

# A creative solution to simple experiments in the subject of technology within the STEM concept

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## Abstract

Teaching with the STEM concept represents education that uses the connection of science, technology, mathematics, engineering, and the natural sciences. The “STEMkey” project, whose solutions are members of the KTIT PF UKF in Nitra, contributes to modernising STEM teacher education in Europe and strengthens teachers' professional development. It supports the development of better quality and more attractive STEM courses for students motivated to teach about individual STEM subjects and how they can use them to solve problems arising from simple experiments. The article describes an activity prepared for the summer school in Lisbon by researchers from Nitra. In a prepared task, it was necessary to solve the pumping of polluted water, controlled by the BBC microcontroller, into a sand filter. Students and future teachers from several European universities participated in the summer school. The prepared activities aimed at developing student teachers' abilities to apply the concept of STEM education in the educational process.

**Keywords:** STEM, Summer school, Technical Education, Teacher Training, International project

## 1 Introduction

One of the goals of education at primary and secondary schools is to prepare students for practical and real life so that every graduate has the same opportunity to join the work process in the current developing information society, knowledge economy, and globalisation. Currently, the prevailing method of teaching and evaluating students by classification level requires implementing research education elements and new evaluation procedures into the teaching process (Depešová, J. et al., 2010).

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Based on the decision of the Ministry of Education and Culture of the Slovak Republic, from šk. in 2015/2016, technical education began to be implemented from the 5th year of primary school (ZŠ) by the updated State Education Program (iŠVP) according to the updated Educational Standard (iVŠ) subject of technology. The subject of technology in lower secondary education has its fixed, specific and irreplaceable place in the system of teaching subjects, which cannot be replaced by any other subject (ŠPÚ, 2015), (Ďuriš et al., 2023). The document Innovative State Educational Program for the Subject of Technology states that technology as a subject must be based not only on the acquisition of theoretical knowledge but, above all, on practical activity. Its content focuses specifically on skills and habits for the students to use in their future lives and society. It is based on the creative thought participation and cooperation of students. Primary education enriches with an essential component by laying the foundations in the field of technology, which are necessary for further study and application of a person in real life. Pupils learn to plan, organise and evaluate work independently and in groups. With its content, the technical subject continuously provides students with important information. It helps them make responsible decisions about their next professional focus and decisions in life (Act 245/2008 Coll.).

With the idea of fulfilling education goals in technology, several projects were developed and are currently being solved. The paper presents some solved problems in the ERASMUS+ KA2 project STEMkey Teaching standard STEM topics with a key competence approach, grant no. 2020-I-DE01.KA203.005671 and KEGA 006UMB-4/2022 Implement a research-oriented education model in the subject of technology in lower secondary education, focusing on the cognitive area. Both projects jointly focus on the creative solution of simple experiments in technology. The Kega project is focused on designing and verifying a research-oriented model of student education in technology in lower secondary education. The project's main goal reflects the long-term current needs of students in the subject of technology, which, despite the innovative content of the curriculum in the Educational Standard of the subject of technology, has not yet been met. The teaching subject of technology must be based not only on the knowledge of theoretical knowledge but, above all, on practical activity and the creative thought participation and cooperation of the pupils. This requires the active participation of students in the teaching process, which can be achieved, for example, using research-oriented teaching. Another need is to carry out activities of an experimental nature using available and inexpensive aids (Čapek, R., 2021).

The proposed activities of an experimental nature solved within the projects are methodically processed with the application of formative assessment of students (self-evaluation sheets for students) with a focus on understanding and specific transfer of the curriculum in the cognitive area. The concrete outcome of the experiment with the application of the STEM concept was an activity implemented as part of the international summer school. The STEMkey summer school, which took place in Lisbon, Portugal, from 26/06/2023 to 30/06/2023, offered future teachers the opportunity to meet experts from various institutions, participate in interesting workshops and excursions that helped them understand

how to integrate knowledge, skills and attitudes into teaching and how to motivate your future students to think responsibly and critically. One of the goals of the summer school organized as part of the STEMky project was to support the EU initiative regarding key competencies in STEM education. The project develops learning modules that cover all STEM disciplines and show their connections and applications in different contexts. These modules will be used in university programs and training for future teachers to help them become "key competent in STEM."

