June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

MATERIALS FOR THE CROSS-CULTURAL COURSE PROGRAMME FOR PREPARING PROFESSIONAL TRAINERS, IN-SERVICE TEACHERS AND PRE-SERVICE TEACHERS ON STEAM

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

INTELLECTUAL OUTPUT DETAILS

INTELLECTUAL OUTPUT (IO) NUMBER AND TITLE	O2: Designing and implementing a Cross-cultural Course programme for preparing professional trainers, in-service teachers and pre-service teachers on STEAM
RESPONSIBLE ORGANISER OF THE IO	Budapesti Metropolitan Egyetem
START DATE	1st October 2020
END DATE	30th June 2023
MEDIA	Report
DISSEMINATION LEVEL	Public

1 Problem-context learning

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

STEAMTeach

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STEAM EDUCATION THROUGH COGNITIVE GAMES: MONDRIAN BLOCKS PUZZLE IN THE MATHEMATICS CLASSROOM

DR. KRISTÓF FENYVESI, UNIVERSITY OF JYVÄSKYLÄ, FINLAND - CONTACT: KRISTOF.FENYVESI@JYU.FI

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

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PROJECT WEBSITE	https://www.steamteach.unican.es/

REPORT DETAILS

VERSION	1
DATE	2021 January
MAIN AUTHORS' NAME AND EMAIL ADDRESS	Dr. Kristof Fenyvesi, kristof.fenyvesi@jyu.fi
CONTRIBUTING INSTITUTIONS	University of Jyväskylä (JYU)
REVIEWED BY	Matias Mäki-Kuutti, JYU

TABLE OF CONTENTS

STEAM Education Through Cognitive Games: Mondrian Blocks Puzzle in the Mathematics Classroom

Mondrian Blocks, an exciting cognitive game, has revolutionized the way we approach education, particularly in the field of mathematics. This game, with roots in an escape room design, requires players to cover a table with pre-defined tiles, with each successful arrangement unlocking a drawer and offering a new puzzle. The design of Mondrian Blocks showcases how a surprisingly diverse range of puzzles can be implemented within a simple structure.

The origin story of the Mondrian Blocks game is as captivating as the game itself. The idea was born during the design process of an escape room by one of the game's creators. Initial play-testing revealed the players' enjoyment of this unique puzzle, sparking an exploration into the world of cognitive challenges. The delight of Mondrian Blocks is not only in the thrill of discovering the solutions but also in the sheer diversity of the puzzles that can be created. This diversity has turned the game into a successful tool, incorporating fun and learning – a combination known as "edutainment".

Comparing Mondrian Blocks with Rubik's Cube, the latter's antithesis, it becomes clear that the Mondrian Blocks game offers a different type of cognitive challenge. Unlike the Rubik's cube that requires prior knowledge to solve, the puzzles in Mondrian Blocks can be solved using everyday logic and cognitive flexibility. Moreover, the process of physically arranging and searching for solutions in Mondrian Blocks leads to a state of "flow", a phenomenon where one becomes completely engrossed in an activity.

Mondrian Blocks as an Edutainment Tool

The term "edutainment" was first coined in 1948 and represents the combination of education and entertainment. This concept has gained momentum over the past three-quarters of a century, becoming a promising tool for revolutionizing teaching methods. The Mondrian Blocks game aligns perfectly with this concept.

Contrary to Rubik's Cube, which was originally designed as an edutainment tool, Mondrian Blocks was conceived as a game. Yet, it can serve as an effective edutainment tool, promoting cognitive development while being thoroughly enjoyable.

Learning Mathematics with Mondrian Blocks

In a research program initiated by the Hungarian Academy of Sciences Public Education Development Research Program, more than a thousand school-starting children were involved. Part of the classrooms provided the opportunity for teachers to prepare for transforming the learning environment while developing children's sensorimotor, linguistic, and thinking abilities. The Mondrian Blocks game played a pivotal role in developing cognitive skills.

20% of the children struggled to make adequate progress in learning calculations during the first semester. When comparing the sensorimotor and cognitive profiles with teacher evaluations, it was found that the profiles of the underperforming children significantly differed from those of the high achievers.

Overall, the integration of the Mondrian Blocks game into the mathematics classroom has shown promising results. As an edutainment tool, it holds the potential to engage children more effectively in learning while developing vital cognitive abilities. With the continued application of such innovative approaches in STEAM education, we can anticipate a bright future for pedagogical practices and student engagement.

1 PROJECT JUSTIFICATION

1.1 Project Overview

Participant age: **12-15 years old**	*No. of participants:* 30, Groups of 2	*Duration:* 2 hours
Level of knowledge: Intermediate	*No. of teachers:* 1	*Type of venue:* Regular classroom
Learning methodologies: Problem-based learning Inquiry-based learning Collaborative learning	*Involved disciplines:* Arts Mathematics	*Technological needs:* Mondrian Blocks puzzle or Mondrian Blocks modules re-created by color paper
Most emphasised learning methodology: Problem-based learning	*Main addressed topics:* Mathematics, Cognitive development, Problem-solving	*Estimated project cost:* 300 € for the toolkits

2 CURRICULAR CONTEXT

2.1 Key competences

Describing the main key competences may be developed during the project development:

- Literacy: Medium (understanding instructions)
- Multilingual: Low (If instructions and research materials are provided in different languages)
- Mathematical, science, technology and engineering: High (Mathematical thinking, problem-solving, reasoning)
- Digital: Medium (If digital versions of the Mondrian Blocks are used)

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- Personal, social and learning to learn: High (Working in groups, critical thinking, problem-solving)
- Citizenship: Low
- Entrepreneurship: Medium (Creativity, problem-solving)
- Cultural awareness and expression: High (Knowledge about Mondrian's art)

2.2 Content

DISCIPLINE	CURRICULAR CONTENT ADDRESSED
Science	Spatial recognition, Symmetry and asymmetry
Technology	Digital tools (if Mondrian Blocks are used in a digital format)
Engineering	
Arts	Visual arts, Symmetry, Geometric shapes
Mathematics	Area of rectangles and squares, Geometric transformations, Spatial orientation

2.3 Expected learning results

Students are expected to develop critical thinking, problem-solving skills, mathematical reasoning, and an understanding of spatial and geometric concepts. They will also

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enhance their ability to work in groups and to understand the intersection of art and mathematics.

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: Pre-defined size of the grid (n x n), fixed number and dimensions of blocks. The difference between the area of the largest and the smallest rectangle/square should be as small as possible

Defining the criteria that the model must meet

3.2 Step 2: Generating ideas

Duration: 10 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

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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: Figuring out the optimal placement of blocks, Understanding how the size of the grid impacts possible solutions

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 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.

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3.3.1 Experiment/task: Experiment with different block placements, Discuss and understand the concept of area and how it applies to the problem.

3.4 Step 4: Designing and Constructing the model

Duration: 20 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: 10 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, 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

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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 can be evaluated based on the student's understanding of mathematical concepts, creativity in solving the problem, their ability to work in groups, and the effectiveness of their final solution.

5 MATERIALS AND ROOMS

Materials: Mondrian Blocks (either physical or digital), Grids of various sizes, Notebooks or papers for sketching

Rooms: Classroom with a projector for presentations

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

Mondrian Blocks effectively integrate art and mathematics, providing a fun and engaging way for students to develop critical skills. The project's success could inspire future efforts to incorporate more interdisciplinary activities into the curriculum.

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References

Diego-Mantecón, J., Blanco, T., Ortiz-Laso, Z., & Lavicza, Z. (2021). STEAM projects with KIKS format for developing key competences. [Proyectos STEAM con formato KIKS para el desarrollo de competencias clave]. *Comunicar*, *66*, 33-43. https://doi.org/10.3916/C66-2021-03

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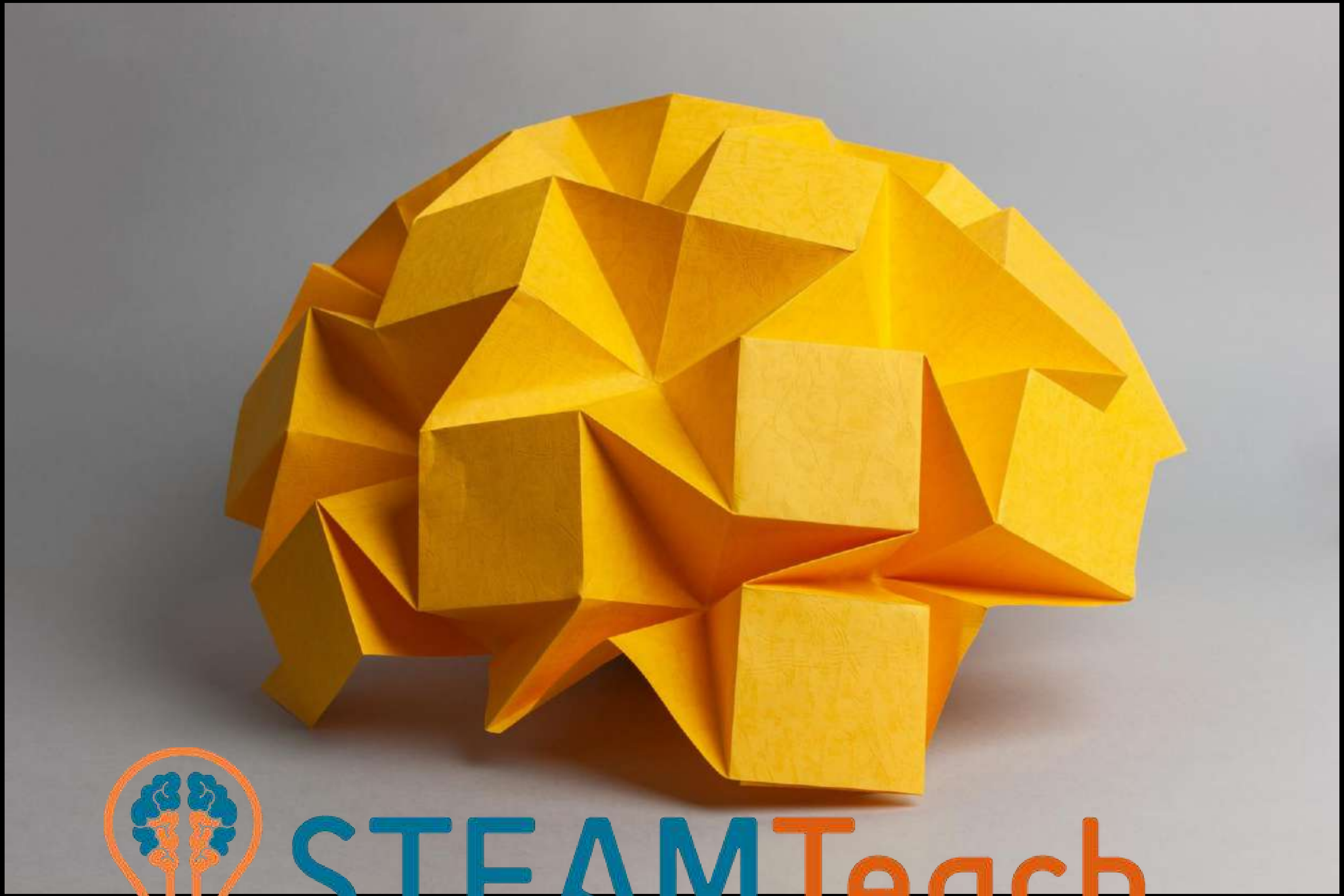

STEAMTeach
STEAM Education for Teaching Professionalism

Education, Games and Creativities

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University of Jyväskylä

Finnish Institute for Educational Research

Innovative Learning Environments Research Group

STEAMTeach
STEAM Education for Teaching Professionalism

Innovative Learning Environments

Finnish Institute For Educational Research

JYVÄSKYLÄN YLIOPISTO
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ILE is a research and education group that focuses on the advancement of children's and young people's 21st Century Skills. The field includes especially user-driven design and study of learning technologies and spaces for enhancement of learning and wellbeing, analyses of innovative teaching and learning practices, technology-enhanced learning, and evaluation and comparison of ICT use in education. When applicable, the research can also be directed to other phases of human life for the study of citizen's knowledge society capabilities.

Team members

Marja Kankaanranta · Kati Clements · Kristof Fenyvesi · Tiina Mäkelä · Piet Sikström

Saana Mehtälä · Mikko Muilu · Mimmu Alanko · Matias Mäki-Kuutti · Takumi Yada

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https://www.jyu.fi/it/en/research/research-areas/cognitive-science-and-educational-technology/ile

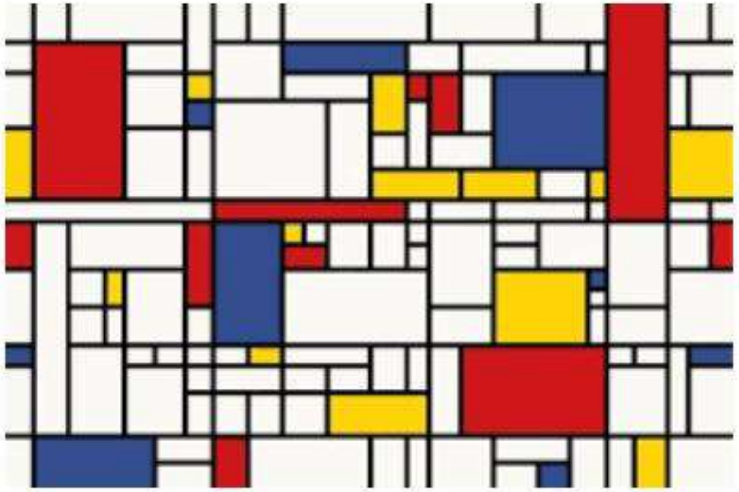
STEAM:

integration between subjects of Science, Technology, Engineering, Arts and Mathematics

Mondrian Art Puzzles

STEAMTeach
STEAM Education for Teaching Professionalism

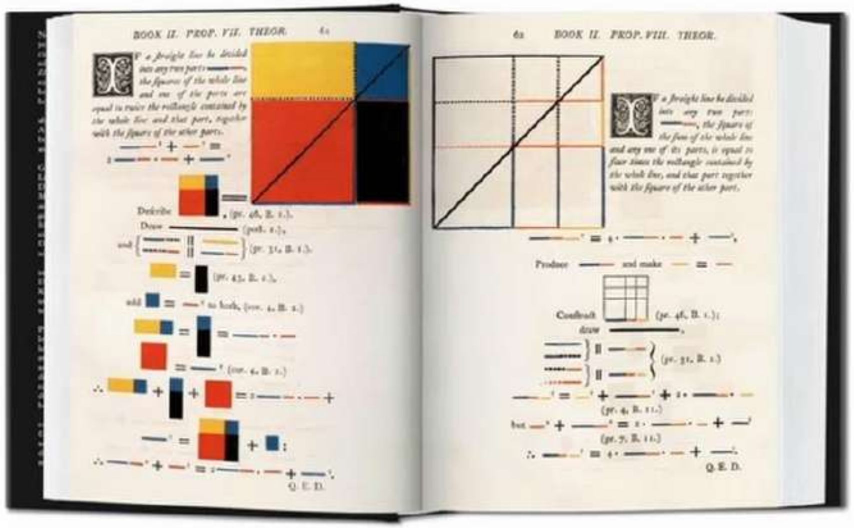
Piet Mondrian was a Dutch painter who is now considered one of the great artists of the 20th century [1]. Among his other works, some of Mondrian's art had a unique, geometric style that (no surprise) attracted the eyes and minds of mathematicians. His art looked a little something like this:



From the clashing of two worlds, math and art, the "Mondrian art puzzle" was born: a fun, creative, and colorful math activity built for almost any age!

Art & Mathematics

Merging art with mathematics was a natural process
for Piet Mondrian to visualize the essential, pure beauty and balance.



Oliver Byrne's 1847 edition of Euclid's Elements

Mondrian: Composition with Red Blue and Yellow

Art & Mathematics

Mondrian's artistic evolution from figural painting to geometrical imagery was a spiritual journey and an intellectual effort.
The goal was to discover the structure beneath the surface and to highlight the profoundly significant.

Evolution

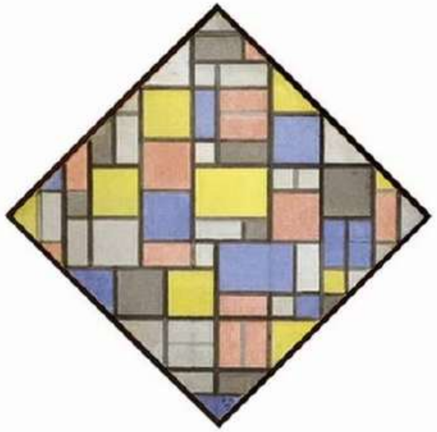
The Large Nude

Pier and Ocean

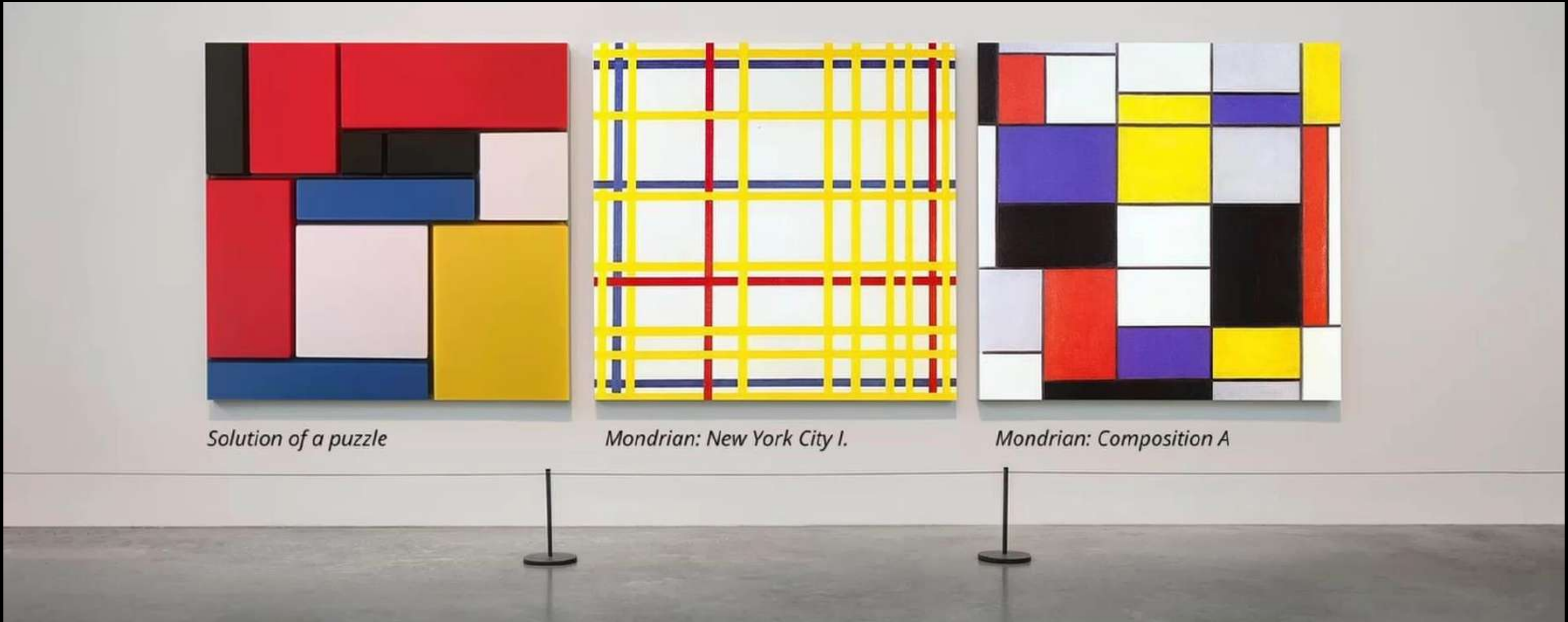
Art & Mathematics

Mondrian's systematically implemented grids and the "primary colors" - red, blue, yellow, and white - express the "universal forces" of his vision of art and reality.

Composition 1916



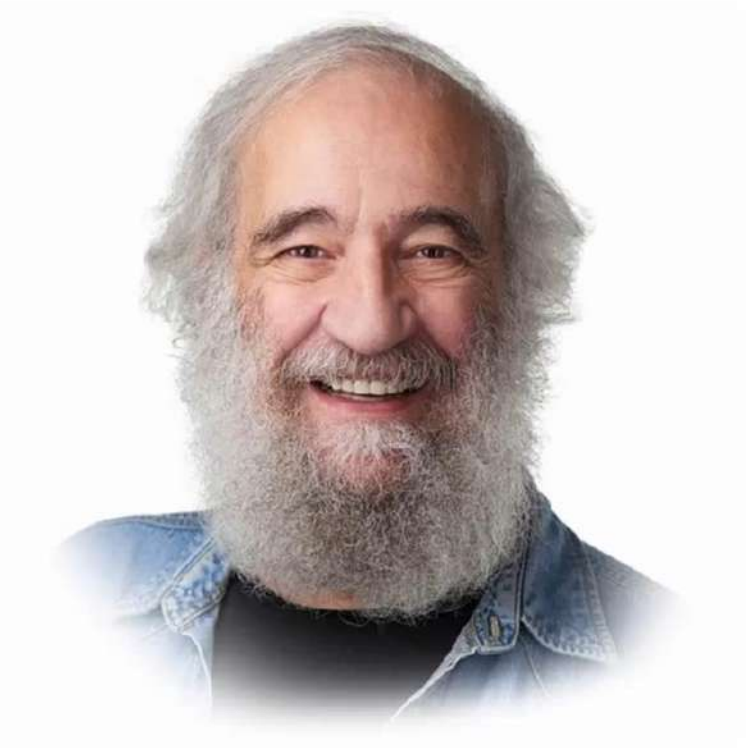
Composition with Grid 6


Solution of a puzzle
Mondrian: New York City I.
Mondrian: Composition A

How it started?

The original idea of Mondrian Blocks
is created by **Prof. Dr. Laszlo Mero**.

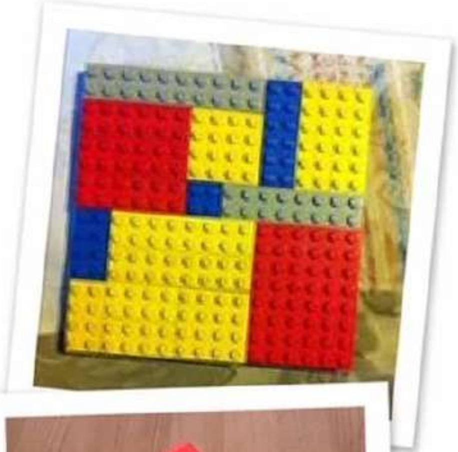
He is a Professor of Math,
a Professor of Psychology,
a research psychologist,
and popular science author.



How it started?

The idea came up when an escape room needed a puzzle.

The first prototype is made of Lego blocks.



How it started?

