STEMkey Module IO8

Electricity

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

Module IO8
Electricity

This Higher Education Module document is based on the work within the project "Teaching standard STEM topics with a key competence approach (STEMkey)". Coordination: Prof. Dr. Katja Maaß, International Centre for STEM Education (ICSE) at the University of Education Freiburg, Germany. Partners: Charles University, Constantine the Philosopher University, Haceteppe University, Institute of Education of the University of Lisbon, Norwegian University of Science and Technology, University of Innsbruck, University of Maribor, University of Nicosia, Faculty of Science of the University of Zagreb, Utrecht University, Vilnius University.

The project STEMkey has received co-funding by the Erasmus+ programme of the European Union under Grant Agreement Number 2020-I-DE01-KA203.005671. Neither the European Union/European Commission nor the German Academic Exchange Service DAAD are responsible for the content or liable for any losses or damage resulting of the use of these resources.

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

CONTENTS

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

Summary

The **electricity module** comprises four activities, which are recommended for using with STEM pre-service and in-service teachers. This topic is usually included in the middle school science curricula (12 to 15 years old students) across Europe. The classroom implementation of this module is over eight lessons (~120 minutes each).

Activity 1 introduces the topic through an everyday context Reverse Engineering. Pre-service and in-service teachers explore electrical circuits. In Activity 2, they must apply the concept of Circular Economy to Toys that are ~~is~~ no longer used. In Activity 3, they develop an investigation on the conductivity of everyday materials. During Activity 4, pre-service and in-service teachers explore Ohm´s law by developing an investigation and use the results on human security regarding electric current. The module should be developed by groups of 3 or 4 pre-service or in-service teachers, with mixed abilities and genders (when possible).

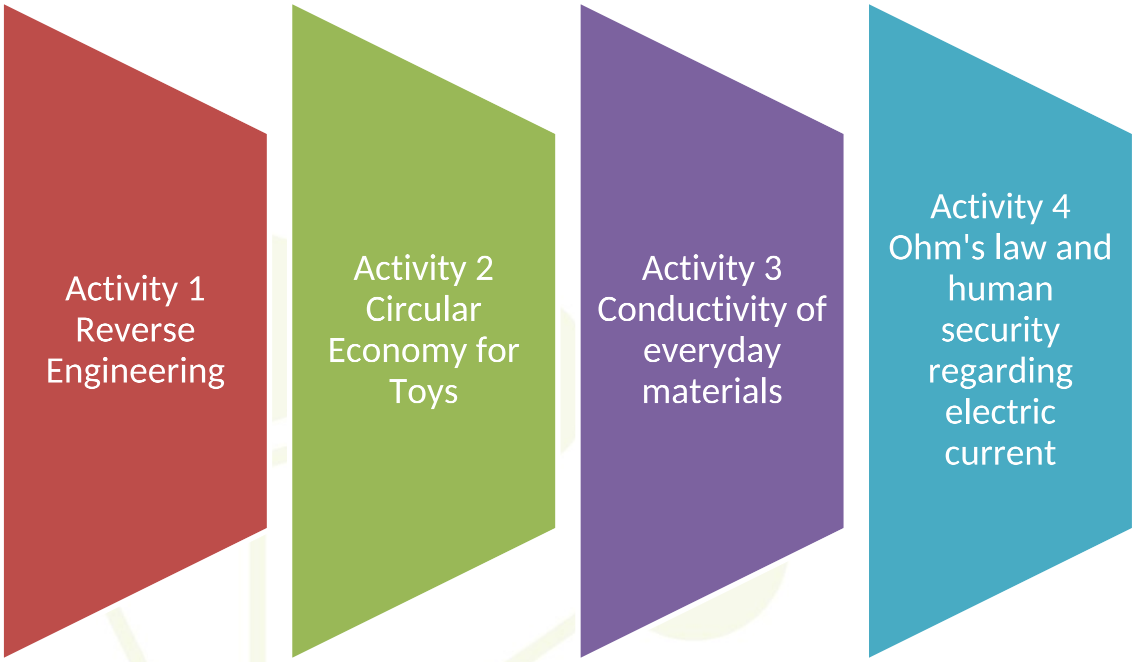

Figure 1 – Module activities

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

Subject Introduction

Electricity is a typical standard topic of Physics, and we highly depend on it. Imagine a world without electricity, only depending on natural light, and absolute darkness when the sun sets. Also, no television, household appliances, telephones, refrigeration, air conditioning, computers, internet, health technologies, spacecraft, etc.

