAM, that is skills and competencies for understanding, organizing, communicating, exploiting in real life, problem solving and reasoning and assessing and investigating relevant concepts and processes.

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

17. Reinforces relevant math and science standards

☐ *strongly agree* ☐ *agree* ☐ *neutral* ☐ *disagree* ☐ *strongly disagree*

- Overall evaluation

Is the problem appropriate to the description given by the project output? yes / *no*

Provide notes about what you noticed and like/don't like about the STEM Labyrinth problem and recommendation for improvement

____

____

Evaluator: ________________________________

Organization: ________________________________

The previous form was used by each organization to peer evaluate the designed problems, before they were ready for upload on the mobile application by the designers. This evaluation took place in the 13th month of the project cycle and it was intended to assess and evaluate the quality of the designed problems, as well as to correct any mistakes if found by the peer evaluators.

5.2. Evaluation form from the pilot testing with students

The following questionnaire was addressed to high school students (age 14 - 18) in the partner countries. It aimed to evaluate the BETA version of the Mobile App. It was administered during the pilot testing of the app and it provide significant information for improvements of the Mobile App.

ANNEX 14 PART A: STUDENTS' QUESTIONNAIRE

Total number of participants on Pilot Testing of Mobile App:

1. Organization

2. Age of the students:

Legibility of Content

3. The font choice, size and color used are legible:

4. The color scheme does not hinder the ability to read

5. Spacing and layout used are legible:

Design and Aesthetics

6. Appropriate use contrast and color:
7. Graphics are good quality, not distracting and consistent:
8. The app is easy to follow, and the overall design facilitates the understanding:
9. It is easy to navigate through the mobile app and you are aesthetically pleased while doing so:

Content

10. The content of the problems depicts a creative approach of explaining the idea suggested by the title:
11. The content of the problems depicts an innovative approach of explaining the idea suggested by the title:

12. The problems provide a framework for developing and enhancing skills and competencies in the context of STEAM, which is skills and competencies for understanding, organizing, communicating, exploiting real life, problem solving, decision making, and understanding causation.

13. The App can help me to achieve my STEM learning goals:

Usability

14. It is a user friendly:

15. Mobile app's features are easy to be used:

16. It is easy for first-time users to complete basic tasks.

17. Users can personalize their journeys (App gives the user a sense of freedom and transparency.)

Overall evaluation

18. Provide notes about what you noticed and like/don't like about the Mobile App, and what can we do to improve the app?

19. How satisfied are you after using the design was?

20. How would you rate your overall satisfaction with our Mobile App?

21. Would you recommend this app to your friend or colleague?

PART B: REMARKS AND COMMENTS FROM TEACHERS/RESEARCHERS

22. Explain briefly and clearly in which problem from the Mobile there was issues and describe it. (This will be allocated to the Mobile App developers for further update and improvement of the Mobile App)

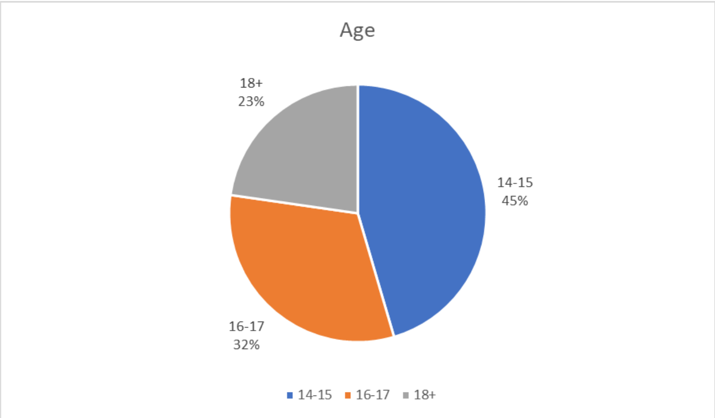
23. Any other comments and suggestions from teachers – piloting the Mobile App

5.3. Report of the pilot testing of the mobile app organized in partner schools

This Report is based on the results from the questionnaires intended to evaluate the Pilot testing of the Mobile App 'STEM Labyrinth' in the partner countries of the project entitled “STEM Labyrinth as a method for increasing the level of knowledge through problem solving" (ref. no. 2020-1-PT01-KA201-078645) funded by the Erasmus+ programme.

Each partner organized a pilot testing of the Beta version of the mobile application with students. This section contains the summary of all partner reports, and the conclusions and recommendations from the teachers/researchers. The pilot testing enabled the teachers / designers of the problems to assess the problems’ appearance in the app, performance, functionality, and overall satisfaction from using it.

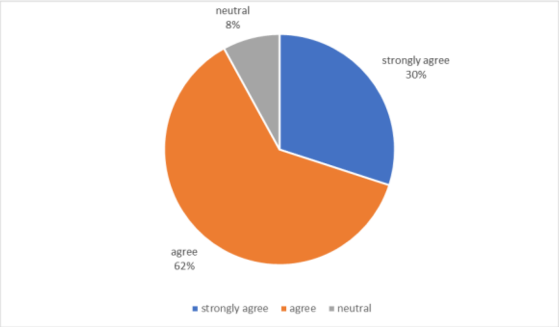
Total number of students who participated in the piloting of the Beta version of the Mobile App was 150 high school students (age 14 - 18) from partner countries.



