INNOVATIVE SCHOOLS: TEACHING & LEARNING IN DIGITAL STEM LABS

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CURRICULUM FRAMEWORK

INTELLECTUAL OUTPUT 2

DEVELOPMENT OF THE CURRICULUM FRAMEWORK "DIGITAL STEM LABS”

OUTPUT TYPE: COURSE / CURRICULUM – DESIGN AND DEVELOPMENT

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OUTPUT TYPE: Course / curriculum – Design and development

Innovative Schools: Teaching & Learning in

DIGITAL STEM LABS

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

Universidad Rey Juan Carlos

ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

INTRODUCTION

The development of a **"Digital STEM Labs" Curriculum Framework** will enable effective embedding of the digitalized STEM (Science, Technology, Engineering and Mathematics) contents into the school curriculum of the secondary schools, contextualized learning of the STEM education contents within the general subjects at the lower/upper secondary school level. This Curriculum Framework is designed to offer a unique secondary school student-centred approach for the wider integration of the relevant STEM contents into the school curriculum with various multidisciplinary features in full compliance with the (a) digital learning resources for distance education integrated with STEM skills and practice, (b) inquiry-based learning that will, in the meantime, encompass elements of the Living Lab methodology (as used at the higher education level) as well as design thinking methodology, (c) adjusted to the needs of the secondary school students/realities of the secondary schools.

This "Digital STEM Labs" Curriculum Framework consists of (a) t**hree modules** that address the educational contents related to the contemporary investigation (valorisation/interpretation and presentation) of STEM education, (b) it defines specific **curricular elements** of theoretical, methodical, technical and functional character, and (c) it uses a **learning outcomes/competency-based approach**, i.e. each module sets out what secondary school students should know, be able to do and value. In addition, this Curriculum Framework will (d) enable **schools and teacher's flexibility and ownership over curriculum** in a rapidly changing environment - sectoral and technological development (distance learning and teaching innovations/smart specialisation) as well as on-going educational reforms and regular school-based modernisation of the school curriculum. This Curriculum Framework also (e) promotes **curricular and pedagogical solutions** that combine Project Based Learning (PBL) and Integrated Learning approaches.

This STEM curriculum framework may be useful in curricular decision making as they try to integrate mechanism to weave sciences, technologies, engineering, mathematics and digital skills together in the classroom to help students appreciate and experience STEM education. In fact, this “Digital STEM Labs” Curriculum Framework will provide guidance for schools in implementing educational best practices in a way that impacts student achievement. Since all students must have access to a rigorous STEM curriculum, this CF takes into account real-world STEM elements in compliance with today’s education based on (a) competencies and learning outcomes (including some concrete tools, e.g. those defined by the Bloom’s Taxonomy), (b) relevant requirements and guidelines set by the European Qualifications Framework as well as the respective National Qualification Frameworks and National Curriculum Frameworks for General Education of Turkey, Greece, Lithuania and Spain in addition to (c) other relevant knowledge and practical experience and good practices gained under STEM joint training activities.

There are several technology-supported pedagogic models that seem to improve students’ learning outcomes (see “Sparking Innovation in STEM Education with Technology and Collaboration”) and having a specific curriculum framework may help produce an increase in students’ STEM content understanding and inquiry skills. The aim is to help raise awareness of STEM experiences among educators and students to drive the emergence of the needs for valorisation of STEM education and present STEM content in a multidisciplinary approach in order to apply STEM skills and knowledge in the context of activities, practices and/or problems (see “STEM Education Framework”). In a STEM learning environment, it is essential to anticipate students’ outcomes (knowledge, skills and competences) since they are tied to educational standards. However, this proposed framework must be tested to determine if it improves the teaching and learning of STEM content (see “A conceptual framework for integrated STEM education.”

References:

- Kärkkäinen, K. and S. Vincent-Lancrin (2013). Sparking Innovation in STEM Education with Technology and Collaboration: A Case Study of the HP Catalyst Initiative. *OECD Education Working Papers, No. 91*, OECD Publishing. http://dx.doi.org/10.1787/5k480sj9k442-en

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- Kelley, T.R., & Knowles, J.G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(11). https://doi.org/10.1186/s40594-016-0046-z

1. Purpose and description of the subject

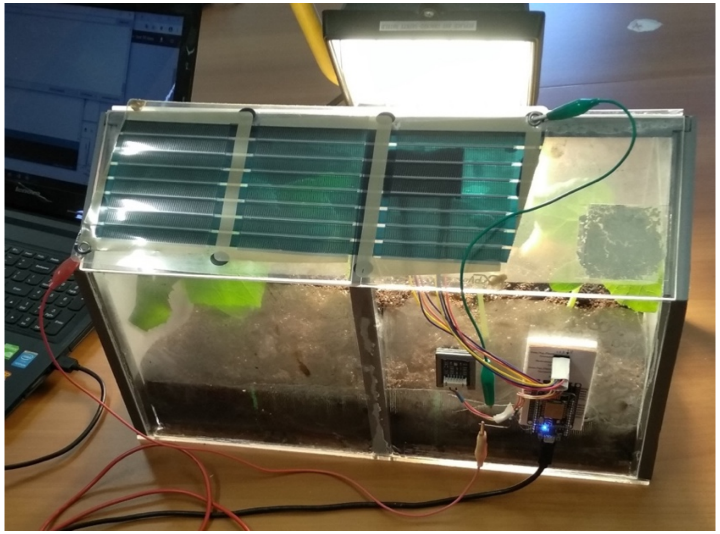
STEM teaching is a complex activity that lies at the heart for the vision of science, technology, engineering and math education. The teaching of STEM education should not be only focus on content knowledge but should also include active learning techniques, inquiry-based instruction, problem-solving skills as it has proved to enhance student learning. STEM education involves more than one STEM subject area, and the activities can be carried out in any teaching environment, remote or f2f. This integrated teaching occurs at the space where two or more STEM subjects intersect and can be an effective mechanism for facilitating educational practices at lower and upper secondary classroom level.