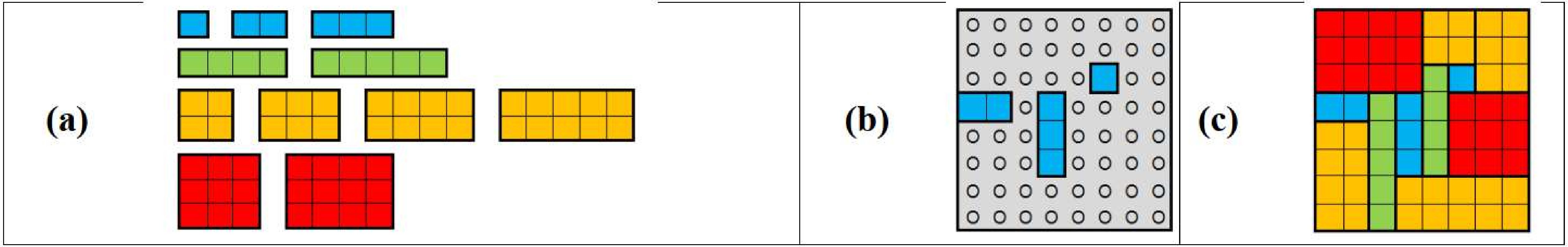
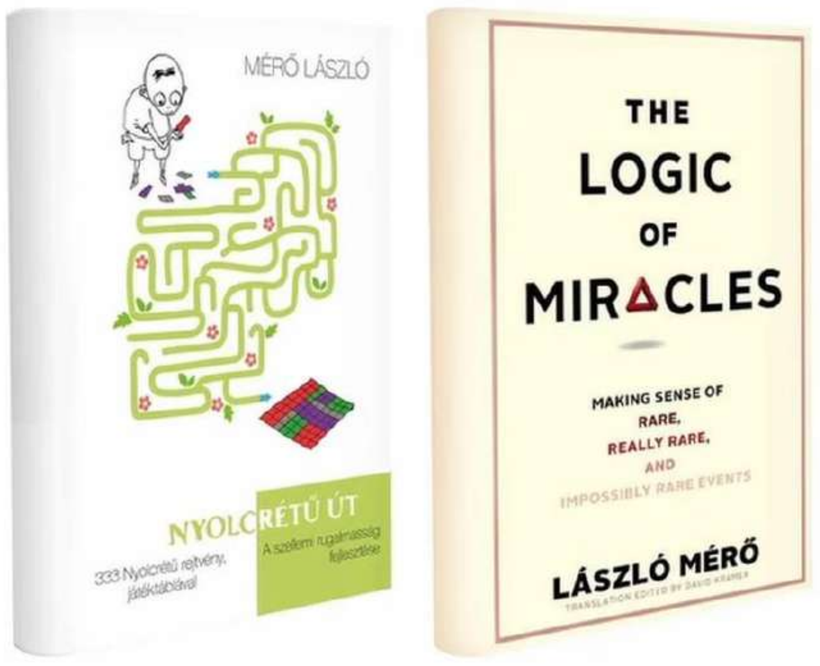


Figure 1a, b, c: *Mérő's idea came up when he was requested to create a logic puzzle for an escape room. (a) The origin of the idea is the recognition: the sum of the squares is exactly 64, which can be fitted in a 8x8 square. (b) A puzzle: the blue modules cannot be moved and all the rest of the modules need to be fitted on the board without gaps and overlapping. (c) A solution. Conclusion: there are a surprisingly large number of puzzles possible.*

How it started?

At first the game became an appendix of a book.

The Eightfold path: Developing intellectual flexibility.



The result of the development

Imre Kökényesi
Product developer
and game designer

MSA
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Best Education & Games
2020 Buyer's Choice Award

The result of the development

Four editions, each with 88 different challenges inside.

MUSEUM STORE ASSOCIATION

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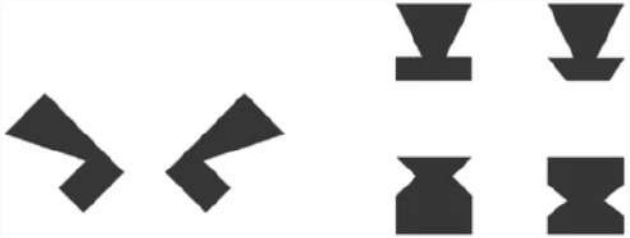
Mondrian Blocks' connection to cognitive skills.

The following cognitive skills are help to improve the ability of learning math:

- Instinct knowledge of numbers, dimensions, areas
- Flexible thinking, changing the point of view
- Reasoning
- Critical thinking
- Perceptual organization
- Working memory
- Processing speed

From: The role of 2D and 3D mental rotation in mathematics for young children: what is it? Why does it matter? And what can we do about it?

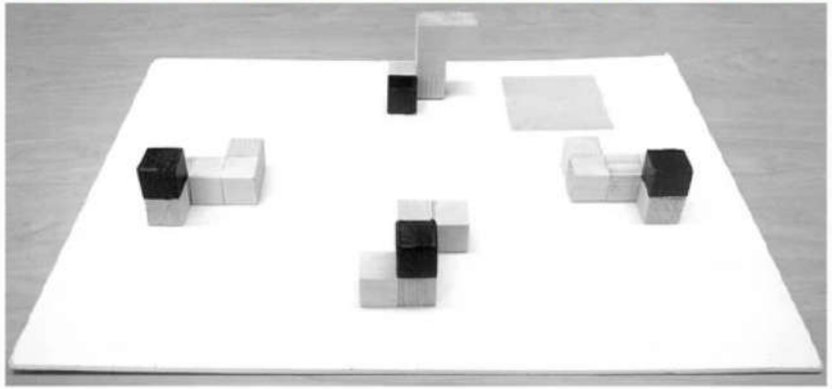


When we mentally rotate the *two shapes on the left* so that they are joined at a centre *y* axis, which figure do they make (of the *four on the right*)? (From Levine CMTT, et al., 1999); see also the classic test of Shepard & Metzler, 1971

From: The role of 2D and 3D mental rotation in mathematics for young children: what is it? Why does it matter? And what can we do about it?

When asking children to think about the area of these two squares, students describe mentally rotating the left square to match the square on the right as a proof that the area of the two squares are the same

From: The role of 2D and 3D mental rotation in mathematics for young children: what is it? Why does it matter? And what can we do about it?



In this 3D mental rotation blocks task (3DMRBT: Hawes, LeFevre, Chang & Bruce, 2014), the participant must identify which of the three figures at the front exactly matches with the figure at the back once rotated

„The ability to mentally rotate objects in space has been singled out by cognitive scientists as a central metric of spatial reasoning (see Jansen, Schmelter, Quaiser-Pohl, Neuburger, & Heil, 2013; Shepard & Metzler, 1971 for example). However, this is a particularly undeveloped area of current mathematics curricula…"

Bruce, C.D., Hawes, Z. The role of 2D and 3D mental rotation in mathematics for young children: what is it? Why does it matter? And what can we do about it?. *ZDM Mathematics Education* **47,** 331–343 (2015). https://doi.org/10.1007/s11858-014-0637-4

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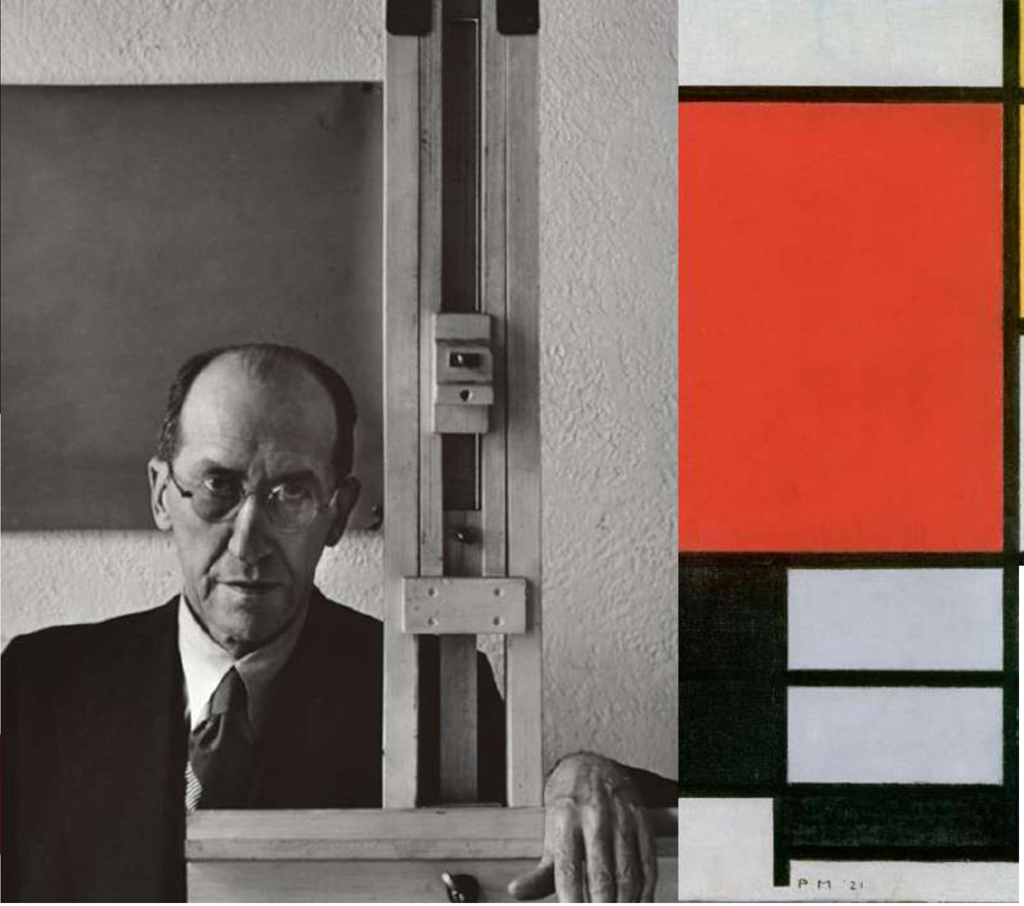

Friday, February 18 at 6:30 pm ET (New York)

TWO SIGMA FAMILY FRIDAYS MOMATH

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Mondrian Day at MoMath

Saturday, February 19
10:00 am – 5:00 pm ET (New York)

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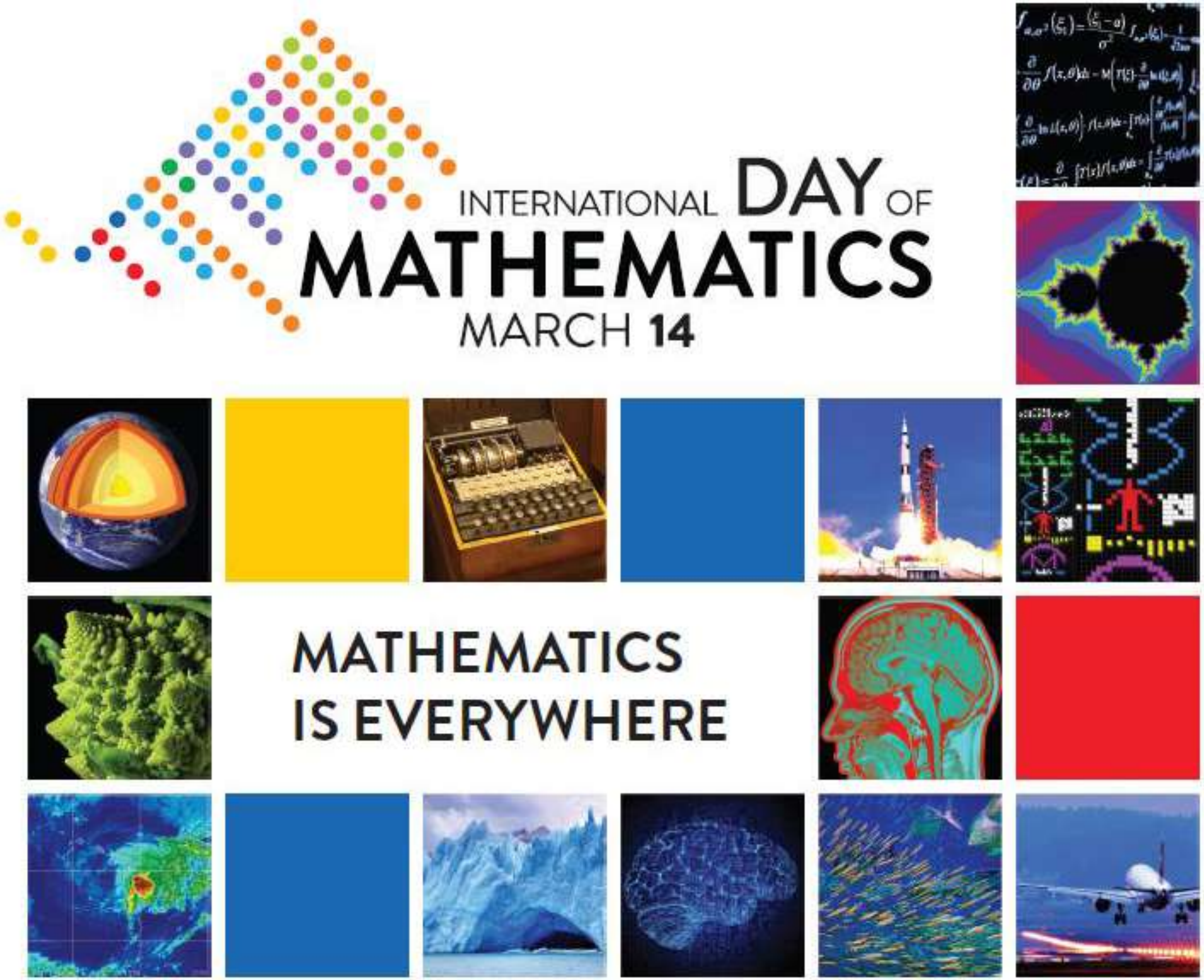
Cognitive Games

Sunday, February 20
10:00 am – 5:00 pm ET (New York)


INTERNATIONAL DAY OF
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MATHEMATICS
IS EVERYWHERE

Kristóf Fenyvesi and Tuuli Lähdesmäki (Editors)

Aesthetics of Interdisciplinarity: Art and Mathematics

This anthology fosters an interdisciplinary dialogue between the mathematical and artistic approaches in the field where mathematical and artistic thinking and practice merge. The articles included highlight the most significant current ideas and phenomena, providing a multifaceted and extensive snapshot of the field and indicating how interdisciplinary approaches are applied in the research of various cultural and artistic phenomena. The discussions are related, for example, to the fields of aesthetics, anthropology, art history, art theory, artistic practice, cultural studies, ethno-mathematics, geometry, mathematics, new physics, philosophy, physics, study of visual illusions, and symmetry studies. Further, the book introduces a new concept: the interdisciplinary aesthetics of mathematical art, which the editors use to explain the manifold nature of the aesthetic principles intertwined in these discussions.

ISBN 978-3-319-57257-4

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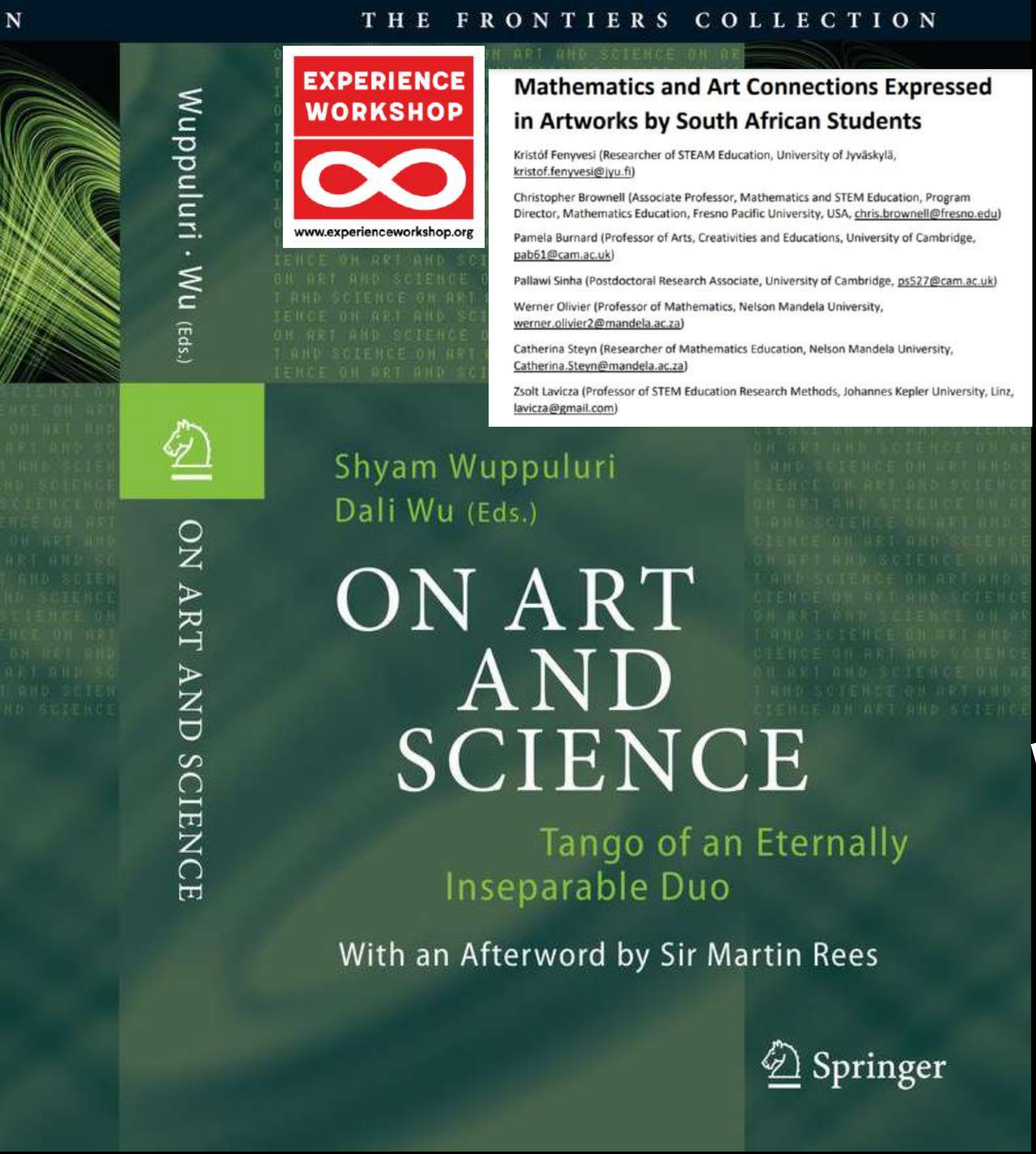
Kristóf Fenyvesi and Tuuli Lähdesmäki (Ed.)

Aesthetics of Interdisciplinarity: Art and Mathematics

Kristóf Fenyvesi
Tuuli Lähdesmäki
Editors

Aesthetics of Interdisciplinarity: Art and Mathematics

Birkhäuser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Mathematics and Art Connections Expressed in Artworks by South African Students
Kristóf Fenyvesi (Researcher of STEAM Education, University of Jyväskylä, kristof.fenyvesi@jyu.fi)
Christopher Brownell (Associate Professor, Mathematics and STEM Education, Program Director, Mathematics Education, Fresno Pacific University, USA, chris.brownell@fresno.edu)
Pamela Burnard (Professor of Arts, Creativities and Educations, University of Cambridge, pab61@cam.ac.uk)
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Zsolt Lavicza (Professor of STEM Education Research Methods, Johannes Kepler University, Linz, lavicza@gmail.com)
Wuppuluri · Wu (Eds.)
ON ART AND SCIENCE
Shyam Wuppuluri
Dali Wu (Eds.)
ON ART AND SCIENCE
Tango of an Eternally Inseparable Duo
With an Afterword by Sir Martin Rees
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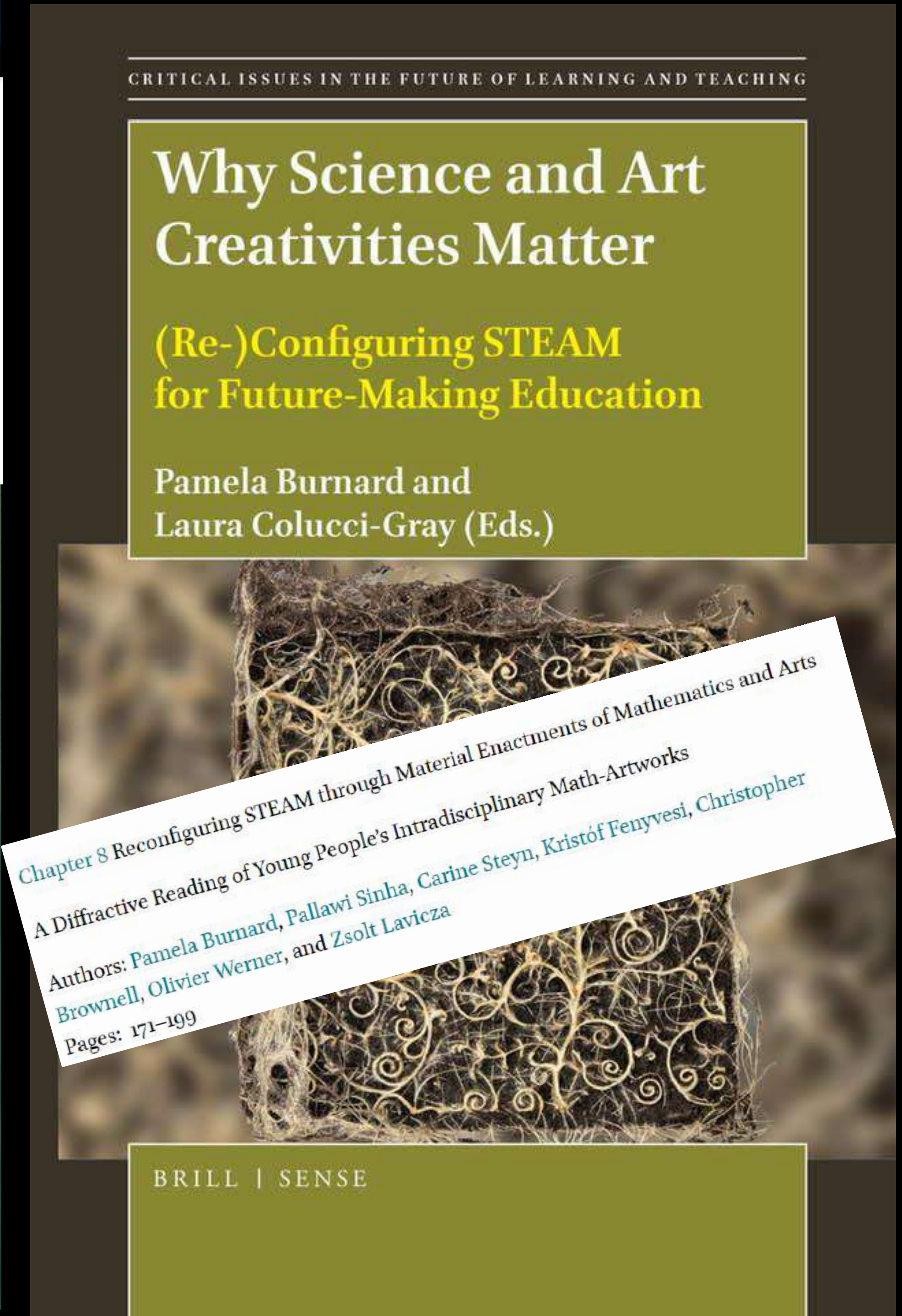
CRITICAL ISSUES IN THE FUTURE OF LEARNING AND TEACHING
Why Science and Art Creativities Matter
(Re-)Configuring STEAM for Future-Making Education
Pamela Burnard and
Laura Colucci-Gray (Eds.)
Chapter 8 Reconfiguring STEAM through Material Enactments of Mathematics and Arts
A Diffractive Reading of Young People's Intradisciplinary Math-Artworks
Authors: Pamela Burnard, Pallawi Sinha, Carine Steyn, Kristóf Fenyvesi, Christopher Brownell, Olivier Werner, and Zsolt Lavicza
Pages: 171–199
BRILL | SENSE


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Dali Wu (Eds.)
ON ART AND SCIENCE
Tango of an Inseparable Duo
Springer

PLAYFUL LEARNING
in Early Childhood Education in Finland

This book is intended for all persons working with children aged 0–7 years who do the vital work, for instance, in Early Childhood Education and Care (ECEC) centres, kindergartens, nurseries and schools in all parts of the world. This book is also an excellent tool for training ECEC teachers.

The book contains over 100 practical and playful activities for children under seven years of age. It will give you concrete examples and ideas for how to implement activities with children in order for them to learn through play. The chapters of the book are based on the Finnish pedagogical practices, scientific research, and development projects of ECEC and is also based on the Finnish National Core Curriculum for ECEC.

We writers hope this book will inspire you in your work with children and promote their lifelong learning. We hope the children will receive beneficial learning experiences through the playful activities we've described – and that you, the reader, will experience happiness working and playing with the children.