The starting point for the activity proposed by KTIT PF UKF in Nitra was that water resources are under tremendous pressure in many parts of Europe, and the situation is constantly worsening. Agriculture, electricity generation, industry, and drinking water supply to households are equally important, and all are fighting for this limited resource. With climate change, water supplies are becoming less predictable. Therefore, Europe must use water more efficiently to benefit all its inhabitants.

In Slovakia, we still have enough drinking water sources, but it is necessary to conserve water. We can use rainwater (e.g., for watering and household maintenance) or obtain drinking water through filtration.

The activity that the students had to deal with was focused on the proposal to collect rainwater from the roof of the building, which needs to be cleaned using a filter. The student's task was to design a system for cleaning and pumping water from catchment containers to the water plant in the house's attic or cottages without access to sufficient drinking water.

## 2 Activity proposal for 8th graders with a STEM concept

**The task:** Create a system for pumping and purifying water using the micro bit Smart Home kit

**Representation of elementary school subjects in the STEM concept**

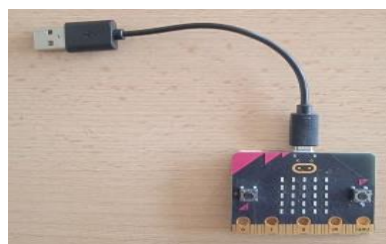
**Science:** Biology, Physics, Chemistry, and Ecology

**Technology:** Informatics, technique

**Economy:** Technique

**Mathematics:** Mathematics

**Technical equipment:** micro: bit, Smart home kit



Picture 1: Microbit

(Source: available <https://www.alza.sk/bbc-microbit-kit-pre-inteligentnu-domacnost-d5655518.htm?layoutAutoChange=1> <https://www.elec Freaks.com/micro-bit-smart-home-kit.html>)

## 1.1 2.1 How Does Water Distribution Work?

Household water that can be used can be:

- drinking water: it is intended for drinking and cooking
- service water is intended for irrigation, washing clothes, etc.
- Wastewater: It arises from drinking water or service water, washing dishes, washing clothes, flushing the toilet, rainwater, etc.

Water distribution works mainly by self-fall in the following way:

Water is distributed to the household from the water source, a well or a tank. Meanwhile, the next steps happened to the water:

1. Water is collected - a well, a water tank, in the case of a wooden house, only a well and rainwater are available.



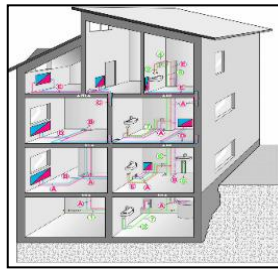
2. The water is purified; the purification can be mechanical using a sand filter or chemical in water plants. In our case, a mechanical water filtering system will be used in the cottage.



3. Reservoir. It collects potable water after treatment for further distribution.



4. The water distribution in the home itself. According to the picture below, it is a technical system of water distribution to individual parts of the building.



- Water in the building is distributed using a system of pipes. There is usually a main valve, a water meter for measuring water consumption, or a filter at the entrance. Furthermore, it is distributed to individual apartments or rooms with a sink, toilet, or water sink or directly to washing machines or dishwashers.

### Activities

- Arrange the water distribution system in the home according to the associated *images*.



- Find out the content of chemical substances in public water in your area.
- The technical standard prescribes the waterfall to a value of 2%. Calculate at what depth and height the well must be placed to collect water for the cottage if it is planned at 100 distances from the dwelling.
- Discover at what height the rainwater collection tank must be placed so that the pressure in the pipeline is 0.4 kPa.

### Activity 1

According to the attached pictures and theory, determine the water distribution system.

