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STEAM EDUCATION MATERIAL: GEOMETRICAL MODELING OF THE WARKA WATER TOWER AND LEARNING ABOUT THE WATER CYCLE

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

PROJECT

PROJECT ACRONYM	STEAMTeach
PROJECT TITLE	STEAM Education for Teaching Professionalism
PROJECT REFERENCE	2020-1-ES01-KA201-082102
START DATE	1st October 2020
KEY ACTION	Cooperation for innovation and the exchange of good practices
ACTION TYPE	Strategic Partnerships for school education
PROJECT WEBSITE	https://www.steamteach.unican.es/

REPORT DETAILS

VERSION	1
DATE	2021 January
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STEAM Education Material: Geometrical Modeling of the Warka Water Tower and Learning about the Water Cycle

This document presents a Science, Technology, Engineering, Arts, and Mathematics (STEAM) educational workshop centered on the 4Dframe modeling kit developed by Korean engineer Ho-Gul Park. The workshop employs the Warka Water social design project, which addresses Ethiopia's diminishing drinking water resources. The project aims to teach students about the geometrical structure of the Warka Water tower and its water harvesting technique, which involves extracting water from the air.

The 4Dframe modeling kit was inspired by traditional Korean architecture and offers considerable structural variability, making it a valuable tool for understanding topics within all STEAM fields. Its adaptability makes it ideal for inquiry-based, experience-oriented, and phenomenon-based learning methods. Its usefulness will be demonstrated in a STEAM workshop adaptation of the Warka Water project.

Engineer Ho-Gul Park developed the 4Dframe system after creating miniature replicas of historic Korean buildings and studying their unique structural features. The set, made of polypropylene, is flexible and suitable for inexpensive mass-production. It contains various types of connectors and tubes, which can be easily adjusted, offering an infinite number of creative solutions.

The workshop allows students of different age groups to explore the environmental, social, and architectural aspects highlighted in the Warka Water project. Furthermore, the 4Dframe system's variability makes it an excellent tool for modeling geometric constructions and problem-solving within engineering, architecture, and applied mathematics contexts.

To date, thousands of Korean teachers have been trained in using the 4Dframe set, and it has started appearing in mathematical education practices globally. The system's international presence is best exemplified by the Northern European center in Sweden, known as Nordic 4Dframe, and its popularity in the Baltics and Nordic countries.

The 4Dframe system allows students to explore complex, interdisciplinary topics related to various fields in an engaging and entertaining manner. By using 4Dframe system techniques, students can develop practical solutions for geometric problems in mathematics and natural sciences and address complex issues in environmental sustainability through creative/architectural designs.

The modern environmental education concept emphasizes the importance of understanding the factors involved in protecting and preserving clean drinking water sources. Warka Water project successfully combines natural scientific, social, and aesthetic aspects to create solutions such as harvesting water from the air. The 4Dframe workshop helps introduce these interlinked challenges and concepts in an engaging manner.

The 4Dframe Warka Water workshop allows students to actively understand the daily challenges faced by Ethiopia's population in their quest for clean drinking water. The Warka Water bamboo tower, with its unique geometrical structure, harvests potable water from condensation in the air. The tower, owned and operated by the villagers, also serves as a community gathering place. The workshop helps students understand the engineering, geometric, and aesthetic aspects of the tower's design.

The Warka Water 4Dframe Workshop is suitable for students of various ages, from elementary school to university level, and can be adapted for both formal and informal educational settings.

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1 PROJECT JUSTIFICATION

The project aims to introduce students to the practical applications of STEAM (Science, Technology, Engineering, Arts, and Mathematics) disciplines in addressing real-world problems. This project will enable students to learn the importance of interdisciplinary collaboration, problem-solving, and critical thinking.

The project is particularly relevant to students as it not only complements their academic learning but also equips them with valuable skills necessary for the 21st century. By integrating science, technology, engineering, arts, and mathematics, it exposes students to a variety of subjects, helping them to understand the interconnectedness of these areas.

1.1 Project Overview

Participant age: **12-16 years old**	*No. of participants:* 30, Groups of 5	*Duration:* 2-8 hours
Level of knowledge: Intermediate	*No. of teachers:* 1-3	*Type of venue:* Regular classroom, Computer Lab, Outdoors
Learning methodologies: Content integration Problem-based learning Inquiry-based learning Collaborative learning Design-based learning	*Involved disciplines:* Science, Technology, Engineering, Arts, Mathematics	*Technological needs:* 4Dframe toolkit, or other physical modelling tool. GeoGebra software
Most emphasised learning methodology: Problem-based learning	*Main addressed topics:* Physics (energy, water), Technology (modeling), Engineering (design, prototyping), Arts (design thinking), Mathematics (geometry, algebra)	*Estimated project cost:* 300 -2,000 EUR for the physical toolkits

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

This project has been funded by the ERASMUS+ programme of the European Union under grant no. 2020-1-ES01-KA201-082102

2 CURRICULAR CONTEXT

2.1 Key competences

Describing the main key competences may be developed during the project development:
Literacy: Through report writing and presentation

Mathematical, science, technology, and engineering: Through problem-solving and application of scientific concepts

Digital: Through use of computer-aided design (CAD) software and other digital tools

Personal, social and learning to learn: Through group work and independent research

Citizenship: Through understanding of the societal implications of technological solutions

Entrepreneurship: Through idea generation and product design

Cultural awareness and expression: Through integration of aesthetics in product design

2.2 Content

Describing the content from each discipline that will be addressed when implementing the project

DISCIPLINE	CURRICULAR CONTENT ADDRESSED
Science	Energy conservation principles, Water
Technology	Computer-aided design
Engineering	Prototyping, Design process
Arts	Design thinking, Aesthetics

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Mathematics	Geometry, Algebra

2.3 Expected learning results

The expected learning results include understanding key scientific principles related to energy conservation, the water cycle process, practical experience in technology and engineering through building a prototype, development of computer-aided modeling, enhanced mathematical reasoning through problem-solving, and appreciation of aesthetics through artistic integration into the design process.