***PLAYFUL LEARNING in Early Childhood Education in Finland** elevates the pedagogical significance of play in learning, as well as children's holistic growth and well-being. This book encourages versatile and functional working methods that promote children's creativity, interaction and participation. Our main task is to help you provide good childhood experiences and consequently a promising future for all children.*

Pia Kola-Torvinen, Counsellor of Education, Finnish National Agency for Education

***PLAYFUL LEARNING in Early Childhood Education in Finland** is a book that gets right to activities that are useful for children. Behind the planned playful activities are education professionals who have proved the effectiveness of these activities based on specific theories and research. The book is useful in daycare centres and is needed in teacher education. It can also be an excellent guide for parents in home education. The book guides children to participate and experience joy together. The book itself plays a valuable part in developing children's culture.*

Ulla Härkönen, professor emerita at the University of Eastern Finland

Finland International Education

1ACS
ISBN 978-951-1-43042-1
otava.fi

PLAYFUL LEARNING in Early Childhood Education in Finland

OTAVA

PLAYFUL LEARNING
in Early Childhood Education in Finland

Integrating pedagogical activity and care through play with language, art, mathematics and motor skills

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Päivi Erkkilä
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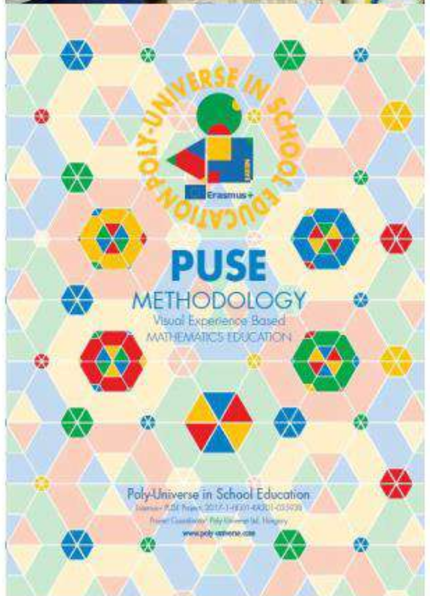
Finland International Education

WORKSHOP 1: SHAPES AND COLORS



The Polyuniverse offers a new perspective for mathematics and art education. Mind-bending combinations made of 24 pieces each of the 3 basic shapes: the triangle, the circle and the square.

WORKSHOP 2: STRUCTURE

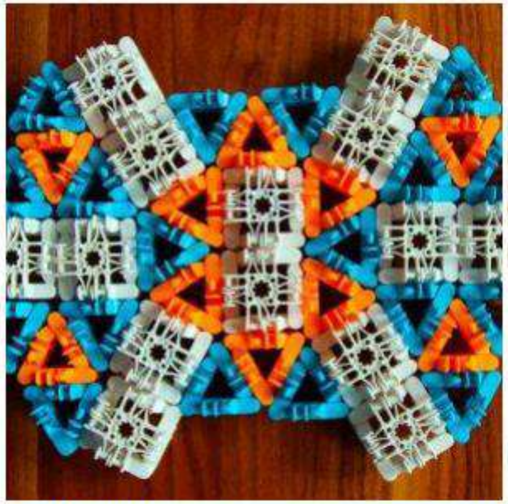
Make a geometrical magic carpet, tapestry or decoration inspired by various patterns, including visual illusions! Determine the colours, think about the pattern, count, and create.

WORKSHOP 3: LOGIC

MONDRIAN BLOCKS are offering cognitive challenges at the conjunction of art and mathematics. Let the flow take your mind to the next level!

METHER-BORGSTRÖM'S STEAM PLAY DAY

WORKSHOP 4: LINKS & FLEXIBILITY



Called the "next level LEGO" by the New York Magazine, LUX is a revolution in construction. Modeled after nature at the molecular level, LUX connects through linking, instead of sticking or stacking, and therefore gives the immediate experience of the world of kinematics. Now this wonderful moving aspect of our universe can be accessed in playing and learning experience!

WORKSHOP 5: MODULARITY

The Design Award Winner Logifaces is the ANALOGUE GAME FOR DIGITAL MINDS. LOGIFACES lets you train your mind, boost your creativity and challenge yourself and your friends.

THANK YOU FOR YOUR ATTENTION!

Contact: kristof.fenyvesi@jyu.fi

CREATING VISUAL ILLUSIONS AND IMPOSSIBLE FIGURES BY COMBINING MATHEMATICS AND ARTS

DR. KRISTÓF FENYVESI, UNIVERSITY OF JYVÄSKYLÄ, FINLAND

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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
MAIN AUTHORS' NAME AND EMAIL ADDRESS	Dr. Kristof Fenyvesi, kristof.fenyvesi@jyu.fi
CONTRIBUTING INSTITUTIONS	University of Jyväskylä (JYU)
REVIEWED BY	Matias Mäki-Kuutti, JYU
STATUS	Ready

TABLE OF CONTENTS

1 Introduction

Visual illusions and impossible figures represent an intriguing intersection of mathematics and art. These paradoxical images, which can be visualized or drawn but not constructed in a tangible form, spark interest and curiosity, offering fertile ground for learning and engagement in Science, Technology, Engineering, Art, and Mathematics (STEAM) education. The combination of mathematics and art helps cultivate an enriched educational environment that promotes creativity, critical thinking, and problem-solving.

This material aims to delve into the historical development of these concepts, explore the mathematical principles behind them, discuss their potential application in STEAM education, and provide strategies for effective implementation and evaluation.

2 Background

The journey of visual illusions and impossible figures in art and mathematics began with Swedish artist Oscar Reutersvärd's groundbreaking arrangement of nine cubes in 1934, leading to the creation of the first impossible tri-bar.

The concept gained significant momentum following the Penroses' publication, 'Impossible objects: a special kind of visual illusion,' in the British Journal of Psychology in 1958.

Renowned artists like M.C. Escher and Victor Vasarely have since created many famous impossible figures-based artworks, further popularizing the field. These figures' mathematical underpinning lies in the illusion of spatiality, where flat lines printed on a piece of paper give the impression of a solid object. The ability to explore, understand, and create these figures can bolster mathematical competence and artistic creativity, making them invaluable in STEAM education.

3 Theoretical Framework

The mathematical basis for creating visual illusions and impossible figures is fascinating. It revolves around concepts like isometric and axonometric projections, geometric transformations, and perceptual inversion, among others. Figures like the Necker Cube, first published in 1832, offer excellent examples of these concepts in action. On the cognitive side, perceiving these illusions involves a complex interplay of visual processing and cognitive interpretation. These figures challenge our standard perspective rules, provoking a fascinating switch between different interpretations, and encouraging a deeper understanding of spatial relationships.

4 Implementation in STEAM Education

Visual illusions and impossible figures offer a potent tool for educators to engage students in mathematics and art in an interesting and interactive manner. Educators can employ these concepts to create immersive, hands-on activities that can foster creative thinking and problem-solving skills.

The work of Tamás F. Farkas and István Orosz, artists known for creating impossible objects, and mathematician László Vörös, who explores geometrical principles based on their artworks, serve as inspirational case studies. Their creations can serve as a foundation for classroom activities and lessons, inspiring students to manipulate shapes, explore geometry, and push the boundaries of their imagination.

5 Assessment and Evaluation

To assess students' understanding of visual illusions and impossible figures, educators can use a variety of methods.

These include project-based assessments where students create their own impossible figures, quizzes to test understanding of the underlying mathematical principles, and reflective discussions to evaluate cognitive perception of the illusions.

Evaluating the effectiveness of these materials in enhancing mathematics and art understanding will rely on longitudinal studies, examining students' performance, engagement, and progress over time. These assessment tools and evaluations can inform adjustments to teaching strategies and curriculum design to maximize the learning benefits derived from visual illusions and impossible figures.

1 PROJECT JUSTIFICATION

The project is relevant for students as it offers a practical and interactive approach to learning mathematical and scientific principles. It is framed within the STEAM education area, integrating Art, Mathematics, and cognitive sciences.

1.1 Project Overview

Participant age: **12-16**	*No. of participants:* 30	*Duration:* 2-8 hours (depends on the depth of the activity)
Level of knowledge: Intermediate	*No. of teachers:* 2 (maths and arts)	*Type of venue:* Regular classroom, Computer laboratory, Art classroom
Learning methodologies: Content integration, Problem-based learning, Inquiry-based learning, Design-based learning, Collaborative learning	*Involved disciplines:* Science, Technology, Engineering, Arts, Mathematics	*Technological needs:* Computer(s), Internet, optionally Graphic design software (like Inkscape or Adobe Illustrator) OR physical art accessories, pens, paper, etc.
Most emphasised learning methodology: Problem-based learning	*Main addressed topics:* Geometry, Art, Cognitive Sciences	*Estimated project cost:* 0 €

2 CURRICULAR CONTEXT

2.1 Key competences

- Multilingual: English (all the resources would be in English)
- Mathematical, science, technology, and engineering: Geometry, spatial perception, computer literacy
- Digital: Usage of graphic design software, Internet research
- Personal, social and learning to learn: Teamwork, problem-solving, creativity

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- Citizenship: Cultural appreciation (through art)
- Entrepreneurship: Initiative, project management
- Cultural awareness and expression: Art appreciation, art history Literacy

2.2 Content

DISCIPLINE	CURRICULAR CONTENT ADDRESSED
Science	Cognitive science, visual perception
Technology	Graphic design software usage
Engineering	Planning and designing impossible figure
Arts	Art history (impossible figures), art creation
Mathematics	Geometry, spatial relationships

2.3 Expected learning results

Students are expected to gain a deep understanding of the mathematical principles behind impossible figures and visual illusions, cultivate an appreciation for art and its historical developments, and develop skills in using artistic AND / OR digital tools. They are also expected to hone their critical thinking, creativity, and problem-solving abilities.

3 STEPS TO BE EXECUTED

3.1 Step 1: Identifying the problem

Duration: 1-2 hours

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Teachers introduce the project to students - creating visual illusions and impossible figures using mathematical concepts and artistic creativity. The problems discussed will be how to integrate mathematical principles with art to create visual illusions and impossible figures.

The available materials would be art supplies, graph paper, mathematical tools (like compasses and protractors), and a variety of books and online resources on visual illusions, impossible figures, and relevant mathematical concepts.

The main project constraints could be time, budget for materials, and student's prior knowledge in the subject.

The criteria for the solution would be that the final product must be a visual illusion or an impossible figure that integrates mathematical concepts.

3.1.1 Constraints

Constraints might include limited time, limited resources (materials available), and varying skill levels among students.

3.1.2 Criteria

The model must illustrate a concept in mathematics, be a piece of art (visual illusion or impossible figure), and should stimulate thought and discussion about the interplay between mathematics and art.

3.2 Step 2: Generating ideas

Duration: 1-2 hours

- During this step, students will break down the main problem into simpler problems, such as understanding mathematical concepts and artistic techniques. Students will brainstorm about how these could be combined to create illusions or impossible figures.

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.

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3.2.1 Sub-problems

Key sub-problems may include understanding the mathematical principles, mastering the artistic techniques needed, and figuring out how to incorporate these two distinct elements into a cohesive piece of art.

3.3 Step 3: Exploring the Science and Mathematics

Duration: 1-2 hours

Students will engage in activities designed to deepen their understanding of the mathematical concepts they will be using. This could include geometric principles, spatial reasoning, and the mathematics of perspective.

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:

- How can geometric principles be utilized to create a perspective that gives the impression of a three-dimensional figure on a two-dimensional surface?

  This question encourages students to investigate how geometry can be used to create visual illusions and impossible figures. They would explore the concept of perspective and how it relates to geometric principles such as parallel and intersecting lines, angles, and shapes. Activities related to this question could involve drawing three-dimensional shapes on two-dimensional surfaces, exploring vanishing points, and creating a simple perspective drawing.

  How can spatial reasoning and mathematical concepts be applied to design impossible figures that defy real-world physical laws?

  This question pushes students to think about how spatial reasoning and mathematical concepts can be applied creatively to design impossible figures. These are figures that can be drawn on paper but could not possibly exist in the three-dimensional world we live in (e.g., the Penrose Triangle). Activities related to this question could involve exploring and drawing impossible figures, trying to understand why they look possible on a flat surface but aren't in three-dimensional reality. This would engage students in understanding the mathematical principles that allow these impossible figures to exist on paper.

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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 1: Students could engage in tasks to learn and practice the principles of linear perspective in art, which have a strong mathematical basis.

3.3.2 Experiment/task 2: Activities might be designed around the exploration of geometric shapes, their properties, and how these can be manipulated to create visual illusions.

3.4 Step 4: Designing and Constructing the model

Duration: 1-2 hours

Students will generate as many solutions as possible for creating a piece of art based on their chosen mathematical concept. They will sketch their designs and list the required materials. Once the design is agreed upon, they will construct their model.

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: 1-2 hours

Students will evaluate whether their models meet the set criteria, solve the stated problem, and work as a visual illusion or impossible figure. 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: 1-2 hours

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If the solution does not meet the criteria or does not work as expected, students will refine their model. This could involve adjusting their design, using a different mathematical concept, or approaching the artistic representation in a new way.

3.7 Step 7: Presenting the project

Students will present their final project to an audience, which could comprise classmates, peers from other high schools, families, and researchers. They will explain the mathematical concepts used, how they incorporated these into their art, and how this created the visual illusion or impossible figure.

4 PROJECT EVALUATION

Students' understanding of the subject matter would be assessed through project-based assessments, where they will be required to create their own impossible figures and explain the principles behind them. In addition, quizzes and reflective discussions can be used to measure their comprehension of the topic.

5 MATERIALS AND ROOMS

Materials required: Art tools AND / OR Computers with internet access, graphic design software, projectors for presentations.

Rooms required: Classroom for discussions and presentations, computer laboratory AND / OR art room for the practical aspect of the project.

6 INSTRUCTIONS ABOUT THE CONSTRUCTION OF PROTOTYPE/SOFTWARE/OTHER

Instructions can be provided by the teachers during the course of the project, guiding students on how to use the art tools AND / OR design software and how to construct their impossible figures.

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7 CONCLUSIONS

The project "Creating Visual illusions and Impossible Figures by Combining Mathematics and Arts" was a highly engaging and successful initiative that helped students understand the integration of mathematics and arts, and their applications in the real world.

Throughout the project, students demonstrated a significant improvement in their understanding of geometric principles and spatial reasoning. The activities spurred their creative and critical thinking, while encouraging them to find innovative solutions to the tasks at hand. They learned how to apply mathematical concepts to create visual illusions and impossible figures, demonstrating the practical utility of these theoretical concepts.

Moreover, the project cultivated collaborative learning, as students worked together in groups to solve problems and complete tasks. This not only improved their teamwork skills but also led to meaningful discussions and exchange of ideas.

The integration of technology with traditional learning methods proved effective in enhancing students' learning experience. The use of digital tools for creating and testing their models provided a hands-on experience, boosting their digital literacy.

Lastly, the presentation of the projects in front of an audience instilled a sense of confidence among students and gave them an opportunity to improve their communication skills.

In conclusion, the project achieved its objectives of imparting key mathematical concepts through a fun and engaging STEAM project. It demonstrated the effectiveness of using an interdisciplinary approach in education to encourage active learning, critical thinking, creativity, and problem-solving skills among students. The success of this project reinforces the benefits of incorporating STEAM education in the curriculum, which can help equip students with essential 21st-century skills.

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STEAMTeach
STEAM Education for Teaching Professionalism

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Visual illusions and impossible figures

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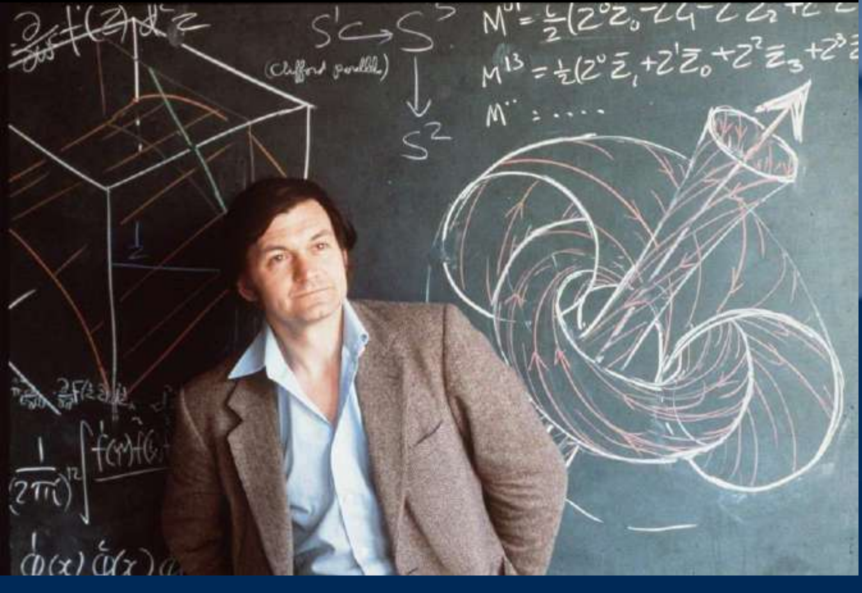
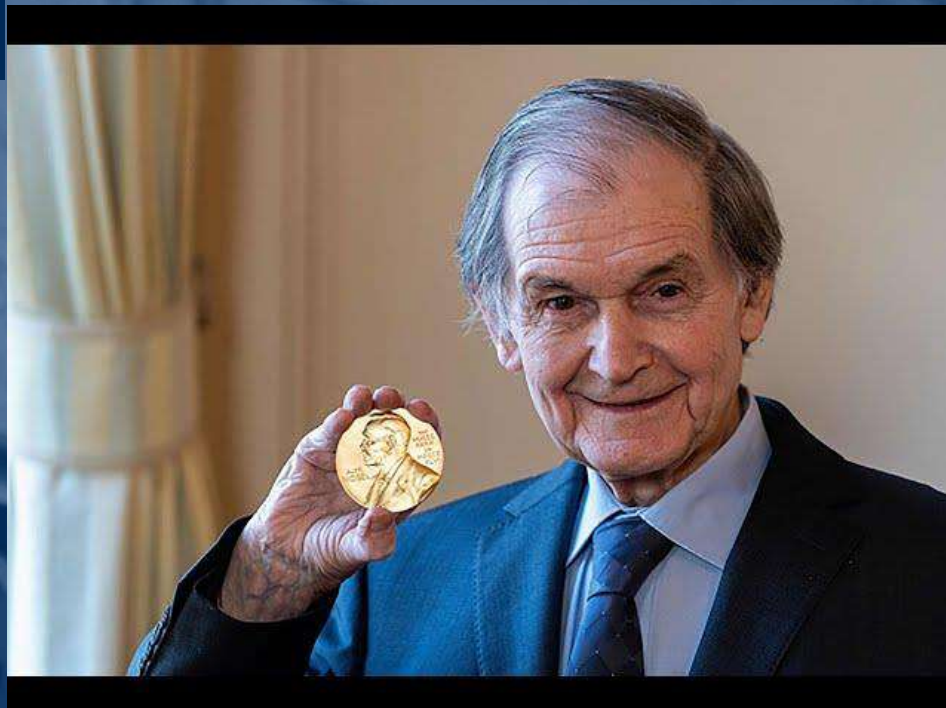
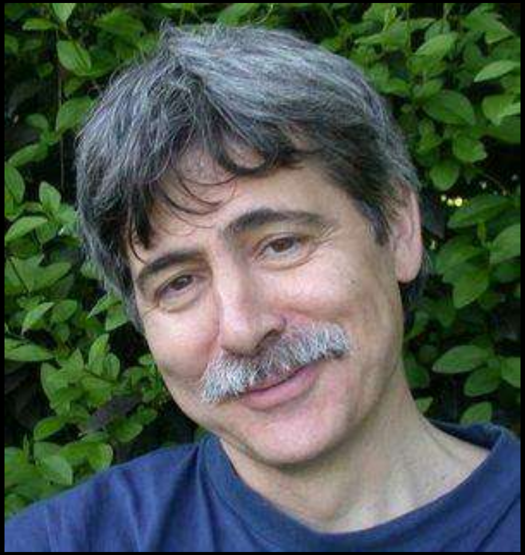
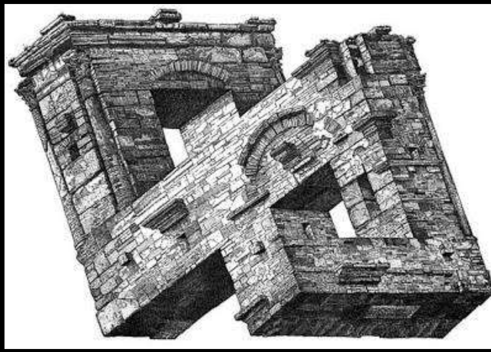


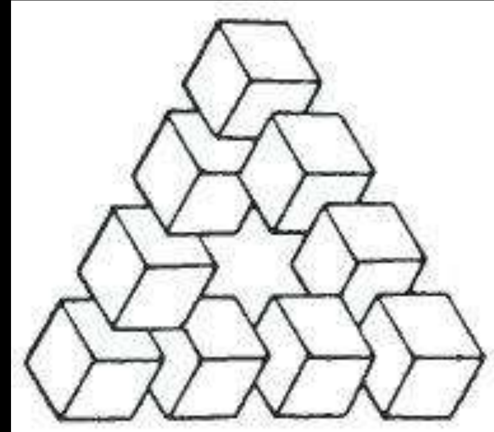
Sir Roger Penrose Nobel Award in Physics in 2020



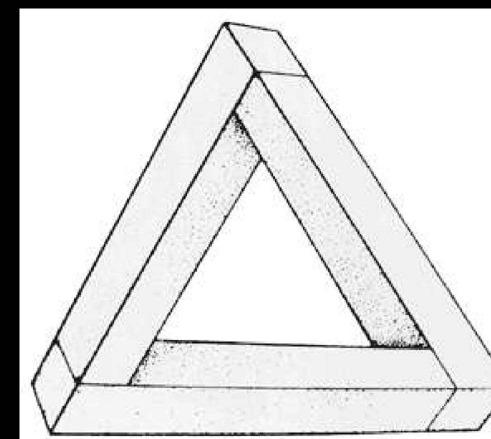


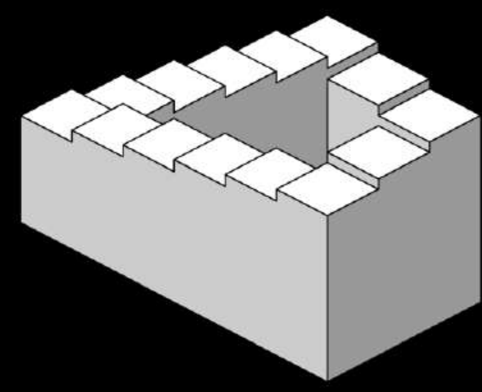





Tamás F. Farkas and István Orosz artists, who create impossible objects; Ildikó Szabó mathematics teacher, who has built a math-art education program on Farkas' and Orosz' artworks; and the mathematician László Vörös, who builds a geometrical research on Farkas' and Orosz' art pieces.