Students who have knowledge about electricity, have the skills to use it safely, reflect on sustainable use, and are able to evaluate its worth and potential for our society, raise their employability in very many STEM sectors. However, in "traditional" teaching, the focus is often on formulas like "U=R×I", whilst experiencing electricity is neglected. Therefore, the aim of O8 is to enable future teachers and in-service teachers to transform teaching and learning of electricity into rich learning experiences for students, nurturing the development of key competences and a better understanding of this topic.

The exploration of this module is guided by big ideas (e.g., why should we use the electrical current carefully at home, what is electric current and why it is important to know its value, to understand that materials must "lose" electrons in order to conduct electricity, why in an electrical equipment we often see the current electric value and not the electric tension; what means that a human body has electric resistance; etc. In order to explore these big ideas, we intend to use situations related to real life (e.g., reverse engineering, toys, use of electricity at home, human body safety, etc.) which typically are of interest to learners. Moreover, we use Inquiry-Based Science Education (IBSE) as the pedagogical approach (Bybee, 2010). Thus, future teachers and in-service teachers will be engaged in several science and engineering practices: asking questions and defining problems, developing models and plans, constructing experiences and explanations, and designing solutions, using different sources of information and an electronics platform based on hardware and software (e.g., Arduino), collecting and processing information/data, and obtaining and communicating information.

In the module, we also offer boys and girls different topics to deal with, according to their interests. We also give suggestions to work on topics inter or transdisciplinary, e.g., chemistry (materials properties used), biology (human body), ecology (recycling material), math (measures, calculation to explore Ohm's law), technology (Arduino and materials properties) and engineering (using the technology to innovate).

This module aims to contribute to the development of STEM knowledge and skills of pre-service and in-service teachers that are needed to construct and implement STEM activities with the students, as well as other ways to work with the curricula. This module also promotes the understanding of inquiry processes, and the development of critical thinking that enables them to take an active role in decision-making about context-based situations.

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

Key Competence Approach

Critical thinking is one of the key competences of the 21st century and is essential in STEM Education. There is a set of activities that the teacher can develop with students that contribute to the development of these skills. For example, questioning and analysing evidence and assertions, applying reasoned approaches or relevant criteria to conceptualize, analyse or make judgments, reflecting upon and evaluating reasoning behind thoughts, or actions, being serious, rigorous, and persistent in the execution of experiments, being fair in the evaluation results and tolerant of ideas different from their own. At IO8, the four tasks aim to develop students' critical thinking in the areas of knowledge, skills, and attitudes:

- Knowledge: Connect electricity to daily life phenomena, construct simple electric circuits, draw the scientific representation of circuits, understand the principles of electronics, build electronic circuits on breadboards, and use different components, check electrical conductivity of different materials and Ohm's law.
- Skills: Search in different information sources, plan and carry out investigations, formulate problems, compare, generalize, and deduce, solve problems with data interpretation, draw conclusions and evaluate results.
- Attitudes: Expose ideas, defend, and argue, cooperate in the group to share information (emotional literacy), and reflect on the work done.

Interdisciplinary Approach

In our modules, IO8 Electricity, it was implemented the educational approach appropriate to the framework for interdisciplinary STEM education. Particularly:

1. inquiry-based learning and experimental learning;
2. real-life context;
3. interdisciplinary connections between science, technology, engineering, and math curricula; and
4. it was considered girls' needs such as activities involving human body, safety, circular economy, and technology (Arduino).

In IO8 module the pedagogical approach is inquiry-based learning (1). The four tasks that make up the module start with a problem that students do not know how to solve. They search for information to solve the problem, plan and/or do experiments to gather evidence, and explain it, thus giving an answer to the problem. Students use scientific knowledge, draw conclusions, and communicate the results to the class.
In the IO8 module, students learn in real-life contexts (2), so that learning is relevant. (3) As an example of interdisciplinary, all tasks aim to promote the development of students' critical thinking. With regard to the interdisciplinary, there are connections between STEM subjects, e.g., in task 1 between physics (electrical circuits), technology (use of technique), and engineering (in creating new solutions for electrical devices). In task 2 there is interdisciplinarity between ecology (use of used materials), technology (in the techniques used to build a recycled doll), and engineering (in

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

problem-solving using technology). In task 3 there is interdisciplinarity between physics (electrical conductivity of materials), science (safety at work), technology (in the electrical components used), and engineering (in solving problems based on the electrical properties of materials). In task 4 there is interdisciplinarity between physics (physics concepts and Ohm's law), biology (the human body), mathematics (in the language they use to perform calculations), and technology (in the techniques they use to carry out experiments).