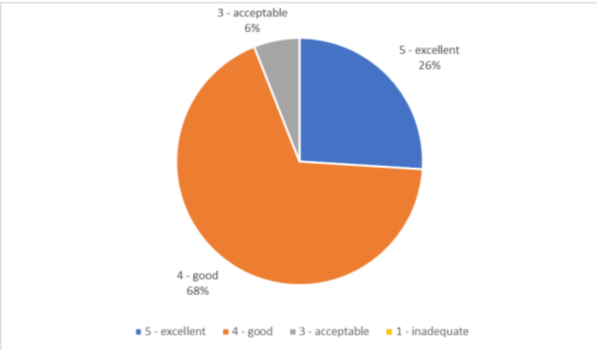
- The font choice, size and color used are legible: strongly agree (35%), agree (55%), neutral (10%)
- The color scheme does not hinder the ability to read: strongly agree (37%), agree (48%), neutral (15%)
- Spacing and layout used are legible: strongly agree (28%), agree (48%), neutral (24%)
- Appropriate use contrast and color: strongly agree (27%), agree (50%), neutral (23%)
- Graphics are good quality, not distracting and consistent: strongly agree (26%), agree (45%), neutral (29%)
- The app is easy to follow, and the overall design facilitates the understanding: strongly agree (27%), agree (50%), neutral (23%)
- It is easy to navigate through the mobile app and you are aesthetically pleased while doing so: strongly agree (25%), agree (70%), neutral (5%)
- The content of the problems depicts a creative approach of explaining the idea suggested by the title: strongly agree (26%), agree (65%), neutral (9%)
- The content of the problems depicts an innovative approach of explaining the idea suggested by the title: strongly agree (25%), agree (60%), neutral (15%)
- The problems provide a framework for developing and enhancing skills and competencies in the context of STEAM, which is skills and competencies for understanding, organizing,

communicating, exploiting real life, problem solving, decision making, and understanding causation. strongly agree (30%), agree (61%), neutral (9%)

- The App can help me to achieve my STEM learning goals



- It is a user friendly: strongly agree (38%), agree (58%), neutral (4%)
- Mobile app's features are easy to be used: strongly agree (31%), agree (64%), neutral (5%)
- It is easy for first-time users to complete basic tasks: strongly agree (24%), agree (55%), neutral (21%)
- Users can personalize their journeys (App gives the user a sense of freedom and transparency.) strongly agree (23%), agree (61%), neutral (16%)
- Provide notes about what you noticed and like/don't like about the Mobile App, and what can we do to improve the app?
  Some of the answers included:
    - It was really user friendly, and I like the fact that you were able to choose your level.
    - Very good app and easy to use.
    - It gives you more chances even if you are wrong, so you can learn.
    - Great app, I will use for the school purpose.
    - It is user friendly and gives opportunity to choose level of difficulty and categories.
    - The links provided are great and the progress through the labyrinth is nice idea
- How satisfied are you after using the design? strongly agree (31%), agree (62%), neutral (7%)
- How would you rate your overall satisfaction with our Mobile App?



- Would you recommend this app to your friend or colleague? Yes (75%), No (0%), Maybe (25%)
- Teachers explained briefly and clearly the problem from the Mobile where issues were founded and describe it. (Issues were allocated to the developers for further update and improvement of the Mobile App) and all the issues were overcome.

6. Assessment of the students' knowledge and skills using the Mobile App

The STEM approach has as its main objective to increase the knowledge and skills of students, in order to educate citizens able to successfully confront the challenges which society is facing in the 21st century. The intention is to enable students to increase their ability to solve problems through the STEM integrated and interdisciplinary experiential learning.

The ability to solve problems is one of the most important aspects in learning science and Mathematics. Problem solving skills are very important and must be developed in science and Mathematics learning, because of the complexity of problem solving as a cognitive process. Moreover, through problem solving students will improve and deepen their conceptual understanding.

Although problem-solving skills are important and are one of the main goals of the STEM approach, several studies show that the students' ability to solve problems is still low. Most of the students do not use a strategic approach but instead use a mechanical approach, through no fault of their own. The relevant literature shows above all that educational systems are failing in presenting students with appropriate learning environments and especially with appropriate assessment methods: the curriculum and its assessment are dull, encourage teaching narrowly to low-level, fact-based tests, fail to encourage creativity and switch the majority of learners off. Research has repeatedly shown, however, that learners and teachers can be excited by science and mathematics activity involving creativity, problem solving, modelling and interest-led projects. Any vision for reform needs to find ways to implement such activities across the curriculum.

The key, central strategy is to engage or re-engage children and youth in Science and Mathematics in ways that are (i) *authentic* and (ii) *interesting and meaningful* to the learners themselves. The term *authentic assessment* is used to describe assessment, which evaluates content knowledge as well as additional skills like creativity, collaboration, problem solving and innovation in realistic contexts. Systematic reform requires attention on many fronts, beginning with assessment. Significant improvements in pedagogy and student engagement must shift the emphasis to *formative* assessment (see *mobile apps*) in the classroom itself, and away from graded, exam-based summative assessment. This is required in particular for higher level learning outcomes such as deep conceptual understanding and problem solving strategies, but it is also a key to encouraging learners to take control of and 'regulate' their own learning. It can also allow the curriculum and teaching to develop around the learner's own interests as is the aim of the STEM approach. For some the need to be re-engaged, arts-led or social-led projects involving STEM might be the way, such as those promoted by STE(A)M and other integrated or interdisciplinary projects.

The school curriculum and its assessment are ultimately determined by politics, but any reform in turn requires teachers to get involved in assessment. The process will be lengthy, one that would likely take 20 years to complete. Nevertheless, the task must be urgently undertaken.

6.1 Assessment of students' learning in interdisciplinary STEM education

STEM education has rightfully received increasing attention in recent years. One essential feature of STEM education is interdisciplinarity. Interdisciplinary knowledge is a critical feature in solving real-life problems. STEM education is driven by today's complex policy and economic, social and environmental problems that require solutions, which are integrated and interdisciplinary in nature. Simply put, it is a means for linking students' learning across the STEM disciplines.

However, developing valid and reliable assessment of interdisciplinary learning in STEM has been a challenge. Given that the traditional discipline-based approach is still dominant in the educational system, how interdisciplinary STEM education should be assessed has raised many concerns. For example, integrating knowledge and skills in teaching and learning as a *measurable* outcome poses significant challenges. Although most of the STEM programs aim at improving students' interdisciplinary understanding or skills, their assessments barely address this goal. There are thus several challenging issues in assessing STEM education, which must be tackled as a way to steer future developments in the right direction.