3 STEPS TO BE EXECUTED

3.1 Step 1: Identifying the problem

Duration: 20 mins

Teachers introduce the project to students. During this initial step, students working in groups are encouraged to ask the following questions concerning the problem:

- What is the problem?
- Which are the available materials?
- What are the main project constraints? (e.g., time, budget, resources…)
- Which are the criteria that must be met so that the solution is acceptable?

Students will discuss in groups of 3-5 the aforementioned questions. They will collect the group ideas in a portfolio. After the group discussion, the teacher will talk with the whole classroom about their findings, and they will agree on the constraints and the criteria.

3.1.1 Constraints

Defining constraints for this project

3.1.2 Criteria: For this project, constraints may include time for the project, and resources (classroom materials and limited access to technology)

Defining the criteria that must meet

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3.2 Step 2: Generating ideas

Duration: 15 mins

The main objective of this step is to help students to realise that STEAM workers do not attempt to plan the whole thing at all, as it can comprise many variables. During this step students will work on the following tasks:

- Breaking the main problem to simpler problems (sub-problems)
- Matching materials to each sub-problem
- Organizing the goals
- Devising a strategy about how they will work

Students will work with the same group on responding to these questions. These responses will also be included in the group portfolio. After the group discussion, the whole classroom and the teacher try to bring a consensus on the sub-problems identified.

Tip for teachers: If necessary, reminding students of the criteria and constraints identified when defining the sub-problems.

3.2.1 Sub-problems

Defining the main sub-problems: Construction challenges, Water cycle, climate conditions.

3.3 Step 3: Exploring the Science and Mathematics

Duration: 20 mins

Experiment with different block placements, Discuss and understand the concept of area and how it applies to the problem

In this step, students will execute activities or experiments that will contribute to the acquisition of mathematical and scientific content that underlie each sub-problem. During this process, students will be encouraged to make conjectures and to experiment. The main questions that should be investigated to support the mathematical and scientific content in this problem are:

- Question 1: How does the placement of blocks affect the total area covered on the grid? How can you visually and mathematically verify this?
- Question 2: How do the principles of area apply when trying to minimize the difference between the largest and smallest rectangle or square that can be created

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with the Mondrian Blocks? Can you provide mathematical proof or reasoning for their block placements?

Students will execute the proposed activities in groups, adding to their portfolio the initial findings. After performing the tasks, the whole classroom and the teacher will discuss the scientific and mathematical principles.

Proposing tasks or experiments to investigate those questions.

3.3.1 Experiment/task:

The first experiment could be to understand the physics principle related to the problem at hand.

3.3.2 Experiment/task 2:

The second task could involve a mathematical calculation or algorithm relevant to the problem.

3.4 Step 4: Designing and Constructing the model

Duration: 40 mins

During this step, students will generate as many solutions as possible by brainstorming to solve each sub-problem. The advantages and disadvantages for each proposed solution will be examined in groups, with the objective of achieving the optimum solution. Students will be involved in the following actions:

- Designing the application of the chosen solution with as many details as possible. Sketching the design and making a list with the required materials and tools.
- Following your design and solving each sub-problem.
- Testing whether the solutions of each sub-problem are compatible with each other.
- Making the necessary corrections and improvements.

Each group of students will suggest solutions for each sub-problem and will sketch a design for their project. The designs will be discussed with the whole classroom and the teacher.

3.5 Step 5: Evaluating the model

Duration: 20 mins

In this stage, students must combine the solutions for each sub-problem to obtain the solution for the main problem. They should be encouraged to test the model elaborated,

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checking the constraints and assess the goal attainment. The teachers may pose the following questions:

- Does it work?
- Does it solve the necessity?
- Does the final design meet the criteria set?
- How could you improve your solution?

3.6 Step 6: Refining the model

Duration: 10 mins

When the solution does not work, does not solve the necessity set, or does not meet the criteria set, it should be improved. The improvement should be executed by reviewing the whole solution process. It may entail, for example, sketching a new design and transforming it to a revised model, modifying the programming code, or working out a mathematical problem.

3.7 Step 7: Presenting the project

This step can be also developed during the project elaboration. Students will disseminate the project in front of an audience (Diego-Mantecón et al., 2021). This audience may comprise classmates, peers from other high schools, families, and researchers.

4 PROJECT EVALUATION

The project will be evaluated based on how well students met the criteria and solved the problem, as well as their creativity, collaboration, and understanding of STEAM principles.

5 MATERIALS AND ROOMS

The list of materials will depend on the specific solution. The room should be a safe and collaborative environment conducive to learning, experimenting, and building.

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6 INSTRUCTIONS ABOUT THE CONSTRUCTION OF PROTOTYPE/SOFTWARE/OTHER

Instructions can be adjusted based on whether physical or digital blocks are being used.

7 CONCLUSIONS

Students' increased understanding of geometric modeling and its application in solving real-world problems. Enhanced understanding of the water cycle, and how innovative solutions like the Warka Water Tower can address water scarcity issues. Improved problem-solving skills, creativity, and collaboration from working in teams on a complex project. An appreciation of the intersection of science, technology, engineering, arts, and mathematics (STEAM) in addressing global challenges.

References

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