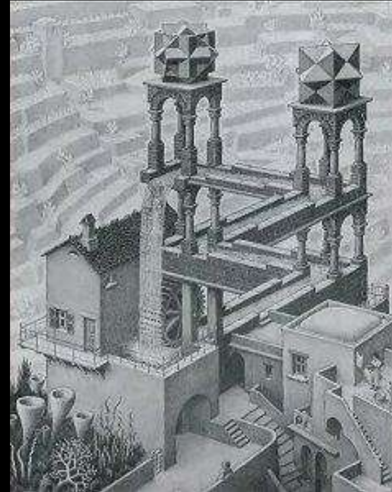


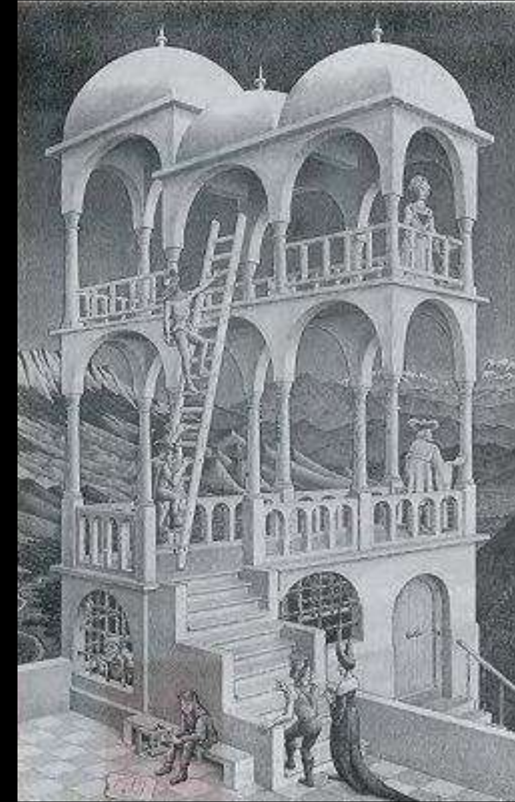
In the year 1934 the Swedish artist **Oscar Reutersvärd** drew a special arrangement of nine cubes and the first impossible tri-bar had been created. He continued to experiment in this new field and made many hundreds of drawings. In 1958 **L.S. & R. Penrose** published an article in the **British Journal of Psychology:** ***'Impossible objects,a special kind of visual illusion'.*** In this article they described the **impossible tri-bar** and the idea of **endless stairs.**

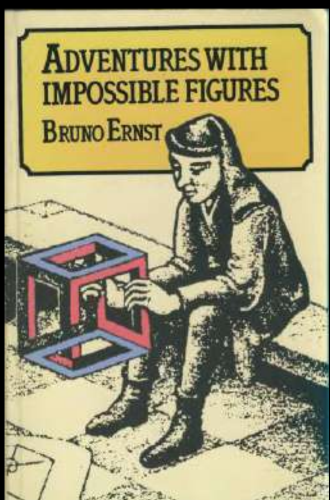




Now, we have learnt, that **WHO** are the **impossible figures. L**et's examine then **WHAT** makes a figure **impossible?**







These ideas were taken up by artists, especially **M. C. Escher**… Bruno Ernst has met with Escher 2 years prior the Penroses' article publication and followed up the design and creation of Escher's most famous impossible figures' based artworks: ***Belvedere (1958), Ascending and Descending (1960), and Waterfall (1961).***

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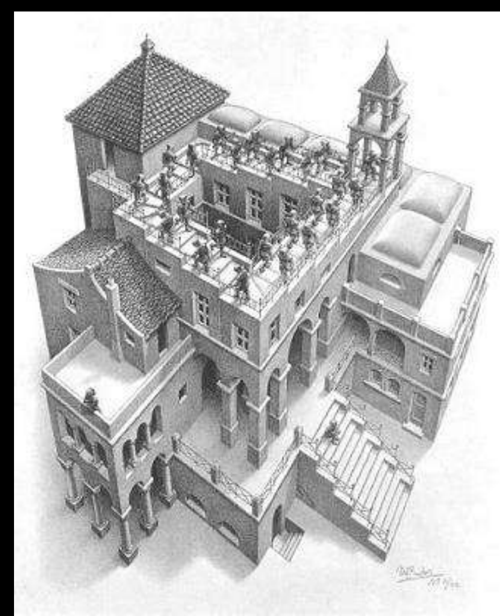
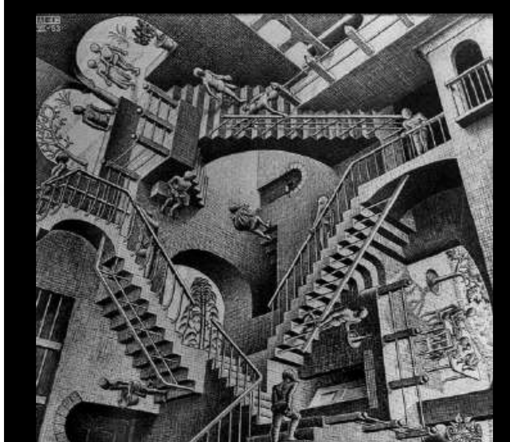
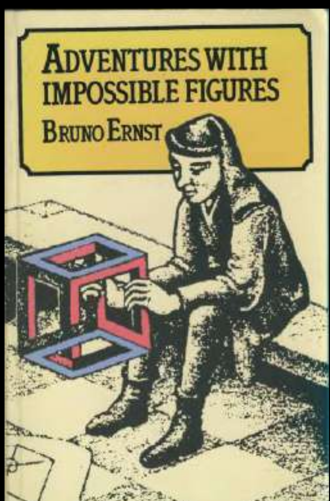
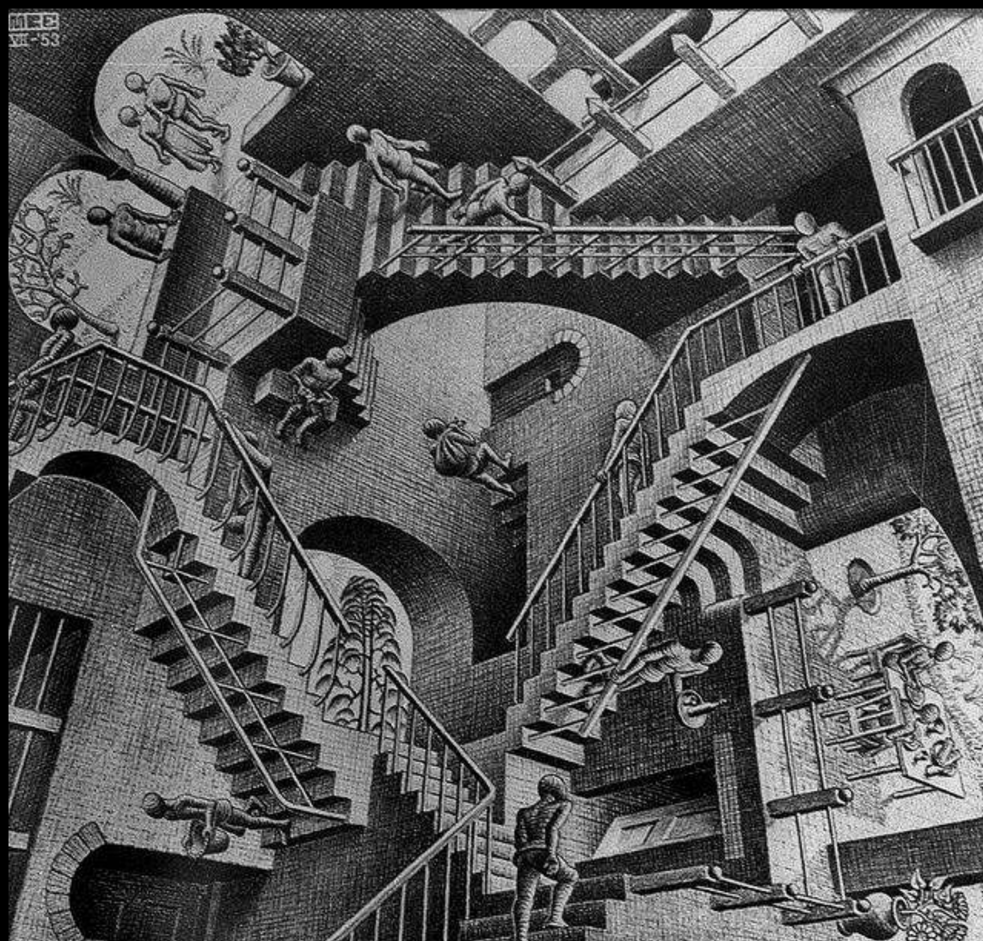
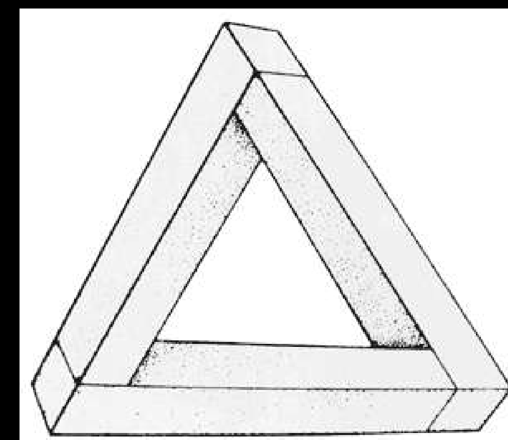


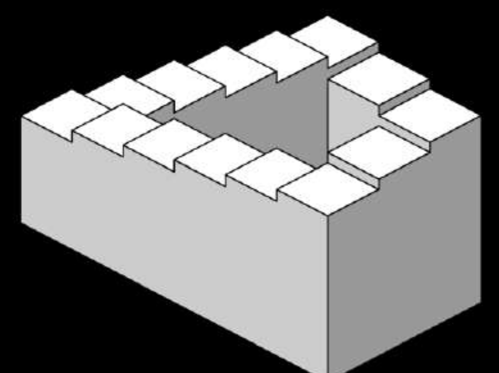


Impossible Figures: figures which can be imagined or drawn, but which cannot be made in any concrete form. Their effect is based on (at least) **two separate layers of illusion**. **(1) Illusion of spatiality:** all we are really looking at is **a set of lines** printed on a piece of paper (flat), yet we appear to see a solid object. **(2)** The bars which make up the impossible tri-bar **cannot meet in real space (different perspectives united in an isometric drawing), but we still try to assign a meaning. Strange consequences…**





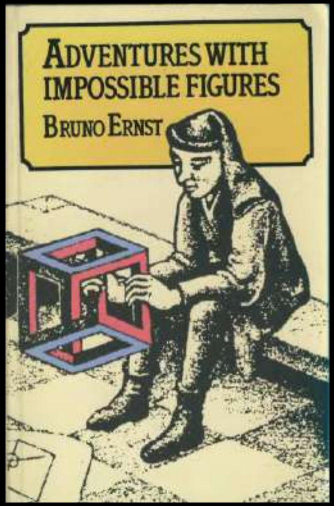


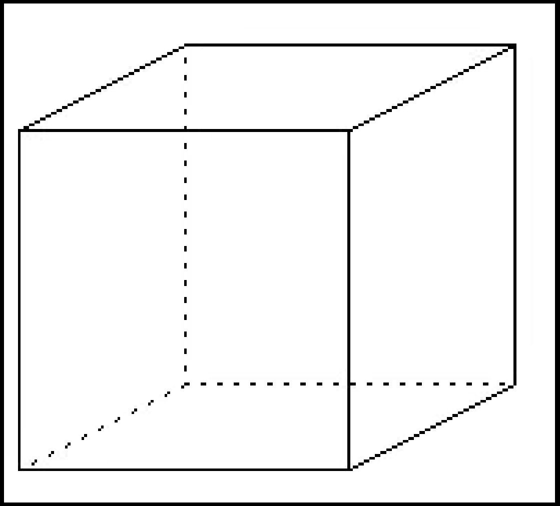


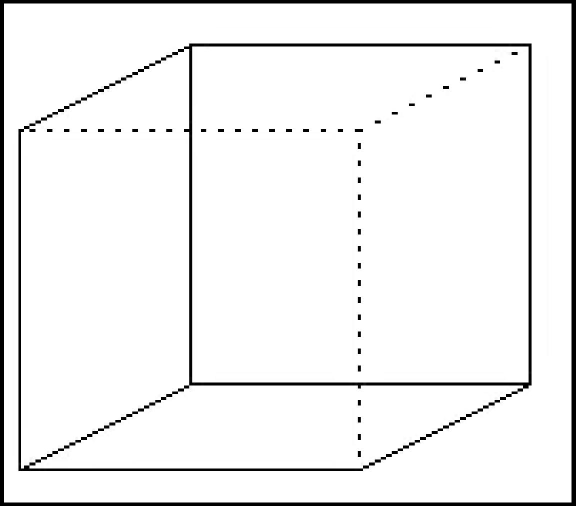
Illusion of Spatiality:

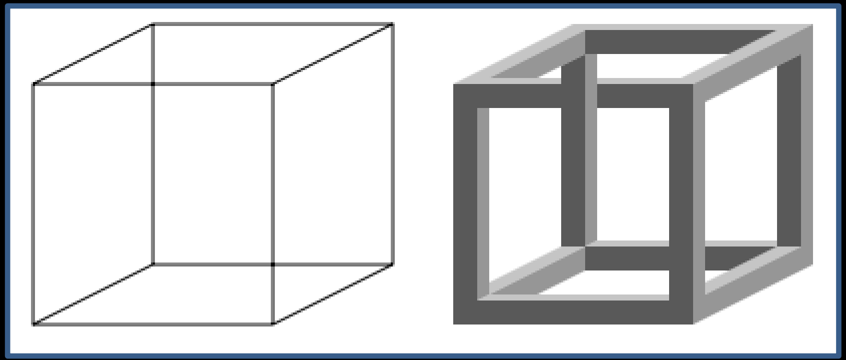
- The **Necker cube** is an optical illusion first published as a rhomboid in 1832 by Swiss crystallographer Louis Albert Necker.

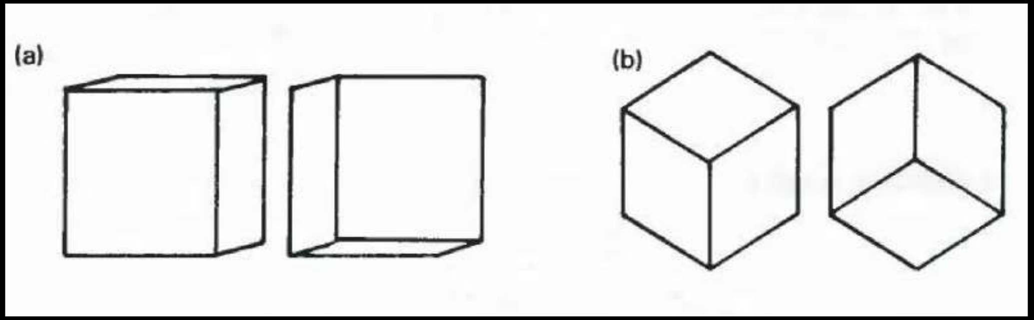
Inside or Outside? Above or Below? Convex or Concave?











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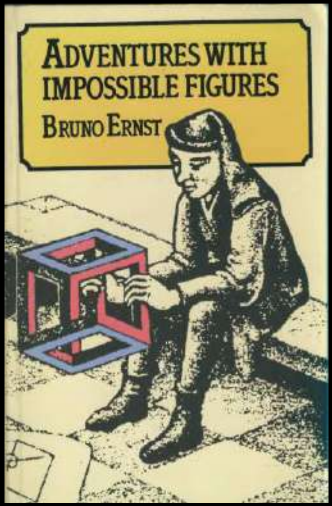
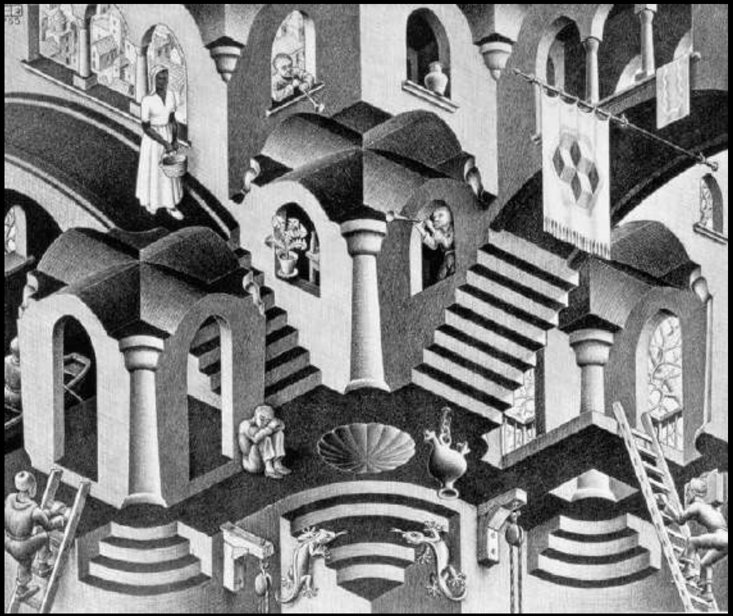
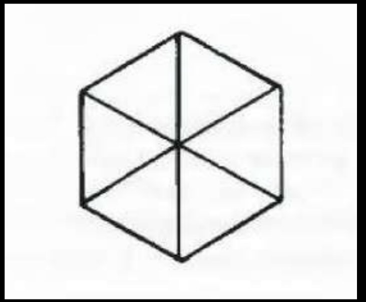




The phenomenon of switching between the two interpretations: ***perceptual inversion.***

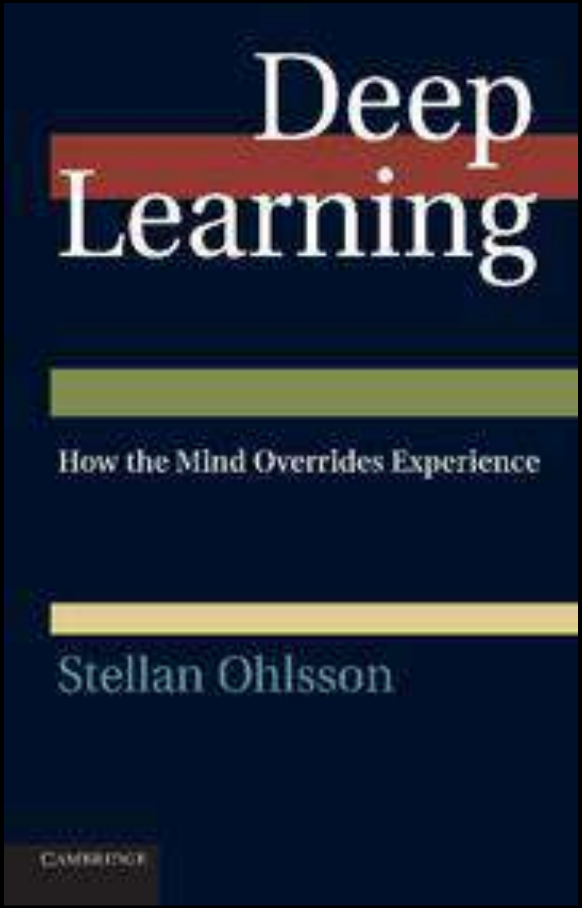
The Necker Cube with the greatest angle of change gives a hexagon. THIS HEXAGON, AS A MODULE, BECOMES VERY IMPORTANT IN THE DESIGN OF IMPOSSIBLE FIGURES!

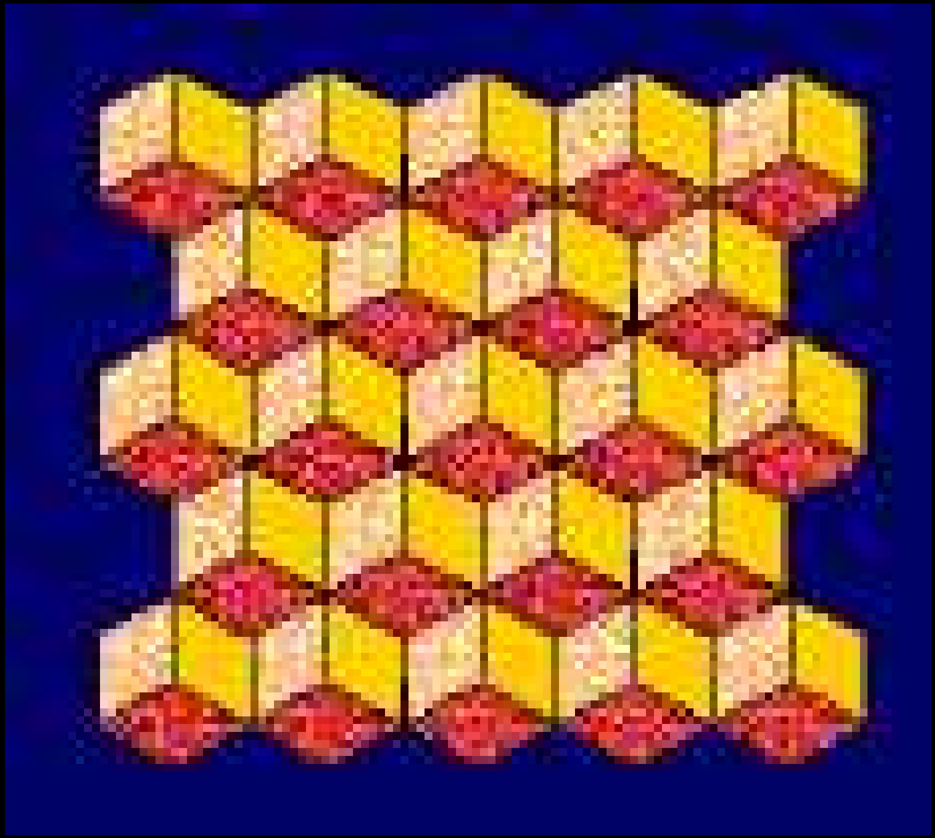


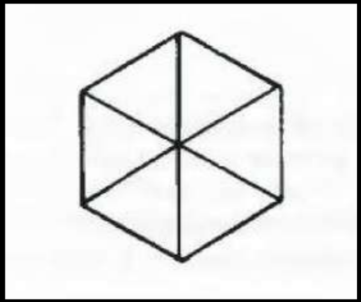
Illusion of Spatiality:

Kurt Koffka - German psychologist. One of the founder of Gestalt psychology. Experiments on problem-solving and creativity. Re-discovery of **reversible figures** like **Necker Cube.**

Crystallography → ***Gestalt Theory*** → ***Visual Mathematics***



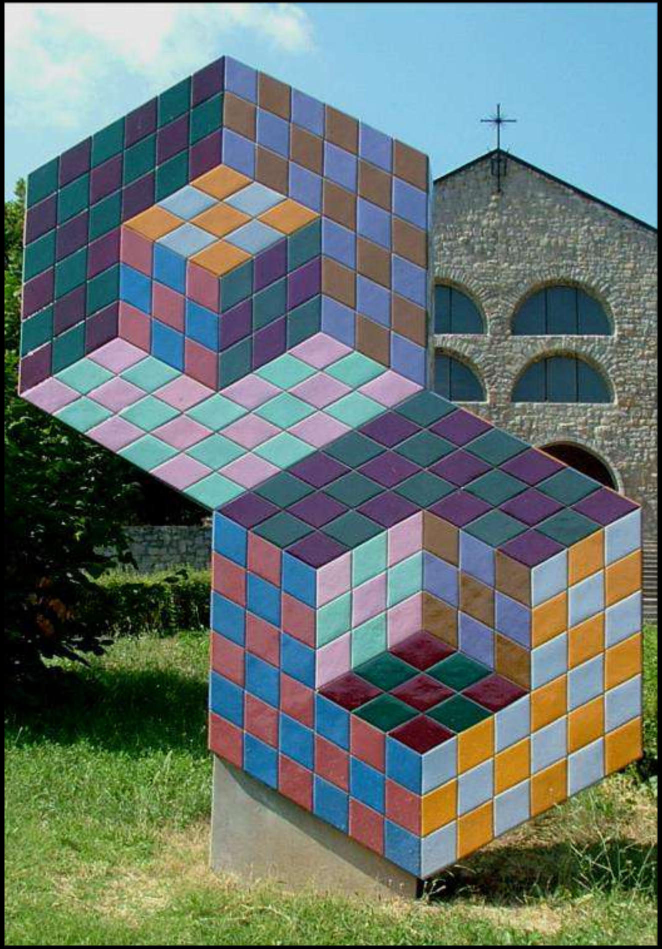




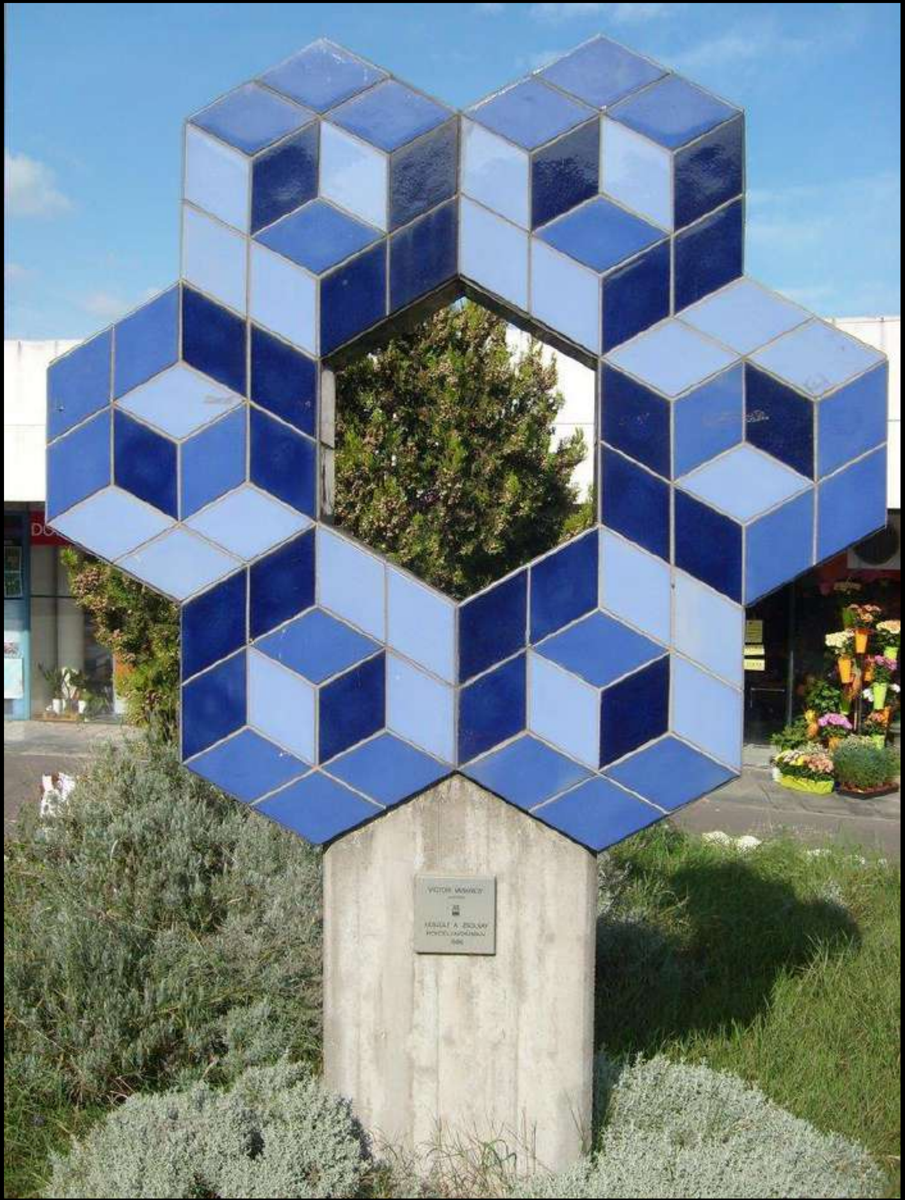
Victor Vasarely: JEL, Pécs city, 1977.

