PhysicsKIT 4STEM

IO2/A1: EDUCATORS HANDBOOK

PhysicsKIT Educator's Handbook & Skills and Achievements Framework

Emphasys Centre & Schole

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

This project has been funded with support from the European Commission.

Project Nº: 2020-1-FR01-KA201-080433

Revision History

Version	Date	Author	Description	Action	Pages
[V1]	26/10/2021	PARTNER ORGANIZATION	[Creation of Educator's Handbook]	[U]	[18]

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

Referenced Documents

ID	Reference		Title
1	2020-1-FR01-KA201-080433		PhysicsKIT4STEM Proposal
2			

Applicable Documents

ID	Reference	Title
1	2020-1-FR01-KA201-080433	PhysicsKIT4STEM Proposal

Table of Contents

1. Overview – Introduction to PhysicsKIT4STEM

PhysicsKIT4STEM has as its primary objective to strengthen the teaching skills of STEM educators by offering a hands-on approach to teaching physics through DIY kits, electronics, and programming, powered by a Raspberry Pi computer. At the same, the project aims to increase the interest of students in sciences and address the issue of gender imbalance in STEM classrooms and encourage young girls in science and engineering subjects.

The main objective will be achieved through the following activities:

- Design and development of a curriculum for using the PhysicsKIT to teach students physics concepts such as motion and forces, gravity, vibration, and electricity, through the creation of hands-on constructions, simple programming, and physical computing;
- Elaborate a Glossary, explaining terms used in physics, programming, electronics, and physical computing;
- Design and development of the PhysicsKIT powered by a Raspberry Pi single-board computer, complemented by sensors and electronics to simulate and experiment on physics phenomena along with a guide to build it;
- Lesson plans that will support the curriculum to build kits and use peripherals in an educational hands-on play approach;
- Prepare a Learning Motivation Environment for the delivery of the curriculum to teachers/educators and skills retention purposes;
- Testing, validation, and finalization of the PhysicsKIT Back-pack and Educators Handbook and Resources;
- Support the outcomes through a dedicated virtual space (PhysicKIT Club) providing access to all project results and infrastructure for supporting the growth of a community of adopters/practitioners/enthusiasts.

1.1 Challenges in STEM education

Teachers are a huge influence on a student's choice of subject matter or their decision to pursue a STEM career. A survey conducted by ICM-S suggests that students' decisions to study STEM in college can be directly influenced by classroom instruction and teacher advice. However, student motivation can be a huge problem for even the best teachers. But teachers also face a lot of challenges when it comes to STEM education.

1. **Teaching STEM at a young age.**
   Student boredom is a huge challenge faced by most teachers. The ICM-S research suggests that most students lose interest in science between 12–13 years of age. A good way to counteract this challenge is to inculcate a love for science early on in the student's life. Educators can integrate STEM lessons into a daily curriculum so children will develop a stronger understanding of these skills early on.
2. **Innovative Teaching.**
   According to a study undertaken by the Institute of Engineering and Technology: *"Most students see the curriculum as boring and irrelevant to life outside school."* Studies show that *"practical activities enable students to build a bridge between what they can see and handle and scientific ideas that account for their observations".* Practical activities also enable group discussions, teamwork, communication, and peer-to-peer interaction, all of which are considered important 21st-century skills.
3. **Making it topical!**
   Most children struggle to understand the importance of science because they cannot see the connection between what they learn in the classroom and the happenings in the real world. Students also have a perception of science subjects being either too difficult or too boring. By making the subjects topical students will be able to understand the relevance of science in everyday life. A typical STEM lesson usually involves four basic steps:
   - Identify a real-world problem.
   - Ask questions to explore the problem (and potentially solve the problem).
   - Develop solutions.
   - Explore a hands-on activity.
4. **Erasing Gender Divide.**
   The ratio of men to women in STEM fields is vastly disproportionate, with men outnumbering women. Including more girls in STEM education is a challenging task, as most girls, unfortunately, grow up with a lot of prejudice, even if it is unintentional. Teachers can do lots of things to help their female students overcome these biases and nurture their STEM education: encourage female students to participate more and introduce them to more female role models.

Teachers can also introduce their female students to the various initiatives that advocate women's role in STEM fields.

2. Principles of the STEM curriculum

The STEM Curriculum will demonstrate an integrated learning approach, and establish STEM learning pathways:

- to be very engaging for both students and teachers
- to develop students' ability to collaborate with others
- to improve students' ability to communicate ideas
- to link school learning to future study and work opportunities
- to identify and consolidate connections between learning areas
- to deliver content from STEM disciplines throughout the life
- to improve students' ability to transfer knowledge and skills from one learning area to other contexts
- to provide a rich context for learning and developing the general capabilities for 21st-century learning.

Learning pathways means:

- Inspiring students about possible futures in STEM-related fields and making connections between their current and future learning and potential career pathways
- Active STEM as a path to learning
- Encouragement of a growth mindset learning
- Pair programming
- Building from concrete to abstract
- Improving the integration of statistical concepts, data analysis, and problem-solving skills into school programs
- Encourage teachers to prioritize STEM content knowledge.

