STEMKIT EDUCATOR'S GUIDE

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1 Overview – STEM learning in schools

International research shows that STEM literacy is increasingly becoming part of the core capabilities that employers need. School systems have a responsibility to enable young people with fundamental level of STEM literacy, to facilitate STEM engagement through effective curriculum.

STEM in education is both a curriculum (what to teach) and **pedagogy** (how to teach or teaching method) (Margot and Kettler, 2019). **STEM curriculum** will be science concepts, principles, theories. **STEM pedagogy** will be engineering and technology using the engineering design process which requires children to solve real-world problems, teaching approaches and assessment resources to improve learning outcomes in the classroom

Learners congruently use both artistic and STEM skills as they navigate the 21st century, to ensure that students are gaining top-quality education. A STEAM approach can equip learners with rigorous STEM skills and understandings as they become critical, creative and reflective artists and communicators. (https://stem.education.tas.gov.au/how-does-stem-work/)

The STEM curriculum drives problem-solving, collaboration and creative-thinking skills to ensure student success in the workforce, also knowledge, understanding and skills:

- strengthened when the connections between learning areas
- enriched authentic learning opportunities for students in answer to an identified problem or in the creation of a solution.

We have designed STEM curriculum to meet educational standards while ensuring that students also develop the critical-thinking, problem-solving and technical skills needed for the workforce of tomorrow. The curriculum is split into modules containing plan lessons, focusing on core STEM subjects such as engineering, technology and robotics that can be directly applied to a STEM career.

Children learn by doing. Research conducted by Fleer (2000) and funded by the University of Canberra and the Curriculum Corporation of Australia for the development of a technology curriculum concluded that children as young as 3 to 5 years of age can engage in oral and visual planning and level of developmental maturity occurred around 5 to 6 years of age, a creative peak occurred at 10 to 11 years old, and after age 12, a gradual rise in creativity occurred through the rest of adolescence until 16 years of age. An integrative STEM approach in general science courses, with exposure to a variety of science, engineering, and technology subjects, would be very age-appropriate.

The development of creative thinking, personal and social capability, will be identified as outcomes for students, in teamwork and collaboration and the creative approaches to the STEM as a whole and to problem-solving.

1.1 What are the challenges in STEM teaching?

Nur Farhana and Othman Talib (2017) identified the following challenges in implementing STEM:

- TIME – Teachers need time and resources to implement STEM
- ADEQUACY OF TRAINING – Teachers need training on STEM teaching
- TAKING THE INITIATIVE – Teachers have to take the initiative to find information about STEM teaching on their own.
- BASIC KNOWLEDGE IN SCIENCE AND MATHEMATICS – Teachers need knowledge about science and mathematics for implement STEM lessons in the classroom.
- FACILITIES – Teachers need facilities for STEM lessons (good science laboratories, well-equipped computer labs with LCD projectors).
- STUDENT INVOLVEMENT – Students need motivation to show interest in STEM lessons.
- SCHOOL ADMINISTRATORS – Teachers need to involve administrators in STEM teaching.

In the STEM framework, particularly in relation to the curriculum:

- Teacher believe that including engineering with mathematics and science builds the problem-solving skills of children
- Teachers need to integrate subjects such as mathematics and science
- Children need lots of practice participating in group work and learning through doing

2 PRINCIPLES OF STEM CURRICULUM

STEM Curriculum is based on the following PRINCIPLES:

STEM CURRICULUM IS INCLUSIVE AND ACCESSIBLE

- 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

QUALITY AND RIGOUR

- 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

RELEVANCE AND AUTHENTICITY

- 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 make 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

The STEM Curriculum will demonstrate an integrated learning approach, 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.

3 WHY IS STEM IMPORTANT FOR ALL STUDENTS?

The STEM curriculum is designed to develop transferable and long-term management, thinking and problem-solving skills which contribute to creating a better future for individuals and society.