In our vision of STEM education, effective teachers create and active learning environment where students are engaged in learning about natural sciences, smart greenhouses and solar panels among others in order to provide more relevant and stimulating experiences. This STEM integration provides real-world experiences to make meaningful connections in a problem-based learning scenario that culminates into several projects that put STEM disciplines into practice and has the potential to be very effective. Through appropriate scaffolding along the years the proposed activities develop students' competences in several STEM areas.

Many global challenges need an international approach supported by further development in STEM to adequately address these challenges and enhance students' interests and motivation. Advancing competencies in STEM education is essential and having an integrated curricular approach can provide a more quality education to all students.

STEM Module

The main axis of the project is related to the structure, operational principles, and innovative trends of “smart greenhouses”. In this module, students design, develop and engage a smart greenhouse, which they use as a STEM artefact in order to learn content, cultivate skills and gain insights of Interdisciplinarity. Therefore, the purpose of this module is twofold: a) to develop content knowledge and skills regarding phenomena and applications related to STEM disciplines, b) to develop epistemological consciousness regarding Interdisciplinarity in order to recognise interdisciplinary connections in several parts of the module. Specifically, students will brainstorm solutions for designing an effective and contemporary ‘smart greenhouse’, by engaging and studying related theory and phenomena, such as the greenhouse effect. Students engage in an engineering design cycle of actually constructing, testing, and improving a model of a greenhouse. Students also design and integrate technological solutions to the greenhouse in order to collect and share experimental data through an open and real-time process. Data are presented in graphs and analysed in order to contribute to their understanding of the phenomena and the theory related is revisited.



NS Module

The natural sciences module is designed to develop students' science competence - the ability and willingness to use knowledge and methods of natural science to answer questions, seek evidence-based conclusions and solutions, understand human-induced changes in nature and take personal responsibility for preserving the environment. Natural sciences are important because they help students to understand the world in which they live, the systems and processes that support life on our planet, and to apply the knowledge of science responsibly in everyday activities. However, it is important that students not only acquire essential natural sciences knowledge, but also develop their general and specific skills and values. Therefore, the purpose of this module is for students to be able to discover and experience the joy of cognition themselves, and to recognize and learn the importance of team dynamics in problem-solving and decision making, essential for the STEM curriculum.

Science education is based on knowledge of STEM subjects such as as biology, chemistry, physics, astronomy or even geography. It helps students to develop healthy lifestyle and environmental skills and to understand that knowledge of science has a significant impact on the social, political and economic life around us. Moreover, since the natural world is seamless, the education of students cannot be limited to the individual sciences teaching subjects and more common points of contact need to be explored, such as common science topics closely related to the daily lives of students, universal concepts and regularities based on common approaches to living and non-living nature. In today's fast-changing world, it is important to teach students how to do science, finding and selecting information effectively and efficiently from a variety of sources, analyse it, critically evaluate it, and communicate it to others. In fact, the natural sciences provide an opportunity to answer many of the questions that interest and matter to humanity about the world around us, and draw evidence-based conclusions on experience, observations and research about STEM related issues.

Heat & Energy Module

The main educational objectives of this module are to understand of phenomena related boiling is an event depending on external pressure (pressure on the liquid)/geographical altitude. Students will analyze the variables that depend on the change in temperature of pure substances that absorb or give off heat. It means that boiling and evaporation are different from each other. Additionally, students will analyze the factors affecting evaporation. They know that the presence of water vapor in the atmosphere is expressed with the concept of humidity. They will also comprehend that the concepts of real and felt temperature given in meteorology news are expressed with the concept of relative humidity.In this way students will interpret the reasons for the difference between felt and actual temperature. By using experiments or simulations, it is ensured that they determine the relationship between the variables. It is ensured that students identify a problem from daily life related to air conditioning systems and produce solutions for this problem. Students will explain the concept of efficiency. The relationship between energy saving and energy efficiency is explained through energy identity documents. They will develop suggestions that will increase the efficiency of an exemplary system or design. The working principle of various efficiency increasing systems designed in the historical process is mentioned. In the designs to be made, the necessity of making a budget calculation should be emphasized in order to develop financial awareness. The importance of the contribution of energy saving to the family budget and the country's economy is emphasized. etc

This module aims at cultivation of some elementary engineering skills, such as:

- brainstorming
- designing a prototype
- testing, evaluation and improvement of the prototype through an engineering design cycle

Students will engage in inquiry-based experimental procedures and cultivation of experimental skills such as making predictions, data collection, analysis and evaluation, interpretation of data and drawing conclusions etc.

2. Educational objectives

STEM teaching is a complex activity that lies at the heart of the vision of STEM education and requires educators to create an environment in which students work as active learners. To teach STEM educators must have theoretical and practical knowledge and abilities about STEM, learning, and STEM teaching since student learning is greatly influenced by how they are taught. We propose a conceptual framework that develops yearlong and short-term goals for students, STEM literacy and competencies, stimulating student's interests that will lead to achieving key learning outcomes.