STEM Curriculum is based on the following PRINCIPLES**:**

STEM CURRICULUM IS INCLUSIVE AND ACCESSIBLE	QUALITY AND RIGOUR	RELEVANCE AND AUTHENTICITY
• makes connections between current and future learning and career pathways • provides access and challenge for all learners • develops insights into the relevance of STEM in society and the world of work	• allows for team teaching, scheduling of regular meetings for the STEM team • encourages working with staff, students and parents to establish a shared understanding of STEM	• apply and integrate the knowledge from each of the STEM learning areas by providing challenge for all learners • use real-world challenges by enabling students to develop as self-directed and lifelong learners

Fig. 1 Principles of STEM Curriculum

Curiosity and Initiative	•Children explore the environment with an increased focus on ways to learn about people, things, materials, and events
Observation and Investigation	•Children observe and investigate and events in the environment to develop new knowledge and spark new interest
Making prediction and risk-taking	•Children are encouraged to m.ake predictions at the beginning of STEM activities on what they think might happen
Experimenting and Task Analysis	•Children are provided with opportunities to formulate ideas, test them, and coming up with conclusions
Engagement and Attention	•Children's interests are sparked by our interactive activities even if they are challenging or difficult
Creativity	•children will engage in creative play and express themselves in different ways
Problem-Solving	•Children construct knowledge by making mistakes and coming up with ways to solve problems
Invention	•Children formulate and explore ideas and develop creativity
Exploration and Play	•Children will learn from each other, will explore their environment
Making Connection	•Children will connect with the world through exploration, self-discovery, and nature

Fig. 2 Principles through implementing a STEM curriculum

3. Why it is important to encourage young girls to follow science and engineering subjects.

"By advancing women's equality, $12 trillion could be added to global GDP by 2025" - Dharmendra Kanani, Director of Insights at Friends of Europe.

Women and girls in STEM are still being excluded from fully participating in the STEM field. The quality of their education and the subjects they study are influenced by biases, stereotypes, and sexism. Most women lack motivation in pursuing STEM careers because they fear that they would not be taken seriously in such positions and that they would not get the same opportunities as their male colleagues. Other reasons that have been reported for the low participation of women in STEM job positions include hostile and sexist work environments, the assignment of boring tasks, pay gaps, and the absence of career development and recognition. Moreover, findings from other studies indicate that gender-science stereotypes negatively influence women's ambitions to enroll in STEM-related courses at university.

According to the European Institute for Gender Equality, the need for STEM professionals is expected to increase up to 8% by 2025, and employment in STEM-related positions by about 6.5%. Thus, the continuous under-representation of women in STEM will result in a loss of talent and will go against the EU's development potential. Reducing the gender gap in STEM education areas could help foster economic growth via both higher productivity and increased labor market activity.

Increasing the participation of women in STEM subjects will have a strong positive GDP impact at the EU level. More specifically it would contribute to an increase in EU GDP per capita by 2.2 to 3.0% in 2050.

On the 11th of February, the United Nations celebrated the International Day of Women and Girls in Science. The United Nations advocate that "science and gender equality are both vital for the achievement of the internationally agreed development goals, including the 2030 Agenda for Sustainable Development."

4. Implementation of STEM methods

STEM Curriculum includes activities that will help students to develop important life skills and that will introduce them to the wonders of electronics, physical computing, and robotics. With STEM activities for students, teachers will present the curriculum, focusing on experiential learning, helping them to develop skills such as DIY-ing, problem-solving, critical thinking, creativity, and teamwork. Theses approach will help students feel more engaged with learning.

STEM Lessons are created to invite students to explore science, technology, engineering, math, outdoor garden, and literacy as a thematic unit. Students become experts in a piece of equipment and teach this to the rest of the class.

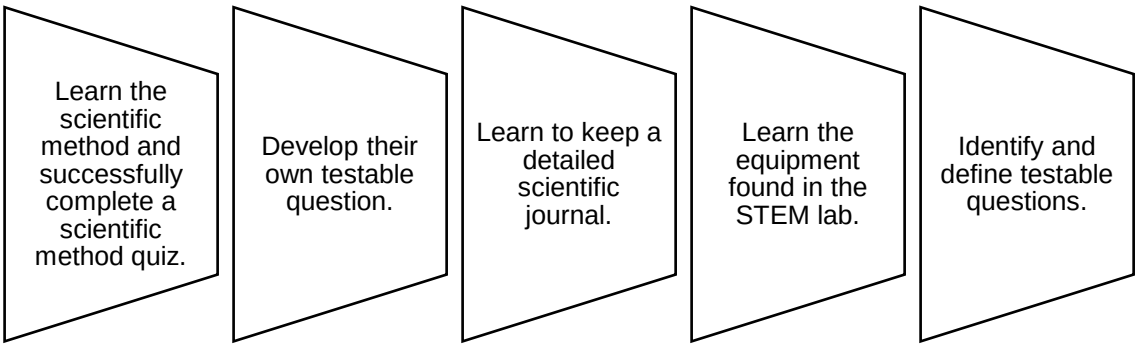


Fig. 3 Student STEM Objectives

Students will use a research plan that includes the development and identification of the following:

- Variables (independent, dependent, controlled for a controlled experiment)
- Materials needed to conduct their project considering
  - Cost

- Availability of resources in school and/or community, following safety rules and procedures

Students must formulate issue hypotheses, review literature as primary reading sources, differentiate between subjective/objective data and their usefulness to the issue, or examine applicable existent surveys, impact studies, or models.

Students will develop the following STEM activities:

- evaluate web resources
- differentiate resources and understand when to use each type
- summarize, analyze, and reflect on scientific investigation
- develop their research plan and share it with their peers
- develop their complete experimental procedure, begin experimenting in the lab
- organize, graph, discuss and statistically analyze the data
- write their conclusion and debate
- prepare an oral presentation that summarizes their research; the presentation will use a digital presentation program (PowerPoint, Keynote, Google Presentation, etc…)
- find the relevant computational formulas
- compare the recorded data to determine the grade level for the inclusion of the topic
- present their work to their peers, teacher, and community (at competitions, at the regional science fair)
- apply the concepts, principles, and processes of scientific inquiry.

