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INNOVATIVE SCHOOLS: TEACHING & LEARNING IN DIGITAL STEM LABS

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METHODOLOGICAL GUIDE
INTELLECTUAL OUTPUT 3

METHODOLOGICAL GUIDE TO TEACH "DIGITAL STEM LABS" AT (LOWER/UPPER SECONDARY) SCHOOL LEVEL

OUTPUT TYPE: Learning / teaching / training material – Manual / handbook / guidance material

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Innovative Schools: Teaching & Learning in DIGITAL STEM LABS

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Universidad Rey Juan Carlos

ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

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Chapter 1: Introduction

In the rapidly evolving landscape of education, Science, Technology, Engineering, and Mathematics (STEM) education in secondary education is more important than ever. STEM education provides students with the critical skills and knowledge they need to navigate the modern world and contribute meaningfully. When delving into the field of online STEM education, it is essential to understand the important role STEM plays in shaping the future and the unique challenges and opportunities that arise in the digital era.

STEM education is the foundation for encouraging creativity, problem-solving, and an in-depth understanding of the world around us. The demand for a qualified STEM workforce continues to rise in an era driven by technology breakthroughs. Science, technology, engineering, and mathematics are all interrelated, which highlights their overall significance on tackling global concerns. STEM education prepares students to be critical thinkers and innovators, from generating sustainable energy solutions to advancing medical advances. (Martín-Páez et al., 2019).

Furthermore, those who can adapt to technological developments and contribute to multidisciplinary initiatives are in high demand in today's workforce. STEM education equips students to succeed in dynamic and complex situations by emphasizing cooperation and real-world application. It fosters creativity and innovation by cultivating a mentality that transcends traditional disciplinary boundaries. (Bybee, 2010).

Challenges and Opportunities of Teaching STEM Subjects Online

The shift to online STEM education presents a unique mix of problems and opportunities. While digital media opens up new opportunities, it also demands careful planning to achieve successful learning results.

Providing fair access to STEM education resources is one of the key difficulties. Not every student has equal access to technology or a suitable learning environment at home. Addressing these gaps is critical to avoiding a digital divide that may impede some children from fully participating in STEM study. Keeping students motivated in an online context, particularly in STEM topics, necessitates novel ways. STEM's dynamic and interactive nature may be used to produce compelling virtual classes, but it requires deliberate design and implementation (De Jong et al., 2014).

STEM subjects frequently entail hands-on experiments and activities which present challenges in a virtual context. Striking a balance between academic understanding and practical application becomes critical. This challenge also gives an opportunity to investigate virtual laboratories and interactive simulations that can emulate hands-on experiences. The move to online STEM education needs ongoing professional development for teachers. Educators must be able to utilize digital technologies successfully and offer interactive and collaborative learning experiences (Altawalbeh & Al-Ajlouni, 2022).

On the other hand, the online environment provides chances for utilizing technology to improve STEM education. Virtual reality, simulations, and online collaboration tools can enhance the learning experience by giving students new ways to explore and comprehend complicated subjects. (Blake & Scanlon, 2007).

The online teaching of STEM subjects in secondary schools has the potential to revolutionize education by navigating these obstacles and seizing the opportunities. Students will be better equipped to meet the demands of the modern workforce and thrive in a future where creativity and adaptability are critical.

Methodological guide to teach "DIGITAL STEM LABS”

In this context the “Methodological guide to teach "DIGITAL STEM LABS” at secondary school level“ is designed to serve as a comprehensive framework for the effective implementation of STEM (Science, Technology, Engineering, and Mathematics) education at the upper-secondary school level. The core objective is to facilitate relevant teaching and learning experiences, demonstrating key quality factors essential for success.

This toolkit encompasses various components to address the unique challenges and opportunities associated with online teaching of STEM content. It begins with the integration of the "DIGITAL STEM LABS" curriculum framework into the secondary school curriculum. Emphasis is placed on incorporating digital elements into STEM education, aligning with the contemporary landscape of technological advancements. Pedagogical concepts tailored for online teaching of STEM subjects are developed, integrating specific theoretical approaches to optimize learning outcomes. The toolkit further provides insights into the most relevant methodological and organizational aids, ensuring the seamless realization and teaching of STEM contents within high-quality learning arrangements.

Another key feature is the presentation of exemplary teaching lessons and assessment tools aligned with the "DIGITAL STEM LABS" curriculum. These resources aim to guide educators in delivering impactful lessons while effectively evaluating student understanding and progress. To create a supportive school environment conducive to cross-curricular and interdisciplinary approaches, the toolkit introduces measures that facilitate the deployment of these strategies in the teaching of STEM educational contents. Concrete exercises for secondary school students are included, encompassing individual tasks, group work, problem-based learning, and peer-learning. These exercises are carefully designed to be applicable within the context of STEM education investigations, promoting active and engaging learning experiences.

The toolkit also addresses the evaluation of student competencies, providing an overview of relevant methodologies and offering examples that illustrate effective assessment practices in STEM subjects. In addition to these fundamental elements, the toolkit integrates optional components aimed at motivating secondary school teachers. These elements encourage the adoption of learner-centered, flexible, and innovative approaches to teaching and learning STEM skills.

A special section is devoted to methods of collaboration between teachers, recognizing the value of collective learning and shared experiences. Peer-observation among teachers is highlighted as an effective way to exchange strategies and ideas. Joint lesson-planning is proposed to encourage cross-curricular approaches, while the formation of an online teacher discussion group facilitates the sharing of methods and reflective discussions on teaching practices.

In summary, the methodological guidelines and toolkit represent a holistic approach to enhancing STEM education in secondary schools. By addressing curriculum integration, pedagogical concepts, organizational aids, assessment tools, and collaborative strategies, the toolkit aims to empower educators and create a dynamic and innovative learning environment for students.

Chapter 2: Employed pedagogical principles for STEM education

Digital STEM Labs modules develop STEM capabilities by challenging students to solve real-world problems set in authentic contexts. The problems engage students in the STEM disciplines and provide opportunities for developing higher order thinking and reasoning, and the general capabilities of creativity, critical thinking, communication and collaboration. In particular the modules developed under Digital STEM Labs project employed pedagogical principles such as inquiry-based learning, problem-based learning, integrated learning and collaborative learning.

Inquiry-based learning

An essential component of STEM education, inquiry-based learning (IBL) transforms conventional teaching strategies and promotes a dynamic, student-centered approach. IBL is essentially a teaching approach that places the students at the center of the learning process and motivates them to actively participate in the investigation and discovery of concepts related to science, technology, engineering, and math. IBL gives students the confidence to pose queries, look for answers, and create knowledge through practical applications. (Van Uum et al., 2016).

IBL serves as a catalyst in STEM education for the development of critical thinking skills, problem-solving abilities, and a thorough understanding of the interconnected nature of scientific disciplines. IBL fosters a sense of curiosity and intrinsic motivation to explore the complexities of the natural world by presenting students with real-world problems and challenges. Forming hypotheses, designing experiments, and analyzing data are all part of the inquiry process, which mirrors the authentic practices of scientists and engineers. This additionally improves students' understanding of STEM concepts, but it also fosters a scientific mindset marked by curiosity, skepticism, and a commitment to evidence-based reasoning (Riga et al., 2017).

Students are encouraged to work together, share ideas, and learn from one another, which fosters a sense of community and collective intelligence. Because inquiry-based activities are open-ended, educators can differentiate instruction to meet the needs of individual students. This personalized approach not only fosters a deeper understanding of STEM concepts, but it also encourages a sense of ownership and autonomy in the learning process.

For example, in the ***Smart Greenhouse module***, while students engage in testing their prototype, they try to enhance its efficiency. Therefore following an inquiry circle, they formulate hypotheses about the right combination of Temperature, Humidity and Light exposure for a specific kind of plant to maximise its rate of growth. Afterwards they test their hypothesis by controlling the aforementioned variables (measured by wireless sensors) and measuring the plant's growth (in cm) per 3-days duration. Finally, they analyse the data from the sensors, discuss statistical measures (mean values, slope, fit curves etc) in order to formulate their final conclusions regarding the factors that influence the plant growth rate and the suitable conditions in a greenhouse.

Likewise, in the ***Natural Science module*** students try to find out how to convert glucose to starch, the importance of plant-derived materials, and fossil fuels. After the information is collected, they analyse the data in order to formulate their final conclusions and to compare obtained results. They also students engage in calculating bench, board or book length and diameter of pea, thin flexible wire or pen. After the calculation they analyse the data in order to formulate their final conclusions and to compare obtained results.

Problem-based learning

By immersing students in authentic problem-solving experiences, problem-based learning (PBL) stands out as an innovative pedagogical strategy in STEM education. PBL encourages students to confront complex, open-ended problems similar to those encountered by professionals in science, technology, engineering, and mathematics. Such challenges become the focal point of the learning process, compelling students to investigate, analyze, and synthesize information in order to devise effective solutions (Hung et al., 2008).

PBL's strength lies in its ability to foster critical thinking and decision-making competencies. PBL encourages students to engage in thoughtful analysis, weigh evidence, and make informed decisions by immersing them in authentic problem-solving scenarios—a skill set critical for success not only in STEM fields but also in broader contexts. Interdisciplinary approaches are frequently required in PBL, reflecting the interconnected nature of STEM disciplines. This interdisciplinary engagement reflects the collaborative dynamics found in professional STEM settings, preparing students for the multifaceted challenges they may face in their future careers (De Graaf & Kolmos, 2003).

Furthermore, PBL promotes a learner-centered environment, allowing students to take ownership of their educational journey. Students develop problem-solving strategies, resilience, and a sense of self-efficacy as they navigate the complexities of authentic problems. PBL fosters teamwork and effective communication skills, which are essential in the collaborative landscape of STEM professions (De Graaf & Kolmos, 2003).

For example the ***Heat and energy module*** presents the experience of a structured problem-based learning approach to the teaching of an introductory study module on heat transfer. A problem about thermal insulation in buildings is posed to students at the beginning of the module. Small groups of students work in a cooperative learning environment, while the teacher acts as the coach and the facilitator of knowledge acquisition. Partial, though not extensive, written reports are collected and the student assessments of the learning environment are measured. The activity closes with a list of recommendations intended to solve the real-world problem.

Additionally, in the ***Smart Greenhouse module*** students are called to 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). Afterwards they reflect on possible ways of raising the yearly production of crops and they are called to answer to the rising challenge of building an operational and efficient greenhouse. In order to design a greenhouse model they engage in brainstorming, group discussion on possible solutions, evaluation of solutions, evaluation of restrictions. In this way they take some initial decisions on the prototype and decisions on alternative solutions. Then they construct an initial version of the prototype and finally test the prototype in terms of stability, weight, symmetry, insulation, soldering etc.

Finally, in the ***Natural Science module***, students are called to find information from the internet or books about photosynthesis, effect of plant synthesis, conversion of glucose to starch. In order to calculate the surface of the leaf they engage brainstorming, group discussion on possible solutions, evaluation of solutions.

Integrated learning

Integrated learning in STEM education is a holistic and cohesive strategy that transcends traditional disciplinary boundaries, enabling knowledge and skills synthesis across science, technology, engineering, and mathematics. Unlike fragmented teaching techniques, integrated learning acknowledges the intrinsic interconnectivity of STEM courses and strives to present them as a whole. This method stresses the seamless integration of concepts and principles from other disciplines, allowing students to comprehend the interdisciplinary character of real-world issues and solutions (Kelley & Knowles, 2016).