One of the issues is that interdisciplinarity in STEM education has been taken for granted. In reality, it is neither explicitly theorized, nor well articulated. STEM integration is not simply putting disciplines together as a conglomerate – it needs to be 'intentional' and 'specific', considering the connections across disciplines in the curriculum. Simply adding engineering into the curriculum is not necessarily supportive of better student learning. Teaching high-quality curriculum units that purposefully and meaningfully connect science concepts and the practice of engineering is essential to produce positive student outcomes. It is also a necessary step on the road of achieving authentic problem-solving skills.

Once the connections across the disciplines are made explicit in the curriculum and instruction, ideally these connections need to be assessed in order to capture students' interdisciplinary learning. Just because interdisciplinary connections might be emphasised in a curriculum, there is no guarantee that the students will identify them or make the connections on their own. Unfortunately, at this stage of development only few STEM programs actually assess explicitly the interdisciplinary connections

Nevertheless, assessing interdisciplinary learning has made many strides. Yet, there is still a long way to go. Developing practical assessment tools and guidelines for classroom use should be prioritized. While STEM education has penetrated many classrooms, most teachers have not received proper training on how to assess student learning in STEM. Building a network or repertoire of resources for classroom practitioners would be a pragmatic step moving forward.

6.2 Mobile apps: mobile-assisted formative assessment

Among other objectives STEM education aims to promote the motivation of students as an essential foundation of learning. *Formative* assessment is considered a crucial ingredient in developing students' motivation and consequently their learning.

Formative assessment, or assessment for learning, is defined as the *assessment for which the first priority in its design and practice is to serve the purpose of promoting students' learning.* Formative assessment shifts the purpose of assessment from a measurement focus to a learning focus.

In this respect, many mobile applications (apps) and mobile technologies are being considered as potential teaching and learning tools, both within the classroom and beyond. Apps can thus be used to bolster STEM education and help achieve its long-term objectives.

With the developments in mobile technologies (there is a widespread ownership of mobile technologies such as smart-phones, tablets, etc. among school-aged youth) there is an increase in the adoption of mobile technologies in educational practice. The integration of mobile technologies in learning has shown to have a significant impact on motivation. Especially the use of mobile technologies for formative assessment, when compared with traditional paper-based means, can be beneficial. Features of mobile technologies, such as their widespread availability and access, personalization and adaptivity, interactivity and immediate feedback provision, facilitate the integration of assessment within teaching and learning, and therefore have the potential to transform formative assessment into a more embedded and pervasive instructional method.

Mobile learning with apps in secondary science education is still in its infancy in many countries. While there is evidence for the motivational impact of mobile-based assessment for learning, not many frameworks exist to better guide the development of mobile-based assessment. This will be an area of development that is expected to enable STEM education to make further progress.

7. How the teacher can motivate and inspire the students to be problem solvers and creative thinkers

7.1 Introduction

Creative problem solving can help foster a more dialogical learning environment in the classroom, which can inspire greatness in students. In addition to using creative problem solving in the classroom, real-life experiences can be a powerful tool in helping students learn and grow. This approach encourages students to become inquiry-minded by both experiencing new things and thinking critically about them. Active learning can be a powerful tool for educators, but it needs to be implemented in a way that is engaging and exciting for students. However, a significant matter of concern involves what engages students in addition to what motivates them in the process of active learning.

Sure, we cannot attract the attention of young learners using traditional learning methods. Traditional learning is unable to lead students towards innovation and creativity because traditional learning cannot motivate students to learn new things. Moreover, the knowledge, which students are gaining from the traditional teaching method, is easily forgotten (Hug & Friesen, 2007). On the contrary, a game-based learning method can be used as one of the ways to engage learners more effectively today. This will increase the student's interest in the content of a subject and learning activities, increase the learning motivation of each student, and provide quick feedback.

Integrating mobile technologies into educational context coincide with the educational purposes of broadening learning opportunities, developing student performance, enhancing learning with diverse needs, aims and styles, and providing learners with authentic learning practices when an alternative way of access to related material is impractical (Kukulska-Hulme, 2009). Mobile learning facilitates personalized learning, considering the individual learner profile and providing learning experiences where the learner wants. Support situated learning through context-sensitive and instant learning, provide authentic learning that is based on real-world problems and projects in relevance with interest of the learner, enable spontaneous reflection and self-evaluation, thus allow students to use less time and space, to collaborate with other students and to receive more teacher support (Traxler, 2007).

A promising education model to teach in today’s digital age is STEM education (Science, Technology, Engineering and Mathematics).

7.2 Motivation

Some researchers believe that students' intrinsic motivations to learn are the main factor influencing their learning, but external incentives such as prizes and teacher support can also have an impact.

The teacher’s role in motivation includes, but is not limited to, creating an environment conducive to learning. The teacher’s role in encouraging support of students’ autonomy, relevance, and relatedness of the material increases motivation to learn. Additionally, the teacher’s ability to develop students’ competence, interest in subject taught, and perception of self-efficacy are all important factors that influence students’ motivation to learn (Schuitema et al., 2016· Zhang, Solmon, & Gu, 2012). Research conducted on the nature of the relationship between students’ perception of social support and autonomy support from their teachers, and self-regulated learning and achievement, showed a significant correlation between the students’ perception of their teachers’ autonomy support and self-regulated learning (Schuitema et al., 2016).

In addition, teachers motivate their students to learn by providing them with positive feedback, in order to develop competence. Providing feedback enables students to gain control over their own learning and a sense of belief about their abilities (Bain, 2004).