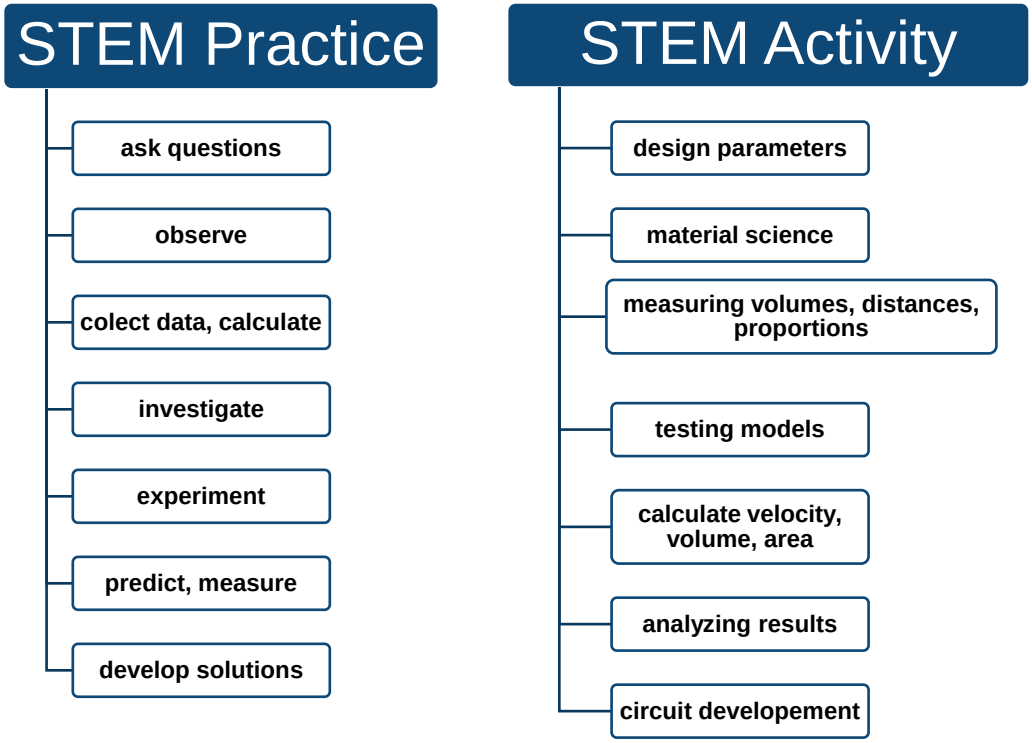


Fig. 4 STEM Practice & Activities

Teachers need to assure that the assessment of these activities includes:

- Class presentations
- Online discussion forum
- A logical conclusion based on the data will be drawn.
- Various competitions.

After completing the STEM curriculum, students will become familiar with programming basics, algorithms, logical reasoning, and coding activities. Students will be able to understand the basics of robotics, and algorithms, with the help of a wide variety of hands-on activities, selecting appropriate simulations or projecting possible viewpoints, variables, applicable data sets, and formats.

Students will get a betting understanding of physical computing, gamification, algorithms, logical reasoning, and conditional programming with the help of a variety of coding activities. The activities in the curriculum will help them develop important skills such as problem-solving, attention to detail, patience, attention to detail, abstract thinking, communication, and empathy.

5. How to use STEM in the classroom

STEM activities are engaging and motivating for many students. However, not all students feel that way when facing a STEM challenge. When this happens, teachers face a problem.

To help teachers overcome this setback and to make sure that they engage all the students in STEM activities, it is important to use these activities in different subjects, finding a balance between hands-on activities and computer-based learning. This will allow students to understand that not all STEM activities require them to sit down and type commands and that they can find activities that are closer to their fields of interest.

This integration may occur at different levels (adopted from Vasquez, Sneider, & Comer, 2013):

1. **Disciplinary**: concepts and skills are learned separately in each discipline
2. **Multi-disciplinary**: concepts and skills are learned separately in each discipline but within a common theme
3. **Inter-disciplinary**: closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills
4. **Trans-disciplinary**: knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus helping to shape the learning experience

This way, it is possible for an English teacher to use STEM in his classroom and kids can create a house for a character or a city map.

Teachers can also rely on STEM to introduce or to help students practice some of the concepts they need to master.

In that sense, physics teachers can use the Lesson Plans that come with the PhysicsKIT4STEM to talk about waves, forces, or even electricity.

The best way to introduce STEM to your classroom is by using a relevant, authentic, and real problem that the students can identify with. Both teachers and students must work together so they can shape the problem-solving process.

5.1 Tips and strategies to make STEM part of your classroom

Incorporating STEM in the classroom implies adjustments that a teacher needs to be willing to do, to prevent STEM to became only another word, instead of the pedagogy and curriculum that it is.

To help teachers implement STEM in the classroom, some steps might be useful:

Teach knowing and doing.

As teachers, we understand that learning needs a purpose. When students find meaning in what they are learning, they show a better engagement in the activities.

So, students need to enroll in activities where they can create products, not just take tests. Those products should be exhibited to their peers, teachers, parents, and adult experts. Teachers can get better results by using the cycle of inquiry to stress continual reflection and refinement of the product. This requires an intentional assessment tool like a design rubric or reflection form that is graded.

Allow for creativity.

To allow students to enhance their creativity, teachers will need to rethink their curriculum and allow some experimentation and, for instance, incorporate a creativity rubric into their projects. Teachers can think about creating a category inside their projects that is open-ended, in such a way that students can think of outside-the-box solutions to the problems or situations they are working in.

Make teamwork central.