Students are encouraged to investigate links across diverse STEM areas in an integrated STEM learning environment, creating a more thorough knowledge of complex phenomena. For example, a project or activity may ask students to address engineering challenges using mathematical ideas or to use scientific principles in technology advancements. This approach reflects the collaborative and multidisciplinary character of professional STEM professions, preparing students to address multiple issues in their future jobs. Integrated learning in STEM cultivates critical thinking, problem-solving skills, and the ability to apply knowledge in a variety of contexts, ultimately empowering students to become well-rounded and adaptable contributors to the ever-changing landscape of science, technology, engineering, and mathematics (Roehrig et al., 2021).

Indicatively, in the ***Heat and Energy module*** integrated Learning is embraced in the curriculum framework as a learning strategy and involves secondary school students' as participants in the life/active citizenship of their communities. Integrated learning combines what students learn in lessons, whether it's theory or technique, with the solution of real-world problems for real-world "clients." Students are provided with an experience of organizing ideas and concepts, which help them develop the bigger picture and not see learning episodically. Instead, they begin to internalize the process of making connections across disciplines and/or among topics within STEM disciplines. Students make connections across curricula and are encouraged to use theory in the real world making connections, engaging in relevant, meaningful activities that can be connected to real life.

Collaborative learning

Collaborative learning in STEM education indicates a paradigm change away from individual-centered instruction and toward a more collaborative and interactive approach that reflects the collaborative character of real-world scientific and technical undertakings. Collaborative learning, at its foundation, enables students to work in groups, enabling a shared study of STEM ideas. This approach emphasizes that many difficulties in science, technology, engineering, and mathematics need collaborative problem-solving and a wide range of perspectives. Students in collaborative STEM classrooms participate in combined activities, conversations, and projects, allowing them to share their experience and learn from one another (Lu & Lin, 2018).

Collaborative learning improves not just subject matter knowledge but also important interpersonal skills such as communication, collaboration, and leadership skills. Collaborative projects frequently mimic real-world circumstances in which people with various skills work together to achieve common goals. Not only does this prepare students for the collaborative demands of STEM vocations, but it also instills a feeling of communal ownership for the learning process. Students who actively participate in collaborative exploration and knowledge construction develop a deeper understanding of STEM concepts as well as the ability to apply them collaboratively, preparing them for the collaborative and interdisciplinary challenges they may face in their future STEM endeavors (Soller & Lesgold, 2007).

All Digital STEM labs modules engage students in collaborative settings while information that can support teachers with aspects of collaborative learning is included in the resource sheets.

Chapter 3: Assessment tools for STEM education

The two pillars of formative and summative assessment constitute a complete framework that drives both teaching and learning in STEM education. Formative evaluation, like a nautical compass, works in real time throughout the learning process. It entails ongoing evaluations that provide real-time feedback on student knowledge. This ongoing interaction enables educators to adjust their course to changing requirements, establishing a climate conducive to the hands-on inquiry and practical learning inherent in STEM fields. Quizzes, conversations, and project milestones are examples of formative assessment strategies that not only test topic knowledge but also foster critical thinking and problem-solving abilities (Grangeat et al., 2021).

Summative assessment, on the other hand, serves as a reflecting picture, documenting the conclusion of students' STEM achievements. These evaluations are often given at the end of a course or project and provide a comprehensive review of overall accomplishment. Summative assessments give useful information on the efficacy of teaching approaches, curriculum design, and student comprehension. They act as indicators of achievement of learning objectives and ensure that students have gained the necessary information and abilities to advance in their STEM education journey. Formative and summative assessments work together to establish a balanced assessment environment in STEM education, allowing educators to effectively guide their students through the complexities of scientific investigation and technological innovation (Grangeat et al., 2021).

Assessment tools are critical in the STEM classroom because they provide instructors with insights into student knowledge and allow for a full review of their development (Mandernach, 2015). Rubrics stand out as important guides among these tools, providing a formal framework for assessing performance against set criteria. They improve consistency in evaluation while increasing transparency and clarifying expectations for both instructors and students.

In turn, concept maps serve as dynamic tools for evaluating conceptual knowledge and the interconnection of STEM disciplines. These visual representations allow students to demonstrate their understanding of complicated relationships, promoting a greater understanding of scientific ideas and their practical applications.

Reflective diaries develop as personal insights into the learning paths of students. These journals, which encourage self-reflection, not only give vital qualitative information but also improve metacognition, allowing learners to explain their changing knowledge, problems faced, and strategies used.

In the digital era, e-portfolios provide a varied manner of exhibiting and evaluating student work. E-portfolios reflect the dynamic nature of STEM projects, allowing students to construct a multimedia record of their achievements. They allow educators to evaluate not just the end results, but also the iterative process of problem-solving and teamwork.

These evaluation methods, when combined, form a comprehensive strategy that responds to various learning styles while capturing the core of STEM education. Rubrics give structure, concept maps illustrate comprehension, reflective diaries promote metacognition, and e-portfolios capture the dynamic growth of student learning. Integrating these tools improves the assessment environment in STEM classes by supporting comprehensive evaluation that corresponds to the multifaceted character of scientific advancement.

In particular activities developed under Digital STEM Labs include several of the aforementioned assessment methods and tools. Indicatively, the ***Natural Science module*** encompasses exit tickets for summarizing learning, one-minute papers for brief open-ended responses, and a list creation activity requiring students to articulate learned concepts, surprises, and intentions for application. The list presentation fosters discussion, prompting students to apply knowledge, express opinions, and engage with peers. These dynamic approaches provide valuable insights into comprehension, allowing teachers to gauge understanding, identify knowledge gaps, and encourage active participation in the learning process.

Moreover in the ***Heat and Energy module*** post-tests assess the increase in these aspects after lesson completion. Formative and summative assessments include a final quiz, STEM resource evaluation, and students expressing their opinions on the topic. Additional assessment involves students hypothesizing about experiments, reflecting on materials' effectiveness, and designing experiments to measure temperature retention. These diverse methods ensure a comprehensive evaluation of understanding and engagement with the STEM content.

Finally, the ***Smart Greenhouse activity*** includes various assessment tools, such as rubrics, concept maps, and reflective diaries. Rubrics, designed for self-assessment or teacher evaluation, gauge inquiry skills during prototype design, providing feedback for improvement. Concept maps and reflective diaries track students' evolving understanding and choices throughout lessons. Continuous assessment, from initial concept maps to final reflections, captures progress and informs teaching strategies. The reflective diary becomes a valuable tool for students to self-assess or engage in peer assessment, fostering a comprehensive and dynamic approach to understanding and applying STEM concepts.

In more detail the assessment tools indicated for each module are described in chapter 5.

Chapter 4: Teachers’ collaborative practices in the context of STEM lessons

Teachers' collaborative practices in STEM classrooms provide a dynamic environment in which expertise from many domains converges. STEM thrives on collaborative education methodologies. Educators work together not just inside their subject areas, but also across disciplines, to create an extensive range of learning experiences. Collaborative lesson preparation enables instructors to capitalize on their distinct strengths by fusing academic knowledge with practical applications. They may develop activities that seamlessly combine scientific ideas with technical tools and engineering issues throughout the planning process, boosting students' overall knowledge (Margot & Kettler, 2019).

Collaborative practices in STEM classrooms extend beyond co-teaching to include joint facilitation of activities, allowing educators to demonstrate successful teamwork—a critical ability in STEM areas. This cooperation is not limited to teacher-to-teacher exchanges; it also includes students who learn to apply STEM principles in real-world circumstances through joint projects. Teachers share their views on effective instructional tactics and change their approaches depending on group reflections. This ongoing cooperation ensures that teachings stay dynamic, sensitive to student needs, and representative of STEM knowledge's ever-changing world. Finally, teachers' collaborative practices in STEM classrooms build an environment of shared expertise, encouraging both educators and students to innovate and think critically (Margot & Kettler, 2019).

Particularly in the ***Natural science module*** mathematicians and physics teachers take responsibility for calculations, measurements, and theory explanation, while art teachers contribute to the design aspect. The IT teacher plays a crucial role in presentation and technology integration. This collaborative model ensures a seamless integration of diverse disciplines, supporting students throughout the teaching and learning processes.

Moreover, in the ***Smart Greenhouse module***, through joint lesson-planning, each discipline contributes to forming a comprehensive STEM lesson, seamlessly integrating elements from biology, mathematics, and technology. The biologist/science teacher guides students in understanding Climate Change scientific content, while the mathematician and technologist contribute expertise in data analysis and greenhouse model design, respectively. Activities and worksheets are collaboratively planned, ensuring a well-rounded incorporation of features from each discipline. In the co-teaching phase, each teacher plays a specialized role during the greenhouse lesson. The biologist delves into Climate Change concepts, discussing topics like photosynthesis and the greenhouse effect. The technologist guides students in the design and construction of the greenhouse model, offering support and ensuring safety. The mathematician aids in measurements, data analysis, and error assessment. Co-teaching fosters interdisciplinary understanding, allowing both students and teachers to appreciate and integrate key features from each discipline into their work.

Finally, in the ***Heat and Energy module*** the science teacher guides students in classifying substances based on heat conduction and facilitates their determination of selection criteria for thermal insulation materials in buildings. The mathematics teacher supports students in calculations and problem-solving involving natural numbers. A technologist aids students in using online tools for data analysis and introduces measurement instruments like thermometers. Engaging in an engineering activity, students follow the design cycle, preparing prototypes, discussing engineering solutions, and presenting their findings. The science component involves research questions, predictions, and investigations on the impact of variables on heat transfer. In technology, students design solutions considering social and economic factors. The mathematics aspect includes the analysis of tree canopy cover using Google Maps and grids, linking it to the heat island effect. This interdisciplinary approach ensures a comprehensive and cohesive STEM learning experience for students.

Chapter 5: Guide to Digital STEM Labs modules implementation

In this chapter the STEM modules developed in the context of Digital STEM Labs are presented in detail.

Natural Science module

Title of STEM module:	**<u>Natural science</u>**
Title of sub-module:	"PRODUCERS PRODUCE FOOD AND FUEL"
Target group:	Lower Secondary education
Duration:	1 – 2 academic hours
Objectives:	The main educational objectives are: ● To learn generalized scheme of photosynthesis, ● To find out how carbon dioxide and water enter the plant, ● To know the effect of plant synthesis on plant leaves, their total surface area, the conversion of glucose to starch, human use of plant-derived materials, fossil fuels.
Necessary materials / equipment:	Computer, multimedia, smartboard, table lamps, chemical glasses, funnels, tubes, plasticine, water, Elodia twigs, matches, scales, soda, water.
Pre-requisite students' knowledge:	Mathematical and physics formulas
Possible difficulties students' may face:	Students may not be able to know the effect of plant synthesis on plants.
Possible difficulties teachers implementing the STEM module may face:	Students may not be familiarised with mathematical and physics aspects
Hints to overcome these difficulties:	Use of worksheets that guide students through calculating the length and area of a leaf.