Another factor that affects students' motivation to learn is the level of teachers' interest in their teaching. Teachers who are energetic and enthusiastic about their subject or task generally attach positive feelings and importance to how they teach (Zhang, 2014). Students observe what their teachers do in class and how they act. A teacher who displays interest and positive feelings about a subject can reflect those positive feelings toward students, thus increasing their motivation to learn the subject (Theobald, 2006).

It is also stated by Treffinger (2008) that creative problem solving (CPS) is an effective teaching strategy that may assist alter the classroom climate in a positive direction while also increasing student involvement and enthusiasm to study. Therefore, because the *STEM Labyrinth* app represents a virtual simulator of real-life problem solving, asking learners to tackle a real-world problem and by doing that to gain knowledge through problem solving, can be used as an effective method for inspiring and involving students in the learning process.

Generally, integrated STEM education carried out through theme-based, problem-based, inquiry-based, and design-based pedagogies, is reported to have advantages of an increase in student achievement, creating generations of STEM professionals, motivating, exciting and interesting to the students, better-preparing students for the workplace, and increasing the quality of learning for the students (Heil, Pearson, & Burger, 2013).

7.3 Students' Participation in the Learning Process

According to Robinson and Hullinger (2008), student engagement is a crucial factor in influencing the overall quality of education that students get at their schools. The more engaged students are in the classroom, the more likely they are to actively participate and contribute to a successful learning environment. Aside from that, students' motivation and involvement in the learning process rise in direct proportion to how fascinating and significant they perceive the learning process to be. As a result, the participation of students in learning and their satisfaction with the process may be seen as mutually beneficial. Students' happiness has been linked to the inclusion of activities that pique their interest, are relevant to their aims and needs, and build confidence in their capacity to achieve in the course, according to research (Goldberg & Ingram, 2011). It is critical therefore, to include active learning strategies into the curriculum in order to keep students interested and engaged (Goldberg & Ingram, 2011).

According to studies examining the concept of student engagement, 1) teaching practices that incorporate active learning activities are positively related to levels of engagement; 2) instructional environments and practices influence student motivation and engagement; and 3) student motivation and engagement are influenced by instructional environments and practices, according to the findings of these studies. Increased student interest in an assignment promotes deeper levels of thinking. Activities involving collaborative investigations and incorporating activities such as observation, guided inquiry, socialization, and interaction increase student engagement. Increased student interest in an assignment promotes deeper levels of thinking (Dixson, 2010· Goldberg & Ingram, 2011). These key findings are further supported by the "Seven Principles of Good Practice in Undergraduate Education". These include increased interaction between teacher and student, opportunities for students to work cooperatively, the use of active learning strategies, timely student feedback, the requirement for students to spend time working on academic tasks, having high standards for academic work, and teaching that recognizes different learning styles.

It is critical therefore, that teachers include active learning strategies into the classroom if they want to properly engage students in the learning process. As shown by Dixson (2010), increasing the number and variety of methods of communication and contact between instructors and students may be connected with higher levels of student participation. Motivation for learning, of which self-directed learning is a core element, is critical to student engagement in the process of acquiring new skills. A critical component of problem-centered methods to learning is the ability for students to engage in their own learning. Self-directed learning incorporates the elements necessary to motivate and engage students in the learning process.

7.4 Mobile Apps in STEM Education to Maximize Student Engagement

Mobile learning has promising contributions to teaching and learning (Kukulska-Hulme, 2009) but also mobile learning has potential to meet unique needs and demands of STEM education (Krishnamurthi & Richter, 2013).

STEM education and mobile learning share similar pedagogies such as problem-based learning, authenticity, student-directed learning, and collaborative learning. Additionally, through STEM programs students are educated putting emphasis on innovation, problem solving, critical thinking, and creativity (Johnson, 2012).

In conclusion, the STEM Labyrinth method and the Mobile App offer the student and teacher the opportunity to bring together knowledge and skills to solve problems through different situations in real life.

8. Developing identities of STEM teachers at emerging STEM schools

8.1 What is a STEM school?

Education has changed dramatically throughout the years because of the introduction of new technologies in the classroom and considerable changes in curriculum. Traditional classrooms with books and a chalkboard are no longer the norm. Interactive smart boards are common in today's classrooms, as are technological projects that equip students with an electronic device such as a laptop or tablet (i.e., iPads, Chromebooks, etc.). However, technology is not the only aspect of education that has evolved. Curricula in all areas of education have changed dramatically over time, from traditional to Common Core, and more recently, STEM (Science, Technology, Engineering and Mathematics). So, how is STEM education different from regular schooling?

Traditionally, education has focused on knowledge and memorization, or, in other words, focusing more on what you remember than what you apply. Quizzes and tests, for example, used to be focused on memory. Studying entailed attempting to remember the facts that would be examined. Knowledge retention is vital in a STEM setting; however, how students apply that knowledge is equally important. STEM education focuses not just on educating a student about a subject, but also on demonstrating how the subject applies in real life and how they will be able to apply it in the future. A standard math course, for example, may teach a student an equation, but the student may not know how to apply it in real-life situations. A STEM curriculum would teach a pupil Math equation and how to use them in various sectors, like science and engineering.

STEM education is noted for igniting kids' enthusiasm in disciplines like science, technology, math, and engineering by involving them in doing rather than just learning. Traditional education offers a broad range of topics without focusing on or delving further into any of them. A typical lecture is also very different from a STEM program course. Returning to the learning vs. doing debate, a standard curriculum lecture entails an instructor lecturing about a topic in the classroom, students taking notes, and then applying what they have learned to a test or exam. Traditional classroom formats and lectures might be tedious for certain students, causing them to lose interest fast. A STEM program engages students in activities that can be applied directly to the subject at hand, piquing their interest and reducing redundancy.

Furthermore, traditional education is more regimented, with established guidelines for how courses should be taught. STEM breaks the mold by limiting the number of lessons that are repeated. According to a recent Times of India article, "traditional education is focused on replicating the correct hypothesis, while one of the most important pillars of the STEM module is to build creativity." STEM is focused on stimulating the brain and allowing it to create rather than simply replicating what is already known to the world.