Learning Outcomes

“2017 European qualifications framework (EQF) recommendation defines learning outcomes as ‘…statements of what an individual should know, understand and/or be able to do at the end of a learning process, which are defined in terms of knowledge, skills and responsibility and autonomy’. The learning outcomes approach strengthens the focus on the individual learner and the level of knowledge, skills, and competence s/he is expected to achieve. This balances a traditional focus on education and training input, notably on duration and location of learning”. https://www.cedefop.europa.eu/en/projects/learning-outcomes

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

HE Module plan

The plan involves four tasks, one of them with a duration of 60 minutes and the other 120 minutes. All tasks include an initial real problem to be solved by the students, workgroup lectures, collective discussion about the lectures, students planning in groups (pairs and with four students), group work on the planning execution, observation and data register, phenomena explanations based on collected evidence, collective discussion of the work done by each group to solve the initial problem. For some tasks, students also make predictions and design artifacts.

Reverse Engineering
- What is eletrical energy and how it works?

Circular Economy for toys
- How can we contribute to reusing electrical and electronic waste?

Conductivity of everyday materials
- Are all material electrical conductors? Why is it useful to know that?

Ohm's law and electrical shocks
- How to use electrical energy safely?

Activity 1: Reverse Engineering

Work in pairs	60 min

Learning outcomes in brief

Knowledge: Connect electricity to daily life phenomena, construct simple electric circuits (i.e., series and parallel circuits), connect different components and draw the scientific representation of circuits.

Skills: Observe, discuss, and apply the principle of reverse engineering to investigate and predict how things work. Think about how a circuit should be constructed to provide a specific application.

Attitudes: Foster a creative mindset through brainstorming new applications and innovations in electric circuits.

This activity aims to introduce the basics of electricity; however, it should be noted that abstract thinking is necessary to conceptualize different circuits. Pre-service and in-service teachers should be able to identify how electric energy is stored and transferred.

Description of the activity

In this activity, pre-service and in-service teachers will apply the concept of reverse engineering, which can be described as the process of discovering the technological principles involved in the design of a device, object, or system, through the analysis of its structure, function, and operation. This technique is widely used in software

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

architecture and also in hardware design. Objectively, reverse engineering consists, for example, in disassembling a machine to find out how it works, evaluate its functionality, and improve its design. Pre-service and in-service teachers are placed in a scenario of a team of engineers from a technology company, challenged to evaluate the product (the box) of a competing company. This box contains some type of device or function that allows the pre-service and in-service teachers to manipulate and predict their function and internal structure (the circuit). Pre-service and in-service teachers are asked to make predictions on the circuits that are hidden inside. Afterward, pre-service, and in-service teachers design their own box with the same features as the mystery box. At this stage, pre-service and in-service teachers explain the functionality of each of the circuit components (battery, wires, light bulb, resistors, switches). The final challenge involves the comparison between the two boxes: the mystery box and their own box. Pre-service and in-service share their constructions and explain how they work.

Brief description of one example (Mystery Box)

Please consider the following example. This box contains a series association of three lamps and two switches (a button and a lever). Although the connections are hidden, students can manipulate the switches and identify the pattern observed in the lights. For example, when you turn on one of the switches, a light bulb lights up, however, when you turn the lever, we now have two more light bulbs on and the first one decreases its luminous intensity. It is possible to discuss various aspects such as the luminous intensity of each lamp, what would happen if a lamp was disconnected from the circuit and the prediction of the circuit itself.

Activity 2: Circular Economy for Toys

Work in pairs	60 min + 60 min

Learning outcomes in brief

Knowledge: Understand the principles of electronics by designing and prototyping different applications with Arduino. Build electronic circuits on breadboards and use different components. Compile code through different applications.

Skills: Observe, discuss, and apply the principle of reverse engineering to investigate how things work. Use the engineering design process to develop new products.