Description of the STEM module:	1. Students are provided with news from several contemporary resources (newspaper articles, podcasts, popular science articles etc) scheme of photosynthesis, effect of plant synthesis on plant leaves, their total surface area, the conversion of glucose to starch, human use of plant-derived materials, fossil fuels’ 2. Students perform a short web-quest and explore how to convert glucose of plant area. 3. After calculating the area they formulate final conclusions regarding photosynthesis and its effect on plant.
Used assessment tools:	Formative assessment
Description of students’ assessment:	Exit tickets. Teacher gathers information about how well students processed lesson by giving them five minutes to write an entry or exit ticket.
Hints for assessment	Exit tickets involve students summarizing what they’ve just learned. Teacher gives students five minutes to write exit ticket what they have just learned. In this way the teacher receives small products that let him easily see how well students processed and summarizing retained key content, indicating knowledge gaps.

Title of sub-module:	Learning calculations of physical - mathematical quantities “FINDING BODY DIMENSIONS"
Target group:	Lower Secondary education
Duration:	(1 academic hour)
Objectives:	The main educational objectives are: ● measurement of length (bench, board, book), ● measurement of diameter (pea, thin flexible wire, pen). ● SI system units of measurement.
Necessary materials / equipment:	● computer and multimedia, smartboard, rulers, measuring tapes, roulettes, meters, peas, flexible thin wire.
Pre-requisite students’ knowledge	▪ physical quantities ▪ mathematical and physics formulas ● SI system units of measurement.

Possible difficulties students' may face:	Students may not be able to distinguish the difference between length and diameter
Possible difficulties teachers implementing the STEM module may face:	● Students may not be familiarised with mathematical and physics formulas.
Hints to overcome these difficulties:	● Use of worksheets that guide students through calculating the length and d and diameter of chosen objects.

Brief description of the STEM module:	1. Students are provided with news from several resources and discuss how to measure length and diameter of some objects. 2. Students discuss SI system units and choose some of them to use in their calculation. 3. Students choose the object: bench, board, book to calculate length. 4. Students choose the object: pea, thin flexible wire, pen to calculate diameter. 5. Then they calculate the length and diameter of chosen objects. 6. After calculating they formulate final conclusions regarding which SI system units are used to calculate length and diameter.
Used assessment tools:	Formative assessment
Description of students' assessment:	One-minute paper
Hints for assessment	Students complete one-minute papers. Students have some time to answer a brief question about the lesson. It is an open question, which allows teacher to easily assess understanding. For example, teacher asks students about the lesson's confusing areas, any unaddressed queries they have or what question from the lesson they think may appear on an upcoming test.

Title of sub-module:	"CALCULATION OF THE SURFACE AREA OF REGULAR AND IRREGULAR BODIES"
Target group:	Lower Secondary education
Duration:	1-2 academic hours

Objectives:	The main educational objectives are: ● Calculating areas of regular shape object (A4 sheet of paper, bench surface, class boards) ● Calculating areas of irregular (hand-shaped) shape object.
Necessary materials / equipment:	computer, multimedia, smartboard, rulers, meters, sheets of paper A4 format, calculators.
Pre-requisite students' knowledge:	● mathematical and physics formulas ● physical quantities
Possible difficulties students' may face:	Students may not be able to distinguish the difference between regular and irregular shape bodies.
Possible difficulties teachers implementing the STEM module may face:	Students may not be familiarised with mathematical and physics formulas.
Hints to overcome these difficulties:	Use of worksheets that guide students through calculating the area of regular and irregular bodies.

Brief description of the STEM module:	1. Students are provided with news from several resources and discuss the differences between regular shape bodies and irregular shape bodies 2. Students discuss formulas to calculate area of regular and irregular shape bodies 3. Students choose regular shape body object: A4 sheet of paper, bench surface, class boards to calculate area. 4. Students choose the irregular shape object to calculate area. 5. Then they calculate area of chosen objects. After calculating they formulate final conclusions.
Used assessment tools:	Formative assessment
Description of students' assessment:	Countdown
Hints for assessment	Teacher asks students to create three distinct lists. They must state and explain (a) one concepts they learned, (b) one concept that surprised them and (c) one thing they intend to start doing based on what they learned.

Title of sub-module:	"SPATIAL FIGURES. BOX PACKING"
Target group:	Lower Secondary education
Duration:	1 – 2 academic hours
Objectives:	The main educational objectives are: ● to learn dimensions of a rectangular parallelepiped ● to calculate rectangular parallelepiped object area ● to learn percentage calculation (applicable to the calculation of packaging paper).
Necessary materials / equipment:	computer, boxes, ruler, paper boxes for packing, tapes, scissors, adhesive tapes.
Pre-requisite students' knowledge:	● mathematical and physics formulas ● physical quantities
Possible difficulties students' may face:	Students may not be able to do percentage calculation
Possible difficulties teachers implementing the STEM module may face:	Students may not be familiarised with mathematical and physics formulas.
Hints to overcome these difficulties:	Use of worksheets that guide students through doing the percentage calculation

Brief description of the STEM module:	1. Students are provided with news from several resources and discuss dimensions of a rectangular parallelepiped shape bodies 2. Students discuss formulas to calculate area of rectangular parallelepiped shape object 3. Students choose rectangular parallelepiped shape object 4. Then they calculate area of chosen objects. 5. Students learn percentage calculation. 6. After calculating they formulate final conclusions.
Used assessment tools:	Formative assessment
Description of students' assessment:	Metacognition sheet

Hints for assessment	Students answer specific questions about the given topic. This starts by distributing sheets of paper with the following questions: (a) “Can you summarize the topic?”, (b) “How can you apply the topic?” and (c) “What questions do you still have about the topic?”

Title of sub-module:	“ROOM REDECORATION”
Target group:	Lower Secondary education
Duration:	5 - 6 academic hours
Objectives:	The main educational objectives are: • To calculate room renovation costs: choose materials for redecoration (floor covering, wall coverings), find out the prices (in the supermarket or online)
Necessary materials / equipment:	Meters, roulettes, computers, calculators, smart devices (cameras).
Pre-requisite students’ knowledge:	• mathematical and physics formulas • physical quantities
Possible difficulties students’ may face:	Students may struggle while doing calculations
Possible difficulties teachers implementing the STEM module may face:	Students may not be familiarised with mathematical and physics formulas.
Hints to overcome these difficulties:	Use of worksheets that guide students through doing the calculation.

Brief description of the STEM module:	1. Students are provided with news from several contemporary resources and discuss how the price and quantity of chosen material can influence the price 2. Students discuss how to calculate the area of walls, ceiling and floor. 3. Students perform a short web-quest and explore the features chosen material for redecoration. 4. Students design a redecoration plan. 5. Finally, they analyze the data in order to formulate their final conclusions regarding the factors that influence the price of the plan. 6. Students make suggestions plans.

Used assessment tools:	Diagnostic assessment
Description of students' assessment:	Classroom discussions
Hints for assessment	Students present their plans to the teacher and other students and their plans are discussed among their peers and teacher. After the students present their plans at the front of the class, the teacher opens a class discussion by asking the students what they like and dislike about the plans. By engaging each student into the discussion, the students are applying the information they have been taught in order to support their own opinions and thoughts. Students may also respond to each other's comments by adding to or questioning what was said in response.

Smart Greenhouse module

Title of STEM module:	**<u>Smart Greenhouse</u>**
Title of sub-module:	Greenhouse model
Target group:	Grades 7-9 - Lower Secondary education
Duration:	7-10 teaching hours

Objectives:	The main educational objectives are:
	● cultivation of elementary engineering skills, such as:
	    o brainstorming
	    o designing a prototype
	    o testing, evaluation and improvement of the prototype through an engineering design cycle
	● understanding of phenomena related to:
	    o Greenhouse effect
	    o Climate change
	● engagement in inquiry-based experimental procedures and cultivation of experimental skills such as
	    o making predictions,
	    o data collection, analysis and evaluation,
	    o interpretation of data
	    o drawing conclusions etc.
	● develop competencies of statistical analysis of data and making inferences
	    o basic statistical measures
	    o evaluation of data
	● developing 21st skills, such as
	    o collaboration and working in groups
	    o critical thinking
	    o problem-solving

Necessary materials / equipment:	● Newspaper articles ● Glass or plastic transparent surfaces for building the greenhouse ● CO_2 wireless sensors ● Humidity sensors ● Temperature sensors ● illuminance sensors ● PC, laptop or portable device ● Various small plants
Pre-requisite students' knowledge:	Basic mechanisms of plant development. ● Physical quantities ● factors that affect plant development.

<table>
<tr><td></td><td>Operational mechanisms of a greenhouse.
Related content knowledge
principles,
phenomena,
applications</td></tr>
<tr><td>Possible difficulties students’ may face:</td><td>Students may have alternative ideas regarding greenhouse effect such as (Shepardson et al., 2011; Choi et al., 2010):
inability to
recognise how fossil fuels contribute to the greenhouse effect,
recognise the role of plants in absorbing carbon dioxide from the atmosphere and
distinguish between incoming ultraviolet radiation and outcoming infrared radiation.</td></tr>
<tr><td>Possible difficulties teachers implementing the STEM module may face:</td><td>Students may not be familiarised with the STEM design process
Students may not be familiarised with conducting inquiries</td></tr>
<tr><td>Hints to overcome these difficulties:</td><td>Use of worksheets that guide students through the design of the greenhouse model. The worksheets should include tasks to guide the brainstorming, the evaluation of possible solutions and their restrictions, the task division etc.
Likewise if students are not familiarised with conducting inquiry-based activities these have to be guided by the teacher, e.g. the selection of particular factors to be tested, the design of the respective experiment etc.</td></tr>
<tr><td>Description of the STEM module:</td><td>Students are provided with news from several contemporary resources (newspaper articles, podcasts, popular science articles etc) and discuss how micro/macro changes in climate affect crop production.
Students discuss the population’s need for increased crop production and reflect on the rising challenge: ‘how could we increase crop production?’
Students perform a short web-quest and explore the features and possibilities offered by the use of greenhouses for increasing crop production and reflect on the rising challenge of building and operational and efficient greenhouse.
Students design a greenhouse model by engaging in brainstorming, group discussion on possible solutions, evaluation of solutions and evaluation of restrictions. In this way they take some initial decisions on the prototype and decisions on alternative solutions.
Then they construct an initial version of the prototype and finally test the prototype in terms of stability, weight, symmetry, insulation, soldering etc.</td></tr>
</table>

	6. After building the greenhouse model students begin working on maximising its efficiency. To this end they firstly have to formulate hypotheses about the factors that contribute to its efficiency and design experiments to test these hypotheses. In order to do so they have to gather some plants (e.g. spinach, tomatoes, peppers etc.) and place half of them in the greenhouse and the other half outside. The factors that they are going to test are Temperature, Humidity and Light exposure. For the influence of each factor, students have to set-up a distinct inquiry cycle using CO_2, humidity, temperature and illuminance wireless sensors to collect the necessary data. 7. 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 8. Finally, they analyse the data from the sensors, discuss statistical measures (mean values, slope, fit curves etc) in order to formulate their final conclusions regarding the factors that influence the plant growth rate and the suitable conditions in a greenhouse. 9. Students make interconnections with the greenhouse effect, formulate suggestions for greenhouse building and for the increase of crop production.
Used assessment tools:	● rubric ● concept map ● reflective diary ● e-portfolio
Description of students' assessment:	In the phase of designing and testing their prototype, while students are trying to enhance its efficiency, a rubric could be used for the assessment of inquiry skills that students cultivate through that process. As it seems in the following rubric, some skills are referred to (such as planning and carrying out of investigation etc) and are described through three levels. Each level describes to what extent students have developed that specific skill. Rubric could be used both as a self-assessment tool and as a tool used by teachers to assess their students. If the rubric is used by students, they can monitor their own progression and at the same time correct themselves based on the rubric's criteria. On the other hand, if the rubric is used by the teachers, they can monitor students' performance and provide them with feedback about how they can more efficiently conduct the inquiry processes. For example, during the planning of the investigation, the student may not consider the potential restriction or the variables that have to be held constant. However, in case that the student uses the rubric for self-assessment, they will realise that those elements are

<table>
<tr>
<td></td>
<td>important for planning the investigation, so they will be considered in next possible investigations.