A lot of today's jobs require teamwork skills. To help students identify the exact tasks associated with 21st-century teamwork and develop these skills, teachers can promote teamwork during the STEM class moments.

Start with questions.

Any important results in science, engineering, or technology start with a question. An engaging, rigorous STEM curriculum emphasizes. A STEM program can teach facts and information -- these are essential to young people. But make sure that students are constantly challenged by interesting, meaningful questions -- with potential answers that matter to the world.

Finally, there is one other step that teachers need to remember, which is to **adjust the language and expectations**. Terms and words like *trial*, *experimental*, *challenge,* or *design*, even though might seem easier to use in a science class, can be used in other subjects and is a good way to start helping students and teachers familiarized with STEM-related words.

The best and easiest way to implement STEM is to start small, choosing a topic that you are familiarized with and modifying it a little so it becomes a problem or a question for students to solve.

Another tip is to use materials available online that have already been used and tested. **PhysiscsKIT4STEM lesson plans** are one example of this.

The PhisicsKIT consortium has created a skills and achievements framework so that teachers can get a better understanding of what is expected of their students to achieve and works also to reward students for their effort in exploring the different activities.

6. PhysicsKIT4STEM

6.1 The PhysicsKIT console

The PhysicsKIT is designed to be possible to be assembled in the classroom by the students under the supervision of the teacher. It is expected that kids from the age of 8 will be able to assemble the PhysicsKIT themselves based on the assembly instructions.

The idea is to provide a full guide on how to build the PhysicsKIT, install and configure the software and then use it for all the envisaged project activities.

The PhysicsKIT elegant design imitates a suitcase with all necessary components included in their own space, offering ease of use in the classroom as it will not be necessary to add any external components. The PhysicsKIT is a fully-fledged Raspberry Pi-based computer as all the necessary components and peripherals are included in one package. The user just needs to connect the PhysicsKIT with a monitor via the HDMI port of the Raspberry Pi, as well as connect a keyboard and mouse via the USB ports.

Fig. 5 The PhysicsKIT (with covers)

FIG. 6 THE PHYSICSKIT (OPENED)

Fig. 7 The PhysicsKIT (CLOSED)

6.2 The PhysicsKIT Glossary

The **PhysicsKIT glossary** aims the creation a **glossary** explaining terms, keywords, and expressions that are used in physics, electronics, programming, and physical computing, but also in developing and building constructs. The glossary will include terms from the modules of the curriculum, technical terms for assembly and configuration, explanation of components, sensors, electronics, etc., and other relevant concepts. The intention is to have a compact list of keywords commonly used in areas relevant to the project together with a simplified explanation or definition, suitable for children in the target group.

This dictionary-style **glossary**, is a complement to the developed curriculum, containing all necessary terms, definitions, keywords, and expressions for physics, programming, physical computing, electronics, sensors, and other components, all defined and explained in simple words so young children/pupils can easily adopt the new vocabulary and can recollect them during the course that will be used in the PhysicsKIT4STEM project

You can also find an **online glossary**, on the PhysicsKIT4STEM webpage: https://physicskit4stem.eu/

6.3 The PhysicsKIT Assembly guide

In other to help teachers and students to assemble our PhysicsKIT, there is an Assembly Guide available.

In this guide, teachers can find information about the KIT and what is included in it; step-by-step instructions to assemble the kit, and information about the software that is included.

For more information, you can see the PhysicsKIT Assembly Guide. The guide is available in different languages, such as English, Greek, French, and Portuguese.

7. Lesson Plans

To help teachers use STEM in their classrooms, the project partners have come up with some lesson plans.

These lesson plans focus on specific physics topics as well as physical computing to engage students in exploring different approaches and ways of using STEM in the classroom. To help students with their coding skills, some of these lesson plans also use Python as an additional challenge.

With each lesson plan, you will find the description of the activity, the learning objectives, the links to the curriculum, and a list of the material required so that the activity can be applied.

Here you can find some information about each lesson plan and you can see the full lesson and download it on the project's website: https://physicskit4stem.eu/intellectual-outputs.

7.1 Motions and Forces

This lesson plan is connected to Module 1: Motion & Forces of the PhysicsKIT Curriculum. It uses an infrared sensor module along with a Python program to collect data on the acceleration of an object.

In this lesson plan, we will conduct a scientific experiment to measure the acceleration of an object caused by the gravitational force of the Earth. For this purpose, we will make an experimental apparatus using our PhysicsKIT and operate it with an appropriate program. Then we will collect data and analyze them to measure the acceleration of the object.

7.2 Conservation Energy and Momentum

This module proposes an introduction to the concepts of conservation of energy and momentum. Energy is, like the principles and concepts presented in this curriculum, very important when it comes to the knowledge of our universe.

The universe is indeed composed of matter and energy. On one hand, matter is concrete and visible, formed by atoms, and has a mass. We observe it with our eye, with a microscope when it is too small, or with a telescope when it is too far. On the other hand, even if we feel what the energy is, we never observe it, only its effect on our environment. Energy is defined by the capacity to change the state of a system. This can be about the system's velocity, temperature, stretching, wave emission... the modification will alter any physic properties of the system.

People know a lot of transformation of energy examples without really understanding them: the photosynthesis by the plants, when you turn on a light bulb, when you use a dynamo, when you watch television, when you use your computer or your optical fiber internet connection. This module will propose simple but essential activities to understand these concepts that are essential in this field of study, to allow young students to improve their knowledge, and encourage them to continue to discover their pathway within science (Image 1).