The main educational objectives for each area are the following ones:

- cultivation of elementary engineering skills, such as
  - brainstorming
  - designing a prototype
  - testing, evaluation and improvement of the prototype through an engineering design cycle
- understanding of phenomena related to
  - basic mechanisms of plant development
  - greenhouse effect
  - climate change
  - planet habitability
- engagement in inquiry-based experimental procedures and cultivation of experimental skills, such as
  - making predictions
  - data collection, analysis and evaluation
  - interpretation of data
  - drawing conclusions

- design and implementation of technological circuits with sensors for real-time data collection, such as:
  - developing programming skills (block-based)
  - downloading and using libraries for sensors, calibration of sensors
  - installation of sensors and hardware systems
- develop competencies of statistical analysis of data and making inferences
  - basic statistical measures
  - evaluation of data
- disseminate experimental data online and develop main understandings and techniques of 'Internet of Things'
  - accessing and using interactive online platform for sharing data
  - gain understanding on basic aspects of open access, and data privacy
- developing 21st skills, such as
  - collaboration and working in groups
  - critical thinking
  - problem-solving
- develop skills regarding modelling and simulations (e.g. by comparing the simulated circuit with the developed one)
- stimulating students' interest in the natural sciences
- develop science literacy and competencies
- to enable all students to acquire science competence framework
- to take over the essentials of nature concepts and concepts of science, acquired skills
- to get to know the world, and develop values
- to prepare students for further life as full citizens capable of living a healthy life and tackling sustainable development
- to use natural research methods and knowledge and understanding of the phenomena, processes and concepts studied in the

natural sciences in search of answers to the questions that arise

- present and evaluate arguments based on the facts and formulate reasonable conclusions
- to explain the importance of knowledge in making personal decisions, the validity of solutions to local and global problems
- to understand the changes in nature caused by human activities and to take personal responsibility for the preservation of the environment, to protect the health of oneself and other people

3. Structure

This CF is organized around three modules:

1) STEM MODULE

The STEM Module consists of two components:

1.1. Greenhouse model (units 1-7)

- Unit 1: Posing real-world problems considering i) the efficiency and development of crop production, ii) the increase of efficiency of greenhouses. Presentation of initial STEM challenges to students, such as ‘build an efficient model of a Greenhouse’.
- Unit 2: Basic mechanisms of plant development. Physical quantities, factors that affect plant development.
- Unit 3: Operational mechanisms of a greenhouse. Related content knowledge, principles, phenomena, applications.
- Unit 4: Brainstorming on the design of an effective greenhouse model. Design potential solutions, consider restrictions and potential improvements. Discuss in groups with peers and decide on best & alternative solution.
- Unit 5: Design on 3D software some basic components and develop a preliminary design. Print the components on 3D printer.
- Unit 6: Construct an initial version of the prototype. Check its, stability, symmetry, insulation, soldering etc.
- Unit 7: Brainstorm the type of plants to include in the greenhouse. Implement plants both inside and outside of the greenhouse

1.2. Smart Greenhouse (units 8-15)

- Unit 8: Design of a simulation (e.g. in Tinkercad) of the electrical circuits with sensors needed (e.g. Temperature, Humidity, Light). Program the code needed for their use. Check connections and applicability.
- Unit 9: Implement the needed electrical circuits and hardware installations. Check the positioning of sensors.
- Unit 10: Download the appropriate libraries for the sensors and calibrate sensors by using relative experiments. Compare the

simulated circuit with the real one.

- Unit 11: Modify the program in order to publish data online, though a platform. Access the platform through students' smart devices and check data online.
- Unit 12: Experiment on factors that could affect the development of the plant: light explosion, water supplied/humidity and temperature (in/out of the greenhouse), etc. Control of variables.
- Unit 13: Analysis of the data from the sensors on graphs. Discussion on statistical measures (mean values, slope, fit surves etc). Statistical analysis on results from the sensors.
- Unit 14: Discuss results from the experiments in the light of photosynthesis and crop development.
- Unit 15: Discuss results in the light of using greenhouses and the greenhouse effect.

2) NS MODULE

The Nature Science Module consists of four components:

2.1. Nature research

2.2. Wildlife (biology)

- Structure and functions of organisms
- Continuity and diversity of life
- Organization and environment. The biosphere and man

2.3 Substances and their changes (chemistry)

- Knowledge of the composition and properties of materials
- Material changes
- Knowledge and use of essential materials

2.4 Physical phenomena (physics)

- Knowledge of movement and strength

- Knowledge of energy and physical processes
- Knowledge of Earth and the Universe

3) HEAT & ENERGY MODULE

The Heat & Energy Module consists of two components:

3.1. Heat & Insulation (Units 1-8)

- Unit 1: Stating a testable hypothesis or prediction based on background data or on observed events.
- Unit 2: Plan an investigation to answer a specific scientific question.Include: Materials, variables, controls, methods, safety considerations.
- Unit 3: Carry out procedures that comprise a fair-test. Include: Controlling variables, repeating experiments to increase accuracy and reliability of results.
- Unit 4: Work cooperatively with group members to carry out a plan, and troubleshoot problems as they arise.
- Unit 5: Select and use appropriate methods and tools for collecting data or information.
- Unit 6: Record, organize, and display data using an appropriate format. Include: label diagrams, graphs, and multimedia.
- Unit 7: Evaluate the original plan for an investigation and suggest improvements (examples: Identify strengths and weaknesses of data collection methods used).
- Unit 8: Reflect on prior knowledge and experiences to develop new understanding.

3.2. Steps in Air Conditioning System Design (Units 8-22)

A) Air Conditioning System model (Units 8-14)

- Unit 8:
  i) Efficiency and development of Air Conditioning Systems, ii) Revealing real-world problems, taking into account increasing the efficiency of systems.
  Considering the size and needs of the air-conditioned space, there are air-conditioning mechanisms that work with very different

physical principles. Each system has advantages and disadvantages depending on the application areas, and their efficiency varies depending on them.

Presentation of initial STEM tasks such as 'building an efficient conditioning model' to students.

- Unit 9:

  Basic mechanisms of the air conditioning process. Physical dimensions, factors affecting air conditioning efficiency.

  The air conditioning process, in its most general sense, is bringing and keeping any space to the desired dry bulb temperature, relative humidity, air velocity and air quality values. In addition to the location, geographical location, temperature and humidity values are the main factors affecting the type and efficiency of the system to be selected.

- Unit 10:

  Basic air conditioning and cooling mechanisms. principles, facts, applications.