Example of rubric for assessment of inquiry skills:
<table>
<tr><th>Inquiry skill</th><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>Planning investigations</td><td>The student suggests design potential solutions, but not in detail.</td><td>The student suggests design potential solutions, but the suggestions are incomplete in some respect. The suggested design potential solutions can, with some revisions, be effective.</td><td>The student plans an investigation about the best design solution, considering:
• which variables to change and which to be held constant,
• the restrictions and the potential improvements and
• which equipment is to be used.</td></tr>
<tr><td>Carrying out an investigation</td><td>1. The student carries out an investigation being in need of constant support by the teacher, peers, or detailed instructions.
2. The equipment is handled in a way that is not always safe.
3. The student sporadically documents the investigation in writing and with pictures.</td><td>1. The student carries out an investigation being sometimes in need of support by the teacher, peers, or detailed instructions.
2. The equipment is safely used.
3. The student documents the investigation in writing and with pictures, but the documentation may be incomplete or inaccurate.</td><td>1. The student carries out an investigation, either alone or as an active participant in a group.
2. The equipment is safely and appropriately used by student.
3. The student documents the investigation in writing and with pictures in an accurate way.</td></tr>
<tr><td>Interpretation of results; Forming Conclusions</td><td>The student
• draws conclusions, but only uses a limited amount of the results from the investigation and
• compares the results from the investigation with the hypothesis.</td><td>The student
• draws conclusions based on the results from the investigation and
• compares the results from the investigation with the hypothesis.</td><td>The student
• draws conclusions based on the results from the investigation,
• relates the conclusions to scientific concepts (or possibly models and theories)
• compares the results from the investigation with the hypothesis and
• reasons about different interpretation of the results.</td></tr>
</table>
</td>
</tr>
<tr>
<td>Hints for assessment</td>
<td>The aforementioned assessment tools can be used to provide (verbal/written) feedback to students about their knowledge (e.g. concept map) and skills (e.g. rubric). During the preparation of a lesson plan, teachers have to take into account <u>what they want to assess</u> and choose the suitable assessment tool.
In addition, it is suggested that assessment <u>lasts from the beginning to the end of the teaching</u>. More specifically, it is suggested that an initial assessment of knowledge and skills is carried out in order to specify the students' background and needs. In addition, the initial assessment is compared with the final one, in order to monitor the students' progress. For example, in the beginning of the lesson, the teacher can ask students (in groups or individually) to create a concept map about the ideas that they already have about the operation of a greenhouse. After the end of the lesson, the teacher can apply the same activity with the forming of a concept map about the students’ ideas about greenhouses, comparing the initial with the final ideas.

Another tool that can support the assessment throughout the teaching is the reflective diary. Students keep notes based on their ideas, thoughts, choices and performance. They keep notes about what design solution worked, what changes happened etc. In the end of the design and testing phase, they reflect upon their notes.
Furthermore, the suggested assessment tools can also be used by the students for <u>self-assessment</u> or providing feedback to their peers</td>
</tr>
</table>

	(peer-assessment). In this case, the teacher has to ask students to keep notes about their performance related to knowledge and skills and the receiving feedback, in order to discuss their progression at the end of the lesson.

Title of sub-module:	Greenhouse simulation
Target group:	Grades 9-12 - Upper Secondary education
Duration:	7-10 teaching hours
Objectives:	The main educational objectives are: ● 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.
Necessary materials / equipment:	● 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.)
Pre-requisite students' knowledge:	Basic concepts regarding: ● Greenhouse effect ● Climate Change ● Photosynthesis ● Design & develop prototypes ● Engineering design cycle
Possible difficulties students' may face:	Students may have alternative ideas regarding greenhouse effect such as (Shepardson et al., 2011; Choi et al., 2010): ● *inability to* ○ recognise how fossil fuels contribute to the greenhouse effect, ○ recognise the role of plants in absorbing carbon dioxide from the atmosphere and

	○ distinguish between incoming ultraviolet radiation and outcoming infrared radiation.
Possible difficulties teachers implementing the STEM module may face:	● Students may not be familiarised with the STEM design process ● Students may not be familiarised with conducting inquiries
Hints to overcome these difficulties:	● Use of worksheets that guide students through the design of the greenhouse model. The worksheets should include tasks to guide the brainstorming, the evaluation of possible solutions and their restrictions, the task division etc. ● Likewise if students are not familiarised with conducting inquiry-based activities these have to be guided by the teacher, e.g. the selection of particular factors to be tested, the design of the respective experiment etc.
Description of the STEM module:	1. 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). 2. 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). 3. 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). 4. Students modify the code in order for the sensors to publish data online in a user-friendly platform (1 hour). 5. 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). 6. 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). 7. Inferences from the experiments and discussions in the light of photosynthesis and crop production (2 hours). 8. Discuss results and revisit the Greenhouse effect (1 hour).
Used assessment tools:	● rubric ● concept map ● reflective diary ● e-portfolio
Description of students' assessment:	In the phase of designing and programing the simulation, while students are trying to enhance its efficiency, a rubric could be used for the assessment of inquiry skills that students cultivate through that process. As it seems in the following rubric, some skills are

referred to (such as planning and carrying out of investigation etc) and are described through three levels. Each level describes to what extent students have developed that specific skill. Rubric could be used both as a self-assessment tool and as a tool used by teachers to assess their students.
If the rubric is used by students, they can monitor their own progression and at the same time correct themselves based on the rubric's criteria.
On the other hand, if the rubric is used by the teachers, they can monitor students' performance and provide them with feedback about how they can more efficiently conduct the inquiry processes.

Example of rubric for assessment of inquiry skills:

Inquiry skill	Level 1	Level 2	Level 3
Planning investigations	The student suggests design potential solutions, but not in detail.	The student suggests design potential solutions, but the suggestions are incomplete in some respect. The suggested design potential solutions can, with some revisions, be effective.	The student plans an investigation about the best design solution, considering: • which variables to change and which to be held constant, • the restrictions and the potential improvements and • which equipment is to be used.
Carrying out an investigation	1. The student carries out an investigation being in need of constant **support** by the teacher, peers, or detailed instructions. 2. The **equipment** is handled in a way that is not always safe. 3. The student sporadically **documents** the investigation in writing and with pictures.	1. The student carries out an investigation being sometimes in need of **support** by the teacher, peers, or detailed instructions. 2. The **equipment** is safely used. 3. The student documents the investigation in writing and with pictures, but the **documentation** may be incomplete or inaccurate.	1. The student carries out an investigation, either alone or as an active participant in a group. 2. The **equipment** is safely and appropriately used by student. 3. The student **documents** the investigation in writing and with pictures in an accurate way.
Interpretation of results; Forming Conclusions	The student • draws conclusions, but only uses a limited amount of the results from the investigation and • compares the results from the investigation with the hypothesis.	The student • draws conclusions based on the results from the investigation and • compares the results from the investigation with the hypothesis.	The student • draws conclusions based on the results from the investigation, • relates the conclusions to scientific concepts (or possibly models and theories) • compares the results from the investigation with the hypothesis and • reasons about different interpretation of the results.

Hints for assessment	The aforementioned assessment tools can be used to provide (verbal/written) feedback to students about their knowledge (e.g. concept map) and skills (e.g. rubric). During the preparation of a lesson plan, teachers have to take into account <u>what they want to assess</u> and choose the suitable assessment tool. In addition, it is suggested that assessment <u>lasts from the beginning to the end of the teaching</u>. More specifically, it is suggested that an initial assessment of knowledge and skills is carried out in order to specify the students' background and needs. In addition, the initial assessment is compared with the final one, in order to monitor the students' progress. For example, in the beginning of the lesson, the teacher can ask students (in groups or individually) to create a concept map about the ideas that they already have about the operation of a greenhouse. After the end of the lesson, the teacher can apply the same activity with the forming of a concept map about

	the students' ideas about greenhouses, comparing the initial with the final ideas. Another tool that can support the assessment throughout the teaching is the reflective diary. Students keep notes based on their ideas, thoughts, choices and performance. They keep notes about what design solution worked, what changes happened etc. In the end of the design and testing phase, they reflect upon their notes. Furthermore, the suggested assessment tools can also be used by the students for self-assessment or providing feedback to their peers (peer-assessment). In this case, the teacher has to ask students to keep notes about their performance related to knowledge and skills and the receiving feedback, in order to discuss their progression at the end of the lesson.

Heat and Energy module

Title of STEM module:	**Heat & Energy Module** **Sub-module 1- Thermal Insulation in Buildings**
Target group:	Lower Secondary education (between 11-14 ages)
Duration:	14 teaching hours
Objectives:	• 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 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
Necessary materials / equipment:	1. Styrofoam foam, Rock wool , glass wool etc. insulation materials 2. Background cardboard, 3. Scissors, 4. Adhesive 5. Thermometer, 6. Beakerglass 7. Stopwatch

Pre-requisite students' knowledge:	● It is expected that students have been previously taught about atoms, their properties heat and conduction of heat.
Possible difficulties students' may face:	● Students may have difficulties in distinguishing between the ideas of 'temperature' and 'heat' and in using these terms appropriately. ● The concepts of energy and heat may be challenging for secondary school students. Because young students are not ready to delve into kinetic theory and molecular motion, much of the explanation of heat and energy transfer is inaccessible to them. In addition, the use of the word "energy" in popular culture may interfere with the development of scientific understanding. Nevertheless, students are capable of exploring heat through observations and qualitative, developmentally appropriate explanations. In fact, the idea that heat is transferred from one object to another via conduction is a grade-level expectation. ● Students may hold a variety of misconceptions about heat, temperature, and energy. A few common misconceptions include the idea that some objects (such as blankets) produce their own heat. Students may believe this because they have experienced feeling warmer after covering themselves with a blanket or putting on a sweater. Another area of misconception deals with the words "hot" and "cold." Students often believe that heat and cold are different, and that they are substances rather than energy. Students may also believe that "cold" is transferred from one object to another – their experience with coolers and refrigerators seems to confirm this misconception.
Possible difficulties teachers implementing the STEM module may face:	● During these initial explorations, teachers may encounter a variety of student misconceptions.
Hints to overcome these difficulties:	● Formative assessment and purposeful teaching will help prepare students to tackle more advanced concepts in the middle grades and beyond. ● While misconceptions can be persistent and tough to correct, well-designed instruction can help students move to an accurate scientific understanding of heat and energy.