Attitudes: Foster a creative mindset in the development of new applications. Discuss the benefits of a circular economy for toys. Sustainability of the recycling of old products.

Pre-service and in-service teachers should apply previous knowledge on series and parallel circuits. Describe the function of different components of a circuit and use proper symbolic representation.

Description of the activity

In this activity, pre-service and in-service teachers apply the principle of reverse engineering to an unused toy. They should gather a set of toys that are no longer used. These toys must have electronics inside which would be our base for work and improvement. They can dismantle and describe each component, explaining their function, how they are connected and why they were chosen. After understanding the inner electronics of the toy, pre-service and in-service teachers should provide a list of possible innovations. These should give ~~to~~ the toy a new or improved utility. To achieve this, we purpose the use of an Arduino Microcontroller which can communicate with different components to design an autonomous and innovative toy. Possible components that can be used include sensors, step motors, switches, led, displays, and so on. The educator can provide a list of materials that the students can use or if possible, display them on a table so the students can freely pick what they need. It is recommended to have one full Arduino kit per group plus a few spare parts, if needed.

Transdisciplinary approach in brief

This activity presents an opportunity for pre-service and in-service teachers to reflect on environmental issues of global waste and the importance of recycling old toys. Pre-service and in-service teachers apply the engineering design process to the development of a new product, use technology as a vehicle for creativity, write and test their own code and apply previous knowledge on building electronic circuits.

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

Activity 3: Conductivity of everyday materials

Group work with four students	60 min + 60 min

Learning outcomes in brief

Knowledge: Check the electrical conductivity of different materials, using an electrical circuit.

Skills: Plan an activity to investigate a research question, observe and record the results, critique experimental design, and draw conclusions.

Attitudes: Foster creativity during the planning and investigation, and find solutions/explanations to the research question.

Pre-service and in-service teachers should apply previous knowledge on series and parallel circuits. Describe the function of different components of a circuit and use proper symbolic representation.

Description of the activity

To engage pre-service and in-service teachers, the activity starts with a text regarding electrical engineers' careers. After that, pre-service and in-service teachers are suggested to work in groups to investigate the following research question: Is there a safe way for electrical engineers to test which materials are adequate without being electrically shocked? Then, they analyse it and plan an activity to solve the problem. They also must collect data and draw conclusions. All pre-service and in-service teachers should participate in the discussion of the results, suggest ongoing paths, point research problems and organize them. The final challenge involves three questions. In the first one, they must search and write the meaning of electrolytes. In the second question, they must prepare a water-based electrolyte and test its electrical conductivity, accordingly with the experiment they have planned. Lastly, they must explain why the human body is a good conductor of electricity.

Transdisciplinary approach in brief

The activity shows the close relationship between physics (electrical properties of the materials), biology (human body electrical conductivity), math (math language), technology (use of electrical components), and engineering (use of techniques to solve problems), and shows how pre-service and in-service teachers can develop responsibility in their own learning, as well as develop emotional and scientific literacy.

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

Activity 4: Ohm's law and Electric shocks

Group work with 4 students	60 min + 60 min

Learning outcomes in brief

Knowledge: Understand Ohm's law, know how to use electric current in different daily life situations, and understand the effects of electric current in the human body.

Skills: Plan an investigation to give an answer to a research question, observe and record the results, criticize the experimental design, and draw conclusions.

Attitudes: Foster creativity during the planning and investigation, and find solutions/explanations to the research question.

Pre-service and in-service teachers should apply previous knowledge on series and parallel circuits, as well as tension, current and know how to measure electrical quantities, I and U.

Description of the activity

This activity starts with four questions, regarding the use of current and its effects on human body. To answer the questions, pre-service teachers and in-service teachers begin searching on the internet for three components that allow building an electrical circuit. Then, they plan an investigation, carry out their plan, collect and analyse data, and draw conclusions. Finally, they describe Ohm's law based on an internet search. All pre-service and in-service teachers should participate in the discussion of the results, suggesting ongoing paths, pointing research problems and how they can be organized. The final challenge involves questions 6 to 10. In this part of the activity, pre-service and in-service teachers search on the internet values of human body electrical resistance, with dry and damp skin. Then, they determine the current that passes through the human body when it is subjected to a potential of 12 V (car battery), with dry and wet hands, using Ohm's law. To understand the effect of current in these two conditions, i.e., with dry and wet hands, they produce the information shown in the table. At this point in the activity, pre-service and in-service teachers answer initial questions. Teachers' educators can also use a simulator of an electrical circuit (e.g., https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html) and explore it with pre-service and in-service teachers.