  The evaporative cooling and air conditioning process is based on a simple principle. Water in the liquid phase takes the latent heat of evaporation from the surrounding air and passes into the vapor phase, thereby lowering the enthalpy of the air. The enthalpy of air, which is considered an ideal gas, is only a function of temperature, so the temperature of the air whose enthalpy decreases also decreases. The moisture content of the cooled air increases due to evaporation. During the evaporative cooling process, the total enthalpy of moist air and the wet bulb temperature are approximately constant. Therefore, this process is considered adiabatic. There are three types of evaporative coolers that perform cooling based on this principle: direct, indirect and semi-direct.

  Thermoelectric Cooling and Air Conditioning: ThermoThermoelectric (TE) is simply about heat and electricity, and the thermoelectric process is the direct conversion of thermal energy to electrical energy and vice versa. Basically, thermoelectric devices are divided into two as thermoelectric generators (TEJ) and thermoelectric coolers (TES). These devices, unlike conventional heat engines and heat pumps; They can work without the need for any working fluid, mechanical connections, moving parts and a closed loop. Using only the properties of semiconductor materials; These devices, which can work bidirectionally (with the movements of atoms and electrons in the solid state) for heating-cooling purposes, if desired, for power generation, have a great potential for clean energy.

They can provide cooling or temperature control in thermoelectric coolers (TES), electronic and medical devices. In addition, due to the many advantages of these devices such as being quiet, reliable, simple and long-lasting (average 25 years), easy temperature control and maintenance-free, these devices are rapidly becoming widespread in many sectors such as military, medicine, scientific studies, especially space vehicles, and they are used for thermoelectric products. The economic volume of the market is growing.

Vapor compression mechanical cooling and air conditioning System: The most widely used cooling process today is vapor compression shown in Figure 1.

It is a mechanical cooling system. refrigerant to compressor. It enters as saturated vapor and is isentropically compressed to the condenser pressure.

During the compression process, the temperature of the refrigerant rises above the ambient temperature. The refrigerant then enters the condenser as superheated vapor at point and leaves the condenser as a saturated liquid at point. From the fluid during condensation heat transfer to the environment. In the case of the temperature of the refrigerant (3), the ambient temperature is on it. The saturated liquid fluid is then through an expansion valve or capillary passed through the pipes and throttled to the evaporator pressure. During this process, the coolant the temperature of the fluid drops below the temperature of the cooled medium. Cooler liquid into the evaporator as a saturated liquid-vapor mixture with a low degree of dryness enters and evaporates completely by taking heat from the cooled environment. Refrigerant from the evaporator exits as saturated vapor and enters the compressor, completing the cycle.

- Unit 11:

Brainstorming on an effective air conditioning system design. Design potential solutions, consider constraints and potential improvements. Discuss with peers in groups and decide on the best and alternative solution.

What are the advantages of evaporative coolers?

- Consumes less energy than gas systems.
- Installation costs are 50% cheaper than system air conditioners.
- Clean and healthy indoor environment by filtering bacteria, dust, pollen and fumes from outside air.

- They give air.

Mechanical compression refrigeration cycle advantages:

- Providing a unique comfort
- Providing reasonable prices
- High efficiency values

Although Thermoelectric Chillers are not as efficient as traditional gas compression chillers, their simple structure, small size and ability to reach cryogenic temperatures makes these devices suitable for some applications. Extremely small size production allows them to be used in the cooling of electronic devices. Microprocessor and sensor cooling are the main ones.

- Unit 12:

  Design some basic components on 3D software and develop a preliminary design. Print the components on a 3D printer.

  In this context, the water dispenser will be designed and produced in a 3D printer.

- Unit 13:

  Build the first version of the prototype. It can improve its stability, symmetry, insulation, soldering, etc. Check.

- Unit 14:

  The refrigerants and principles used in the systems will be discussed comparatively.

B: Air Conditioning Systems (units 15-22)

- Unit 15:

  Design of a simulation of electrical circuits with sensors to be used in prototypes. Program the code necessary for their use. Check connections and applicability. In this context, the sensors, examples of which are given below, will be programmed.

The Testo 435-3 anemometer, which works according to the heated wire (hot wire) velocity measurement method, was used at the specified fixed velocity measurement points in order to determine the magnitude of the average velocity of the fresh, total (mixture) and air inside the cabin.

In the work to be done, **T and K types of E-TC-15-K portable thermocouple**, which are used in surface measurements and calibration processes, will be used to measure temperatures.