Time 5 minutes

### Activity 2

They can find out the chemical composition of the water in the specified location from Internet sources. The location of the teacher training institution conditions the location of the water purity. They detect chemical substances in water that are harmless to human health, as well as chemical substances and their limit values that are dangerous for humans. They will discover possible ways of treating water to be safe for humans. The determined values are

recorded and evaluated in groups. The group of cooperating students must be a maximum of 3.

Time: 30 minutes.

### Activity 3 and 4

Based on the direct ratio, they calculate the necessary data and design the essential parts of the water distribution from the well to the cottage and from the rainwater tank for the house. In the essential parts of the water supply and the water system, individual technical elements of the water system must be included, such as the main valve, water meter for each branch separately, rainwater filtration, the length of the water pipe, what material the water pipe must be made of, what the diameter of the water pipes should be, in what way they will connect.

Time: 30 minutes

### What will students learn?

Teacher students will acquire the following competencies:

They will understand the water distribution system in the home and the technology of its construction.

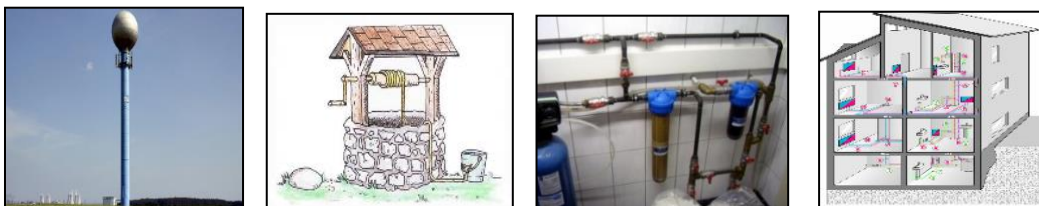
They can calculate and compare the waterfall according to technical standards.

They will be able to describe and understand the composition of water in terms of health and safety.

### Approach

#### Activity 1

Arrange the water distribution system in the home according to the associated images:



According to the attached pictures, students will determine the water distribution system.

### Intersubject relations:

#### Technique

- Water distribution in the home

#### Physics

- properties of liquids: incompressibility, fluidity, divisibility, Pascal's law, use of properties of liquids

#### Chemistry

- Substances and their properties

- water as a chemically pure substance (distilled water)
- water as a mixture of substances (mineral, potable, industrial, waste)
- treatment of drinking water
- wastewater treatment

**Biology**

- environment
- components of the human environment

**Activity 2**

1. Find out the content of chemical substances in public water in your area
2. They will find out the chemical composition of the water in the specified location from Internet sources.
3. Through analysis, they will find chemical substances in the water that are harmless to human health. They will determine their quantity, measurement units, detection methods, methods, devices, and chemical analyses.
4. Through analysis, they will find chemical substances and their limit values, which are dangerous for humans. They will determine their quantity, measurement units, detection methods, methods, devices, and chemical analyses.

**Intersubject relations:****Technique**

- Water distribution in the home

**Chemistry**

- Substances and their properties
- water as a chemically pure substance (distilled water)
- water as a mixture of substances (mineral, potable, industrial, waste)
- treatment of drinking water
- wastewater treatment

**Biology**

- environment
- components of the human environment

**Activity 3**

1. Students will find out the density of water and the physical laws necessary for the given calculation.
2. They perform the calculation according to the formula  $p = \rho \cdot g \cdot h$
3. They will find out what materials water tanks can be made of
4. They will find out how the height of the building affects the container's location.
5. From the following picture, they will find out why there are water tanks on individual buildings in New York.

**Intersubject relations:****Physics**

- Power and movement. Work. Energy
- gravitational field, compressive force, hydrostatic pressure, and atmospheric pressure.

**Technique**

- Graphic communication in technology design, sketch, technical sketch, pictogram, technical drawing,
- Technical materials and working procedures for their processing: working procedures: measuring and contouring, cutting, filing, drilling

**B Making a sand filter.**

The sand filter consists of several layers of sand with different fractions. For the correct functionality of the filter, the correct layering of the individual layers of sand according to the fraction is essential. A layer of the finest sand with the smallest fraction is applied to the bottom of the container. Additional layers are applied gradually according to sand (aggregate) availability with a more significant fraction. For our model, we recommend at least three different layers with different fractions.