“Koffka-art”

How many aspects, how many views are possible?



Victor Vasarely's "visual mathematics"



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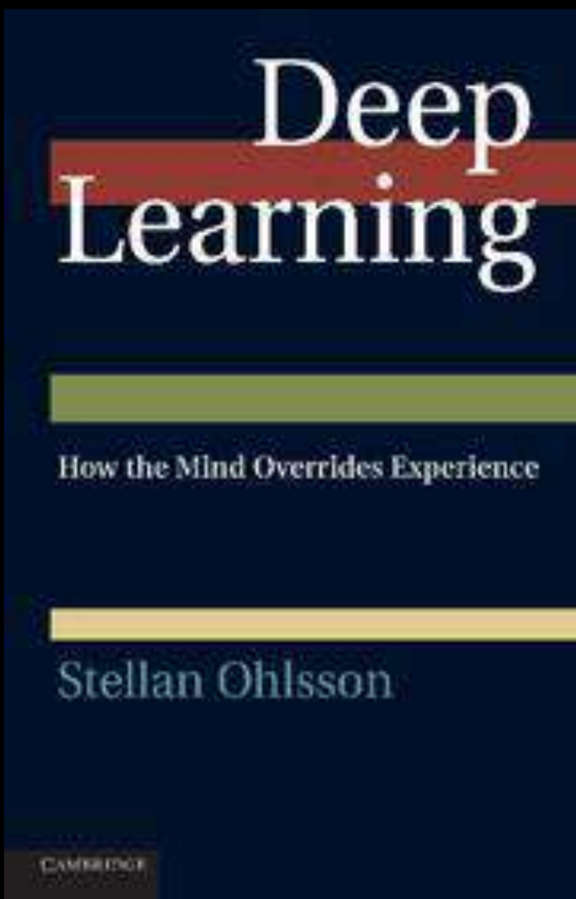
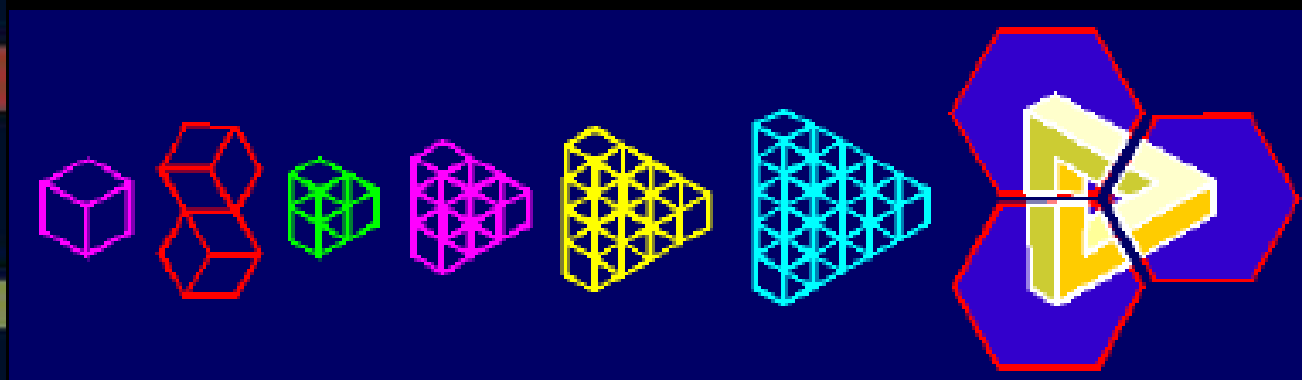
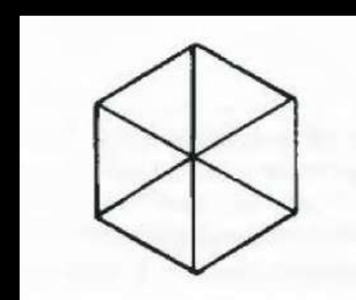




Development from Koffka cube to Penrose Tribar.



Tamás F. Farkas's Impossible Art:

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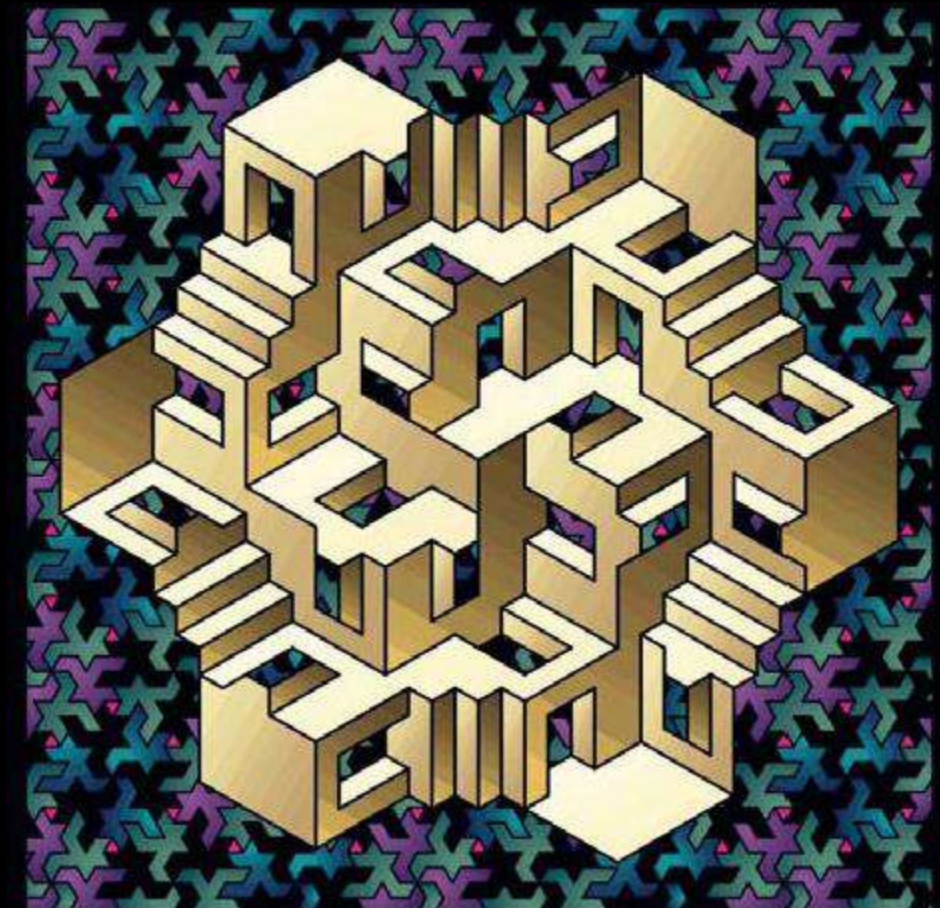


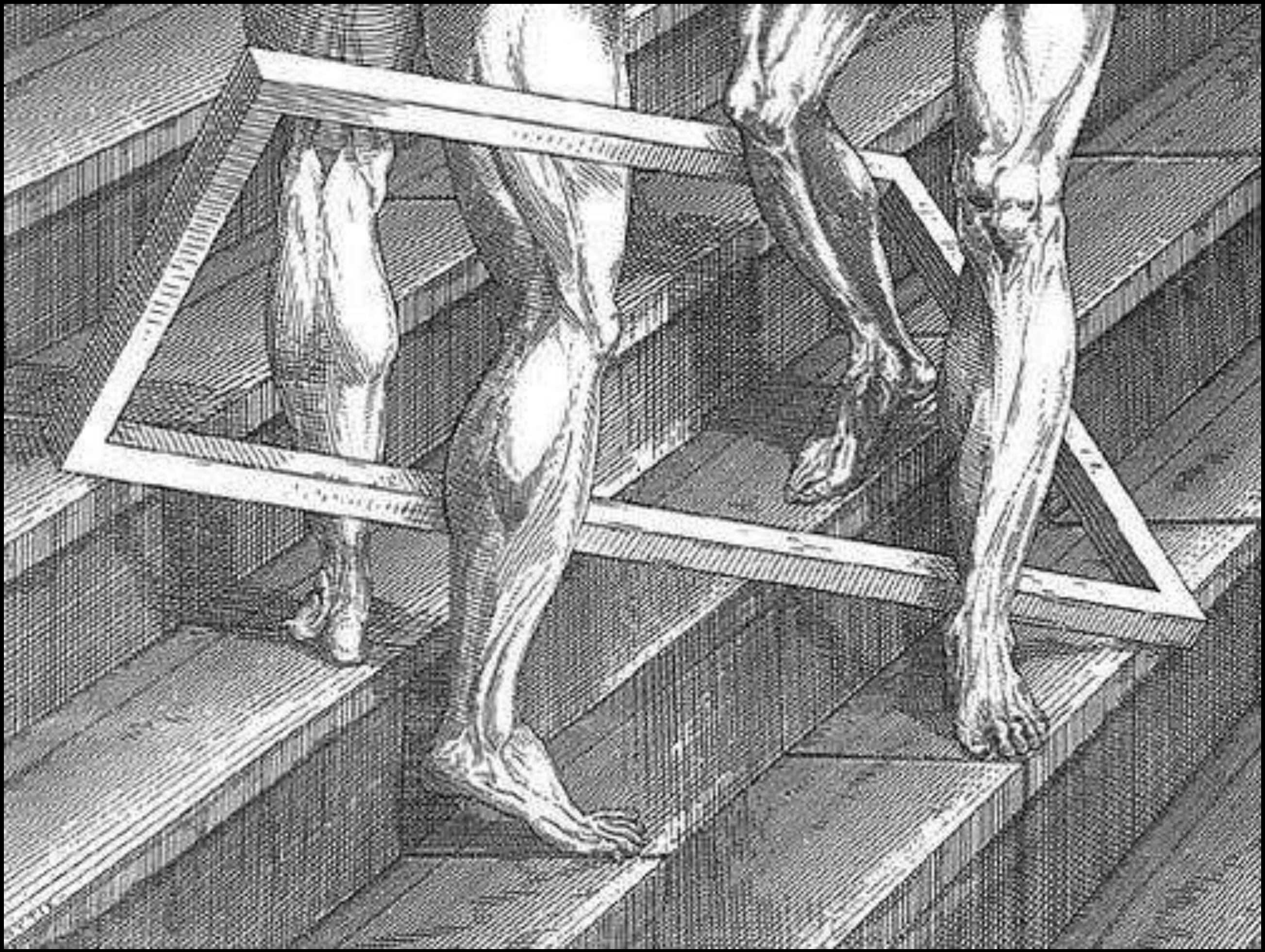
Tamás F. Farkas's Impossible Art:

Tamás F. Farkas's Impossible Art:

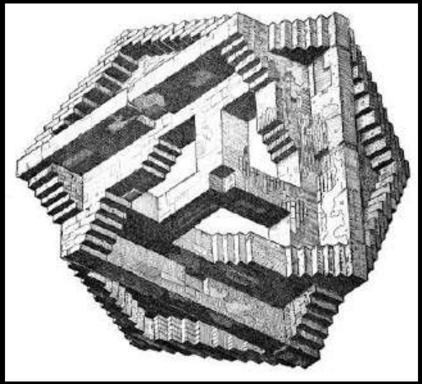
"Farkas's work defies categorization. If we want to label it (…) perhaps we could proceed from M. C. Escher's activity, that is, geometry is always at the root of his works. However, while Escher's geometry is always connected in some way to figurative representations (strange buildings, animal and human figures), **Farkas's work eschews any link to the 'real'. His art is built on clear-cut, geometric figures.** (…) **his pictures is about governing the space or the structure of the space** (…) Tamás F. Farkas's career is considerable, not only from the point of view of art but also science; **he looks at geometry not with the eye of a scientist nor that of an artist but both**, thus achieving results that can be utilised in unique ways, ways that would never have been possible with traditional geometry. So his works can, for example, be used to illustrate phenomena of other sciences based on mathematics (such as crystallography, quantum physics etc.), allowing us to better understand abstract-rational results incomprehensible by sensory organs."

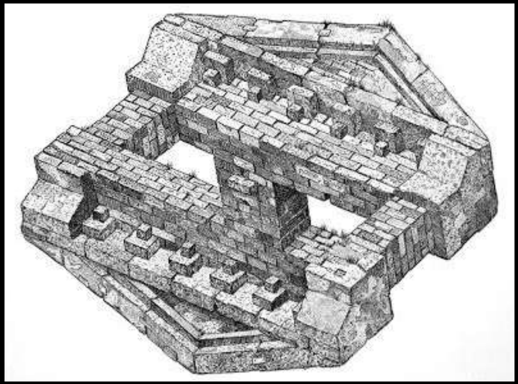
Dr. György Darvas, symmetrologist

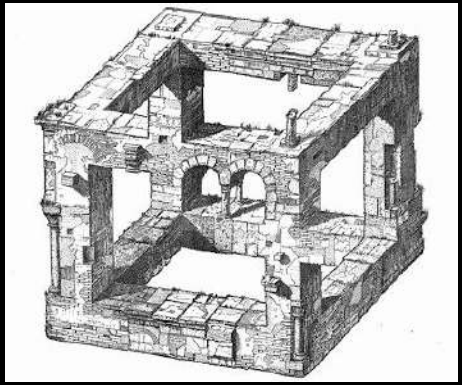
István Orosz's Impossible Staircase – a nonetheless philosophical reminiscence of Escher's Ascending and Descending:

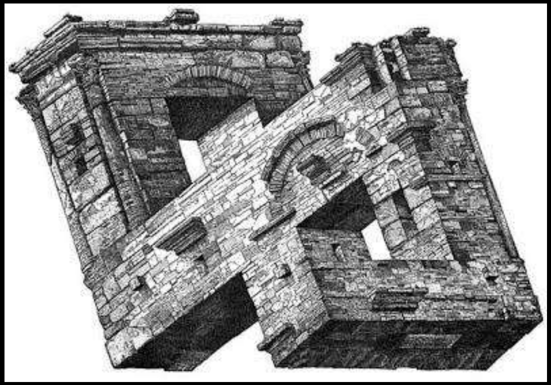


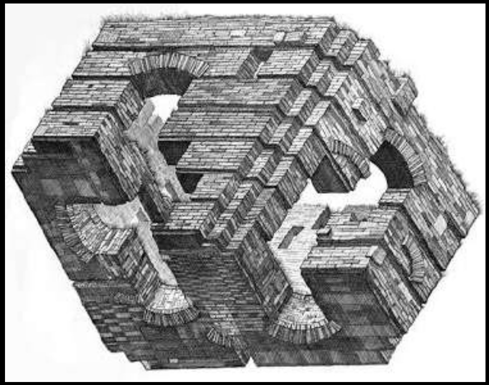
István Orosz's Impossible Buildings:

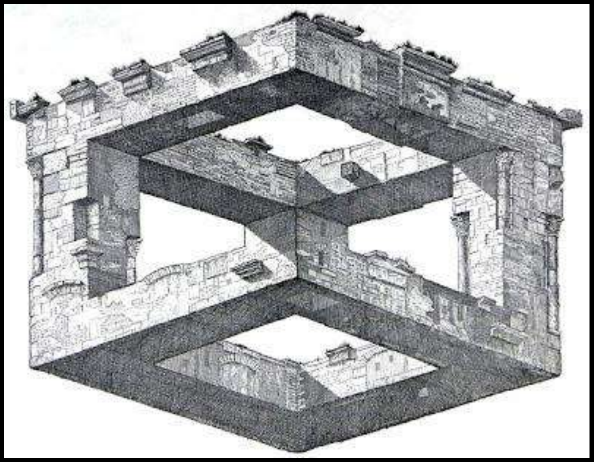


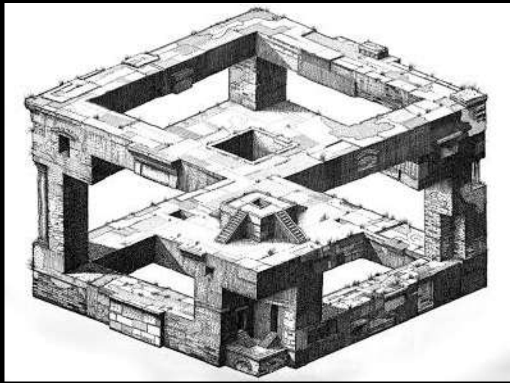


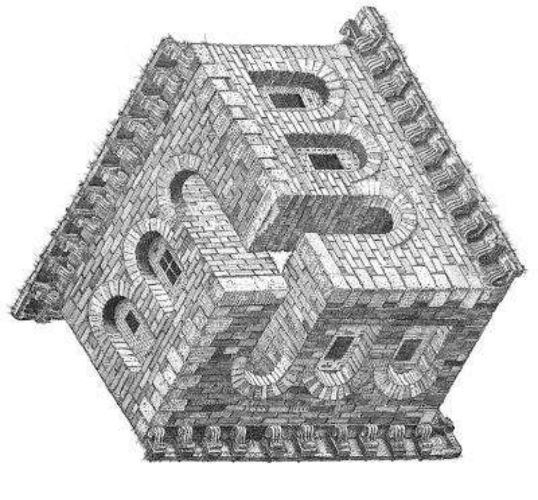






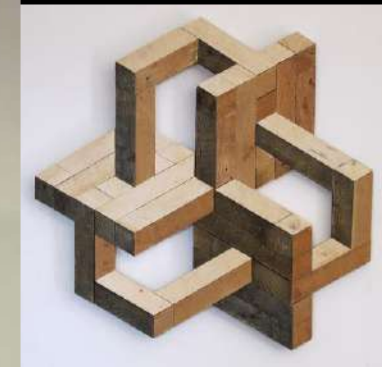


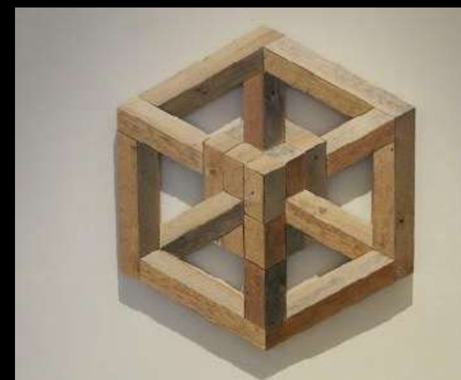
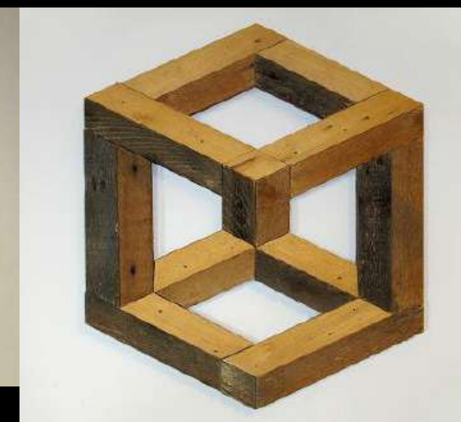
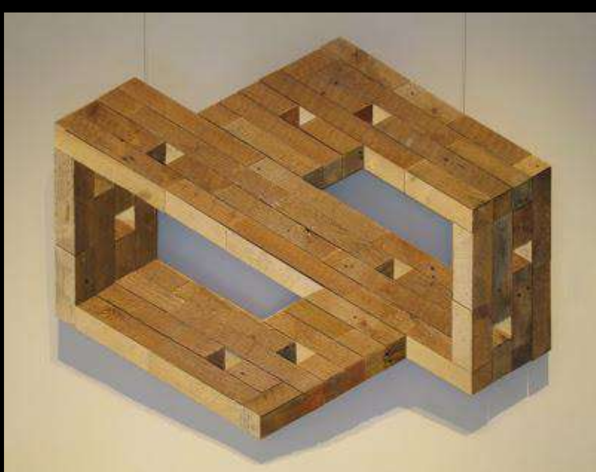
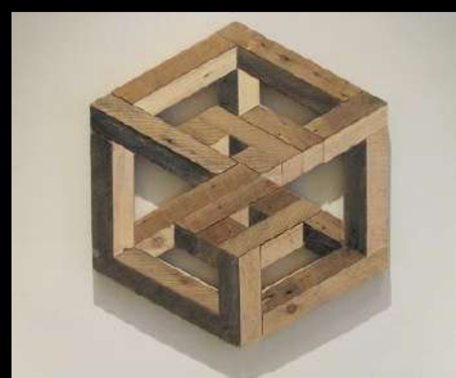
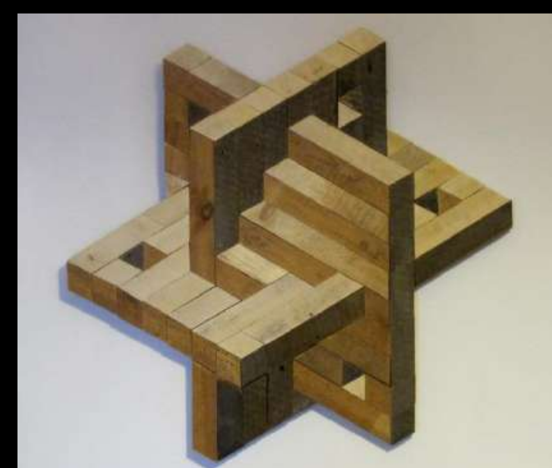




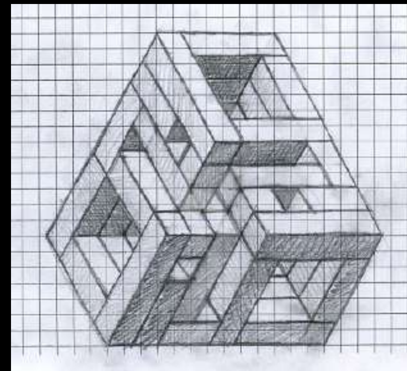
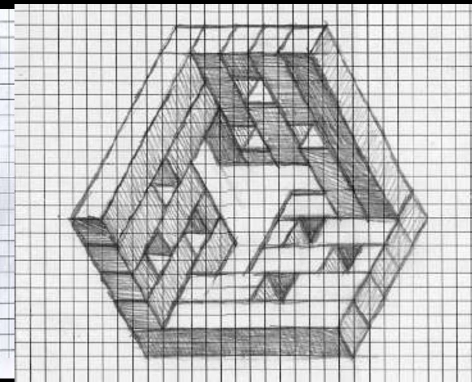
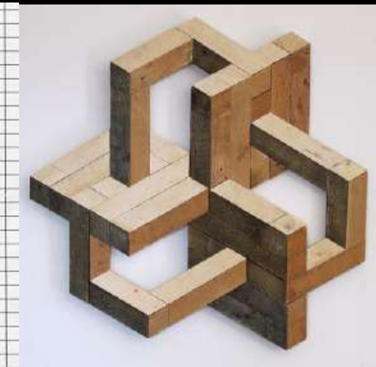
István Orosz's Impossible Planks:

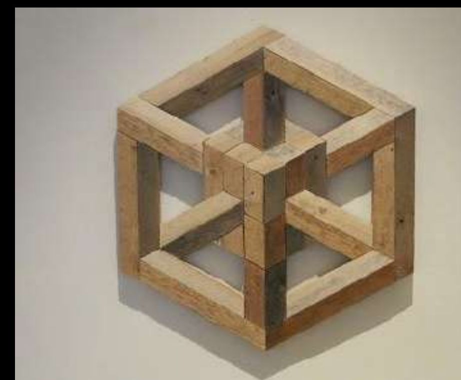
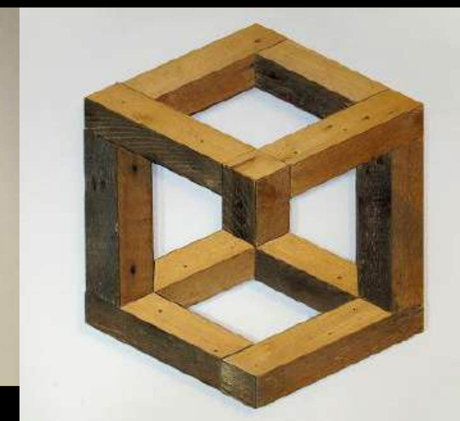
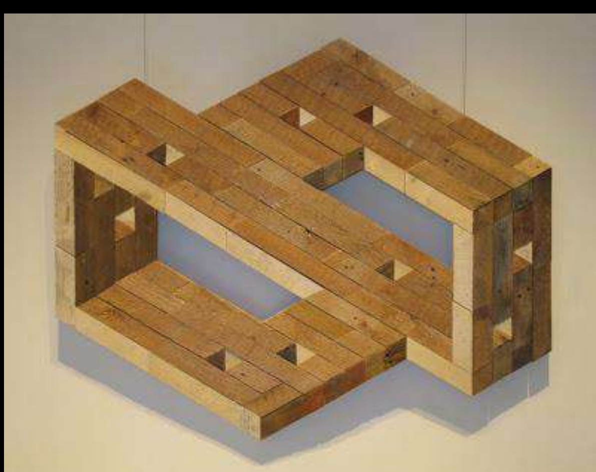
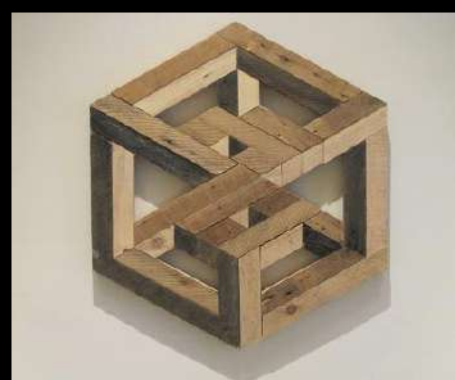
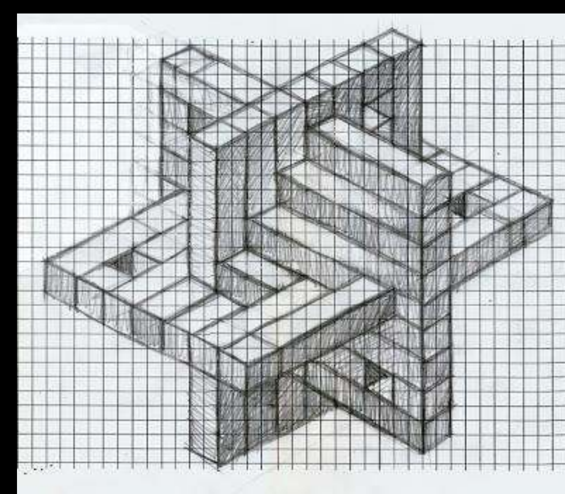




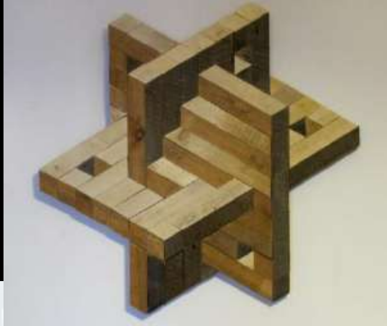
István Orosz's Impossible Designs:

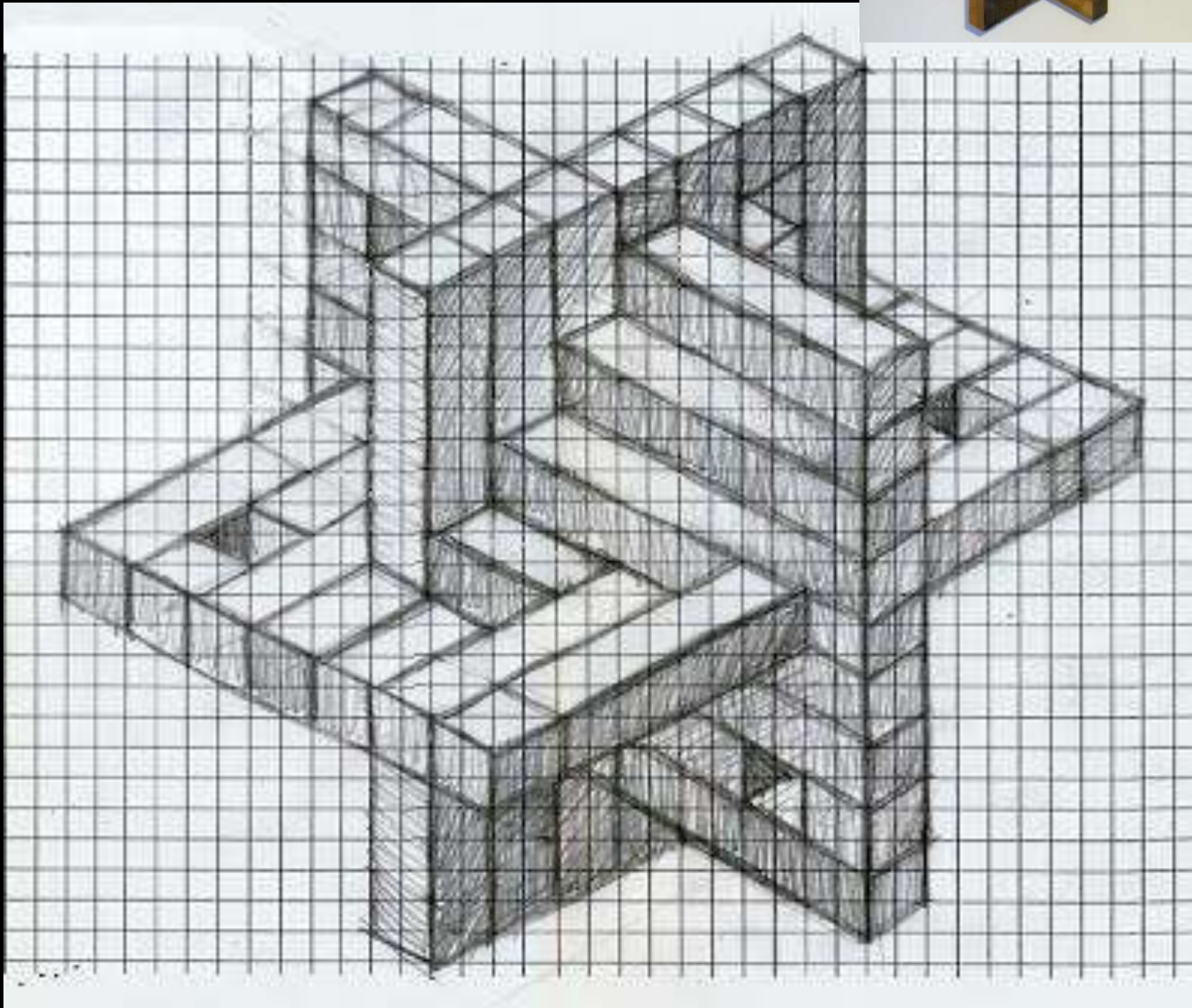




István Orosz's Impossible Designs:

Video: ***http://utisz-utisz.blogspot.hu/p/mertan.html***





"The procedure is a piece of cake: nailing. But the precedent is maybe more interesting. After changing the roof some planks had left in the garden and they became black. Some other planks we stored in the attic, and those became brown. Then I bought some new planks too, which were white."

István Orosz in personal communication


Hyllning till
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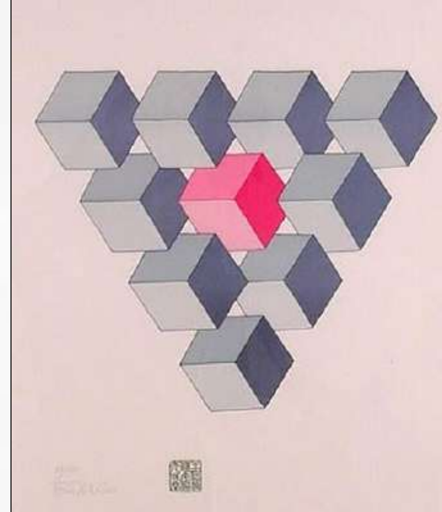
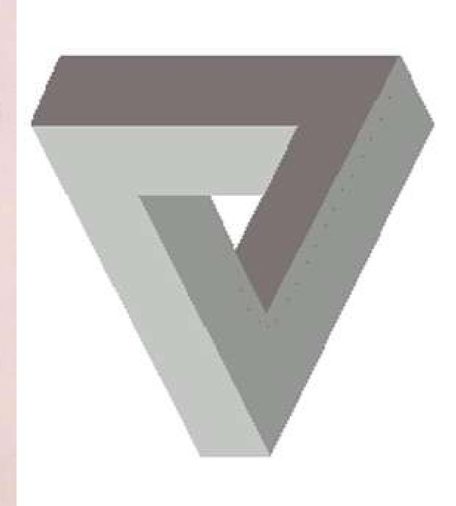
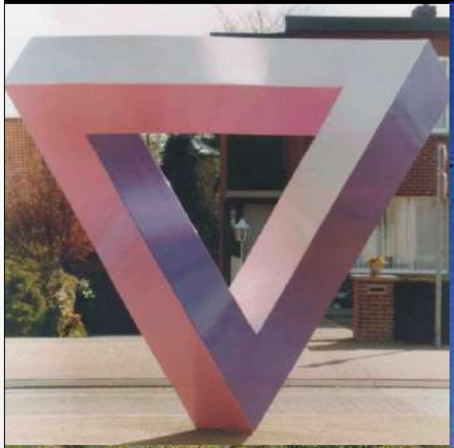




[Impossible Triangle]

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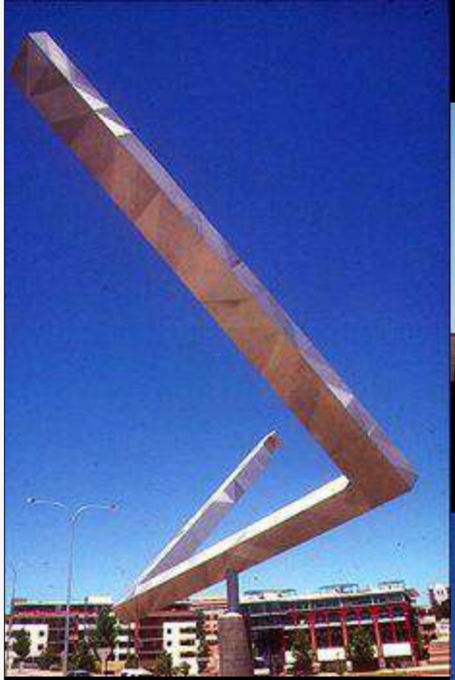


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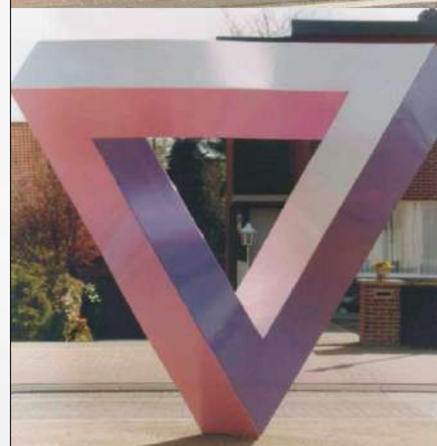

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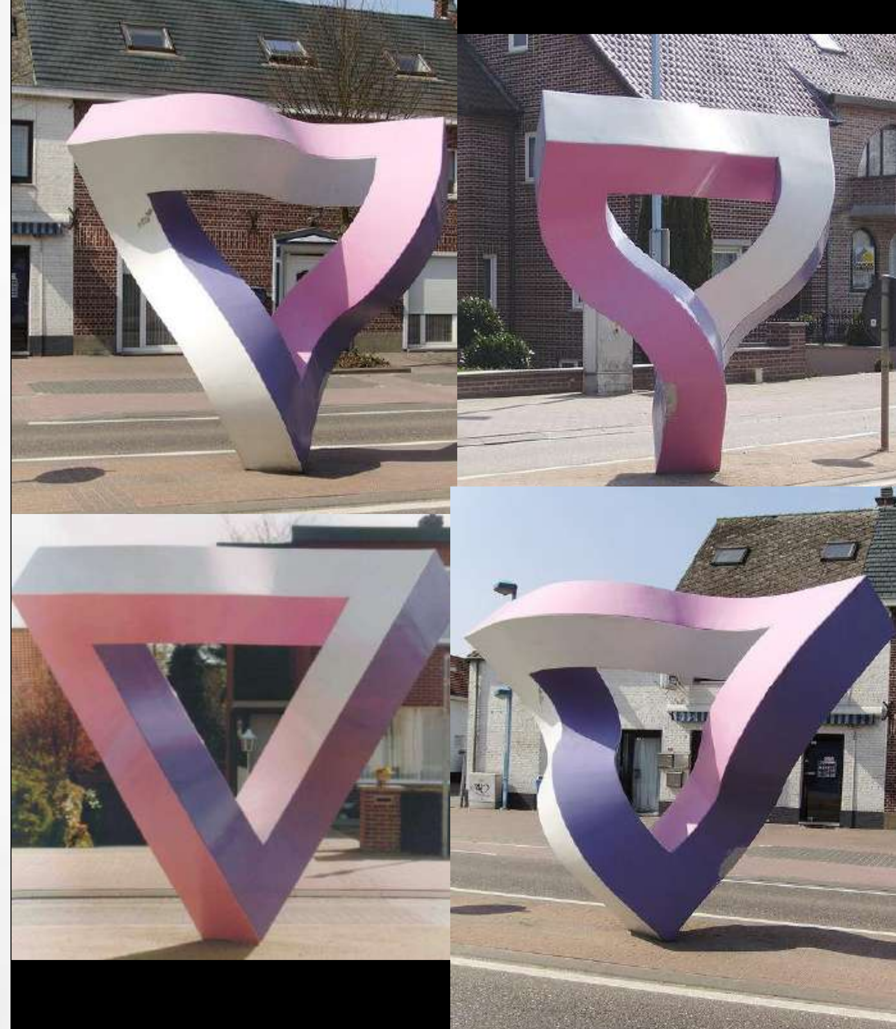

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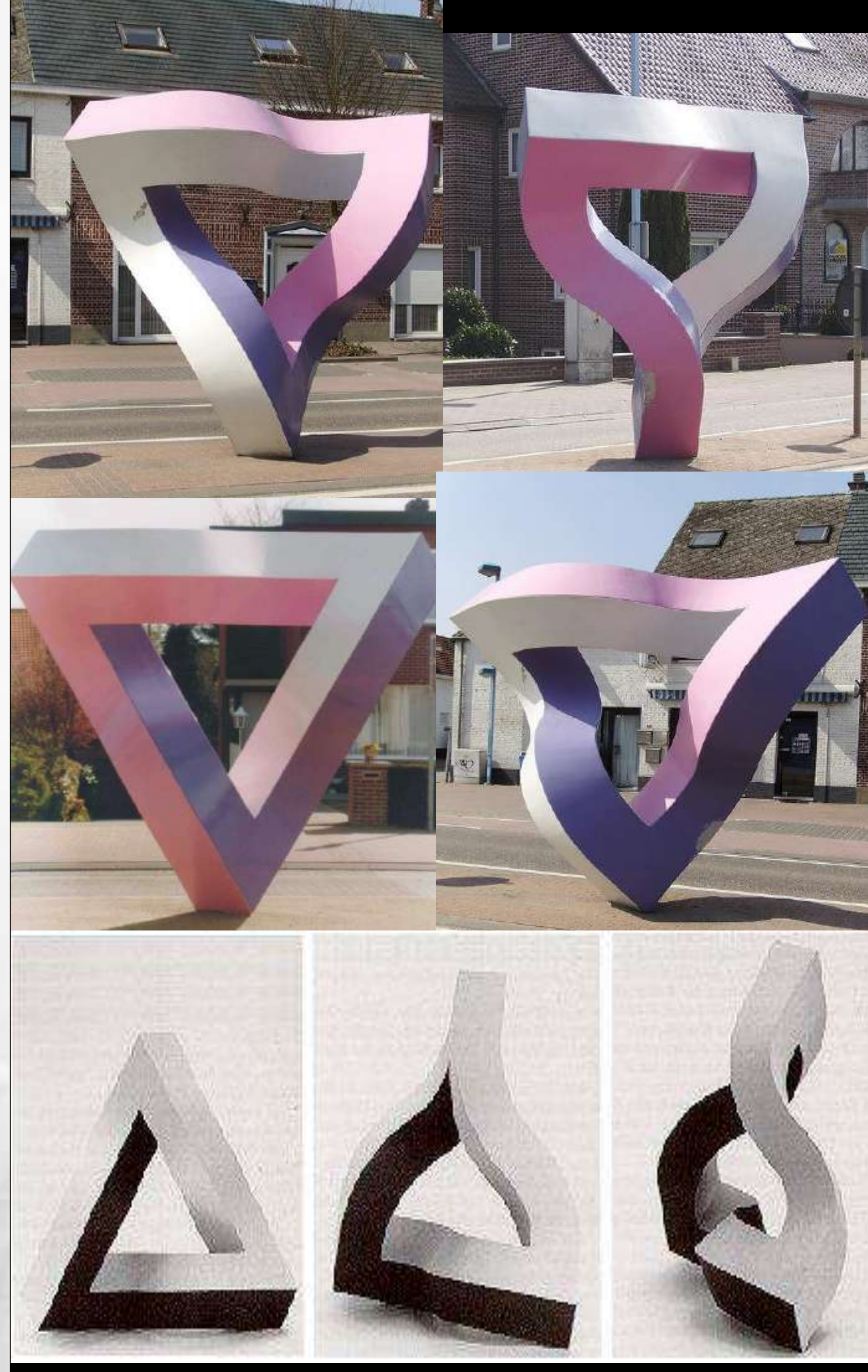

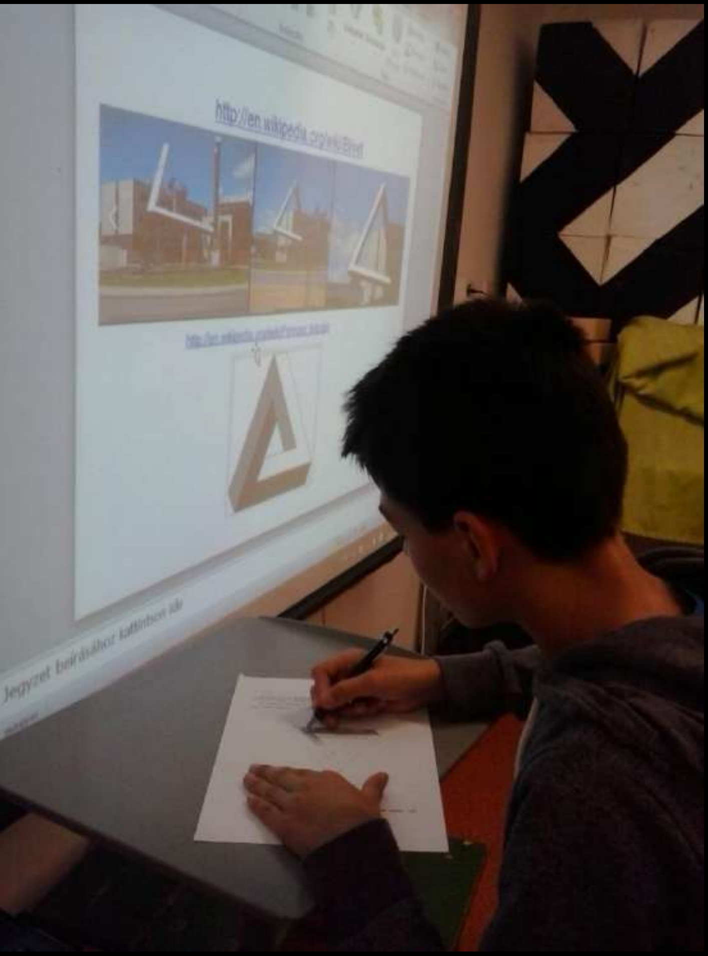
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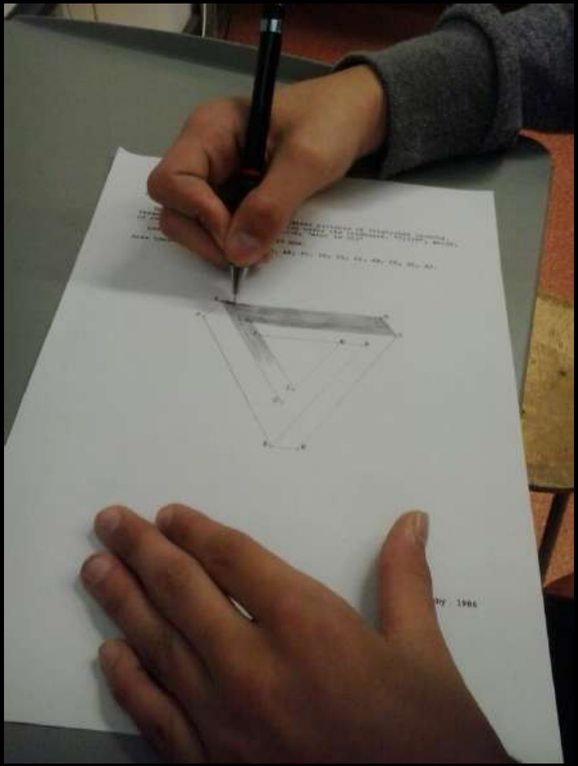