Description of the STEM module:	Learning Objectives: - Students classify substances in terms of heat conduction - Students determine the selection criteria for thermal insulation materials used in buildings. - Students develop alternative thermal insulation materials - Students discuss the importance of thermal insulation in buildings, family and country economy and effective use of resources 1. In this activity students are given this learning scenario and are encouraged to read and work on the scenario. **SCENARIO:** You are civil engineers working in different companies. You and your group friends are representatives of a company that produces building materials. Each company is responsible for the promotion of a different thermal insulation material. You need to convince the management staff of a large complex of buildings that wants to have thermal insulation about the thermal insulation material that you will decide on as a group. Next week, you need to introduce the thermal insulation material you have chosen and prove why this insulation material is better than those of other companies. For this reason, your company manager asks you to do research on the insulation material you have chosen within a week and prepare a model house using the insulation material you have chosen. 2. Students do research on the subject and discuss it with their group friends. Students find answers to these questions. - What is insulation? Why is it done? What are insulation materials? Which is the most efficient and economical insulation material used in homes? What is the importance of insulation? 3. Students are asked to prepare three house models of the same size using existing materials. Then, students will furnish the inside of each of these house models with different insulation materials. The students' task is to find the most efficient and economically suitable insulation material. 4. The same amount of 100 ml of water with an initial temperature of 75 degrees is poured into three beakers to be placed inside the houses that the groups have furnished with insulation material. Beakers are placed inside the houses and then they are asked to measure the temperature of the water with thermometers at 10-minute intervals.

<table>
<tr><td></td><td>5. A student in the group observes the temperature of the water in the beaker every 10 minutes and the table is filled in. Students are asked to take measurements 5 times, including the beginning.
6. Students are asked to observe the decrease in the temperature of the water over time. Draw your temperature-time graphs after 5 measurements. Compare your graphs to determine which insulation material you use to cool the water less.</td></tr>
<tr><td>Used assessment tools:</td><td>● Peer evaluation
● Self-evaluation
● Rubric</td></tr>
<tr><td>Description of students' assessment:</td><td>The formative as well as summative assessment will be carried out during the lesson for assessing the learning outcome of the lesson. Before the introduction of the lesson to the students, pre-test will be subjected to check the knowledge, understanding and awareness level of the students about the matter. After the completion of the lesson post-test will also be conducted to know the increase in the level of knowledge, understanding and awareness. At the same time formative as well as summative assessments will also be conducted.
A final quiz with questions related to the topics covered in all the lessons
The evaluation of the STEM resources
The students will express their opinion saying what they have learned on this topic.</td></tr>
<tr><td>Hints for assessment</td><td>Students will fill up evaluation list
<table>
<tr><th>Elements</th><th>YES</th><th>PARTIALY</th><th>NEEDS CHANGES</th></tr>
<tr><td>Have we successfully answered the research question asked?</td><td></td><td></td><td></td></tr>
<tr><td>Have we successfully presented the conclusion of the research?</td><td></td><td></td><td></td></tr>
<tr><td>Did I give my best in solving the tasks?</td><td></td><td></td><td></td></tr>
<tr><td>Did each member of the group give their maximum in solving the tasks?</td><td></td><td></td><td></td></tr>
<tr><td>Do you like this way of learning?</td><td></td><td></td><td></td></tr>
</table></td></tr>
</table>

Title of STEM module:	**Heat & Energy Module**
	Sub-module 2- Keeping Cool
Target group:	Lower Secondary education (between 11-14 ages)
Duration:	14 teaching hours
Objectives:	As a result of climate change, communities are becoming aware of the need for more shade to help in keeping cool. In new housing areas there is often less shade from established trees and the ambient temperature can be as much as 6°C higher than in shady suburbs. This can impact on energy consumption and the health and wellbeing of a community. **What is the problem?** How can a community reduce the heating effect of the Sun? **How does this module support integration of the STEM disciplines?** Students are introduced to the technology of thermal (infrared) imagery. This technology, along with government reports, provides evidence of the 'heat island' effect. **Science** After writing a research question and making predictions students design and conduct a science investigation and represent and analyse data about the effect of a variable on the transfer of heat energy to surfaces. Students summarise and interpret data from a number of investigations about shade and surface types on ambient temperature. **Technology** Students imagine and design a biological or engineered solution that reduces the heat island effect in their community. They take into account social, economic and sustainability considerations in their design. The design is communicated to an authentic audience using appropriate representations and technologies. **Mathematics** Using *Google Maps* and grids, students analyse percentage tree canopy cover in local suburbs as well as the variation in cover and identify that tree canopy cover is related to the heat island effect.

	There are opportunities for the development of general capabilities and cross-curriculum priorities as students engage with Heat & Energy Module. In this module, students: ● Develop problem solving skills as they research the problem and its context; investigate parameters impacting on the problem; imagine and develop solutions; and evaluate and communicate their solutions to an audience. ● Utilise creative thinking as they generate possible design solutions; and critical thinking, numeracy skills and ethical understanding as they choose between alternative approaches to solving the problem of reducing ambient temperatures resulting from heat island effects in ways that are sustainable. ● Utilise personal and social capability throughout the module as they develop socially cohesive and effective working teams; collaborate in generating solutions; adopt group roles; and reflect on their group work capabilities through self and peer evaluation. ● Utilise a range of literacies and information and communication technologies (ICT) capabilities as they collate records of work completed throughout the module in a journal; represent and communicate their solutions to an audience using digital technologies. ● Communicate and, using evidence, justify their group's design to a local government councillor or community member either face-to-face, by letter or email.
Necessary materials / equipment:	The following materials are required to complete this module activity. **Cover type calculations:** A 1 cm^2 grid on clear plastic A4 sheet. This is for estimating the percentage of different types of cover. These grids can be made by photocopying 1 cm^2 graph paper (preferably black) onto clear plastic overhead transparency sheets. The 1 cm^2 graph paper can be printed from the internet (ensure the correct type of transparency sheets are being used when photocopying). **Heat transfer investigations:** ● Shade cloth of varying densities ● Tin cans of equal sizes painted black, green, white and silver ● Electric fans ● Heat sources ● Thermometers, data loggers or temperature probes

	Images: ● A4 size thermal image of a city area ● A4 size *Google Earth* satellite image of a ity area ● Device for projection, internet connection. ● Five thermal images (supplied) to project onto the classroom screen. **For additional learning opportunity:** To construct a model of their design students will require suitable materials, dependent on the design.
Pre-requisite students' knowledge:	● It is expected that students have been previously taught about atoms, their properties heat and conduction of heat.
Possible difficulties students' may face:	There are potential hazards inherent in these activities and with the equipment being used, and a plan to mitigate any risks will be required. Potential hazards specific to this module include but are not limited to: ● Possible exposure to cyber bullying, privacy violations and uninvited solicitations when using the internet. ● Sun exposure. ● Breakage of glass thermometers. Only digital or alcohol thermometers should be used. ● Hot water and hot calorimeters. ● Scissors, hot glue guns and sharp objects.
Possible difficulties teachers implementing the STEM module may face:	● During these initial explorations, teachers may encounter a variety of student misconceptions.
Hints to overcome these difficulties:	The following vocabulary list contains terms that need to be understood, either before the module commences or developed as they are used. ● abiotic, absorption, ambient, biotic, conduction, convection, emission, heat island, heat sink, infrared, radiation, thermal image, tree canopy, transpiration.
Description of the STEM module:	**Activity 1: Keeping cool** Analysis of thermal and *Google Earth* images captures students' interest and engages them with environmental conditions that can create heat islands.

This activity is designed to capture students' interest, provide an authentic data interpretation experience and engage students with the concepts of energy transfer and transformation. Students identify the problem of the heat island effect, its significance to communities and how this problem may be solved.

Students will:

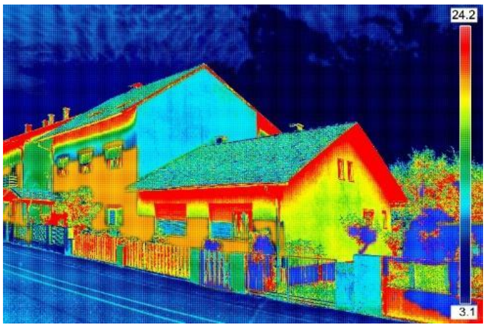
-compare *Google Earth* images and thermal images to identify the relationship between types of ground cover and ambient temperatures

-calculate and compare the proportion of tree canopy cover to grass cover to hard surface cover in each area

-explain how different ground covers affect ambient temperatures in terms of heat transfers and transformations.

Students will be able to:

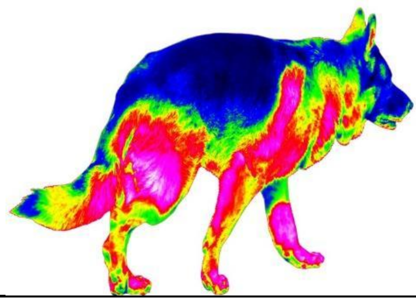
- Analyse and interpret thermal images and *Google Earth* satellite images (Science).
- Classify cover as tree canopy, grass or hard surface (Science).



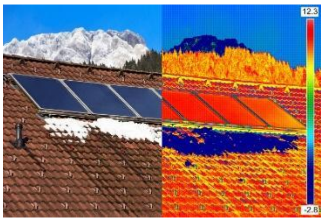
- Calculate the percentage of tree canopy cover, grass cover and hard surface cover in an area (Mathematics).
- Use ratios and percentages to compare the proportion of tree canopy cover to grass cover and hard surface cover in different locations (Mathematics).
- Analyse and interpret data to determine the relationships between the types and proportions of cover and the heat island effect (Mathematics, Science).

Activity: Students are shown the five infrared images. Students share their ideas about infrared images and how they can be interpreted. Students should record their responses in their journals. They identify warm and cool areas in the infrared image..

As before, question the students to help them identify the relationships between types of ground cover and surface temperatures. Establish that areas of tree or grass cover are cooler than areas of hard surface cover.



Introduce the problem of the heat island effect and its impact on quality of life and explain that in this module they will research and design solutions to the problem.



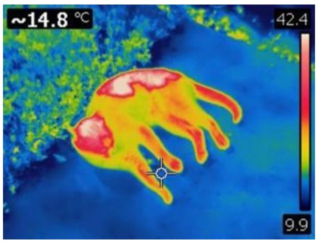
When making the comparisons it is important to have maps of the same location and of an equivalent scale.

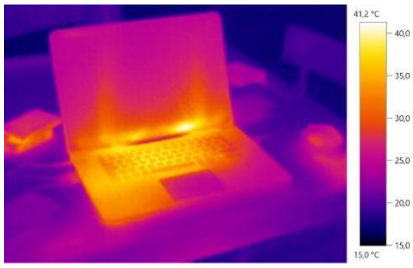
Students discuss the findings of the activity with the class. This should be followed by an outline of the scientific principles that explain these findings.

Dark surfaces such as the bitumen of roads reflect very little solar energy (about 5%), most of it is absorbed (95%) and transformed into heat energy. Some of this heat is then radiated back to the air above the road so that both the road and the air above it become warmer.

Trees and grass reflect about 30% of solar radiation and absorb 70%.

Of the absorbed energy some is used in photosynthesis and a high proportion is used to evaporate water from the pores in the leaves (latent heat of evaporation), and just like an evaporative air conditioner, this cools the surrounding air.





Activity 2: How cool is your surface?

Students plan and conduct an investigation to gather evidence about factors that impact on the heating of surfaces and ambient air temperature.

In this activity, students will be challenged to design, conduct and evaluate a science investigation that will provide evidence about factors impacting on heat transfer.