The datalogger to be purchased has 32 independent channels and can send data to a computer with an E-IB-11 USB converter.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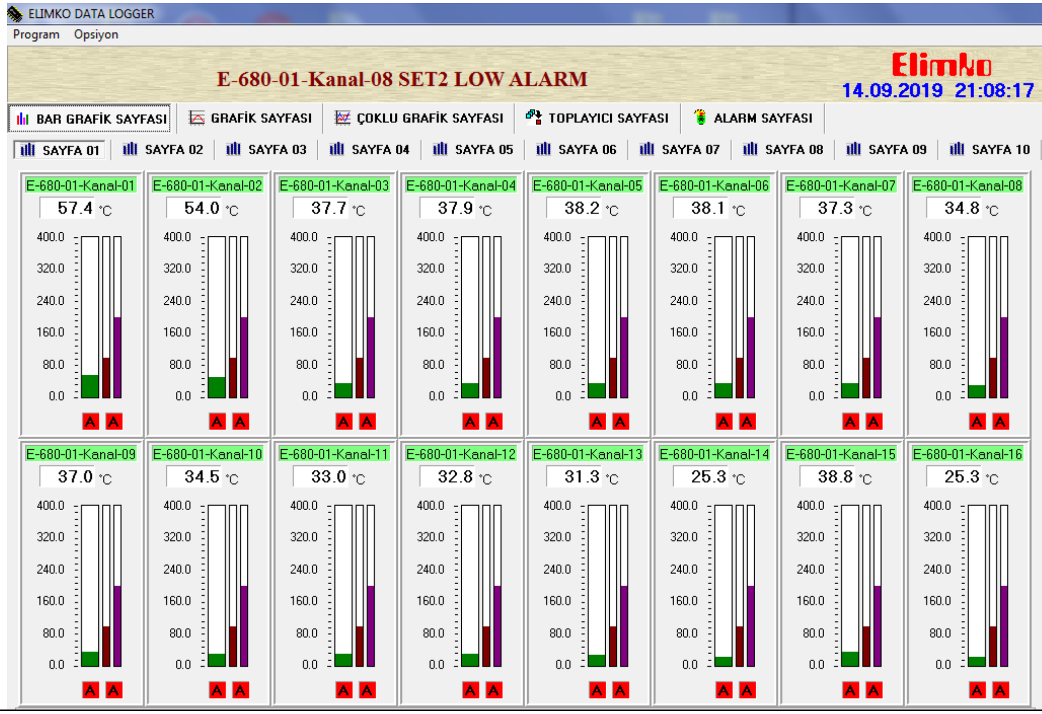
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CEM DT-8852 noise measurement device will be used. The data measured by the noise measuring device USB connection can be saved to the computer environment as an excel file.

Entes MPR 45S energy analyzer will be used.

Images will be taken with the Flir Thermovision A20M infrared thermal camera, which is in the infrastructure of Pamukkale University Mechanical Engineering Department.

- Unit 16:

  Make the necessary electrical circuits and hardware setups. Check the location of the sensors.
- Unit 17:

  Download the appropriate libraries for the sensors and calibrate the sensors using the corresponding experiments. Compare the simulated circuit with the real circuit.
- Unit 18:

  While there is a platform, modify the program to publish the data online. Access the platform via students' smart devices and check data online.
- Unit 19:

  Parametric experimental investigation of air velocity, dry bulb temperature, relative humidity, and geometry effect that may affect air conditioning efficiency.
- Unit 20:

  Graphical display and interpretation of results
- Unit 21:

  Comparison of data from alternative air conditioning systems
- Unit 22:

  Discussion of suggestions for efficiency improvement

4. Educational outcomes by year, module and key contents		
1st Year of Study: LOWER SECONDARY (ages 14-15) Title of Module: STEM (Greenhouse model) Duration: 6.5 weeks – number of hours: 13		
MODULE OBJECTIVES	**LEARNING OUTCOMES (Knowledge, Skills, Attitudes)**	**RECOMMENDED ACTIVITIES**
• Students engage in real-world problems and seek scientific solutions. • Students engage in engineering practices: brainstorm, design, develop and test prototype. • Students use digital software to design and fabricate custom components.	**Knowledge:** – crop production – climate – greenhouse effect – photosynthesis **Skills:** – design – simulation/modelling – brainstorm ideas – problem-solving – creativity **Competences:** – creativity – decision-making – design	➢ Students read news from several contemporary resources (simplified scientific ones & informal ones) and discuss how micro/macro changes in climate affect crop production (year/decade scale). (1 hour) ➢ Discussion on plant development, reflection on basic natural mechanisms and procedures for crop production. Discuss the population's need for increased crop production. Rising challenge: 'how could we affect crop production?' (1 hour) ➢ Students read news from several contemporary resources (simplified scientific ones and informal ones) and discuss innovative features in greenhouses. (1 hour) ➢ Students' research and discussion on greenhouses: operation, principles, features,

		types. Demonstration of images & examples from local contexts. Sharing and discussing personal experiences. Rising challenge: ‘build an operational and efficient greenhouse!’ (1 hour) ➢ Experience interactive simulations on the greenhouse effect and reflect on greenhouses’ use, operational principles, and features. (1 hour) ➢ Design a greenhouse model: brainstorming, group discussion on possible solutions, evaluation of solutions, evaluation of restrictions. Initial decisions on the prototype. Decisions on alternative solution/s. (2 hours) ➢ Digital design of 3D printing components (e.g. frame & roof) of the greenhouse). 3D printing of the components (2 hours). ➢ Construct an initial version of the prototype. Test the prototype (stability, weight, symmetry, insulation, soldering etc.). (3 hours) ➢ Brainstorm the type of plants to include in the greenhouse. Considerations of the plants that would demonstrate best the phenomena (photosynthetic, size, conditions). Implement the selected plants. (1 hour)

Key contents:

- Engineering practices: design & develop a prototype
- Real-world contexts
- Crop production
- Greenhouse
- Climate change

1st Year of Study: LOWER SECONDARY (ages 14-15)

Title of Module: Natural Science

Duration: 6 weeks – number of hours: 10

MODULE OBJECTIVES	LEARNING OUTCOMES (Knowledge, Skills, Attitudes)	RECOMMENDED ACTIVITIES
• Students learn calculation of physical – mathematical quantities	**Knowledge:** – calculation of physical – mathematical quantities **Skills:** – determine the division value of the device, to estimate the absolute measurement error – select measuring instruments with the required accuracy – use formulas, calculate the surface	➢ "Finding body dimensions" (Bloom's Taxonomy categories: remembering, understanding, applying). The topics covered are determination of length (bench, board, book), diameter (pea, thin flexible wire, pen); SI system units of measurement; device division value and measurement error. (1.25 hour) ➢ "Calculating the surface area of regular and irregular bodies" (Bloom's Taxonomy categories). The topics covered are body areas of regular (A4 sheet of paper, bench