Students will learn transferable skills responding to the challenges of the complex environmental, social and economic pressures of this century; young people will require to be creative, innovative, enterprising and adaptable, with the motivation, confidence and skills to use critical and creative thinking purposefully.

The STEM curriculum also fosters the development of the critical and creative thinking general capability as learners imagine, generate, develop and critically evaluate ideas. Students will learn to generate and evaluate knowledge, clarify concepts and ideas, seek possibilities, consider alternatives and solve problems. Critical and creative thinking are integral to activities that require learners to use imagination and innovation in all learning areas at school and in their lives beyond school.

Design thinking, problem solving and inquiry are key ways that STEM challenges are addressed through an iterative cycle to develop, test and refine solutions. Design solutions may be in the form of a product, service or STEM environment.

Learners will use strategies for understanding design problems and opportunities, visualising and generating creative and innovative ideas, and analysing and evaluating those ideas that best meet the criteria for success and planning through the process. Essentially it involves:

Fig. 3 Responding to the challenges of STEM

Teachers needs to involve their students to analyse problems, refine concepts and reflect on the decision-making process by engaging in systems, design and computational thinking and also to identify, explore and clarify information in a range of situations.

Students will learn to consider how data, information, systems, materials, tools and equipment (past and present) impact on their lives, and how these elements might be better designed and managed. Learners will build their visual and spatial thinking and will create STEM solutions, experimenting, drawing, modelling, designing and working with digital tools, equipment and software.

4 IMPLEMENTATION OF STEM METHODS

STEM Curriculum includes activities that will help students to develop important life skills that will introduce them to the wonders of electronics, physical computing, and robotics through STEM activities. 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.

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.

The STEM curriculum is investigating real world questions and refers to activities which focus on programming, data representation and computational thinking involving students in generating designed solutions for future needs and opportunities; students will develop computational thinking and programming skills to devise digital solutions. In the context of a STEM challenge, digital technologies will be integrated with Science, Mathematics and Technologies.

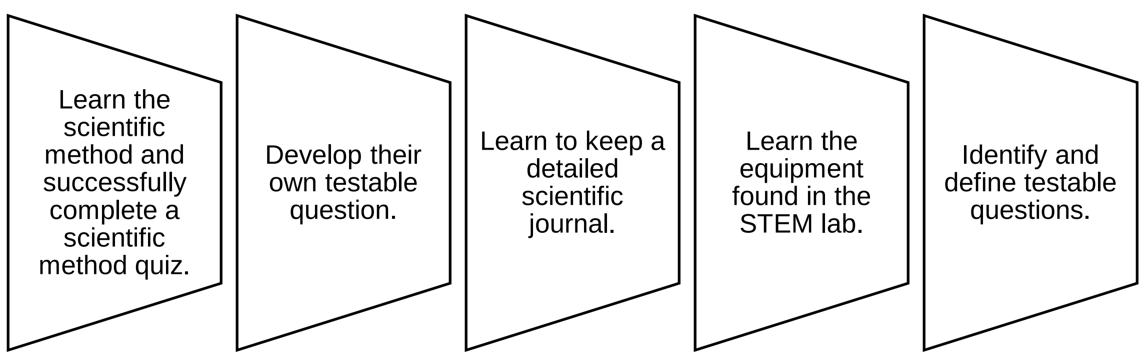

Fig. 4 Student STEM Objectives

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

- Variables (independent, dependent, controlled for a controlled experiment)
- Materials needed to conduct their project taking into account