8.2 What a STEM teacher is and how to become a good one?

STEM (science, technology, engineering, and mathematics) teachers are educators who teach these subjects. Most STEM teachers, especially at the secondary and post-secondary levels, specialize in one subject area, such as algebra or chemistry. Primary school teachers, on the other hand, frequently give general STEM lessons. Your key tasks include teaching kids about science, math, and technology and motivating them to become interested in STEM subjects. Curriculum creation, lesson implementation, student evaluation, and collaboration with other teachers are all part of your job responsibilities. Because the field of STEM is always expanding, you must participate in professional development and continuing education to ensure that you stay current in your field. In addition to subject area expertise, you need excellent public speaking skills to inspire your students to learn the complex and challenging material.

The educator, or the teacher, plays a very important role in student learning. For a student to gain and maintain interest in a STEM subject, it is necessary for the teacher to facilitate such a learning environment where the student understands the concepts and is able to apply them to real-life applications.
One effective way to enhance the students' interest in STEM is to organize a number of field trips. Since STEM is an application-based curriculum, the principles taught here are applied in many scientific fields and major industries across the world.

The teacher's role is to:

- Cover all the necessary material in the classroom.
- Act as a knowledge medium between the student and the concepts being taught.
- Act as an informed guide whenever the student is unsure of how to proceed with a problem or an assignment.

It is, therefore, of utmost importance for educators to stay constantly up-to-date with the current trends and advancements in STEM learning.

8.3 How STEM education helps students?

STEM Education has developed to be more significant for the world as it poses a range of advantages in a myriad of fields. As most of the sectors are dependent on the STEM fields, it indirectly plays a significant role in the flourishing of the economy. In the coming years, the STEM sector is expected to be one of the largest employers in the world. We see new and innovative technologies being developed every day, and this number is only expected to increase in the coming years.

With significant advances in each of the STEM domains, new career prospects are popping up at a very fast pace. In recent years, there has been a shortage of well-trained STEM workforce in several parts of the world. While the demand of trained students is increasing by the day, the number of students interested in pursuing a career in STEM is going down at an alarming pace.

For example, in the United Kingdom alone, there is the requirement to graduate at least 120,000 STEM majors every year just to meet the demand. Although STEM summer school programmes in the UK have traditionally been well subscribed, the number of students focusing on these topics has gone down recently. This has called for major revamps in the education system, in order to inspire students to opt and excel in STEM subjects. STEM education can be looked upon in two different aspects; from the periphery of students in school and the teaching methodology incorporated therein, and two; for the perspective of the general public, comprising parents, and teachers who can indirectly assist students in opting for the programme.

Students and educators must work together so that subjects are presented and understood in a manner that can be practised in real-life. A better understanding of a STEM programme not only helps us in getting a clear picture of what all it includes, but also presents us with a platform to become more aware of STEM as a learning medium.

- **It provides an abundance of job opportunities**

Education is a vital component of building a great career. When it comes to STEM, countless jobs offer enriching opportunities and good pay. In 2018, in comparison to other jobs that pay an average salary of 12-17$ per hour, the average pay for a STEM job is approximately 20-30. Moreover, with a scarcity of talent in the field of Science, Technology, Engineering, and Mathematics, more and more companies are opting to pay extremes to candidates who fit the category well. This brings us to the next question, why there are so many openings under STEM. All the jobs that fall under the umbrella of STEM are continuously expanding over the years. There is a gradual rise in the demand for jobs. In addition to newer opportunities in the form of AI and Machine Learning are also gaining significant limelight lately. In the present time, STEM fields are much bigger and play a prominent role.

- **Innovation is the breeding fuel**

When it comes to Science, Technology, Engineering and Mathematics, innovation is its other name. As the field is ever dynamic, it presents to students the opportunity to innovate and challenge their knowledge. This is one of the primary reasons for the rising demand for STEM jobs, thereby leading to a surge in the demand. Besides, herein children are presented with the opportunity to work in jobs, which are different and hardly dreamt of. In all senses, STEM jobs make for an interesting future. Whether the factors are money or subject matter, STEM provides a panoramic view of the future. This provides a great platform for students, a future that is filled with innovation, futuristic learning, and a lot of exploration of skills.

- **Introducing STEM at an early age**

Children are often introduced to reading and sports at a young age. The pretext of this is to instill in them curiosity and stimulate their interest. This with time is seeped into their system and they form an interest in exploring it further. The same technique fits well for adults too. When we look back on our educational interests it holds a deeper connection to areas, we excelled or skilled ourselves during our childhood. Thus, introducing kids to STEM during their early years of learning can eventually go on to help generate further curiosity and even ability. It will also assist in sharpening their scientific disciplines too.

Students and youth have a sense of curiosity that constantly looks for activities that can challenge them. Keeping this inquisitiveness and curiosity sparked helps them to maximize their capacities. Science camps assist students to draw inferences, drive connections, and explore deeper meaning and understanding of fields that interest them.

- **Hands-on Learning in STEM**

Many organizations are well known for the science camps and STEM summer schools they organize for enthusiastic young students. These organizations work on a non-profit basis and have tie-ups with many renowned industries and state-of-the-art research facilities. They allow students to visit these places to gain hands-on experience with current scientific research.
The students also get to interact with scientists and industry professionals working in various fields of STEM. They get to explore a number of these fields, while also interacting with other students, from all over the world, having similar interests.

Lastly, speaking about how and where to go from here? As the world is speeding towards a new future, grab STEM learning opportunities as best you can. There is no shortage of opportunities for children and youth who have the curiosity to build their careers. Besides, with plenty of STEM jobs available and its effect felt on almost every sector, makes it a great field for the future. You can take up courses and attend events to build up your knowledge. We should aim at bringing together scientifically inclined minds to equip them with the necessary knowledge, skills, and connection to view the world from a broader perspective and create a promising future.