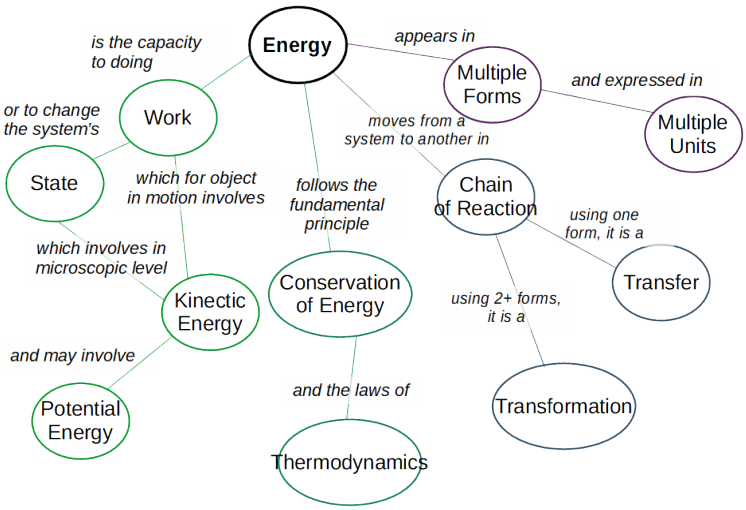


IMAGE 1: **MINDMAP OF ENERGY AND THE CONCEPTS AROUND IT**

7.3 Electricity and Magnetism

Electricity has existed since the beginning of the universe, which is composed, according to the physical principles of "matter". Its human-created history dates to the beginnings of mankind. It is very discreet most of the time but sometimes manifests itself in a very spectacular and brutal way: for example, in the form of lightning associated with thunder and the attraction of some substances by others (amber and magnet stones).

Discovered in the 18th century, electricity can be made from different sources of energy. The most common is thermal energy, that is, heat produced by burning coal, oil, or gas. This heat can also come from groundwater hot water, this is called geothermal. It also comes from radioactive metals such as uranium or plutonium used in nuclear power plants. On the other hand, this heat can simply come from the sun, solar energy, or from the wind, wind energy.

The electricity we receive in our homes, factories, schools, ... is produced in power plants.

7.4 Waves

In this module, you will learn about waves and the differences between their types. Also, the theory of how waves travel and behave when traveling through different mediums will be explored. The learning material will cover wave equations, longitudinal waves, transverse waves, as well as their properties, similarities, and differences. Along with the teaching material, you will find some experiments that you can perform using the Raspberry Pi and various other sensors. In addition, resources, references, and other useful material have been included at the end of the chapter to improve your learning and understanding of the topic. By the end of this module, you should have a basic understanding of the field of waves and the theory around them.

7.5 Gravity

This lesson plan is about gravity. Gravity is a force that is all around us and it is responsible for attracting two objects towards each other.

This force has been around since the beginning of the universe, and it works the same way everywhere. It is the gravitational force that keeps us from falling off the Earth and what keeps Earth and all other Solar System planets orbiting around the sun. It was thanks to the gravitational force that the sun was formed, four and a half billion years ago.

In this lesson plan, and using everyday objects, students will be able to understand what gravity is and how you can see its effect on objects.

They will also be able to correctly use the vocabulary and terms regarding the gravity topic, such as gravity, mass, weight, force, attraction, for example.

8. Skills and Achievements

8.1 Introduction

The PhysicsKIT4STEM Skills & Achievements Framework offers informal recognition to students who have successfully completed a series of quests and/or challenges of the PhysicsKIT Curriculum. These quests/challenges may refer to one module or to the whole curriculum and are based on the Open Badges framework (openbadges.org).

The main aims of the PhysicsKIT4STEM Skills & Achievements Framework are:

- To design the ecosystem where Open Badges will identify, recognize and validate certain skills of students.
- To set the quests/challenges for each of the PhysicsKIT Badges to be gained for each main module of the curriculum.
- To promote the use of innovative multi-level tools in the form of e-resources and hands-on material for educational play.
- To implement all technological actions to link the Open Badges Framework to the learning portal in terms of participating in quests/challenges, issuing and exhibiting Open Badges on students' and teachers' profiles.
- To initiate the creation of synergies between schools, institutions, STEM centers, NGOs, the labor market, and other stakeholders for the endorsement and accreditation of the PhysicsKIT Curriculum and the hard and softs skills of students.

This document provides detailed information regarding the following:

- Theoretical background of the methodology used.
- Description of the ecosystem in relation to the structure, criteria and description for issuers, graphic design, technological integration and endorsement procedure of Open Badges.
- Practical guidelines for issuing an Open Badge by using the learning portal developed.

The final Skills & Achievements Framework will be integrated into the Learning Portal which will check conditions and will award the PhysicsKIT Badges.

8.2 Open Badges

Open Badges are a digital representation of skills, learning outcomes, achievements, or experience such as:

- Hard skills: knowledge, competences, etc.
- Soft skills: critical thinking, communication, etc.

- Participation and community involvement
- Official certification
- Authorization

An Open Badge is an innovative system used in the USA and many EU countries for the validation and recognition of learning, using the OB technology offered as an open educational resource. It is a technology which promotes open access and participation of all stakeholders involved in badges process, while allowing the creation of synergies between the learners-earners (i.e. young people, students), the issuers (i.e. schools, stakeholders, enterprises, NGOs including trainers/ volunteers as facilitators) and the badge consumers (i.e. formal education, public authorities, official bodies, (potential) employers). This will lead to the endorsement process leading to a transparent, transferable, valid and credible validation of a body of skills and knowledge related to a set of competences for students and teachers.