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

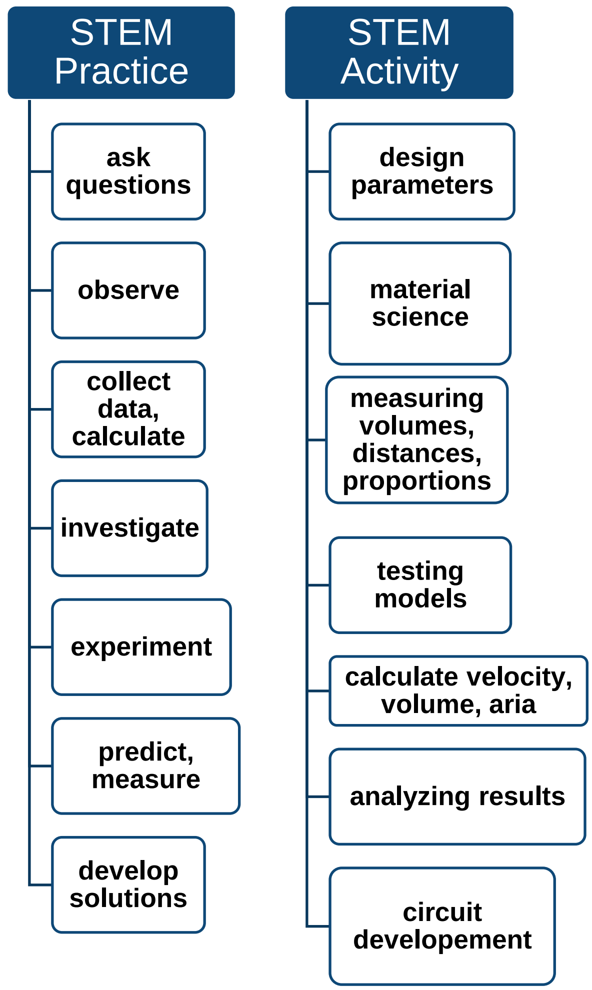

Fig. 5 STEM Practice & Activities

Students have to formulate issue-hypothesis, reviewing literature as primary reading sources, differentiating between subjective/objective data and their usefulness to the issue, or examining applicable existent surveys, impact studies, or models.

Students will develop the following STEM activities:

- evaluate web resources

- differentiate resources and understanding when to use each type
- summarize, analyse and reflect 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 analyse the data
- write their conclusion and debate
- prepare an oral presentation that summarizes their research; presentation will use of 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.

The assessment has to include:

- 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, 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 curriculum will help them develop important skills such as problem-solving, attention to detail, patience, abstract thinking, communication, and empathy.

4.1 Learning Targets for STEM teachers:

- Formulate a research question that is testable and measurable, testing applicable simulation models, or completing all data collection requirements.

- Write a research question that is practical and considers time, cost and instrumentation availability.
- Establish a STEM professional learning exchange, in partnership with universities.
- Encourage the uptake of online learning materials, linked to classroom practice, to support the development of students' problem solving and reasoning skills which are at the core of mathematical thinking, scientific literacy and a deep engagement with coding.
- Use coding to develop mathematical thinking and solve real world problems.
- Design applicable survey and interview instruments and methodologies.
- Conduct issue investigation (following all procedural and safety precautions), interviewing associated entities or experts.
- Interpret and analyse results to produce findings and issue resolution options, evaluating validity and reliability, deductions, and perceptions.
- Formulate proposals for innovative technological design, generating ideas for innovations and tools, materials, or researching applicable scientific principles or concepts.
- Design safety, available technology and equipment to collect and record data accurately.
- Design solution proposal in relation to variables.
- Interpret and represent results of analysis to produce findings, comparing data sets to design solutions.
- Report the process and results of a design investigation, communicating quantitative observations, analysing a logical explanation of success or errors.
- Procedure will be organized into presentations to share with the class.

5 HOW TO USE STEM IN THE CLASSROOM

STEM activities can be fun and absorbing, but if some of the students do not find these interesting, teachers will be facing a problem.

To keep students motivated and engaged in the challenges, it is important to show students that not all STEM activities require them to sit down and type commands. You should find activities that pique their interests and that blend hands-on and computer-based learning.

For that, you can choose to use STEM activities in different subjects, allowing kids to understand how they can connect their interests with STEM.

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 the 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 STEMKIT to talk about the speed of light, or what does it take to make an electronic circuit to function.