STEM learning is the way of the future. With humans being ever more dependent on technology, it is necessary to undertake substantial technological developments to meet the demand. This can only be performed sustainably with the help of STEM education. Where STEM proves to be better than a traditional Math and summer programme is the blended learning environment and in showing students how the scientific method can be applied to everyday life. It teaches students to think computationally and focus on the real-world applications of problem solving.

9. School principals and educational community in process of adapting Action plan for STEM education

How well prepared are young students to solve the problems that they will encounter in life beyond school, in order to fulfil their goals in work, as citizens and in further learning?

For some of life's challenges, they will need to draw on knowledge and skills learned in particular parts of the school curriculum – for example, to recognise and solve a mathematics related problem. Other problems will be less obviously linked to school knowledge and will often require students to deal with unfamiliar situations by thinking flexibly and creatively.

Nowadays, the world has been changing rapidly, and the knowledge and skills acquired today are not foreseen to be sufficient while preparing our students for life. It is emphasized that the 21st century skills, such as digital skills, critical thinking, cooperation, problem solving, innovative and analytical thinking, are more than required.

In addition, STEM (science, technology, engineering and mathematics) education prepares all students for the challenges and opportunities in the 21st century economy.

The situation in the job market related to STEM shows that the employment rate of STEM skilled labor is on the rise, despite the economic crisis, and is expected to keep on rising because of the growing demand. At the same time, a large number of STEM professionals are approaching retirement age. Around 7 million job openings are expected until 2025. The demand for STEM skills requires specialized training in both secondary and tertiary education.

STEM learning is largely about designing creative solutions for real-world problems. When students learn within the context of authentic, problem-based STEM design, they can more clearly see the genuine impact of their learning. Indeed, individual competencies in STEM subjects are getting more important for the occupations of the future, which are based on high technology.

The era of the fast moving technology needs to be brought in the classroom, and more teachers need to be aware of the patterns that these students need, in order to capture their attention and make them acquire skills and competences.

However, STEM subjects and skills are considered to be very challenging and not attractive to students, which is shown in the latest PISA (Programme for International Student Assessment) tests, which clearly show that students need different teaching and learning models.

The 2018 Pisa test results, announced in 2019, showed no progress in the EU students' performance in Mathematics and Science (European Commission, 2019). From 2000 to 2015, the advancement of STEM (Science, Technology, Engineering and Mathematics) Education has not been very encouraging. More specifically, although the goal is 15%, the 2015 results show that 22, 2% of European students in Mathematics and 20, 6 students in Science were not admitted to the third level of the Pisa test. Consequently, the United Nations SDG4 (Sustainable Development Goal 4) goal for quality education and sustainable development was not achieved.

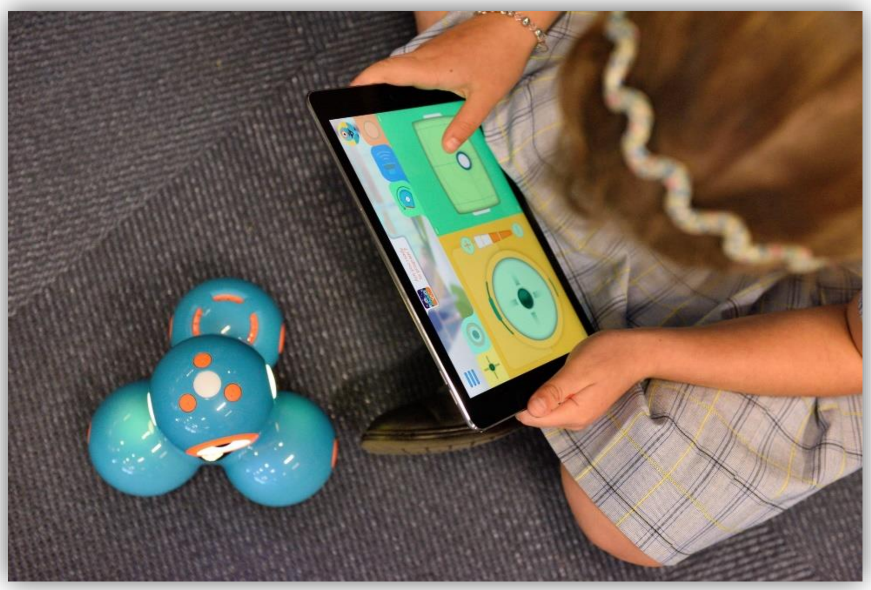
Hence, the development of a solid, relevant scientific understanding of pre-university school students, as well as their preparation to face the challenges of an increasing technical world, requires an exposure to specific teaching practices, beliefs and attitudes. The teachers are key agents so they should promote high self-efficacy and learning outcomes expectancy, engage in challenging but also of impact practices, well aware of the 21st century skills and the future careers in the field.

Therefore, we need to prepare all students for success after high school, regardless of whether they specialise in STEM fields or not.

Finally, innovative approaches are required in education and innovative teachers too. Be one of them! Start innovating yourself, now! Use our STEM Labyrinth App!

In our Toolkit (available here: Toolkit - STEM Labyrinth) you can already find a STEM community map (Activity A1.3, page. 20-39) with several good-practices from each partner Country: therefore we invite you to discover them all!

Not least, in the same document you will find an additional six useful lesson plan scenarios (Activity 1.6, page. 47-82).



10. State boards of education can create a supportive state policy framework as a key foundation to successful STEM education redesign

STEM education has become one of the main priorities at European level closely connected to countries global score related to competitiveness. The World Competitiveness Report 2015-2016, which provides an overview of competitiveness in 140 countries, reveals that education reform must be a key focus of the agenda of governments and policymakers to increase the competitiveness of the economy today, an economy based on innovation, technology and entrepreneurship.