Transdisciplinary approach in brief

The activity shows the close relationship between physics (several physics concepts), biology (human body electrical resistance and damage due to electric shock), math (in math language), technology (in the use of various electrical components) and engineering (using technology to solve problems) and shows how pre-service and in-service teachers can develop responsibility in their own learning, as well as develop emotional and scientific literacy.

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

Materials and resources

Examples of materials:

Presentation 1 (pptx)

Reverse Engineering // The principle of reverse engineering is to investigate and predict how things work and innovate and design how they can be more attractive and/or more efficient and/or to achieve higher sales.

Readings

Conceptual Physics // The damaging effects of electric shock are the result of current passing through the body (Hewit, 2015, page 435-437)

Presentation 1 (pptx)

Circular Economy // Use the engineering design process to develop new products with reused electrical and electronic waste

Presentation 1 (pptx)

Conductivity of everyday materials //Electrical conductivity of different materials, using an electrical circuit

Presentation 1 (pptx)

Ohm’s law and Electric shocks//The Ohm's law, use the electric current in different daily life situations, and the effects of electric current in the human body

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

Assessment

With this module, pre-service teachers and in-service teachers can develop critical thinking in the classroom, in the domains of knowledge, skills and attitudes. The following table contains the critical thinking that they can develop with the module:

Knowledge:

Connect electricity to daily life phenomena	X
Construct simple electric circuits	X
Draw the scientific representation of circuits	X
Understand the principles of electronics	X
Build electronic circuits on breadboards and use different components	X
Check the electrical conductivity of different materials	X
Understand Ohm's law	X

Skills:

Search in different information sources	X
Carry out investigations	X
Plan investigations	X
Analyse evidence	X
Formulate problems / hypothesis	X
Compare, infer, generalize, or deduce	X
Solve problems with data interpretation	X
Draw conclusions	X
Predict and evaluate results	X
Expose ideas, defend, and argue	X

Attitudes:

Develop curiosity, perseverance, and seriousness at work	X
Cooperate in the group to share information (emotional literacy)	X
Reflect on the work done	X

Assessment instruments' examples:

Skill: Search information

Emerging	Developing	Consolidating	Extending
Search for information, but does not distinguish the essential from the unessential	Search for information, distinguish the essential from the unessential, but does not extract the necessary information	Search for information, distinguish the essential from the unessential and extracts the necessary information, but does not work with it successfully	Search for information, distinguish the essential from the unessential, extract the necessary information and work with it successfully

Skill: Plan investigation

Emerging	Developing	Consolidating	Extending
The research designs is not related to the hypothesis/questions or contains	The research design is incorrectly constructed based on the hypothesis/questions.	The research design is reasonably constructed based on the hypothesis; the experiment gives an	The research design is appropriately constructed based on the hypothesis; the experiment gives a

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

serious mistakes. There is problems with the experimental procedure.	Some steps of the experiment are described but some crucial details are omitted.	answer to the research question. The steps of the experiment are described.	complete answer to the research question. The individual steps of the experiment are described accurately.

Attitudes: Work collaboratively

Emerging	Developing	Consolidating
Observe and accept the proposals of colleagues but does not make any suggestions. Only accept what colleagues are doing (due to difficulties in interpersonal relationships).	Participate in the structuring of the group's work but contribute only with one or two suggestions (due to difficulties in interpersonal relationships).	Participate in structuring of work and con positive sugge productive dy group.

(www.sails-project.eu)

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

References

Al-Khalili, J. (2020). *The Physics Book*. DK Publishing

Bybee, R. (2010). Advancing STEM education: a 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30–35.

Bybee, R. W. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children*, *51*(8), 10-13.

Hewitt, P. (2015). *Conceptual Physics* (20th Ed.). Pearson

Sawah, R., & Clark, A. (2017). *What's your STEM? Activities to discover your child's potential in science, technology, engineering, & math*. Adams Media.

Harrison, C. (2014). Assessment of Inquiry Skills in the SAILS Project. *Science Education International*, *25* (1), 112-122.

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