The best way to introduce STEM to your classroom is 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

If teachers want to incorporate STEM in their classroom, there are a few easy steps they can start with.

First, teachers need to **shift their language** and their expectations. They can use language like trial, experiment, challenge, or design. Even though this might seem easier to use in science class, this kind of approach can be used in other subjects.

After that, teachers should look at what they are teaching and ask themselves how can that content be presented as a **problem or a question**. If it is possible, try to involve science, math, social studies, physics, in the challenge you are creating.

These tips suggest that without adapting inquiry-based, student-centred, skill-driven approaches to teaching and learning, STEM education will become just another term to work additional math or science curriculum.

In order to help teachers, implement the STEM in the classroom, here are some ideas:

Teach knowing and doing. For this is important that we understand that learning needs a propose. It is important for students to enrol 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 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. In order to help students identify the exact tasks associated with 21st century teamwork and develop these skills, teachers can promote team work during the STEM class moments.

Start with questions. Any important results in science, engineering, or technology starts with a question. An engaging, rigorous STEM curriculum encourages. 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.

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

Another tip is to use materials available online and that have already been used and tested. One example of these is the **STEMKIT4Schools lesson plans**.

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

6 STEMKIT4Schools

6.1 The STEMKIT Computer

The STEMKIT computer is designed to be possible to assemble 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 STEMKIT themselves based on the instructions.

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

The specification and inventory for the STEMKIT computer, as well as custom components and kits to be created, and assembly instructions will be provided in the present guide as annexes.

The STEMKIT's elegant design imitates an all-in-one desktop computer, offering ease of use in the classroom as it will not be necessary to connect to an external screen to use it while it will be easier to connect external kits and electronics for physical computing and enhancement of STEM-related teaching.

The STEMKIT is a fully fledged Raspberry Pi based computer. All the necessary components and peripherals are included in one package, so the student, after assembling it, can start right away using it.

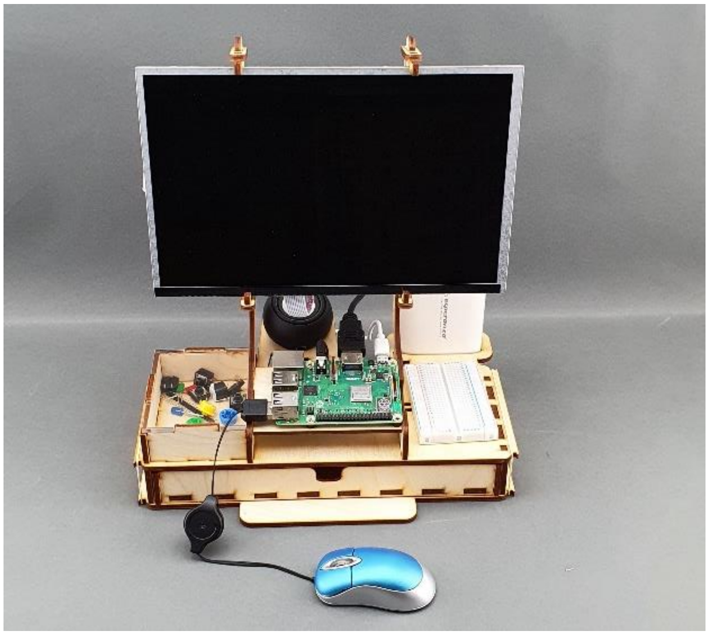

Fig. 6 The STEMKIT computer

STEMKIT runs on Raspbian Buster, which is a free operating system based on Debian optimized for the Raspberry Pi hardware. Raspbian provides more than a pure OS: it comes with over 35 000 packages, pre-compiled and pre-installed with plenty of software for education, programming and general use bundled in a nice format for easy installation for the Raspberry Pi. It has Python, Scratch, Sonic Pi, Java and more.

The initial build of over 35,000 Raspbian packages, optimized for best performance on the Raspberry Pi, was completed in June of 2012. However, Raspbian is still under active development with an emphasis on improving the stability and performance of as many Debian packages as possible.