	area and volume of the figures – apply percentage calculation and rounding in practice – make an estimate for the repair of the room – apply knowledge and skills in everyday life. **Competences:** – critical thinking – communication – collaboration – creativity – digital literacy – autonomy	surface, class boards) and irregular (hand-shaped) bodies in which students repeat, interpret and demonstrate area formulas and units of measurement (1.25 hour). ➢ “Spatial figures and box packing” (Bloom’s Taxonomy categories: remembering, understanding and applying). The topics covered are the dimensions of a rectangular parallelepiped (box), surface area, measurement error, rounding, percentage calculation (applicable to the calculation of packaging paper) in which students interpret and apply the use of ICTs to present their work. (1.25 hour) ➢ “Body volume calculation” (Bloom’s Taxonomy categories: remembering, understanding and applying). The topics covered are body volumes of regular (empty matchboxes) and irregular (nut) shapes by repeating volume formulas and units of measurement, interpreting and demonstrating their work. (1.25 hour) ➢ “Room redecoration project” (Bloom’s Taxonomy categories: analysing, evaluating, creating) in which students have to find the dimensions of the room (area and measurement units), choose materials for redecoration (floor covering, wall coverings), find out the prices (percentage calculation)

		and making repair estimates before presenting their works. (5 hours)

Key contents:

- Drawing pie and bar charts using a spreadsheet
- Drawing graphs of linear dependence quantities using value tables
- Writing standard expressions of a number and perform simple operations
- Using basic units of measurement and setting average values
- Converting multiple or partial units into basic SI units
- Key length, mass, area, volume, temperature, density, speed, force, pressure, working, energy, units of power and time

1st Year of Study: LOWER SECONDARY (ages 11-14)

Title of Module: Heat & Energy

Duration: 6 weeks – number of hours: 12

MODULE OBJECTIVES	LEARNING OUTCOMES (Knowledge, Skills, Attitudes)	RECOMMENDED ACTIVITIES
• Students inquire to understand the nature of a problem and classify factors and variables within the problem. • Students build knowledge and competence through meaningful investigations and challenges set in local contexts and/or global issues. • Students engage with meaningful phenomena to develop explanations and solve complex problems.	**Knowledge:** – atoms, their properties heat and conduction of heat – Concepts such as energy, geometric relations, – material and structural properties, – ecosystem principles – How knowledge is built in the STEM disciplines, – social and personal settings of STEM knowledge building, – nature of models in maths and science, – design processes, – algorithmic coding processes	➢ Students discuss the importance of thermal insulation in buildings, family and country economy and effective use of resources They determine the selection criteria of thermal insulation materials used in buildings. ➢ Students know what insulators are. They are able to give examples of insulators and understand how insulators work. ➢ Students develop alternative thermal insulation materials ➢ Students make the necessary calculations ➢ They use the engineering design cycle. They prepare the prototype of the product. ➢ Students use the necessary technologies to design the components. They use the necessary measuring instruments and laboratory equipment to develop the

	Skills: – Complex and creative problem solving, – design thinking, – critical thinking, – systems analysis, – computational skills, – complex, model-based reasoning **Competences:** – Interpersonal skills, – cooperation/ collaboration – curiosity, – aesthetic preferences – responsibility (Personal-global) –	prototype. ➢ Students prepare an engineering presentation where solutions are discussed whether they meet the initial problem and opportunities. ➢ Students share thoughts, questions, ideas and solutions. They collaborate with group mates to achieve a goal. ➢ They look at problems from a new perspective, connecting learning objects and disciplines. They try new approaches to innovation and invention, design new products
Key contents: – Posing Questions /Defining Problems – Developing and Using Models – Using transdisciplinary Thinking – Thermal Insulation – Engineering design cycle		

2nd Year of Study: UPPER SECONDARY (ages 16-17) Title of Module: STEM (Greenhouse model) Duration: 7.5 weeks – number of hours: 15		
MODULE OBJECTIVES	**LEARNING OUTCOMES (Knowledge, Skills, Attitudes)**	**RECOMMENDED ACTIVITIES**
• Students simulate a project before they construct it. • Students compare the simulated and constructed versions of the circuit. • Students learn to set up and calibrate sensors. • Students share and access data from sensors using the web. • Students analyse graphs to make inferences for the phenomena. • Students reflect on the photosynthetic process by making inferences from the data.	**Knowledge:** – algorithm – photosynthesis – greenhouse effect **Skills:** – coding – calibration – simulation/modelling – variable testing – critical thinking **Competences:** – inquiry – computational thinking – open data & data privacy	➢ Students design and program a simulation of an electrical circuit for the smart greenhouse with an Arduino board, double sensors of Temperature, Humidity, Light in Tinkercad. They test its applicability before constructing it. (2 hours) ➢ Students implement the hardware installations of the simulated circuit they previously designed, and check the positioning of the sensors. They install sensors both out and inside the greenhouse. (2 hours) ➢ Students learn about sensor libraries and download the libraries for the sensors. They also calibrate the sensors with the appropriate tests and experiments. They compare the simulated circuit with the manufactured one. (2 hours) ➢ Students modify the code in order for the sensors to publish data online in a user-

		friendly platform. (1 hour) ➢ Students use the sensors in order to conduct a series of experiments for the development of the plants by testing each variable at a time: temperature, humidity, light. (3 hours) ➢ Analysis of the data from the sensors. Discussion on statistical measures (mean values, slope, fit curves etc). Comparisons of the two data sets in each experiment. (2 hours) ➢ Inferences from the experiments and discussions in the light of photosynthesis and crop production. (2 hours) ➢ Discuss results and revisit the Greenhouse effect. (1 hour)

Key contents:

- Simulations
- Internet of Things
- Variable testing
- Photosynthesis

2nd Year of Study: UPPER SECONDARY (ages 16-17) Title of Module: Natural Science Duration: 10 weeks – number of hours: 10		
MODULE OBJECTIVES	**LEARNING OUTCOMES (Knowledge, Skills, Attitudes)**	**RECOMMENDED ACTIVITIES**
• Students learn the importance of photosynthesis in the production of oxygen.	**Knowledge:** – the importance of photosynthesis in the production of oxygen **Skills:** – understand the importance of photosynthesis and respiration and the relationship between the two processes – understand how fossil fuels are formed and what they are used for – compare respiration and combustion reactions, pointing out similarities and differences – understand how to reduce fuel use, how each family can contribute to reducing fuel use	➢ "Producers produce food and fuel" (Bloom's Taxonomy categories: remembering, understanding, applying, analysing and evaluating). The topics covered are the role of producers in nature, the generalized scheme of photosynthesis, how carbon dioxide and water enter the plant, the effect of plant synthesis on plant leaves, their total surface area, the conversion of glucose to starch, human use of plant-derived materials and fossil fuels. (2 hours) ➢ "Calculating the leaf area of a plant" (Bloom's Taxonomy categories): remembering, understanding, applying, analysing, evaluating, creating). The topics covered are calculating the area of an unknown figure by dividing the figure into known figures whose areas students are able to calculate: a square, a rectangle, or a right triangle. Repeat units of length and area, their enlargement, crushing and conversion. (2 hours)

	Competences: – critical thinking – communication – collaboration – creativity – digital literacy – autonomy	➢ “Combustion reaction” (category of Bloom’s Taxonomy categories: remembering, understanding, applying, analysing, evaluating, creating). The topics covered are the atoms as flammable materials and the generalized scheme of the combustion reaction process. (2.5 hours) ➢ “Getting energy by breathing” (Bloom’s Taxonomy categories: remembering, understanding, applying, analysing, evaluating, creating). The topics covered are the body needs oxygen for, why heat is released during respiration, respiratory response scheme, comparison of the respiratory process with the combustion response, and the relationship between photosynthesis and respiratory reactions. (1.5 hours). ➢ “Reducing consumption of fuel” (Bloom’s Taxonomy categories): remembering, understanding, applying, analysing, evaluating, creating). The topics covered are the substances released during fuel combustion, their impact on nature and living organisms, the "greenhouse effect" and ways to reduce fuel consumption. (2 hours)
Key contents: – Energy accumulation and separation processes: photosynthesis and breathing – photosynthesis as a process occurring in a plant in cell chloroplasts, during which energy is stored – respiration as a process occurring in a plant and in the cells of an animal during which energy is released. – the importance of photosynthesis in organic matter accumulation in plant organs and respiration of these substances’ degradation.		

2nd Year of Study UPPER SECONDARY (ages 15-17)

Title of Module: Air Conditioning System model
Duration: 8 weeks – number of hours: 16

MODULE OBJECTIVES	LEARNING OUTCOMES (Knowledge, Skills, Attitudes)	RECOMMENDED ACTIVITIES
• Students comprehend that boiling is an event depending on external pressure (pressure on the liquid)/geographical altitude. • They analyze the variables that depend on the change in temperature of pure substances that absorb or give off heat. • It means that boiling and evaporation are different from each other. • Students analyze the factors affecting evaporation. • Students know that the presence of water vapor in the atmosphere is expressed with the concept of humidity. • Students know that the concepts of real	**Knowledge:** – Air Conditioning – Climate Change – Evaporative cooling – Prototype design and development – Engineering design cycle – Internet of Things – Simulation/modeling – Electrical circuits and sensors – Prototype production **Skills:** – Cultivation of elementary engineering skills, such as: - brainstorming - designing a prototype - testing, evaluation and improvement of the prototype	➢ Comprehends that boiling is an event depending on external pressure (pressure on the liquid)/geographical altitude. ➢ It analyzes the variables that depend on the change in temperature of pure substances that absorb or give off heat. ➢ It means that boiling and evaporation are different from each other. ➢ Analyze the factors affecting evaporation. ➢ Knows that the presence of water vapor in the atmosphere is expressed with the concept of humidity. ➢ Knows that the concepts of real and felt temperature given in meteorology news are expressed with the concept of relative humidity. ➢ Interprets the reasons for the difference between felt and actual temperature. ➢ By using experiments or simulations, it is ensured that they determine the relationship between the variables. ➢ It is ensured that students identify a

and felt temperature given in meteorology news are expressed with the concept of relative humidity. • Students interpret the reasons for the difference between felt and actual temperature. • By using experiments or simulations, it is ensured that they determine the relationship between the variables. • It is ensured that students identify a problem from daily life related to air conditioning systems and produce solutions for this problem. • Students explain the concept of efficiency. The relationship between energy saving and energy efficiency is explained through energy identity documents. • Students develop suggestions that will increase the efficiency of an exemplary system or design. The working principle of various efficiency increasing systems designed in the historical process is mentioned.	through an engineering design cycle – Engagement in inquiry-based experimental procedures and cultivation of experimental skills, such as: - making predictions, - data collection, analysis and evaluation, - interpretation of data - drawing conclusions etc. – Design and implementation of technological circuits with sensors for real-time data collection - developing programming skills (block-based) - downloading and using libraries for sensors, calibration of sensors - installation of sensors and hardware systems	problem from daily life related to air conditioning systems and produce solutions for this problem. ➢ Explains the concept of efficiency. The relationship between energy saving and energy efficiency is explained through energy identity documents. ➢ Develops suggestions that will increase the efficiency of an exemplary system or design. The working principle of various efficiency increasing systems designed in the historical process is mentioned. ➢ In the designs to be made, the necessity of making a budget calculation should be emphasized in order to develop financial awareness. ➢ The importance of the contribution of energy saving to the family budget and the country's economy is emphasized. etc

• In the designs to be made, the necessity of making a budget calculation should be emphasized in order to develop financial awareness. • The importance of the contribution of energy saving to the family budget and the country's economy is emphasized. etc	**Competences:** – Develop competencies of statistical analysis of data and making inferences - basic statistical measures - evaluation of data – Disseminate experimental data online and develop main understandings and techniques of 'Internet of Things' - accessing and using interactive online platform for sharing data - gain understanding on basic aspects of open access, and data privacy – Developing 21st skills, such as: - collaboration and working in groups - critical thinking - problem-solving – Develop skills regarding modelling and simulations (e.g. by comparing the simulated circuit with the	

	developed one).	