Students will:

work in collaborative learning groups to plan and conduct an investigation submit an individual written report.

Any solution that reduces the heating effect around our homes would need to take into account variables such as materials, shading and wind. Groups of three or four students investigate one of these variables, confer with others who have studied the same variable, and then report their findings to the class.

Variables and research questions that could be investigated might include:

	How does the colour of a material affect how much heat it absorbs? ● Colour of surfaces can be investigated using tin cans painted different colours placed at equal distances from a heat lamp or incandescent globe and the temperature inside the cans recorded at standard time intervals. *How does the rating of shade cloth affect the temperature of a shaded surface and the air above?* The effect of shade density can be investigated using shade cloth of different percentage ratings. This could be done using a heat source suspended over the different shade cloths for standard times over standard surfaces. This would allow comparisons to be made between the temperature of the shaded surface and the temperature above the shade cloth using a temperature probe or thermometer. *How does the density of natural shade affect the temperature of soil and the air above the soil surface?* ● The effect of natural shade from trees on air and ground temperatures can be investigated by recording air and surface soil temperatures in more and less densely shaded locations under trees on a warm and sunny day. *How does the speed of wind affect the temperature of a surface and the air above?* ● The effect of wind speed can be investigated by suspending a heat lamp or incandescent globe over a surface which is exposed to wind of different speeds generated by an electric fan. Temperatures of the surface and air above the surface could be measured with a temperature probe or thermometer. Students should collect and represent data from these investigations for analysis. Depending on the investigation, the data collected may be continuous (time, temperature, shade cloth density) or discrete (colour, high/medium/low wind speeds). Graphical representation of the data will be either a line graph (continuous data) or a bar or column graph (discrete). Correct selection and use of these graphs is an important skill for students to learn. Note: Temperature change will only occur over extended periods of time, especially with wind effect which causes only a marginal

	shift in temperature. Plan to provide other learning for students to engage in while they are monitoring their experiments. Groups conduct their investigations, document their findings in their journals and interpret their results with support as appropriate. The use of various types of temperature measuring devices such as alcohol thermometers, maximum minimum thermometers and digital data loggers in these investigations will provide the opportunity for comparisons between data as well as extending skills in digital technology. The data interpretation and reporting of findings can be completed as an individual activity and submitted to facilitate individual assessment. **Activity 3: Design a solution to keeping cool** Using evidence from their investigations, students design a solution that will reduce ambient temperatures. In this activity students will design a solution to reduce the heating effect of the Sun taking account of the evidence from the investigations in *Activity 2*. The main variables that can reduce the heating effect are shade, air flow and the size and nature of exposed surfaces which vary in the extent to which they reflect or absorb radiant energy. Any design solution will need to take account of these variables. While the students are completing their designing of the solution, use the following questions to ensure they have considered necessary factors. ● How can shading and air flow be increased? ● How can surfaces that are good absorbers of radiant energy be reduced in area? ● How can surfaces that are good absorbers be replaced or covered by surfaces that absorb less energy? Design solutions might involve engineered mechanical structures that maximise shade or biological solutions such as street trees, more grassed areas or alternatives such as wall gardens. Solutions may also be a combination of changes. A set of design principles or objectives helps a design team ensure they develop a design that meets the requirements of the community and goals related to sustainability. Hence student groups should be encouraged to formulate a set of design principles.

	To offer a sustainable solution, the design would need to: ● be acceptable to the community ● be aesthetically pleasing ● be inexpensive ● minimise the use of non-renewable resources ● be energy efficient ● be durable ● need little maintenance ● satisfy Local Government regulations. It is expected that students will work in groups to develop a design solution. To allow for individual assessment, students will individually document their design, the design principles they followed and the scientific justification. **Additional learning experiences:** ● Students could construct a 3D model of their design. Students could work with a Design and Technology teacher to build the design. Review examples of solutions. Decide the extent to which digital technologies will be utilised in designing, documenting and sharing processes, and which hardware and software options will be utilised. If students choose to draw their plan digitally then software such as *Sketch Up* or *Tinkercad* will need to be organised. Engage students in the concept of a solution to keeping cool by researching different types of solutions. Most local government councils provide street tree planting programs and guidelines which can be accessed from their websites. Local parks within suburbs are also a means of reducing the heat absorbed from the sun. 

	Students work in groups and decide whether the product will be a drawn plan (digital or by hand) and/or a 3D model. Both will require written documentation and a scientific and design justification. Introduce the task and offer the following guiding questions: 1. What type of location will you choose: the students' school, suburb, a local park, street or playground? 2. What parameters impact on ambient temperatures? 3. What scientific principles should inform the design? 4. How can you ensure the solution is one that is acceptable to the community and the local council, and is sustainable? 5. Is a biological (biotic) or engineered (abiotic) solution the best option for your location? 6. How will you know your solution is effective? Note: It is important to ensure that students understand the local council requirements as mentioned in Question 4 and these should be sourced by the teacher and provided to the students. As a class, produce a checklist and timeline for progress and completion of the design project. This might involve a mix of Science class time, Design and Technology class time and homework. Student groups discuss plans and progress them with support. On completion of the design phase, students document their design. This documentation could be shared using technology such as *Office365*, *Google Docs* or *Discussions* in *Connect classroom.* **Activity 4: Communicate, evaluate, justify** Groups pitch their solutions to a suitable audience such as a representative of local government. They provide a justification for their design based on evidence of a cooling effect and their reflections on the challenges faced when balancing financial, ethical and community concerns. In this activity groups 'pitch' their designs, or the best designs selected by the class, to representatives of the community for which they have developed the solutions. The pitch will describe their proposed solution and their reflections on the challenges faced. These may include balancing financial, ethical, sustainability and community concerns. The students will justify their design using scientific, mathematical and design principles explaining how their solution would ameliorate the heating of the location in summer. The pitch may involve face-to-face presentations or the writing of emails or letters. **Expected learning**: Students will be able to:

1. Analyse and interpret digital thermal and satellite images and use these to calculate the percentage of tree canopy and hard surface areas in a location and compare percentages between locations.

2. Explain the relationship between types of ground cover, energy transfer and transformations and the heat island effect.

3. Formulate a question, make predictions, plan and conduct an investigation of the impact of a variable on the heating of surfaces and the air above the surface.

4. Create tabular and graphical representations of investigation data, and analyse and interpret the data using scientific principles.

5. Research, imagine possibilities, design, develop, evaluate and improve a solution to the heating of our suburbs taking into account social, sustainability and economic considerations.

6. Work effectively in groups to document their design using an appropriate graphical representation, technical terms and technology.

7. Effectively communicate their ideas, arguments and evidence supporting their solution using appropriate technical language, representations and digital technologies.

Groups review the peer evaluations of their designs

Class meeting-style discussion where decisions are made about which designs should be communicated and the appropriate audience and mode of communication. Tasks are allocated to students to identify key people from the relevant community groups (eg local councillor, chairperson of school P&C, a parent who is a member of a street community or a resident close to a park), find their contact details, and to arrange appropriate times and means of communicating the design solutions. A school P&C meeting with invited guests might be a suitable forum for the presentations.

Provide a combination of class and homework time for the development and review of the letters, emails or presentations.

Invite community members to the presentation of the students' solutions or develop a covering letter to go with the design solutions to be posted to community members.

Delivery of the presentations. This should be using a digital presentation format such as *PowerPoint* or similar.

Drawing in the design process

Incorporating the design process into the STEM modules will often result in the need for students to draw plans of their designs. This can be done at a simple level using

	hand drawn sketches or at a more technical level using computer-aided design (CAD). By developing skills using industry standard software, students may be well-placed to explore future career pathways. 7. There are a number of CAD software options, two free examples are detailed below. *Autodesk* is a third package that is also free for educational use.
Used assessment tools:	● Peer evaluation ● Self-evaluation ● Rubric
Description of students' assessment:	The formative as well as summative assessment will be carried out during the lesson for assessing the learning outcome of the lesson. Before the introduction of the lesson to the students, pre-test will be subjected to check the knowledge, understanding and awareness level of the students about the matter. After the completion of the lesson post-test will also be conducted to know the increase in the level of knowledge, understanding and awareness. At the same time formative as well as summative assessments will also be conducted. A final quiz with questions related to the topics covered in all the lessons The evaluation of the STEM resources The students will express their opinion saying what they have learned on this topic.
Hints for assessment	Students will fill up evaluation list

	Always	**Usually**	**Sometimes**	**Rarely**
Remains focused on tasks presented				
Completes set tasks to best of their ability				
Works independently without disrupting others				
Uses time well				
Cooperates effectively within the group				
Contributes to group discussions				
Shows respect and consideration for others				
Uses appropriate conflict resolution skills				
Comes to class prepared for activities				
Actively seeks and uses feedback				

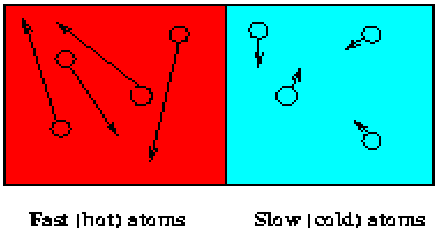
Title of STEM module:	**Heat & Energy Module** **Sub-module 3- Heat Loss & Insulation**
Target group:	Lower Secondary education (between 11-14 ages)
Duration:	4 teaching hours
Objectives:	Students will: Know what insulators are. Be able to give examples of insulators. Understand how insulators work. Use instruments to make measurements. Record measurements. Understand what a fair test experiment is. Carry out a fair test experiment. Know that wool is a good insulator.
Necessary materials / equipment:	-Diagrams (to be drawn on the overhead) -Overhead projector -Science textbook -3 different types of coats (windbreaker, fleece, parka) -Materials for experiment (Wool, Thermometer, 2 glass jars approx 200 ml, rubber bands, scissors, stopwatch, cylinders, electric kettle, spray bottle containing water)
Pre-requisite students' knowledge:	• It is anticipated that students know or use specific terms related to heat and insulation. The focus of this experiment is a fair test comparison to compare the ability of dry and wet wool to prevent internal heat from escaping. The term insulation would have already been introduced. This is an interesting investigation because usually insulation, to be effective, must be kept dry. However some students may have hiking experience and as any hiker will attest, wetted woollen garments still help retain body heat (whereas the old synthetic materials would not). Results here will probably depend upon the extent of the rain.