Raspbian uses PIXEL, **P**i **I**mproved **X**-Window **E**nvironment, **L**ightweight as its main desktop environment as of the latest update. It is composed of a modified LXDE desktop environment and the Openbox stacking window manager with a new theme and a few other changes. The distribution is shipped with a copy of computer algebra program Mathematica and a version of Minecraft called Minecraft Pi as well as a lightweight version of Chromium, Thonny Python, Scratch and many more.

6.2 The STEMKIT Assembly Guide

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

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

For more information you can see the STEMKIT Computer Guide. Guide is available in different languages, such as English, Greek, Polish, Romanian, 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 use Scratch, Minecraft Pi as well as physical computing to engage students into exploring different approaches and ways of using the 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.

7.1 Introduction to Scratch 2.0

In this lesson plan the teacher will present the Scratch application, used to create projects containing media and scripts and programming language design for young people to explore, express themselves, and learn. The activities encourage exploration of key computational thinking concepts and key computational thinking practices.

With this lesson, the teacher can explain different domains, like science (scientific method, investigation, experimentation, analysis and interpretation of results), computer science (processing unit and peripherals, interfaces, programming language and main structures, coding), technology (electronics, open-source hardware and software, sensors, digital signal, circuits, single board computers) or math (spreadsheets and basic statistics).

7.2 Sound to Scratch

In this lesson plan teacher will present the Scratch application, used to create projects containing media and scripts and programming language design for young people to explore, express themselves, and learn. The goal is for students to create a band and present to their friends a musical project.

With this lesson plan teachers can approach different domains like science (scientific method, investigation, experimentation, analysis and interpretation of results), computer science (processing unit and peripherals, interfaces, programming language and main structures, coding), technology (electronics, open-source hardware and software, sensors, digital signal, circuits, single board computers) or math (spreadsheets and basic statistics).

7.3 IR Sensors in Alarm Systems in Scratch 2.0 and GPIO

This lesson introduces the use of TCRT5000 reflective optical sensor with transistor output to design a simple circuit that will act as an alarm for windows that might have been opened by an unauthorised person. The positioning of such a sensor can be introduced in real set up next to the window frame due to operating range of the sensor that is from 0.2 mm to 15 mm.

Using this lesson plan will allow the teacher to explore topics like voltage, power, circuits or scientific method in the science domain, as well as interfaces, programming language or coding in computer science or informatics.

7.4 Photoresistor as a dusk sensor in Scratch 2.0 and GPIO

This lesson introduces the use of a simple circuit that with the use of a photoresistor can be set up in a way to power on and off bigger appliances through the relay. The use of the relay enables to use more power-hungry devices such as the outside lightning. This lesson, we will simulate the external circuit to be switched on and off with the use of a battery-powered LED.

Teachers can use this lesson plan to explain domains like science (voltage, power, circuits, photo resistance, light intensity, scientific method, investigation, experimentation, analysis and interpretation of results), computer science (processing unit and peripherals, interfaces, programming language and main structures, coding) or technology (electronics, open-source hardware and software, sensors, digital signal, single board computers, console).

7.5 Making a detonator in Minecraft Pi

With this lesson plan, students will be able to program a button to work as a bomb in Minecraft so they can create a crater that is as big or as small as they choose.

The teacher can talk to the students about programming language, about hardware and software, circuits, and physical computing.

7.6 Detecting diamonds in Minecraft

With this lesson plan, students will be able to program an LED, using Python, to light up every time the player in Minecraft finds a diamond.

The teacher can talk to the students about programming language, about hardware and software, physical computing or even about different kind of material (since the students will find diamonds).

7.7 Measuring the Speed of Sound using Python and GPIO

With this lesson students will conduct a scientific experiment to measure the speed of sound. For this purpose, they will make an experimental apparatus using the STEMKIT and operate it by appropriate program. Then they will collect data and analyse them to measure the speed of sound. Just like real scientists and researchers do!