Key contents:

- Air Conditioning
- Climate Change
- Evaporative cooling
- Prototype design and development
- Engineering design cycle
- Internet of Things
- Simulation/modelling
- Electrical circuits and sensors
- Prototype production

5. Teaching and learning of interdisciplinarity in STEM

POSSIBLE INTERDISCIPLINCARY CONNECTIONS OR CORRELATION WITH OTHER SUBJECTS

- graphic representation of data (Science-Mathematics-Technology)
- photosynthesis (Science disciplines: Physics-Chemistry-Biology)
- data collection and analysis with sensors (Science-Technology-Mathematics)
- designing a prototype (Engineering-Mathematics-Science)
- constructing a prototype (Engineering-Technology-Science-Mathematics)
- simulating/modelling a construct/circuit: (Technology-Engineering-Science)
- programming/coding & Computational Thinking (Technology-Engineering-Mathematics)
- greenhouse effect (Science-Technology-Mathematics)
- hardware installations of circuits & sensors (Technology-Engineering-Physics)
- internet of Things (Technology-Science)
- automation systems (Technology-Science-Engineering)
- brainstorming (Engineering-Science)
- renewable energy-solar cells (Engineering-Science-Technology)
- soldering of substances (Science-Technology-Engineering)
- calibrating sensors (Technology-Science-Mathematics-Engineering)
- conditioning (Science disciplines: Physics-Chemistry-Engineering-Technology)
- prototype design (Engineering-Math-Science)
- prototyping (Engineering-Technology-Science-Math)
- to simulate/model a structure/circuit: (Technology-Engineering-Science)
- assembly operations (Science-Technology-Engineering)

LEARNING AND TEACHING

- Greenhouse effect
- Climate Change
- Photosynthesis
- Design & develop prototypes
- Engineering design cycle
- Internet of Things
- Simulation/modelling
- Electrical circuits & sensors
- Crop production
- Air Conditioning
- Climate Change
- Evaporative cooling
- Prototype design and development
- Engineering design cycle
- Internet of Things
- Simulation/modeling
- Electrical circuits and sensors
- Prototype production

MATERIALS AND INSTRUCTIONAL RESOURCES

For the STEM Module:

- construction materials (plastic glass, plastic sticks, wood, etc.)
- sensors & electronic components
- Arduino microcontroller board & wireless shield
- simulation software, e.g. Tinkercad
- 3D printer
- organic solar cells
- dye-sensitised solar cells (TiO_2-based)
- plants for photosynthesis (e.g. spinach, tomatoes, peppers etc.)

For the NS Module:

- computers and multimedia resources (internet…)
- smartboard, rulers, measuring tapes, roulettes, meters, peas, flexible thin wire
- sheets of paper A4 format, calculators
- boxes, rulers, paper boxes for packing, tapes, scissors, adhesive tapes
- demonstration tools for measuring volume, empty matchboxes, nuts, measuring cylinders, calculators
- smart devices (cameras)
- table lamps, chemical glasses, funnels, tubes, plasticine, water, Elodia twigs, matches, scales, soda, water
- whiteboard, plant leaf clippings, graph paper, pencils
- candles, ceramic tiles, glasses, erasers, clock
- empty rectangular 1 litre milk sachets, polyethylene bags, scissors, adhesive tape, two thermometers for each group to measure the air temperature

For the Heat & Energy Module:

- mechanical, electrical and construction materials
- cellulose based paper
- Recine and glue
- Plastic and metal sheets
- Dust Filter
- Aluminum and copper pipes
- Small water pump
- Compressor
- Evaporator
- Condenser
- Expansion valve
- Float valve
- Level sensor
- Bolts and nuts
- sensors and electronic components
- Arduino microcontroller board and wireless shield
- simulation software,
- 3D printer
- Evaporative cooling
- Thermoelectric Cooling
- Mechanical vapor compression cooling

GROUPING STUDENTS AND TIME FRAME

- Students work independently, in pairs and in small groups (4-6 students)
- Each unit lasts between 1 and 3 hours

EVALUATION

Evaluation is possible to be done through:

- interactive group discussion (understanding, argumentation, critical thinking etc.)
- experimental activities/inquiry process
- observation of design process
- pre-post questionnaires
- individual interviews with an indicative sample
- interpretation - demonstration, students' independent work, work in pairs, comparison of the obtained results, reflection
- practical work of students, presentation and comparison of results, self-assessment and evaluation
- independent - practical work of students, presentation of works, reflection
- practical work of students in groups, application of the obtained results, comparison, conclusion

ELEMENTS OF ASSESSMENT

- conceptual understanding
- technical skills development
- creativity
- critical thinking
- decision-making
- collaboration skills

- argumentation
- formative assessment and feedback

LINKS TO USEFUL RESOURCES

- Bybee, R. W. (2002). Scientific inquiry, student learning, and the science curriculum. *Learning science and the science of learning*, 25-35.
- Care, E., Kim, H., Vista, A., & Anderson, K. (2018). Education System Alignment for 21st Century Skills: Focus on Assessment. *Center for Universal Education at The Brookings Institution*.
- IBM SkillsBuild STEM Labs (English, Spanish and Turkish) https://skillsbuild.org
- Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, *103*(4), 799-822.
- Moore, T., Tank, K., Glancy, A., & Gajdzik, E. (2017). Board# 102: PECASE: Implementing K-12 Engineering Standards through STEM Integration-An Executive Summary of the Products and Research.
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