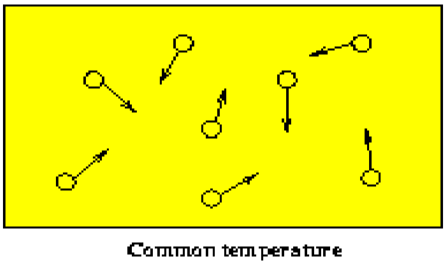
	• It is expected that students have been previously taught about atoms, their properties heat and conduction of heat.
Possible difficulties students' may face:	• Students may have difficulties in realization of fair testing.
Possible difficulties teachers implementing the STEM module may face:	• Finding wool may be difficult • Experimental set-up may be difficult.
Hints to overcome these difficulties:	• Students need to realize that to make an authentic comparison the same volume of water at approximately the same starting temperature must be used. If the two 'sheep' are run concurrently the amount of insulating material, and size and shape of the sheep must be the same. (This problem is probably best avoided by using the same 'sheep' twice, first dry and then wet, although there could be problems if the activity is started and completed on different days if the temperature of the room is very different). To avoid too much heat loss through the base and through the top of the open jar, stand the jars on an insulating material (such as a corrugated cardboard from a photocopying paper box, cork tile or polystyrene meat tray) and cut a lid for the jar from one of these materials too. Alternatively more wool could be used. • Wool can be bought at most fabric craft shops. Any type works fine. • The usual solution is to test the insulating properties of dry and wet wool using a beaker or jar of hot water as a source of heat. The temperature fall of a given volume of water can be measured over a given time period for the dry wool. The experiment can then be repeated after wetting the wool. The activity can be expanded by pupils recording the temperature every minute (or every two minutes or every five minutes) and producing a line graph for each condition.
Description of the STEM module:	Get 3 student volunteers to come up to the front of the class. Wrap up each of the students in one of the 3 coats. Dismiss the students back to their seats. Begin a review of heat studied last class. After a few minutes, ask the students if they are comfortable? Do you feel warmer? Ask the students to brainstorm reasons why the extra clothing provides warmth. (assessing students existing knowledge). Write the list on the board. Discuss how some materials might retain heat better than other materials do. What materials can you think of

in your daily lives. (assessing students existing knowledge) Write the list on the board.

As a review ask the students to give a definition of conduction and conductors. Write the definitions on the board (assess existing knowledge). Write on the overhead: “The flow of heat by conduction occurs via collisions between atoms and molecules in the substance and the subsequent transfer of kinetic energy. Let us consider two substances at different temperatures separated by a barrier, which is subsequently removed, as we can see in these diagrams:”

Heat transfer by conduction





Explain to students that insulators are materials or devices to inhibit or prevent the conduction of heat. Common heat insulators are, fur, feathers, fibreglass, cellulose fibers, stone, wood, and wool; all are poor conductors of heat. In the diagram the barrier represents an insulator. Therefore Conductors do the opposite of what Insulators do. When the barrier is removed, the fast (``hot'') atoms collide with the slow (``cold'') ones. In such collisions the faster atoms lose some speed and the slower ones gain speed; thus, the fast ones transfer some of their kinetic energy to the slow ones. This transfer of kinetic energy from the hot to the cold side is called a flow of heat through conduction. However, if the insulator is not removed the heat would not be able to transfer and the temperature of the two substances would remain the same. Write the definition of insulators on the board. The coats you tried on earlier are insulators, they trapped your body heat inside and kept you warm. (Makes the concept relevant to students lives, evidential) Different materials transfer heat by conduction at different rates this is measured by the material's thermal conductivity. This can be measured by measuring the amount of time it takes for the temperature to change

	(increase/decrease). For example the different types of coats worn by the students were three different types of insulators. They are each made of different materials. The windbreaker would provide the least amount of insulation resulting in loss of heat (this is because windbreakers are made to protect from winds as opposed to retaining body heat). The fleece on the other hand is a single layer of polyester that is meant to retain body heat, however the parka contains several additional layers including fleece, which results in a better insulation for retaining body heat. Insulators are the opposite of Conductors The better the Insulator the poorer it is as a conductor Insulator = heat retention (heat is trapped and cannot escape) Insulation = Heat Retention The better the insulator the more heat (Less heat escapes) it keeps. Insulation = Heat Retention The worse the insulator the less heat (More heat escapes) it keeps. Today you will have the opportunity to plan your own experiment. Does anyone have any ideas, related to this lesson, that are potentially worthy for us to investigate? Write some of the ideas on the board. Some ideas for investigation include: What if we had two jars and one jar had double the amount of water. We could test the effect of different layering combinations to test if the order of layering affects insulation. We could test if the mass has an effect on insulation. Is aluminum foil a good insulator? Your experiment will determine the effectiveness of a certain insulator. This will be achieved by conducting a fair-test experiment. Explain what a fair-test experiment is. If we want to do a scientific experiment, we should try to think of all the possible variables that might influence our final results, then control all but the ones we want to investigate. For example, if we want to know the effect of temperature on the solubility of a chemical, we should ensure all other things that might influence solubility (volume of water, mass of

solute, pressure, purity of water, etc.) are held consistently the same for all our experiments, these are the constant variables also called the control. The one variable that you are changing is called the test variable. For example, if we wanted to test the effect of solute concentration on the taste and colour of fruit powder, students would fill three beakers with water. One would consist of the amount of water and fruit powder according to the instructions; this would be the control. The other beakers would be filled with water and fruit powder as well. The control variables would be the amount of water, the temperature of water, the beakers and the type of fruit powder. The test variable (the only one that will change) would be the amount of fruit powder put into the beaker. One beaker would have a higher amount of fruit powder than the control beaker, and the other would have a lower amount of fruit powder. Discuss experimental errors with students. You should always criticize your results. All experiments are vulnerable to errors, whether by equipment or human error. It is important to reflect on the process and results of ones experiment. Identifying possible errors such as: misreading a thermometer or using broken equipment can seriously alter the results. Finding solutions to fix such errors would provide more accurate results in the case the experiment was conducted again.

ACTIVITY:

Which is a better insulator WET or DRY wool?

SCENARIO:

James and Mary went walking in the Zoo. The weather was rainy. Mary felt rather sorry for the sheep. She thought that the rain would make them cold. James did not agree. Instead he thought that the water on the wool would help to keep the heat in.

Who is right James and Mary?

Instructions:

A. Design your experiment.

B. Carry out your experiment after your teacher has checked your ideas.

C. Record your results.

	D. Complete the discussion questions. Guiding Questions: 1.The question I will try to answer is (my purpose): 2. I predict that the following will happen (my hypothesis): 3. What will you measure? 4. Write down your ideas about how you will test your hypothesis. 5. The procedure I will follow to test my variable is (space for 6 steps is provided you may use as many as you wish): Step 1: Step 2: Step 3: Step 4: Step 5: Step 6: 6. Draw a diagram of your lab set-up. 7.In order to make my experiment a fair test, I will keep all of these variables constant(unchanged).This will be my control group: a) ……. b) …… c) ……. d) ……. e) ……. 8. In order to make my experiment a fair test, I will change one variable. This will be my test group: 9. I will observe the following: 10. Record your observations as necessary for your experiment:

<table>
<tr><td></td><td>Discussion Questions:

1. Use your results to suggest an answer to the problem. Who was right,

James or Mary? Was your prediction correct?

2. What errors do you think occurred that might have affected your results?

3. How could you make your results more accurate (how could you minimize the errors you identified above in question #2)?

4. If you could do it again, would you make any changes to how you did the experiment?

5. How do you think the information you discovered could be applied/used in general?</td></tr>
<tr><td>Used assessment tools:</td><td>● Peer evaluation
● Self-evaluation
● Rubric</td></tr>
<tr><td>Description of students' assessment:</td><td>The formative as well as summative assessment will be carried out during the lesson for assessing the learning outcome of the lesson. Before the introduction of the lesson to the students, pre-test will be subjected to check the knowledge, understanding and awareness level of the students about the matter. After the completion of the lesson post-test will also be conducted to know the increase in the level of knowledge, understanding and awareness. At the same time formative as well as summative assessments will also be conducted.
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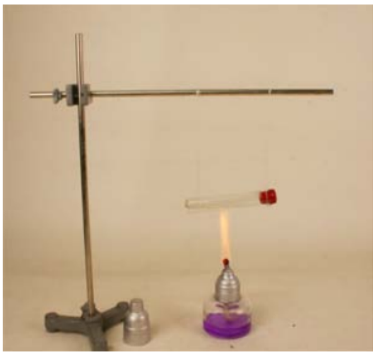
</table>

Did each member of the group give their maximum in solving the tasks?			
Do you like this way of learning?			

Title of STEM module:	**Heat & Energy Module** **Sub-module 4- Transformation of Heat Energy into Motion Energy**
Target group:	Lower Secondary education (between 11-14 ages)
Duration:	4 teaching hours
Objectives:	Students will: ● see the transformation of heat energy into motion energy by experimenting
Necessary materials / equipment:	● Three legs (large size) ● Test tube ● Support bar ● Connecting piece ● Spirit stove ● Rubber stopper (without holes) ● Water ● Rope
Pre-requisite students' knowledge:	● Heated substances expand and their volume increases. If they are in a closed container, the pressure they apply to the container increases. Heat energy turns into motion energy and the cap or stopper at the mouth of the tube pops off. This is why kitchen cylinders or spray bottles explode if exposed to fire.
Possible difficulties students' may face:	● If the tube is not tied carefully, it may fall and break. ● If the mouth of the tube is turned towards you, it may hurt something when it pops out. ● Fire can burn your hand

Possible difficulties teachers implementing the STEM module may face:	
Hints to overcome these difficulties:	● When connecting the tube, tie it tightly so that it does not fall. Be careful not to burn students' hands with fire. Turn the stopper at the mouth of the tube towards the wall. When it jumps, it should not hurt anyone or drop or break anything (window glass, computer, experimental materials, etc.).
Description of the STEM module:	Experimental Procedure : 1- Put some water into the test tube and close it gently with a suitable non-perforated stopper. 2- Tie the test tube to the support rod with a rope. (As in the picture) 3- Heat the water in the test tube with the alcohol stove. 4- Observe the tube and rubber stopper. Result of the Experiment: The water in the tube evaporates. When the mixture of water vapor and air is heated, its pressure increases and the plug ejects. Meanwhile, it moves in the opposite direction of the stopper in the glass tube. Heat energy has been transformed into motion energy. 
Used assessment tools:	● Peer evaluation ● Self-evaluation ● Rubric
Description of students' assessment:	At the end of class, ask students a quick question that covers what they should have learned that day. For example, "Describe the relationship between heat energy and motion energy." Students can write their answers on a sticky note, index card, or just a paper scrap. You can then sort the exit slips into piles to see how many students got it, and how many students need more help to understand the concept. Another option is for students to place their exit tickets in colored baskets according to their level of understanding.

	This also allows students to take it a step further and self-assess their understanding. 
Hints for assessment	Students will fill up evaluation list

Elements	YES	PARTIALY	NEEDS CHANGES
Have we successfully answered the research question asked?			
Have we successfully presented the conclusion of the research?			
Did I give my best in solving the tasks?			
Did each member of the group give their maximum in solving the tasks?			
Do you like this way of learning?			

Title of STEM module:	**Heat & Energy Module**
	Sub-module 5- Insulation Experimentation
Target group:	Lower Secondary education (between 11-14 ages)
Duration:	4 teaching hours

Objectives:	This lesson explores conduction, convection, and radiation in respect to insulation, the method of preventing heat from escaping a container or entering a container. Students will: 1. Use science process and thinking skills 2. Manifest scientific attitudes and interests
Necessary materials / equipment:	• Baby food jars (size 2 recommended) • Various insulating materials • Small disposable containers • Plastic Wrap • Scissors • Tape • Research materials about insulation • Microwave • Microwave-safe bowl • Water access • Thermometers • 50 mL measuring syringes • Stopwatches

Pre-requisite students' knowledge:	• It is anticipated that students know or use specific terms related to heat and insulation. The term insulation would have already been introduced. • It is expected that students have been previously taught about atoms, their properties heat and conduction of heat.
Possible difficulties students' may face:	• Students may have difficulties in realization of fair testing.
Possible difficulties teachers implementing the STEM module may face:	• Finding different insulation materials may be difficult • Experimental set-up may be difficult.
Hints to overcome these difficulties:	• Students can increase the validity of the experiment by controlling more variables, improving measurement technique, increasing randomization to reduce sample bias, blinding the experiment, and adding control or placebo groups.