The teacher can talk about physics and motion, oscillation, waves, types, characteristics, propagation of waves, sound between other topics. In the science domain, teacher can approach the scientific method. Teachers can also use math, when analysing the data, the students collected.

7.8 Creating Traffic Lights using Python and GPIO

With this lesson plan we will learn how to build traffic lights in the real world and control them through the GPIO and the Python programming language. The lesson plan involves the creation of the circuit using the GPIO pins of our Raspberry Pi and electronic components, and the development of a program in Python that will control the traffic lights sequence.

The teacher can approach domains like math (queuing theory, waiting lines), computer science (processing unit and peripherals, interfaces, programming languages) and technology (electronics, open-source hardware and software, sensors, digital signal, circuits, single board computers).

7.9 Home Assistant using Physical Computing

With this lesson plan, students will learn how to turn their STEMKIT Raspberry Pi into the ultimate home automation hub.

The teacher can use this lesson plan to explain physics (motion, oscillation, waves or sound), computer science (processing unit and peripherals, interfaces, programming language and main structures, coding) or technology (electronics, open-source hardware and software, sensors, digital signal, circuits, single board computers).

7.10 Solar Tracking using Physical Computing

With this lesson plan, students will be able to implement a two-axis (azimuth and height of the sun) solar tracking system controlled by an Arduino board with measurements of current intensities and voltages and compare the powers with those of a fixed photovoltaic panel.

The teacher can talk to the students about physics (waves, sound, speed of sound), science (scientific method, investigation, experimentation, analysis and interpretation of results) or technology (electronics, open-source hardware and software, sensors).

8 SKILLS AND ACHIEVEMENTS

8.1 Introduction

The STEMKIT Skills & Achievements Framework offers informal recognition to students who have successfully completed a series of quests and/or challenges of the STEMKIT 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 STEMKIT 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 STEMKIT 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 centres, NGOs, the labour market, and other stakeholders for the endorsement and accreditation of the STEMKIT 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 STEMKIT 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 Badges 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 labour 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 in order 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 STEMKIT consortium)

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 STEMKIT

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 STEMKIT4Schools project.

Main characteristics of the STEMKIT Skills & Achievements Framework include:

The STEMKIT consortium has designed STEMKIT Curriculum - learning material for the following modules (which are presented in IO2) based on the teachers' feedback of IO1, targeted to the needs of students, as well as on partners' suggestions based on their expertise and experience in the field:

- Module 1: Introduction to Scratch 2.0 – The objective is to obtain the Scratch 2.0 Badge.
- Module 2: Scratch GPIO – The objective is to obtain the Scratch GPIO Badge.
- Module 3: Introduction to Minecraft Pi – The objective is to obtain the Minecraft Pi Badge.
- Module 4: GPIO Programming using Python – The objective is to obtain the GPIO Python Badge.
- Module 5: Physical Computing - The objective is to obtain the Physical Computing Badge.

The STEMKIT consortium has created the corresponding badges for each of the modules (Figures 7).

Upon completion of all the modules and the developed activities, the students will be awarded the corresponding STEMKIT 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 STEMKIT4Schools project.

- Students are invited to register in the learning portal and complete the STEMKIT 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 in order 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.

Fig. 7 STEMKIT badges

Students may achieve a badge for each of the modules in the STEMKIT Curriculum. The STEMKIT Overall Completion 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 STEMKIT overall badge. Thus, in total 6 Open Badges will be developed and awarded (5 for the modules + 1 Overall OB).

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 7).
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 in order 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 STEMKIT Consortium.