The Open Badges system is a very inclusive solution: it enables anyone to get actively involved in designing, testing, implementing, and promoting the learning outcomes and achievements. This is what major European documents on Recognition are calling for, as well as Erasmus+ in emphasizing the “transparency and recognition of skills and qualifications to facilitate learning, employability and labor mobility: priority will be given to actions promoting permeability across education, training and youth fields as well as the simplification and rationalization of tools for transparency, validation and recognition of learning outcomes. This includes promoting innovative solutions for the recognition and validation of competences acquired through informal, non-formal, digital and open learning” (Horizontal Priorities).

An Open Badge is visual verified evidence of achievement. It has a visual part (image) and meta-data, which is encoded in the image. Each digital badge must comply with the required standard data fields, such as: issuer, date of issue, description of the badge, link to assessment criteria, link to evidence of what a badge owner is claiming, link to a specific competence framework and tags, which puts an Open Badge in relation to specific context.

Some of the benefits of Open Badges are presented below:

- Badges can demonstrate a wider range of skills and achievements of a learner acquired through formal, non-formal and informal learning methods and activities.
- Badges are portable and verifiable digital objects. All this information may be packaged within a badge image file that can be displayed via online CVs and social networks.

- Each Badge includes the description of the achievement: i.e., it describes the path a learner undertook for his or her achievement, accompanied by the evidence to support the badge award.
- Each Badge includes information about the earner's identity, a link to information about the issuer and a link to a description of what a badge represents.
- Badges can be used to unlock learning and career pathways. They can be used to support individuals to achieve learning goals, to provide routes into employment, and to nurture and progress talent within organizations.
- Badges can represent personal attributes that matter to employers (digital skills and soft skills).
- Badges can be used in a professional or educational context. Thousands of organizations, including non-profit organizations, major employers or educational institutions, issue badges in accordance with the Open Badges Specification.

8.3 Key Elements

Issuer

The issuer defines a competence that could be acquired by a user, designs the learning material for it and assesses the users with regards to the acquisition of the competence. The issuer then creates a relevant badge and makes it available for earning by any user. For each badge, the issuer should make available details of the criteria that an earner must meet to be awarded the specific badge. The reviewer of an assessment compares the evidence provided by the earner against the specific badge criteria.

Any individual or organization can create an Issuer profile and begin defining and issuing Open Badges. This is done by a diverse range of organizations and communities, including:

- Schools and universities
- Employers
- Community and non-profit organizations
- Government agencies (including NASA)
- Libraries and museums
- Event organizers and science fairs (Including Intel)
- Companies and groups focused on personal development (such as the PhysicsKIT partnership)

An entity that can be described with a name, a description, a URL, an image, and an e-mail address is a potential candidate to become an issuer. Furthermore, it needs a technology platform that supports the Open Badges Framework to issue Open Badges.

Badge issuing platform

Many companies have badge issuing platforms, compliant with the Open Badges Framework. They provide a wide range of services which allow non-technical users to issue Open Badges credentials. The platforms used for issuing Open Badges offer a variety of custom services including online badge designers, badge discovery, issuing, assessment workflow, display, user profiles, social sharing and tools to integrate with existing learning systems. All Open Badges issuing platforms allow recipients to export their badges to other online options. This allows users to stack and share their badges earned on different platforms and to choose their own spaces to establish their identity on the web.

Earner

Open Badges help recognize skills gained through a variety of experiences, regardless of the age or background of the learner. They allow earners to get awards for following their interests and passions, and to unlock opportunities in life and work by standing out from the crowd. Earners have to register on the organization's platform and can claim a badge when the pre-defined criteria have been met during the evaluation phase.

Evaluation

There are different options for the assessment process:

- Asynchronous assessment: learners seek out the assessment when it is convenient for them instead of being required to take an exam at a pre-determined time.
- Stealth assessment: assessment and awarding badges can happen automatically and provide immediate feedback.
- Portfolio assessment: work samples, projects, and other artefacts the learner has produced can be used as evidence for claiming a badge.

Displayer

Open Badges are designed to be shared. By sharing them, individuals exhibit their achievements to others and turn them into a valuable currency to unlock new opportunities. Displayers can utilize the Displayer API for retrieving earner badges from the Mozilla hosted Backpack. Mozilla set up the first Backpack in 2011. Most issuing platforms provide users with the ability to connect and store their badges to this Backpack. When retrieving badges form the earner's Mozilla Backpack (using the account connected to the email address), the displayer will only be able to access those badges that the earner has chosen to be public.

Badges can also be shared:

- On blogs, websites, e-Portfolios, and professional networks
- In job applications

- On social media sites - Twitter, Google+, Facebook, LinkedIn
- In an e-mail signature

8.4 Technical Aspects

An earnable badge is defined as a badge class, using a variety of data items including descriptions, criteria and information about the issuing organization. When an issuer decides to award that badge to a specific earner, he or she creates a badge assertion. A badge assertion describes the data for an awarded badge. It includes the earner's identity and a link to the generic badge class, which in turn is linked to information about the badge issuer. All the data for the badge is defined using JSON structures. To award a badge to an earner the issuer creates a badge assertion in JSON.

The image for a badge should be a square PNG (or SVG). The file size should be a maximum of 256KB and should not be smaller than 90 px square.

Things you can verify and explore in a badge:

- Details about the organization issuing the badge.
- What the individual has done to earn the badge.
- The criteria that the badge has been assessed against.
- That the badge was issued to the expected recipient.
- The badge earner's unique evidence (optionally included).
- When the badge was issued and whether it expires.

8.5 Open Badges for PhysicsKIT4STEM

Open Badges provide portable and verifiable information about various skills and achievements. Students can unlock opportunities by sharing collections of badges representing desired skill sets in a dynamic, evidence-based way. Open Badges represent legitimate, authenticated achievements described within the badge and linked to the PhysicsKIT4STEM project.