Therefore, we embrace the following five actions to advance effective STEM education, as indicated by the Scientix Observatory report of December 2018 on the STEM Education Practices in Europe:

- Supporting innovative STEM teaching practices and networks based on Inquiry based Science education (IBSE), and other student-centred pedagogies: there is still a lack of confidence, at the level of STEM teachers, in approaching more innovative pedagogies;

- Offering relevant professional development opportunities for STEM teachers and strengthening school-industry collaboration: there is a clear need to support the development and dissemination of relevant STEM training programmes which encourage teachers to build their subject and pedagogical knowledge as well as their confidence in using new technologies in the classroom;

- Innovating the STEM education curriculum and assessment: an important factor is the way the curriculum is written and expected to be taught. Assessment policies that give sufficient weight to formative evaluation methods are needed so as not to inhibit the use of innovative pedagogies in the final years of education;

- Supporting the development and implementation of whole-school STEM oriented strategies: developing a clear STEM strategy at the school level to promote and support innovative STEM teaching can play an essential role in coordinating efforts to improve the quality of STEM teaching and to ensure that STEM teachers benefit from the appropriate support to improve their practice;

- Strengthening trans-disciplinary collaboration to encourage the uptake of integrative STEM teaching: consider strengthening teachers' collaboration and encouraging the exchange of good practices across disciplines to ensure that the conditions are met for a meaningful integrative STEM education in classrooms.

We can innovate - we have to. We can succeed - we have to. For a better present and for a brighter future of our new generations. Moreover, for us all! Use our STEM Labyrinth App!

11. Developing bonds between the schools, community, and policymakers

Globally, strengthening Science, Technology, Engineering and Mathematics (STEM) education is recognized as embedding solutions to many societal problems like the depletion of natural resources and issues related to climate change. The recognition of STEM disciplines as economic drivers motivated the initiation of STEM education in both developed and developing nations. This is based on the thinking that an effective STEM education is a vehicle for developing in students the much desired twenty-first century competences.

Even for students not pursuing STEM-related careers, responsible citizenship today requires a foundation of solid STEM education; be engaging in health care, understanding environmental stewardship, understanding current geopolitics, or explaining global opportunities and crises.

Change begins in our communities. Using our *STEM Labyrinth* App and method will also foster the development of stronger bonds between schools, together with their students and schools, and their local communities. But obviously this is not an easy process, nor automatic.

Communities play a unique and vital role in the development of equitable and sustainable innovation. Engaging a community and its members in its own future provides fertile ground for new ideas, and the opportunity for broad ownership of the ideas and plans that are adopted. Key community stakeholders do not always serve as public officials, business titans or even community leaders. By identifying a diverse sampling to support and engage in the design process, a community is more likely to have a path of more impactful and sustainable innovations.

The STEM Community Engagement process develops a long-range plan to improve STEM education by bringing together a diverse group of community members to plan, design, and create innovative changes in how we teach and learn. National research, education best practices, engineering design processes, and other community engagement protocols have informed the development of the phases, activities and milestones of the process. All stakeholders in these efforts are united y 5 Design Principles to drive the work:

- Equitable: Make STEM literacy and economic opportunity attainable for ALL students.

- Scalable & Sustainable: Drive educational innovation and economic alignment in a coordinated and methodical way

- Innovative: Give communities the tools needed for transformative changes to STEM education

- STEM-Focused: Empower and support a culture that nurtures and supports innovative STEM professionals, and brings businesses, schools, nonprofits and other community institutions together to prepare students and communities for 21st century jobs

- Collaborative: Develop a statewide network for STEM excellence through local, state, and national networks and evidence-based research.

As an example, citizen science offers youth and educators unique opportunities to observe and explore the world through authentic research experiences that are necessary for robust STEM learning. And also in this framework, our STEM Labyrinth App and method can be a valid companion for learning.

Out-of-school settings are an essential part of the ecosystem of education for STEM learning. Activities outside of the school day have great potential to provide STEM experiences that are engaging, responsive, and make connections. Research suggests that engagement in authentic science experiences is required to develop fluency with STEM—we have to do science to learn science (2). But youth have limited chances to participate in this kind of immersive, student-centered experience with STEM topics. Even more rare are opportunities to connect authentic science practices to students' own lives, interests, and learning contexts. Educators and youth increasingly seek out ways to work with real data and scientific problems, particularly those that have a connection to their local community and environment (3). Citizen science directly engages youth and educators in real-world research, wherever they are and whatever their interests may be. Through citizen science, youth take part in active investigations connected to science that has significance in the wider world. Citizen science immerses youth in the practices of science, and makes sense of those practices in the places where they live, learn, and play. Citizen science provides a context where youth educators can help learners develop STEM skills such as observation, technology use, and data literacy, and weave those skills together to apply them directly to problems they care about. In these ways, citizen science can uniquely address robust STEM learning goals through learning that is as much about personal interest and identity as it is about content and concepts.

References

(1) Parno, Estianinur and Eny Latifah, The Increase of Problem Solving Skills of Students through STEM Integrated Experiential Learning with Formative Assessment, *The 2nd Science and Mathematics International Conference (SMIC 2020), AIP Conf. Proc.*

(2) Gao et al, Reviewing assessment of student learning in interdisciplinary STEM education, *International Journal of STEM Education (2020 ,7:24)*

(3) Howes et al, Re-envisioning STEM education: curriculum, assessment and integrated, interdisciplinary studies, *Royal Society Report (August 2013)*

(4) Papadopoulou et al, Revisiting evaluation and assessment in STEM education: A multidimensional model of student active engagement, *Proceedings of EDULEARN 17 Conference (Barcelona ,Spain, 2017)*

(5) Nikou & Economides, A Framework for Mobile-Assisted Formative Assessment to Promote Students' Self-determination, *Future Internet 2021, 13, 116*