8.6 Awarding Criteria

STEMKIT4Schools offers 5 module badges and 1 overall completion badge. The specific criteria for these six badges are presented below:

- **Scratch 2.0 badge**: to obtain the Scratch 2.0 badge, the student needs to complete all activities of the “Introduction to Scratch 2.0” module and score a minimum grade of 80% in the “Introduction to Scratch 2.0” assessment quiz.
- **Scratch GPIO badge**: to obtain the Scratch GPIO badge, the student needs to complete all activities of the “Scratch GPIO” module and score a minimum grade of 80% in the “Scratch GPIO” assessment quiz.
- **Minecraft Pi badge**: to obtain the Minecraft Pi badge, the student needs to complete all activities of the “Introduction to Minecraft Pi” module and score a minimum grade of 80% in the “Introduction to Minecraft Pi” assessment quiz.
- **GPIO Python badge**: to obtain the GPIO Python badge, the student needs to complete all activities of the “Raspberry Pi GPIO programming using Python” module and score a minimum grade of 80% in the “Raspberry Pi GPIO programming using Python” assessment quiz.

- **Physical Computing badge**: to obtain the Minecraft Pi badge, the student needs to complete all activities of the “Physical Computing” module and score a minimum grade of 80% in the “Physical Computing” assessment quiz.
- **STEMKIT Overall Completion badge**: to obtain the STEMKIT Overall Completion badge, the student needs to earn all 5 of the module badges as explained above.

8.7 Open Badges for all Modules

Name of OB	Learning Outcomes	Design of OB	Assessment criteria	Evidence	Issued by
Scratch 2.0 Badge	**Module 1: Introduction to Scratch 2.0. The student will: 1. Learn the basic structure, functions and capabilities of Scratch 2.0. 2. Understand how to create simple programs and visualisation in Scratch 2.0. 3. Familiarise with Scratch 2.0 mechanics and connectivity with physical electronic components.**		Complete the „Introduction to Scratch 2.0" 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.	**STEMKIT Consortium**
Scratch & GPIO Badge	**Module 2: Scratch & GPIO. The student will: 1. Learn how to connect Scratch 2.0 with Raspberry's GPIO. 2. Learn how to create simple circuits using electronic components and peripherals and manipulate them in Scratch 2.0 environment. 3. Understand how Scratch 2.0 can be used to connect the virtual world with the physical world.**		Complete the „Scratch GPIO" 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.	**STEMKIT Consortium**

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Minecraft Pi Badge	**Module 3: Introduction to Minecraft Pi. The student will:** **1. Learn the basic functions, controls and gameplay of Minecraft Pi.** **2. Learn how to connect and control Minecraft Pi with Python programming language.** **3. Learn how to build simple programs that will automate processes in a Minecraft Pi game.** **4. Learn how to connect Minecraft Pi with the physical worlds and develop interactions through GPIO**		Complete the „Introduction to Minecraft Pi" 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.	**STEMKIT Consortium**
GPIO & Python Badge	**Module 4: Raspberry Pi programming using Python. The student will:** **1. Learn how to program Raspberry's Pi GPIO using the Python programming language.** **2. Learn how to develop and program simple electronic circuits to be controlled through the GPIO.**		Complete the „Raspberry Pi programming using Python" 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.	**STEMKIT Consortium**

Physical Computing Badge	**Module 5: Physical Computing. The student will:** **1. Learn what physical computing is and how to use the STEMKIT computer for physical computing experiments.** **2. Use the Raspberry's GPIO to connect electronics, sensors and peripherals.** **3. Know how to control and manipulate electronic components using simple programs.**		Complete the „Physical Computing" 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.	**STEMKIT Consortium**
STEMKIT Overall Completion Badge	**Overall STEMKIT Badge for completing each and every activity in STEMKIT Curriculum.**		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.	**STEMKIT Consortium**

8.8 Conclusion

This document presented the theoretical background of the Open Badges framework, in addition to its benefits and endorsements. Most importantly the STEMKIT ecosystem of Open Badges was presented, with a detailed analysis of the benchmarks required to achieve each one.

By using the Open Badges system, the STEMKIT4Schools project will not only help students validate the skills they will acquire through this project, it also introduces them to the innovative practice of the Open Badges, which can be used throughout their lives to log their achievements, and potentially open new pathways for them in career and education.

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