**Material:**

Plastic container (PET bottle, one pc

Sand (aggregate) of three different fractions approx. 3 x 0.5 kg

Filter paper one pc

Plastic (silicone) tube

Hot melt gun with glue

Drill

Drill with the diameter of the tube.

Sand filter - plastic container (in the picture), it can also be made from a PET bottle, into which the filter is made as follows:

1. Make a hole in the bottom of the plastic container so that a plastic (silicone) tube can be inserted. If we used a PET bottle as a container for the filter, we drill a hole in the lid and cut off the bottom of the bottle
2. Place the filter paper on the bottom of the plastic container so that it covers the entire bottom
3. Pour individual layers of sand into the plastic container so that the sand with the smallest fraction is on the bottom and the other layers with the more significant fraction are on top. Layer at least three layers of sand in the sand filter. You can also use fine aggregate if sand with a more significant fraction is unavailable. The layers of the filter should be up to two-thirds of the height of the entire container.



4. Place a second plastic container under the filter, representing the reservoir for water distribution in the cottage. The presentation (video) uses a teaching aid distributed to primary schools within the Slovak Republic, which the participants of the STEMkey project may not have available. Therefore, it is good to use your own container to represent a water reservoir for the cottage.



Picture 2: Water distribution system

In the student's learning process, feedback about his learning is essential. This information regulates his understanding, and if the student obtains it himself, it significantly affects his self-evaluation and self-awareness. Implementing a research-oriented education model in the subject of technology represents an innovation in the formal assessment of the student in the teaching process. In this way, the results of students' learning activities can be improved in cooperation with the application of experiential learning. At the same time, students' research activities aim to support students' key competencies and 21st-century skills (creativity and innovation, creative and critical thinking, problem-solving, etc.).

The proposed activity and experimental tasks were designed for the 8th year of elementary school (Ďuriš, M. et al., 2023; Pavelka, J. et al., 2020; Stebila, J. et al., 2020). We consider defining intersubject relationships in the individual steps of solving tasks necessary. Emphasis was placed primarily on the Performance Standard, in which performances are formulated in the given thematic unit, which determines what the student should master and be able to perform at the end of the given year in the given thematic unit. Part of the formulated performances also includes the implementation of simple experiments, which should significantly affect the acquisition of knowledge and skills of students in the higher levels of the taxonomy of educational goals, which are necessary for further education and life in the 21st century.

## Conclusion

Key competence includes every citizen's knowledge, skills and attitudes to ensure personal fulfilment, sustainable lifestyles, employability, social inclusion, and active citizenship. The core of education in the STEM summer school focused on developing students' ability to apply acquired knowledge and attitudes. Prospective STEM teachers were allowed to expand their understanding of core STEM topics and thus broaden the skills and attitudes of their students. Participating in STEMkey summer school, students had numerous opportunities for cross-cultural exchange, both within the international student body and outside of it, by meeting local students, teachers, and pupils. This allowed them to gain rich experience related to their future profession. The activity that we presented at the event was mainly focused on the issue of water conservation. This appears to be primarily connected with ecology. The solution to the task showed a connection with several subjects of the elementary school curriculum. Although the assignment of the task mainly evokes the financial effect, the economic impact is not as crucial in this case as the ecological and moral aspects. A comparison of water prices in different European countries further emphasises this importance.

The contribution was created as part of the project solution: ERASMUS+KA2 STEMkey Teaching standard STEM topics with a key competence approach, grant no. 2020-I-DE01.KA203.005671 and KEGA 006UMB-4/2022 Implement a research-oriented education model in the subject of technology in lower secondary education, focusing on the cognitive area. The contribution was created as part of the project solution: ERASMUS+KA2 STEMkey Teaching standard STEM topics with a key competence approach, grant no. 2020-I-DE01.KA203.005671 and KEGA 006UMB-4/2022 Implement a research-oriented education model in the subject of technology in lower secondary education, focusing on the cognitive area.

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