(6) Nikou & Economides, Mobile-Based micro-Learning and Assessment: Impact on learning performance and motivation of high school students, *Journal of Computer Assisted Learning, Volume 34, Number 3, June 2018*

(7) Kousloglou, Mobile Learning in Science: A Study in Secondary Education in Greece, *Creative Education, 2019, 10 (1271 – 1284)*

(8) A. Popovici, O. Istrate, C. Mironov (2019). *Teachers' Perspective on the Premises and Priorities of STEM Education*, European Schoolnet

(9) AfterSchoolSTEM-170510.pdf (citizenscience.org)

(10) Akua Carraway, Karl Rectanus, Mark Ezzell (2012). The Do-It-Yourself Guide to STEM Community Engagement. How to Build Sustainable Education Innovation in YourCommunity, diy-guide.pdf (indianaafterschool.org)

(11) Nistor, A., Gras-Velazquez, A., Billon, N. & Mihai, G. (2018). *Science, Technology, Engineering and Mathematics Education Practices in Europe. Scientix Observatory report - December 2018*, European Schoolnet

(12) Roungos G., Kalloniatis C., Matsinos Y. (2020). *STEM Education in Europe & the PISA Test,* Scientific Educational Journal "educ@tional circle"

(13) Schwab, K. (2015). *The Global Competitiveness Report 2015-2016*, World Economic Forum

(14) Vongai Mpofu (2019). A Theoretical Framework for Implementing STEM Education, A Theoretical Framework for Implementing STEM Education | IntechOpen

(15) Bain, K. (2004). What the best college teachers do. Harvard University Press.
(16) Dixson, M. D. (2010). Creating effective student engagement in online courses: What do students find engaging? Journal of the Scholarship of Teaching and Learning, 10(2) 1-13.
(17) Goldberg, N. A., & Ingram, K. W. (2011). Improving student engagement in a lower- division botany course. Journal of the Scholarship of Teaching and Learning, 11(2), 76-90.
(18) Heil, D. R., & Pearson, G., & Burger, S. E. (2013), Understanding Integrated STEM Education: Report on a National Study Paper, ASEE Annual Conference & Exposition, Atlanta, Georgia, June 23. Georgia: ASEE.
(19) Hug, T., & Friesen, N. (2007). Outline of a microlearning agenda. Didactics of Microlearning. Concepts, Discourses and Examples, 15-31.
(20) Johnson, C. C. (2012). Implementation of STEM education policy: Challenges, progress, and lessons learned. School Science and Mathematics, 112(1), 45–55.
(21) Krishnamurthi, M., & Richter, S. (2013). Promoting STEM education through mobile teaching and learning. International Association for Development of the Information Society. Retrieved, March 20, 2017,
(22) Kukulska-Hulme, Agnes (2009). Conclusions: Future Directions in Researching Mobile Learning. In: Vavoula, Giasemi; Pachler, Norbert and Kukulska-Hulme, Agnes eds. Researching Mobile Learning: Frameworks, tools and research designs. Oxford, UK: Peter Lang Verlag, pp. 353–365.
(23) Robinson, C., & Hullinger, H. (2008). New benchmarks in higher education: Student engagement in online learning. Journal of Education for Business.
(24) Schuitema, J., Peetsma, T., & van der Veen, I. (2016). Longitudinal relations between perceived autonomy and social support from teachers, and students' self-regulated learning and achievement. Learning and Individual Differences, 49, 32-45.
(25) Traxler, J. (2007). Defining, discussing and evaluating mobile learning: The moving finger writes and having writ. The International Review of Research in Open and Distributed Learning, 8(2), 1–8.
(26) Treffinger, D. J., Selby, E. C., & Isaken, S. G. (2008). Understanding individual problem-solving style: A key to learning and applying creative problem-solving. Learning and Individual Differences, 18, 390- 401. http://dx.doi.org/10.1016/j.lindif.2007.11.007

(27) Theobald, M. A. (2006). Increasing student motivation: Strategies for middle and high school teachers. Thousand Oaks, CA: Corwin Press.

(28) Zhang, Q. (2014, February 14). Assessing the effects of the instructor enthusiasm on classroom engagement, learning goal orientation, and academic self-efficacy. Communication Teacher, 28(1), 44-56.

(29) Zhang, T., Solmon, M. A., & Gu, X. (2012). The role of teachers' support in predicting students' motivation and achievement outcomes in physical education, Journal of Teaching in Physical Education, 31(4), 329-343.

(30) Green, M. (2019, May 12). STEM Teacher: What Is It? and How to Become One?

(31) Ziprecruiter. ZipRecruiter. Retrieved May 2, 2022, from https://www.ziprecruiter.com/Career/STEM-Teacher/What-Is-How-to-Become

(32) Myhill, R. (2022, April 21). What Is Stem Education? A Beginner's Guide. LIYSF. Retrieved May 2, 2022, from https://www.liysf.org.uk/blog/what-is-stem-education

Authors

- **Association of European Movements (ATLME), Portugal** (Diogo Mota)
- **Learnmera Oy, Finland** (Julia Heubuch)
- **Association for European education and mobility (AMETA), North Macedonia** (Mariche Koleva, Hristina Leova)
- **Doukas School , Greece** (Yiannis Kotsanis, Spiridon Mondelos, Emmanouil Mogios)
- **MARTNA PÕHIKOOL, Estonia** (Järvi Kimst, Kairi Mustjatse)
- **Saint George Lyceum, Cyprus** (Giorgos Chimonides, Elena Hadjigeorgiou)
- **Enjoy Italy** (Alessandro Gariano)

STEM LABYRINTH

VISIT US ONLINE:

@STEMlabyrinth

www.stemlabyrinth.com

Disclaimer:

“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 herein.”

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

The project is financed by Erasmus+ KA2: 2020-1-PT01-KA201-078645