Main characteristics of the PhysicsKIT Skills & Achievements Framework include:

The PhysicsKIT4STEM partnership has designed the PhysicsKIT Curriculum - learning material for the following modules (which are presented in IO1) based on the teachers' feedback, targeted to the needs of students, as well as on partners' suggestions based on their expertise and experience in the field:

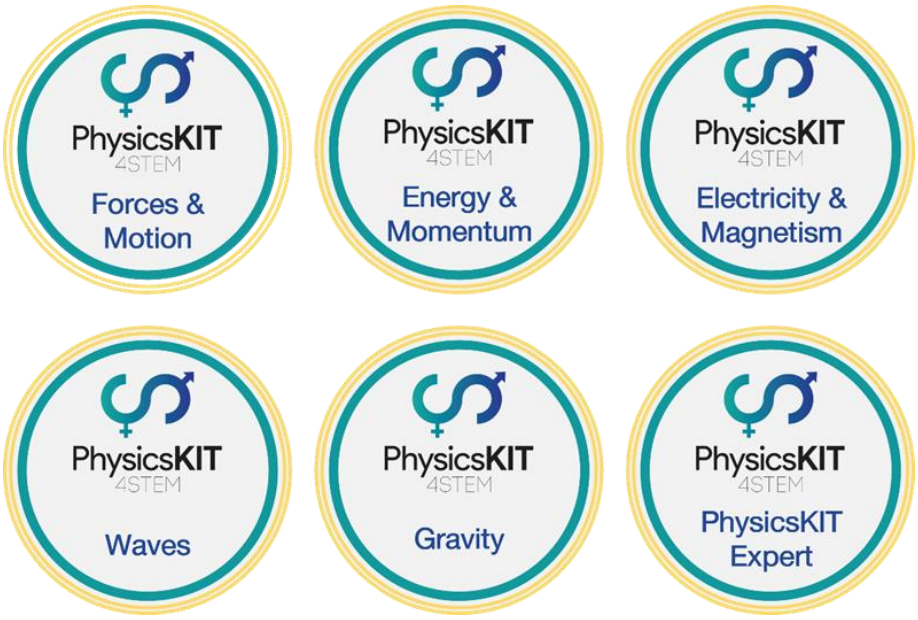
- **Module 1: Forces & Motion** – The objective is to obtain the Forces & Motion Badge.
- **Module 2: Energy & Momentum** – The objective is to obtain the Energy & Momentum Badge.

- **Module 3: Electricity & Magnetism** – The objective is to obtain the Electricity & Magnetism Badge.
- **Module 4: Waves** – The objective is to obtain the Waves Badge.
- **Module 5: Gravity** - The objective is to obtain the Gravity Badge.

The PhysicsKIT4STEM partnership has created the corresponding badges for each of the modules (Figure 1).

Upon completion of all the modules and the developed activities, the students will be awarded the corresponding PhysicsKIT Badge, if they achieve a mark of 80% or higher on each of the assessments. These badges are made available for earning via the learning portal, which has been designed specifically for the learning and assessment purposes of the PhysicsKIT4STEM project.

- Students are invited to register in the learning portal and complete the PhysicsKIT Curriculum.
- The learning portal specifies to students the criteria for earning each of the badges shown below. These criteria will be elaborated in the following section.
- Students must provide evidence to meet the badge criteria to claim a specific badge. This process is done automatically on the learning portal.
- The badges will be awarded automatically through the learning portal based on certain criteria, which are presented in the next section.



Students may achieve a badge for each of the modules in the PhysicsKIT Curriculum. The PhysicsKIT Expert badge (overall badge) will be awarded to students once they have completed all the topics and activities. Completing all the modules automatically rewards the student with the corresponding PhysicsKIT overall badge. Thus, in total 6 Open Badges will be developed and awarded (5 for the modules + 1 Overall).

Each Open Badge consists of the below:

1. **Name:** The name of the Open Badge is comprised by the name of the Module and the description of the level of difficulty
2. **Learning Outcomes:** A list of the learning outcomes to be acquired.
3. **Design of Open Badge:** The Visualization (image) of the Open Badge for each Module (see Figures 1)
4. **Main Objective:** A description of the Open Badge related to the main objectives.
5. **Assessment Criteria:** The criteria to be used to assess whether the learning outcomes have been achieved and whether the set of skills and competences of all modules have been acquired by the students. The criteria and the assessment methods that must be followed to receive a badge are described in the following sections.
6. **Evidence:** The proof and the evidence of the acquired skills i.e., quiz grades, etc. This process is fully automatized on the learning portal where the assessment tests are automatically graded.
7. **Issued by:** In this section the issuer of the Open Badge is specified, which in this case is the PhysicsKIT4STEM Partnership.

8.6 Awarding Criteria

PhysicsKIT4STEM offers 5 module badges and 1 overall completion badge. The specific criteria for these six badges are presented below:

- **Forces & Motion badge:** to obtain the Forces & Motion badge, the student needs to complete all activities of the “Forces & Motion” module and score a minimum grade of 80% in the assessment quiz.
- **Energy & Momentum badge:** to obtain the Energy & Momentum badge, the student needs to complete all activities of the “Energy & Momentum” module and score a minimum grade of 80% in the assessment quiz.
- **Electricity & Magnetism badge:** to obtain the Electricity & Magnetism badge, the student needs to complete all activities of the “Electricity & Magnetism” module and score a minimum grade of 80% in the assessment quiz.
- **Waves badge:** to obtain the Waves badge, the student needs to complete all activities of the “Waves” module and score a minimum grade of 80% in the assessment quiz.