Brief description of the STEM module: *(Please provide an overview of the structure of the STEM module)*	This lesson explores conduction, convection, and radiation in respect to insulation, the method of preventing heat from escaping a container or entering a container. An understanding of conduction, convection, and radiation are needed for optimal understanding of these concepts. As the students will engage in a group experiment, they will need background in the scientific method. The steps in this method are ask a question; gather background research; form a hypothesis; experiment; analyze your data; draw conclusions; and record your results. It is helpful if the students have already done several guided experiments using this method in class. If not, differentiation should be used to help those students who need more guidance, whereas more advanced students may discover on their own. Baby food jars and several insulation materials are needed for this lesson. These include: down, gloves/mittens, cotton sock, wool sock, other types of cloth or clothing, sand, plastic foam, dirt, large piece of paper, foam packing peanuts, wood, aluminum foil, leaves, paper towels, cardboard, cotton balls, shredded paper, fiberglass insulation, etc. Collect them on your own before the experiment or have your students bring in items easily accessible from home. If using fiberglass insulation, you will need gloves so the material does not irritate the skin. The ability to transfer heat within an object is called thermal conductivity. It varies for different materials. Gold, silver and copper have high thermal conductivity so these materials are also good conductors of electricity. Other materials, such as glass and mineral wool, have low thermal conductivity. This quality makes them good insulators. A good insulator is a poor conductor. Less dense materials are better insulators. Thus, gases insulate better than liquids, which in turn insulate better than solids. An interesting fact is that poor conductors of electricity are also poor heat conductors. **Instructional Procedures** 1. Introduce the term energy conservation (saving energy) in relationship to heat. What do we do to stay warm outside on a cold day? (wear a coat) How do we save money on heating our homes in the winter? (appropriate insulation) What are some examples of insulation? (animal fur, towel, blanket, portable cooler, fiberglass, wool, foam, down, etc.) 2. Insulators are materials that help prevent any of the three types of heat transfer to keep heat in one place (either in or out). This aids in energy conservation. Homes need insulation on the roof for protection from the sun (radiation); on the floor to protect from the cold ground (conduction);

	and on the walls to protect from the wind (convection). A well insulated home will not have wasted energy and will therefore not use as much heat in the winter or air conditioning in the summer. 3. Explain that the students are going to participate in an experiment that explores different types of insulation. They will select a material to insulate a jar of warm water and determine whether or not it is a good insulator. Various insulation materials are needed and should be set out prior to the lesson. Fabrics should be labeled. You will need about 40 baby food jars for this experiment. You may ask the students to bring some materials from home. 4. Students should be in groups of about four. Allow for differentiation when appropriate; some students may be ready to plan an experiment on their own. See that all students are using their notebooks to record each step of the scientific method. 5. Before the students begin, discuss some of the following questions: What are the variables in your project? (insulation materials) How can you make sure to only test one variable? (jars should be the same size; water should be the same amount and initial temperature in each jar; all temperature readings should be recorded at the same time) What time intervals are appropriate for temperature testing? (I would suggest 1-3 minutes between each reading. Stopwatches may be used for accuracy.) How will you record your observations? (tables, graphs, report format) Where will you keep your jars? (students may opt to take them outside if the temperature is cooler) 6. While the students are working, begin warming water in microwave. Ensure it is hot, but not hot enough to burn someone. You may also want to walk around to each group and review how to read the thermometers. 7. After forming a hypothesis, each student in the group should surround a baby food jar or something similar with one type of material, making sure to keep a small amount of the jar available on top for sealing. Each jar should be the same size, and each material should be different. If using dirt or sand, set the baby food jar in the center of a small disposable container and surround it with the selected material. 8. When one or two jars per person are finished, use a measuring syringe to fill each jar with 100 mL of water, or enough to almost fill the jars you are using. Then place a thermometer in each. Students should immediately record the temperature. Seal with the Seal Wrap while keeping the thermometer in the jar for easy readings.

9. One unsealed jar with a thermometer and no insulation should act as the control. Timed temperature readings should be recorded every few minutes. Observations should be recorded.

10. As the students are working, monitor student progress by asking thought provoking questions that focus on student understanding. Use the tables they prepare as a tool to help guide your students' thinking.

11. When students are finished, they should record and analyze their data and draw conclusions to answer their question. Remind them that all parts of the scientific method need to be written up in their science journals.

12. On day two, have a class discussion about the experiment. Based on all data, which insulation was the best? Which was the worst? Did any jars remain the same temperature? Share differences in experimentation and data. At the conclusion of your discussion, instruct the students to share their conclusions in their journals, as well as write any questions they still wonder about.

INSULATION TABLE

Material Time, & Degrees (C)	Control	Material 1 ________	Material 2 ________	Material 3 ________	Material 4 ________	Material 5 ______
Starting Temp						
___ min						
___ min						
___ min						
___ min						
___ min						
___ min						

<table>
<tr><td>Used assessment tools:</td><td>Peer evaluation
Self-evaluation
Rubric</td></tr>
<tr><td>Please describe an example of students’ assessment:</td><td>Hypothesize about what might happen if you tried the experiment again, this time recording the temperature for a longer amount of time (one, two, even three hours). Which materials might work better? Will there be a point when none of the jars are insulated well enough to keep the water warm? To assess a students' understanding of the scientific method and the experiment done in class, have them write up how to set up this experiment. If more time is available, try it!
Remind the students that metals are excellent conductors of heat. Based on your experiment, did that make them good or poor insulators? Why? (Good conductors cannot be insulators because conductors remove heat, not sustain it.)
Could you design an experiment to measure keeping things cool? Ask students to journal their ideas.</td></tr>
<tr><td>Please provide instructions and hints for teachers on how to use these assessment tools:</td><td>Students will fill up evaluation list
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<tr><td>Have we successfully presented the conclusion of the research?</td><td></td><td></td><td></td></tr>
<tr><td>Did I give my best in solving the tasks?</td><td></td><td></td><td></td></tr>
<tr><td>Did each member of the group give their maximum in solving the tasks?</td><td></td><td></td><td></td></tr>
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	Do you like this way of learning?			

Title of STEM module:	**<u>Heat & Energy Module</u>** **<u>Sub-module 6- Heat in liquids and gases</u>**
Target group:	Lower Secondary education (between 11-14 ages)
Duration:	3 teaching hours
Objectives:	This lesson explores conduction, convection, and radiation Students will: 1. learn that heat in liquids spreads by convection. (activity 1and 2) ● learn personal properties of heat in gases via convection (activity 3)

Necessary materials / equipment:	Activity 1: ● Convection pipe 1 piece ● Three legs (small size) 1 piece ● Connecting piece (double) 1 piece ● Bunzen clamp (small size) 1 piece ● Support bar 1 piece ● Spirit stove ● Wood shavings or food coloring ● Activity 2: ● ● 2 glass bottles of the same size ● Hot water (Just warm it enough to not burn your hands.) ● Cold water ● 1 colored food coloring (Ink can also be used.) ● Greaseproof paper Activity 3: ● One piece of play dough ● One garbage skewer ● One A4 paper ● Candle
Pre-requisite students' knowledge:	How Does Convection Happen? The liquid or gas heated during convection begins to rise in its environment as its density decreases. Meanwhile, it transfers some of its high energy to the surrounding low-energy particles. As the heated substance rises, it is quickly replaced by the surrounding cold substances. We can give an example of this situation: boiling water in a pot. The heated water at the bottom of the pot begins to rise, and the places emptied by the hot water are filled with relatively cold water from above.

Possible difficulties students' may face:	● The convection pipe can be broken because it is glass ● You may burn your hand when using hot water. ● When pulling wax paper from between glass containers, the containers may slip. Spiral paper is flammable
Hints to overcome these difficulties:	● When attaching the convection pipe to the clamp, it should not be tightened too much to prevent it from breaking. If you leave it too loose, it may fall off. Be careful when attaching the clamp. ● Be careful not to burn your hands with hot water ● In Activity 2, while pulling the wax paper from between the glass containers, make sure that the edges of the containers remain on top of each other. Be careful to shoot very slowly. You can try using a thin plastic. Make sure that the water in the containers is filled to the brim. ● When applying the candle to the spiral paper, pay attention to the distance between the paper and the candle, otherwise the paper may catch fire and cause an accident. You can also try using aluminum foil instead of paper to prevent it from catching fire.

Brief description of the STEM module: (Please provide an overview of the structure of the STEM module)	Activity 1: 1- Install the mechanism in the picture. 2- Fill the convection pipe with water. 3- Throw some wood sawdust into it (food coloring can also be dropped) 4- Heat one corner of the convection pipe with the alcohol stove. 5- Observe the movement of the chips (or paint) in the water. As you can see in our experiment, the movement of the chips in the water shows the direction of the convection currents occurring in the water. Activity 2: Figure a: Let's put cold water in a bowl and hot water in a bowl. Let's add food coloring to the hot water and color it. Let's cover it with wax paper. Let's cover the container with hot dyed water over the cold container so that the mouths are aligned. Let's slowly and carefully pull the wax paper out of the way. When we placed the glass bottle filled with hot water on the glass bottle filled with cold water, the cold water with more density remained in the lower bottle, and the hot water with less density remained in the upper bottle. So convection did not occur. Figure b In the second stage, let's reverse the mechanism we made in Figure a. This time the hot water will remain at the bottom. The heated hot liquid rises above the cold liquid because it is less dense than the cold liquid. During this movement, heat is transferred from the hot liquid to the cold liquid. At the same time, the rising hot liquid is replaced by cold liquid. In other words, heat spreads within the container by convection. You can also do this activity at home with glasses. The colors will mix in the glass where the hot water is at the bottom, while the colors will not mix if it is at the top as there is no convection. Activity 3: We draw a large circle on A4 paper. We cut it to form a finger-thick spiral as shown in the image. We fix the stick skewer in the middle of the rolling play dough so that it stands upright. We fold the A4 paper we cut on it slightly, without applying too much pressure, to prevent it from slipping while turning, and fix it on the garbage

	bottle. Then, we place the candle in the middle of the spiral so that the paper does not burn and light it. We observe that the spiral begins to rotate. Since the density of the warm air is less than the cold air, it is displaced by convection. As the heated air rises, the paper spiral begins to spin. Hot air balloons also work this way.
Used assessment tools:	● Peer evaluation ● Self-evaluation ● Rubric
Please describe an example of students' assessment:	The teacher will assess learning by: 1. Observing their group discussions. 2. Looking over their student work packets. 3. Answers during the wrap up, class discussion. Could you design an experiment to measure keeping things cool? Ask students to journal their ideas.

Chapter 6: Conclusions

The Digital STEM Labs modules provide a diverse approach to addressing current STEM education trends. These courses, which include a wide range of areas such as natural science, mathematics, and technology, are in line with the current emphasis on interdisciplinary learning. By focusing on lower and upper secondary education, the modules address the increasing trend of teaching STEM topics at a younger age, laying the groundwork for further investigation. The incorporation of multiple educational objectives, such as practical computations, measurements, and comprehending complicated scientific processes, represents the current trend in STEM education toward hands-on and experiential learning. The incorporation of technology, multimedia, and collaborative activities into these courses reflects the rising relevance of digital literacy and cooperation in STEM subjects.

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