- **Gravity badge:** to obtain the Gravity badge, the student needs to complete all activities of the “Gravity” module and score a minimum grade of 80% in the assessment quiz.
- **PhysicsKIT Expert badge:** to obtain the PhysicsKIT Expert badge, the student needs to earn all 5 of the module badges as explained above.

Open Badges for all Modules

Name of OB	Learning Outcomes	Design of OB	Assessment criteria	Evidence	Issued by
Forces & Motion Badge	**Module 1: Forces & Motion. The student will learn about:** **1. Net force, motion, friction, acceleration.** **2. Newton's Laws of Motion.** **3. Force values, sum of forces, resistances and velocity.**		Complete the „Forces & Motion" Assessment with an overall mark of 80%	The proof and the evidence of the acquired skills are the grade marks. This process is fully automatized on the e-tool where the assessment tests are automatically graded.	**PhysicsKIT4STEM Partnership**
Energy & Momentum Badge	**Module 2: Energy & Momentum. The student will learn about:** **1. Definition of energy, forms of energy, transfer and tranformation of energy.** **2. Conservation of energy and its laws.** **3. Momentum conservation.**		Complete the „Energy & Momentum" Assessment with an overall mark of 80%	The proof and the evidence of the acquired skills are the grade marks. This process is fully automatized on the e-tool where the assessment tests are automatically graded.	**PhysicsKIT4STEM Partnership**

Electricity & Magnetism Badge	**Module 3: Electricity & Magnetims. The student will learn about:** **1. Electricity laws and formulas of basic electrical systems.** **2. Production of electricity, voltage, current and resistance.** **3. Constitution of matter, electrical circuits.** **4. Ohm's Law.** **5. Magnetism.**	PhysicsKIT 4STEM Electricity & Magnetism	Complete the „Electricity & Magnetism" Assessment with an overall mark of 80%	The proof and the evidence of the acquired skills are the grade marks. This process is fully automatized on the e-tool where the assessment tests are automatically graded.	**PhysicsKIT4STEM Partnership**
Waves Badge	**Module 4: Waves. The student will learn about:** **1. What a wave is and types of waves.** **2. Anatomy and properties of waves.** **3. Wave equations.** **4. Reflection, Refraction and Diffraction.**	PhysicsKIT 4STEM Waves	Complete the „Waves" Assessment with an overall mark of 80%	The proof and the evidence of the acquired skills are the grade marks. This process is fully automatized on the e-tool where the assessment tests are automatically graded.	**PhysicsKIT4STEM Partnership**

Gravity Badge	**Module 5: Gravity. The student will learn about:** **1. Gravitational force.** **2. Gravity strength.** **3. Gravity, mass, weight, force, attraction.** **4. Gravitational pull.**		Complete the „Gravity" Assessment with an overall mark of 80%	The proof and the evidence of the acquired skills are the grade marks. This process is fully automatized on the e-tool where the assessment tests are automatically graded.	**PhysicsKIT4STEM Partnership**
PhysicsKIT Expert Badge	**PhysicsKIT Expert Badge for completing each and every activity in PhysicsKIT online course.**		Achieve all previously mentioned badges.	The proof and the evidence of the acquired skills are the grade marks. This process is fully automatized on the e-tool where the assessment tests are automatically graded.	**PhysicsKIT4STEM Partnership**

9. References

1. Twig Education 2021, Challenges in STEM education and how teachers can overcome them.
   Retrieved from: https://twigeducation.com/blog/challenges-in-stem-education/
2. Hill, R. B. (2006). New perspectives: Technology teacher education and engineering design. Journal of Industrial Teacher Education, 43 (3),
   Retrieved: http://scholar.lib.vt.edu/ejournals/JITE/v43n3/hill.html
3. Chow, C. (2014, August 31). Microsoft Partners in Learning Network Badges.
   Retrieved from: http://dpdproject.info/details/microsoft-partners-in-learning-network-badges/
4. Council of the European Union. (2016, November 23). Outcomes of proceedings - Promoting new approaches in youth work to uncover and develop the potential of young people. Council of the European Union.
   Retrieved from: http://data.consilium.europa.eu/doc/document/ST-14277-2016-INIT/en/pdf
5. Finkelstein, J., Knight, E., & Manning, S. (2013). The Potential and Value of Using Digital Badges for Adult Learners (Final Report). Washington, DC: American Institutes for Research.
   Retrieved from:
   https://lincs.ed.gov/publications/pdf/AIR_Digital_Badge_Report_508.pdf
6. Lithuanian National Commission for UNESCO. (2016). Recommendations for achievement programme at UNESCO associated school.
   Retrieved from:
   https://issuu.com/nerijuskriauciunas/docs/recommendations_for_unesco_achievem
7. Microsoft. (2016). Introducing Microsoft badges [Institutional].
   Retrieved from: https://www.microsoft.com/en-us/learning/badges.aspx
8. Mozilla Foundation. (2016a). Earning Open Badges [Institutional].
   Retrieved from: https://openbadges.org/get-started/earning-badges/
9. Mozilla Foundation. (2016b). History of Open Badges [Institutional].
   Retrieved from: https://openbadges.org/about/#history
10. Mozilla Foundation. (2016c). Who's Issuing Open Badges? [Institutional].
    Retrieved from: https://openbadges.org/about/participating-issuers/
11. NASA. (2016). Digital Badges [Institutional].
    Retrieved from:
    https://www.nasa.gov/offices/education/programs/national/dln/special/DigitalBadges.html
12. Open Badges. User Documentation.
    Retrieved from: https://docs.moodle.org/dev/OpenBadges_User_Documentation
13. Open Badges. Wikipedia.
    Retrieved from: https://en.wikipedia.org/wiki/Mozilla_Open_Badges