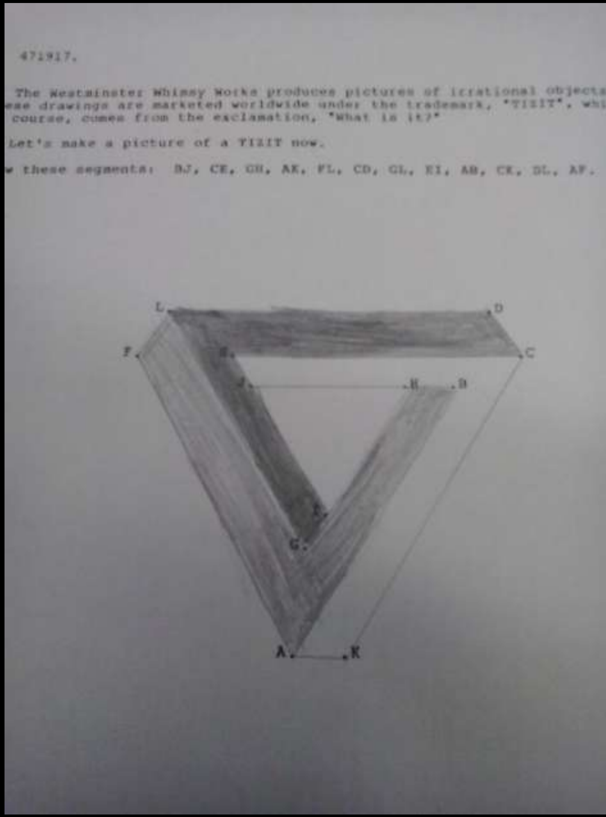
471917.
The Westminster Whimsy Works produces pictures of irrational objects
ese drawings are marketed worldwide under the trademark, "TIZIT", whi
course, comes from the exclamation, "What is it?"
Let's make a picture of a TIZIT now.
w these segments: BJ, CE, GH, AK, FL, CD, GL, EI, AB, CK, DL, AF.
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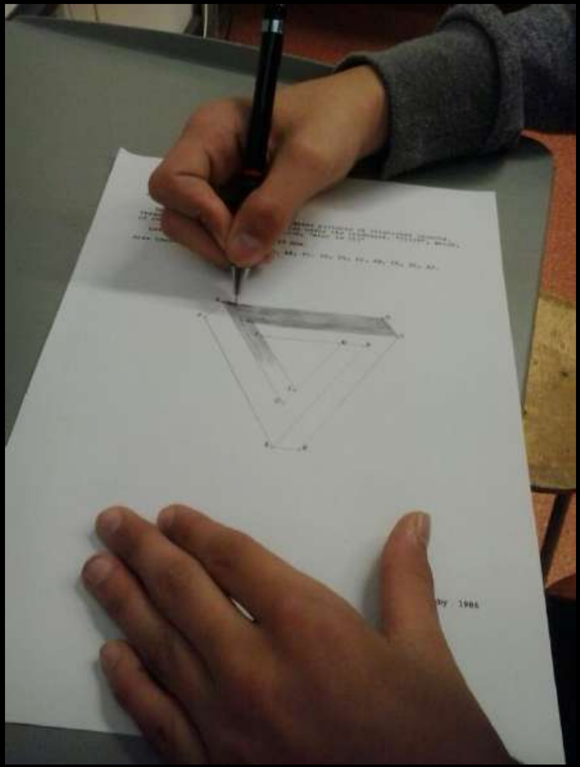

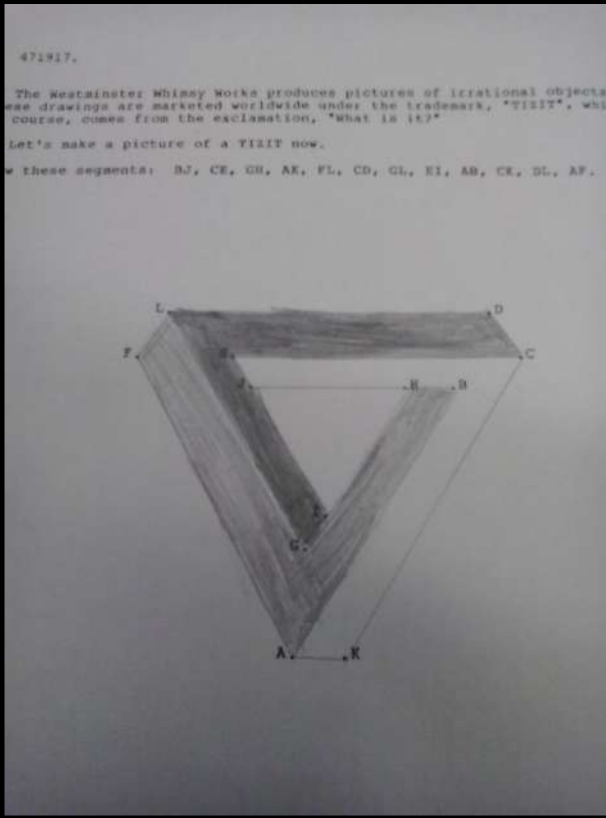
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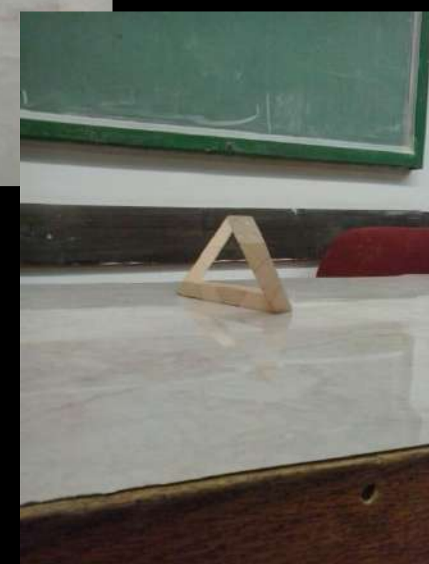
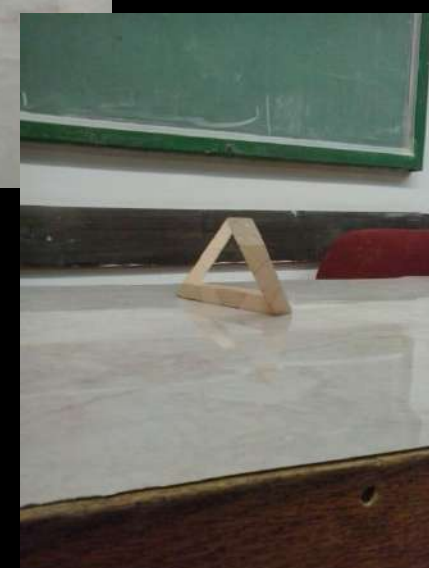
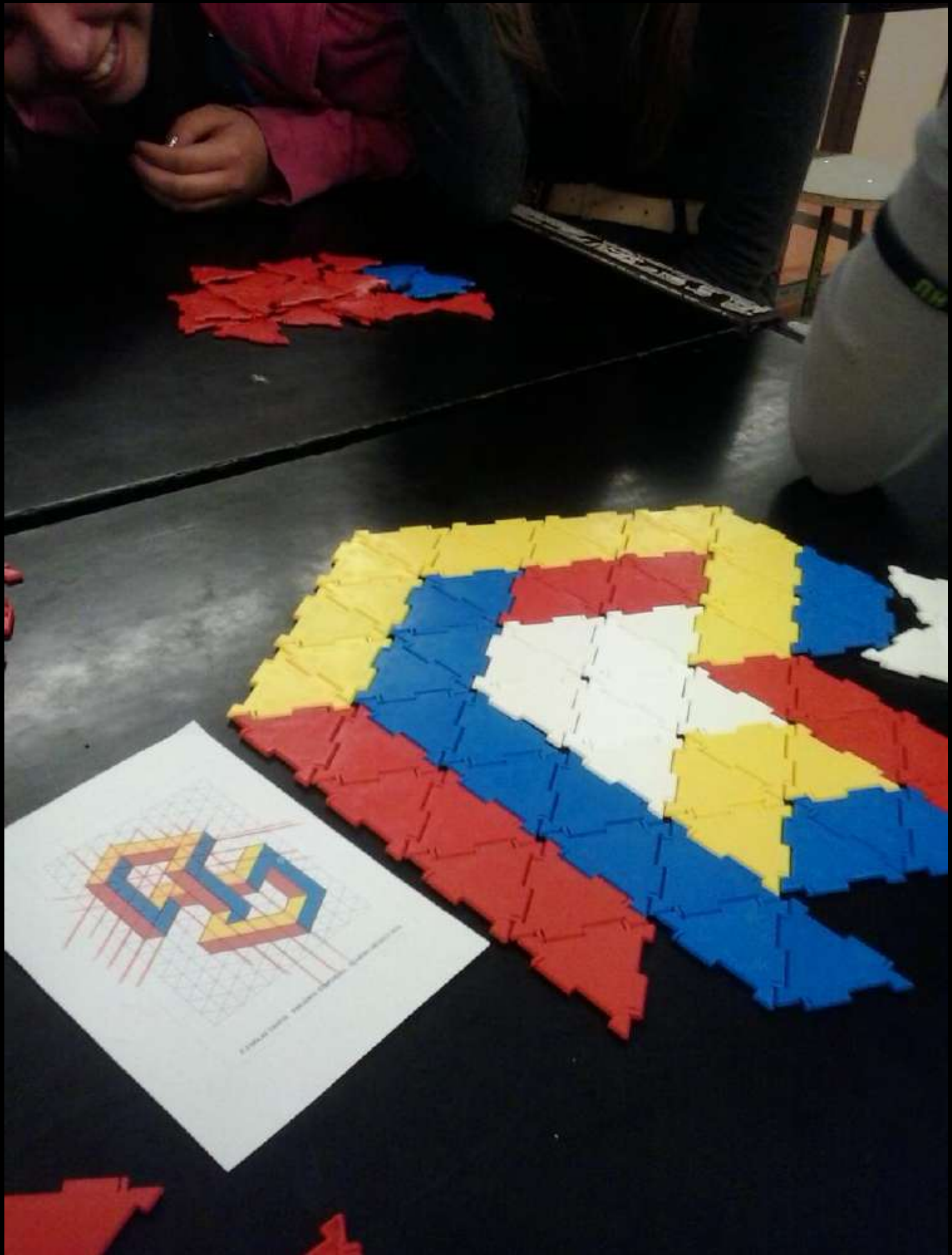









http://en.wikipedia.org/wiki/Blivet
MATHMAKER


http://en.wikipedia.org/wiki/Blivet

László Vörös's Impossible Research and Experience Workshop based on F. Farkas's, Victor Vasarely's, Escher's Impossible Figures:

Vörös builds **spatial reconstructions of impossible figure's pictures with help of 3-dimensional models of the 6-dimensional cube and of derived lower dimensional parts of those. The isometric, isogonal axonometric projection of these joins a net of regular triangles.** Vörös shows and tells how to transform these spatial shapes to get the same pictures by oblique parallel or central projections.

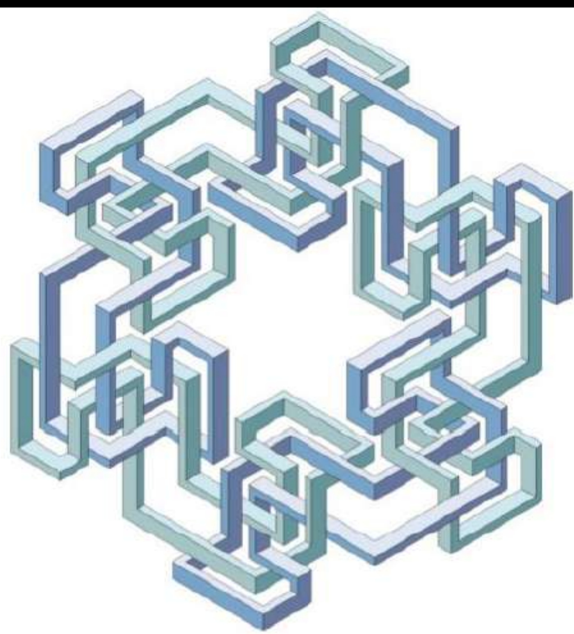


Fig. 1: *Picture plan of T. F. Farkas*

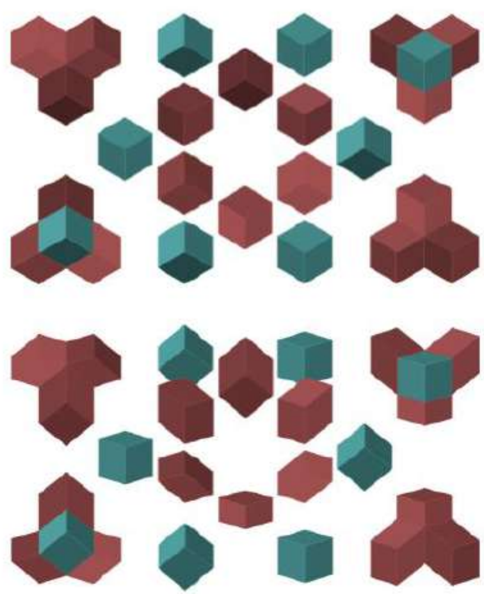


Fig. 2: *Applied 3D elements*

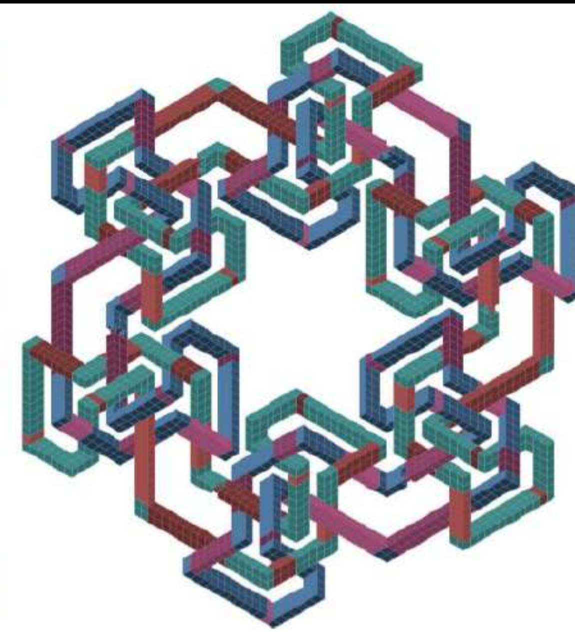


Fig. 3: *Modified 3D reconstruction*

László Vörös's Impossible Research and Experience Workshop based on F. Farkas's, Victor Vasarely's, Escher's Impossible Figures:

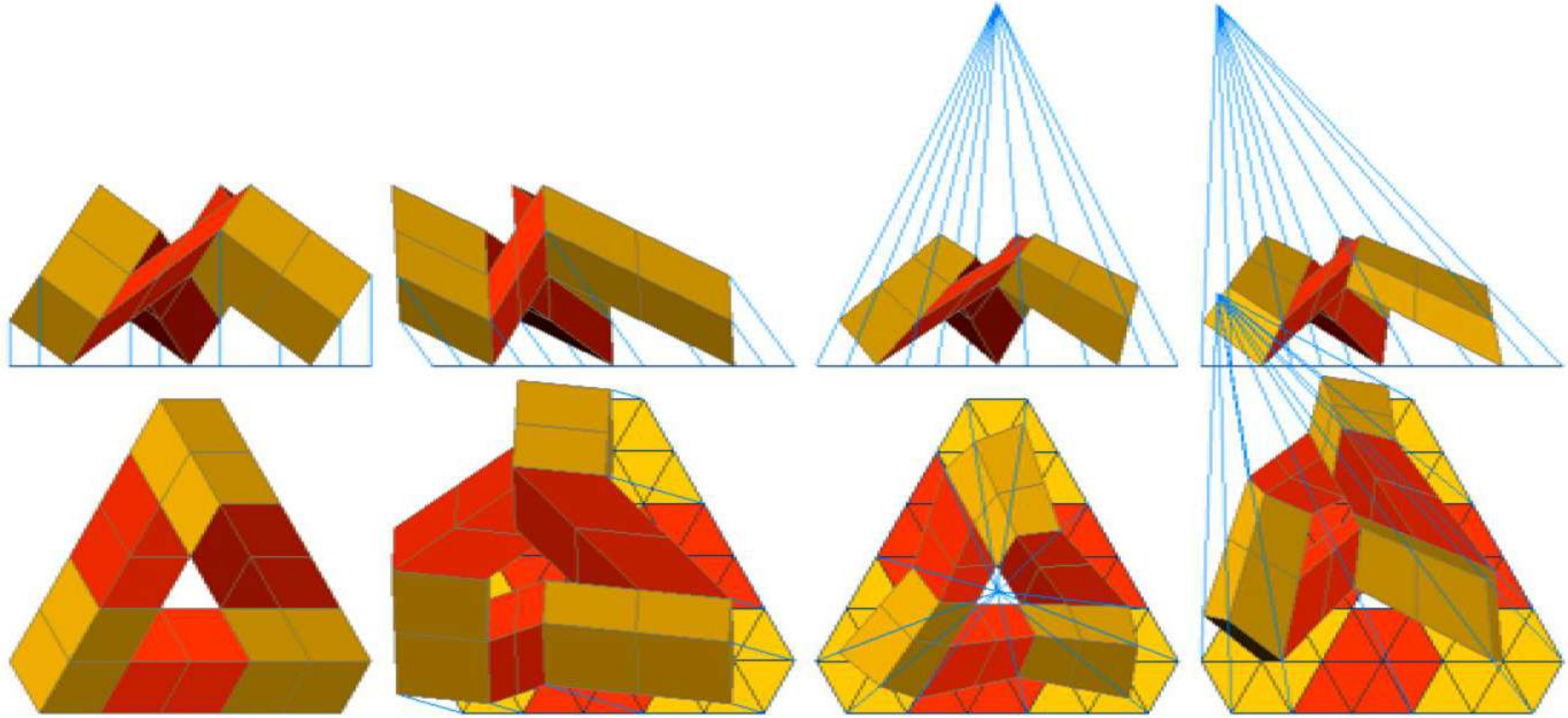
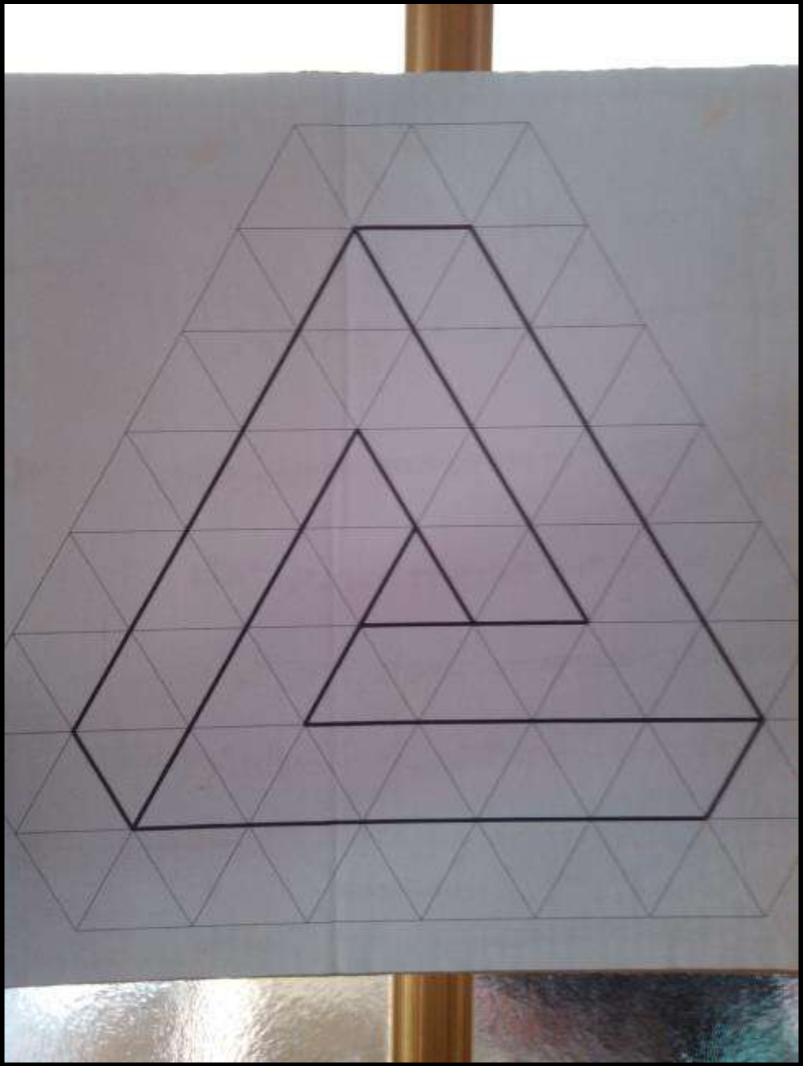
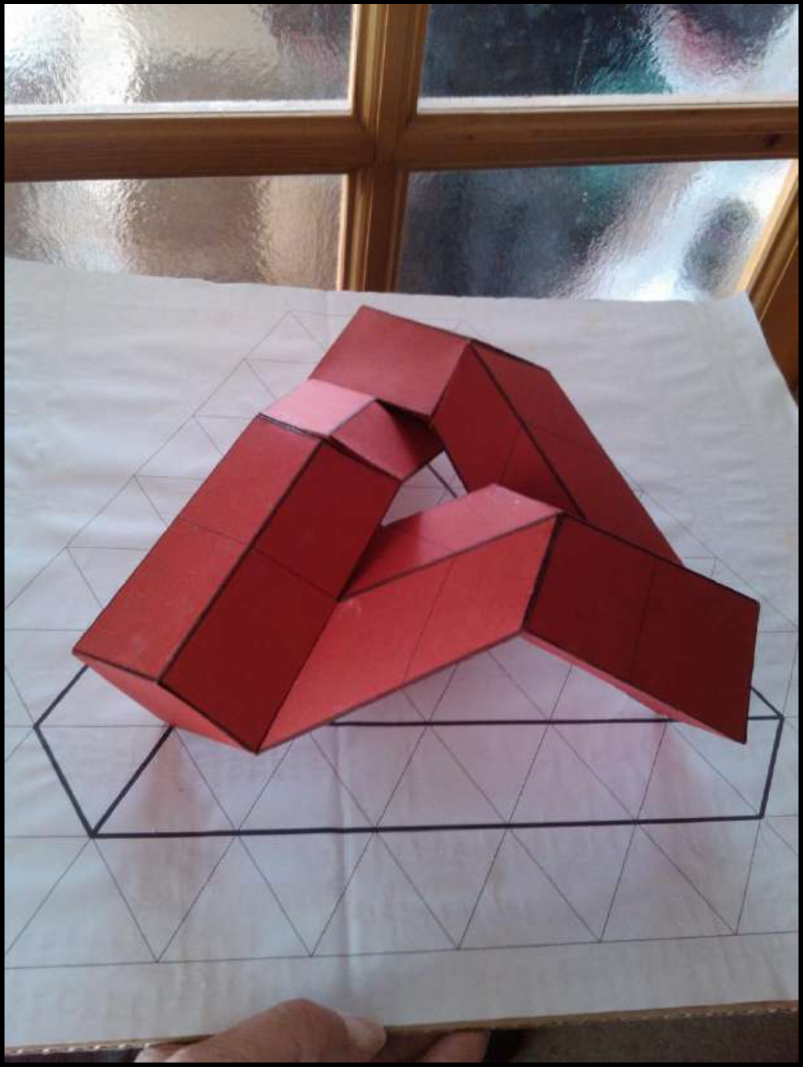


Fig. 5a-d: *Modified shapes and different kinds of projections creating the image of the Penrose triangle*

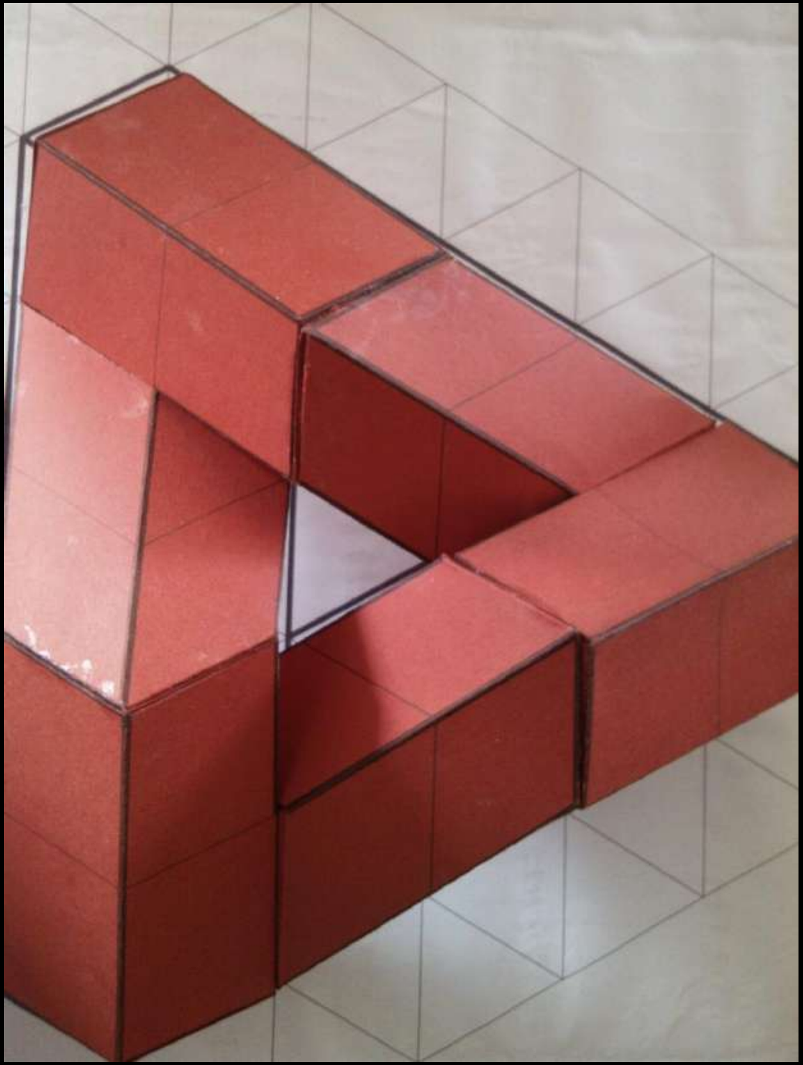
László Vörös's Impossible Research and Experience Workshop based on F. Farkas's, Victor Vasarely's, Escher's Impossible Figures:



László Vörös's Impossible Research and Experience Workshop based on F. Farkas's, Victor Vasarely's, Escher's Impossible Figures:



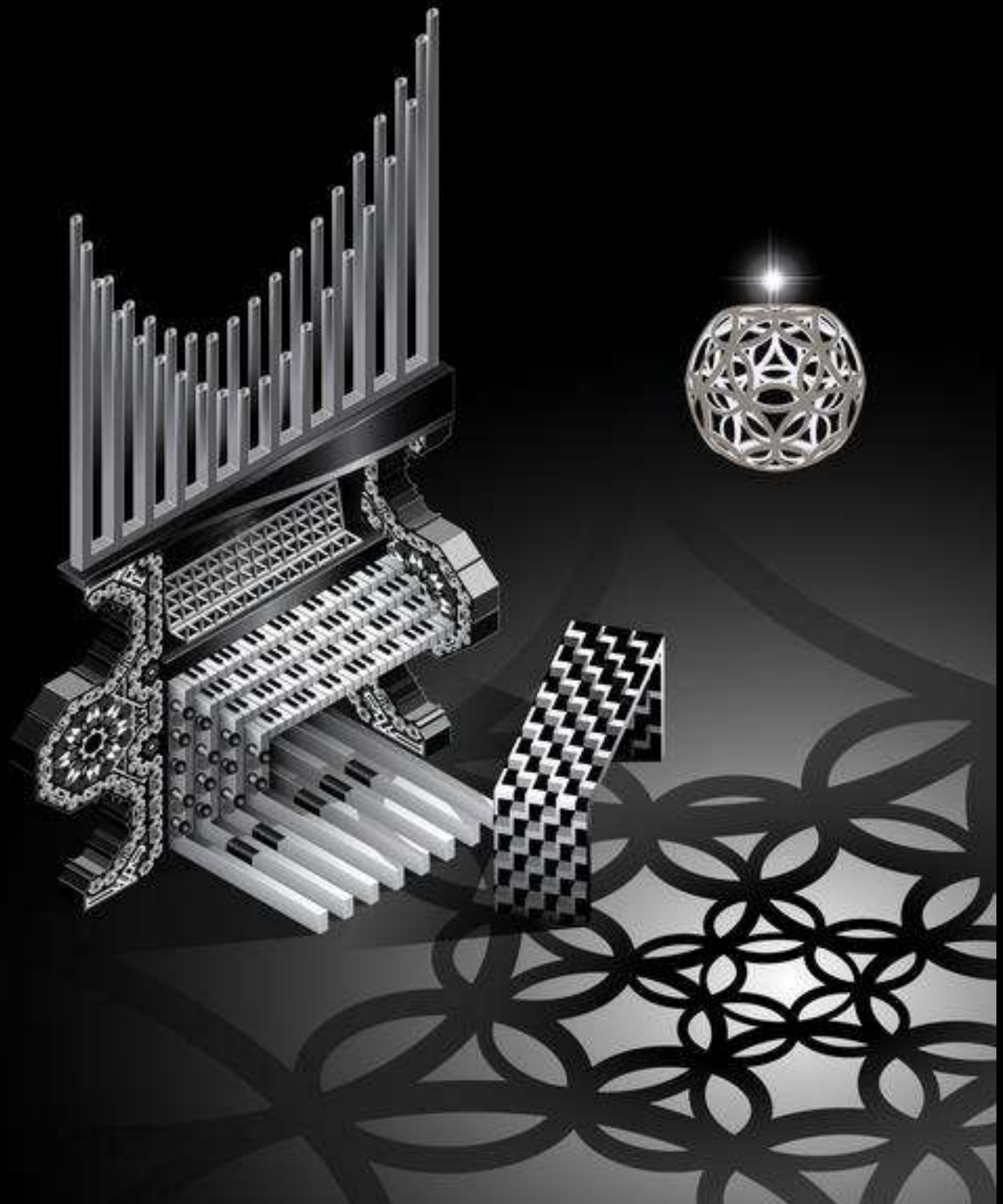
László Vörös's Impossible Research and Experience Workshop based on F. Farkas's, Victor Vasarely's, Escher's Impossible Figures:



László Vörös's Impossible Research and Experience Workshop based on F. Farkas's, Victor Vasarely's, Escher's Impossible Figures:

Tiffany Inglis' Impossible Research and Impossible Art:

As we have seen, there are various techniques for constructing impossible figures both in 2D and 3D, but most **involve tricks that are not easily generalizable.** Inglis describes a simple framework that uses axonometric blocks for construction and permits pseudo-3D manipulations even though the figure may not have a real 3D counterpart.



Koji Miyazaki's Impossible Research on Multidimensional Impossible Polycubes:

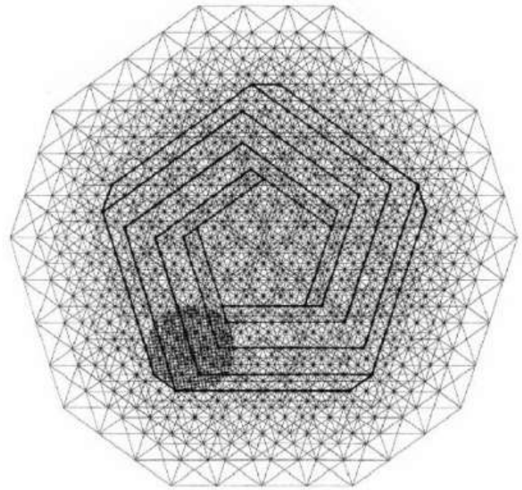


Figure 13 : *An impossible 5-bar embedded in an impossible 5-polycube. The shaded decagon highlights a 5-cube as a base of a 6-cubic prism. CG: M. Ishii.*

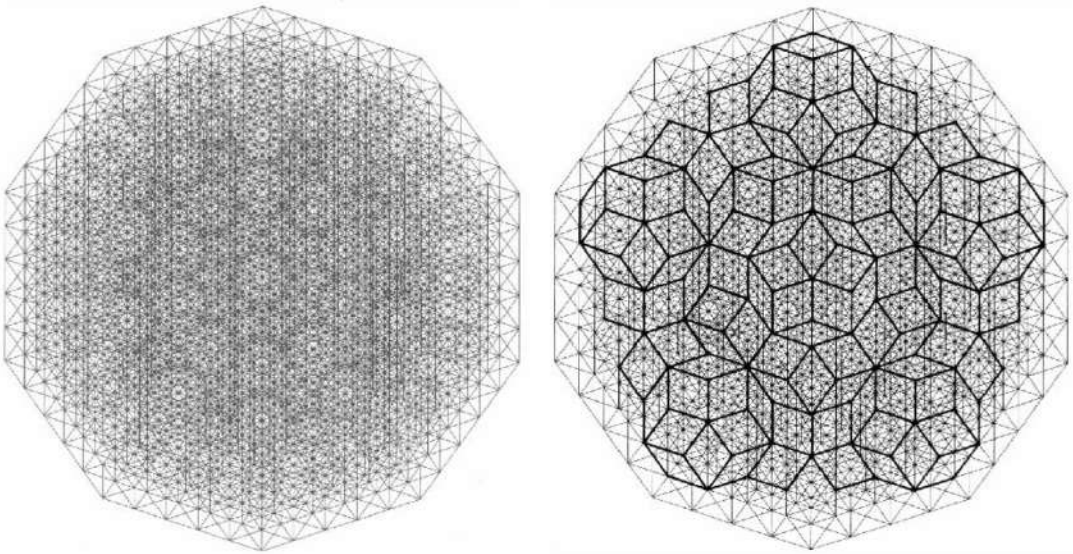
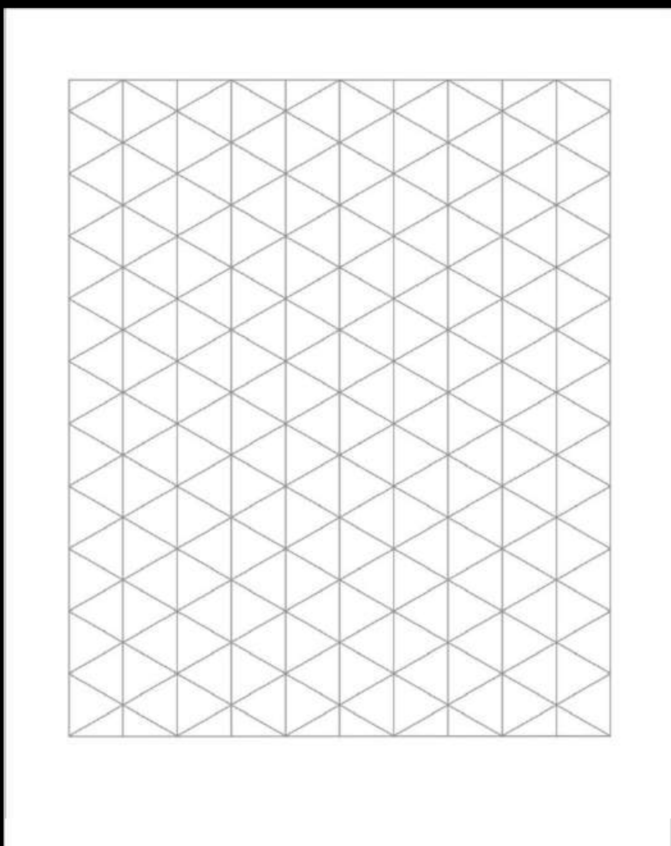
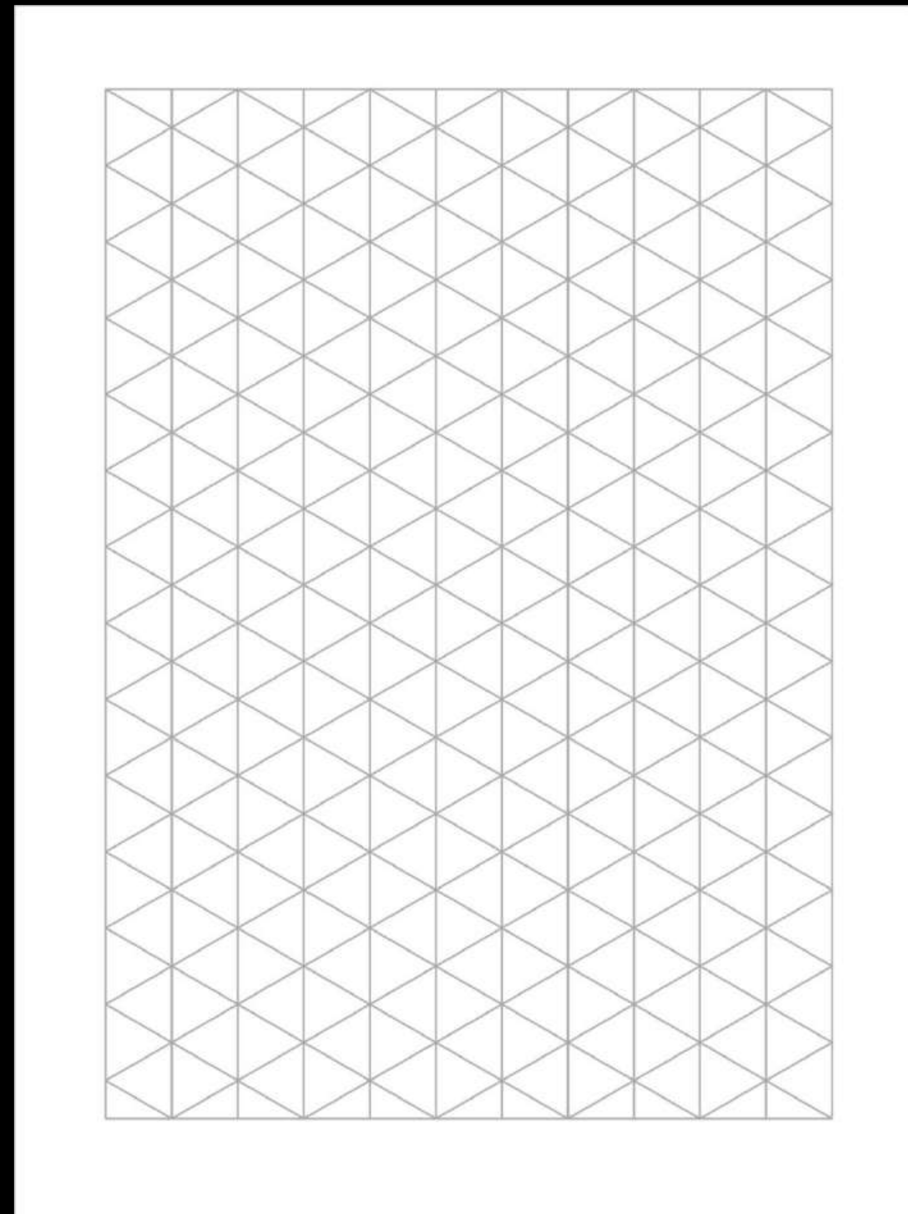
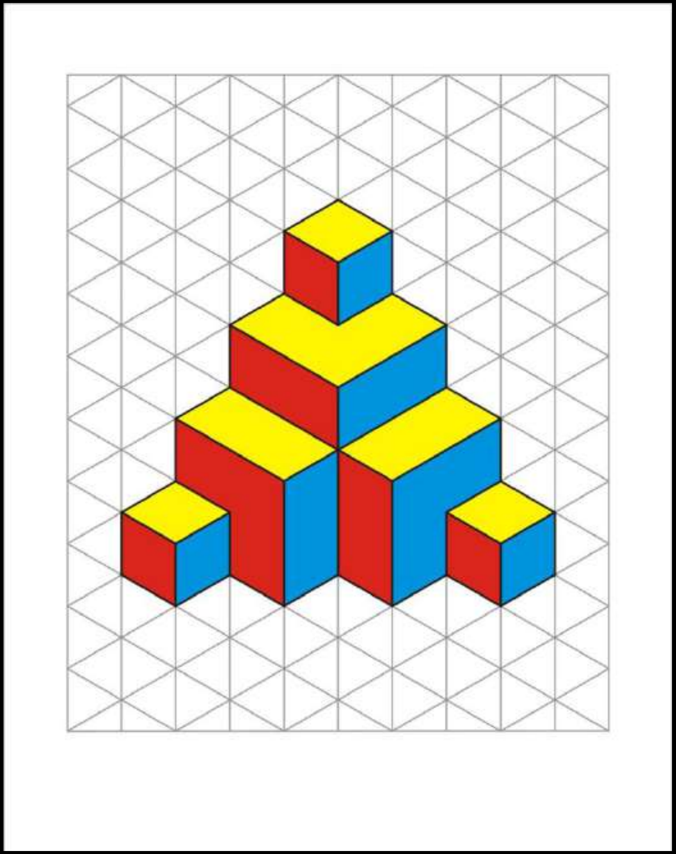
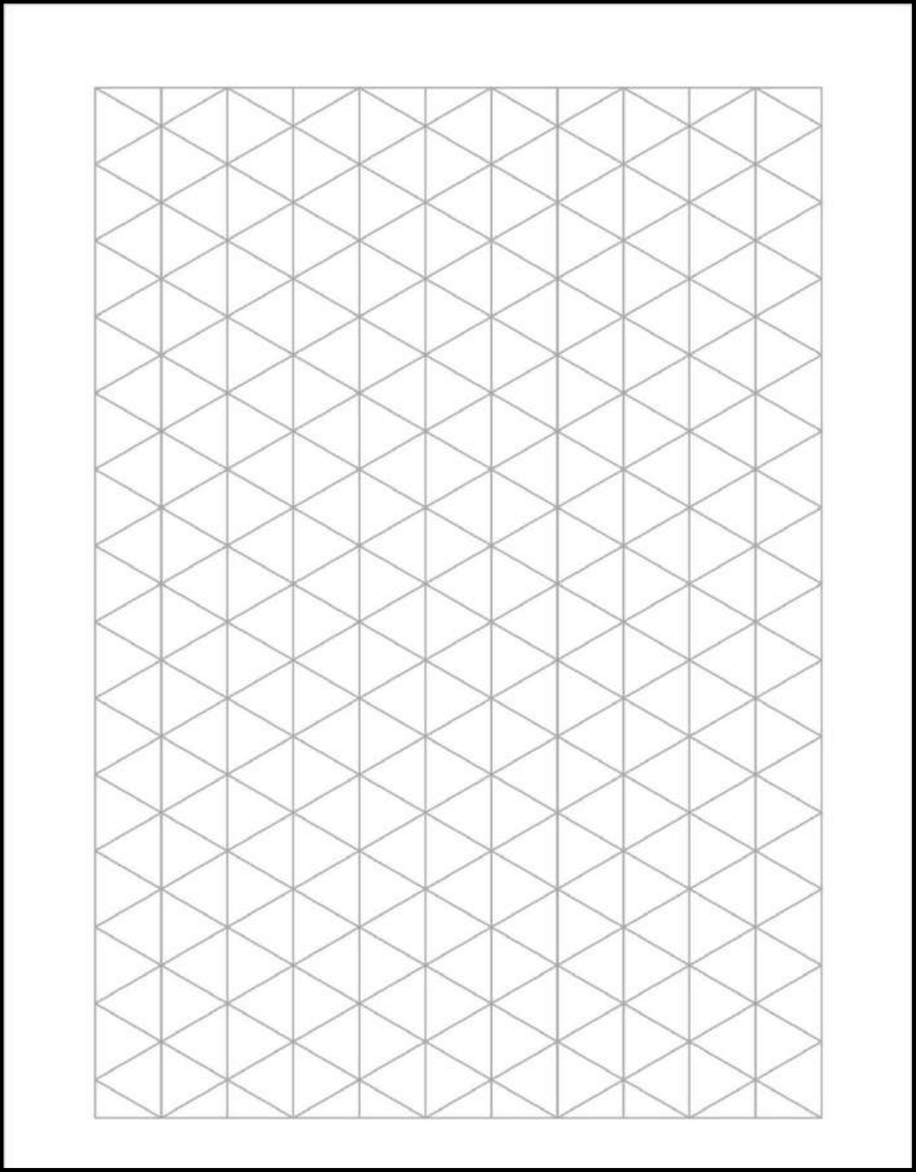


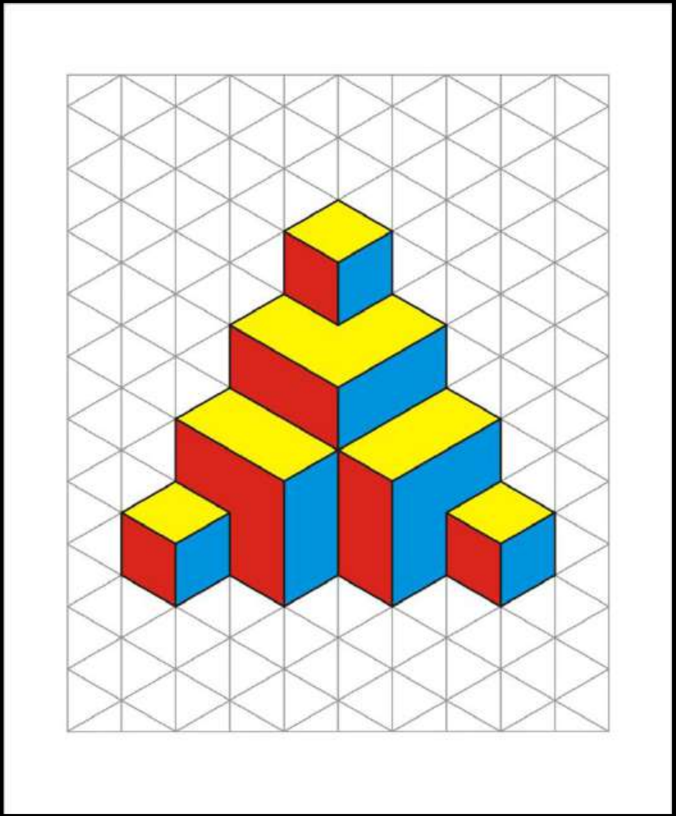
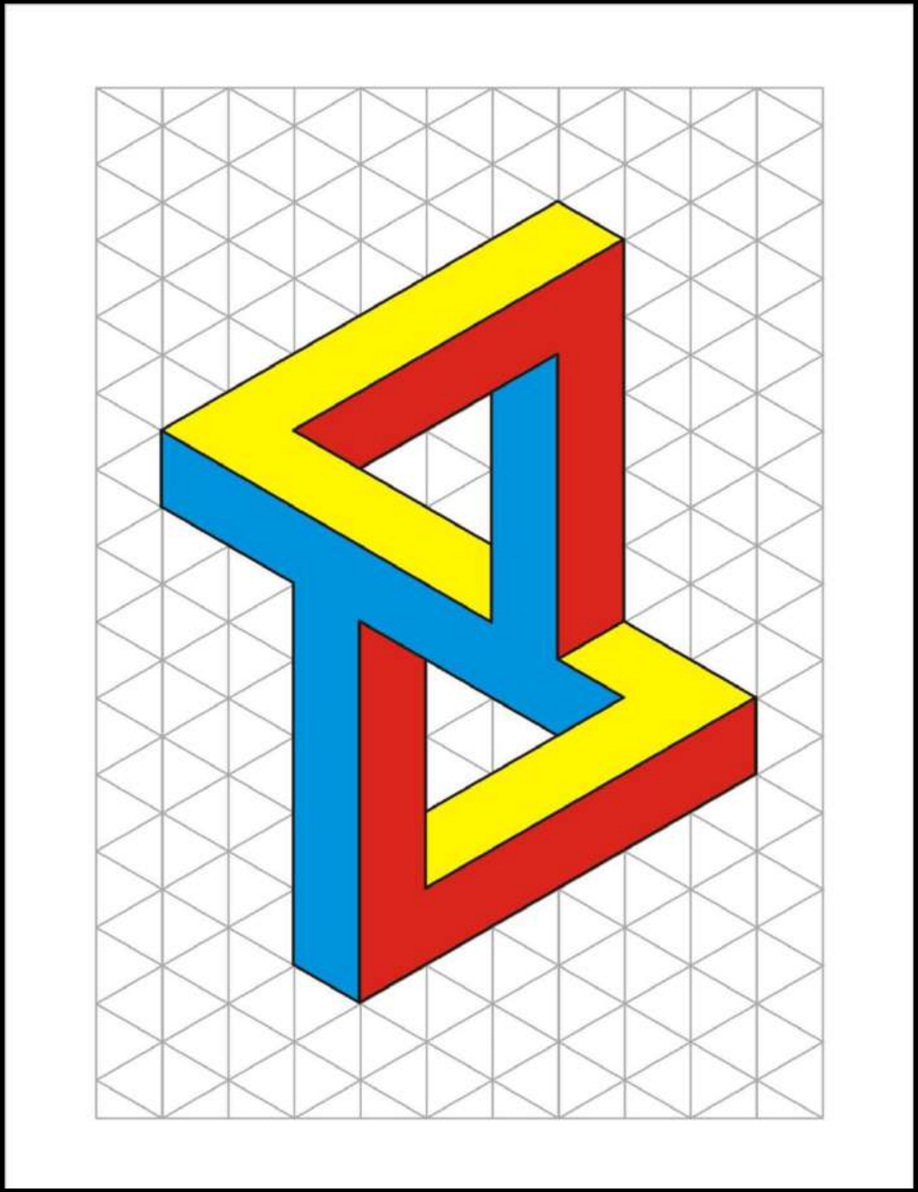
Figure 14 : *The transparent representation of the projection onto 2-space of a 5-polycube (left) and a radial quasi-periodic pattern appearing in it (right). CG: M. Ishii.*

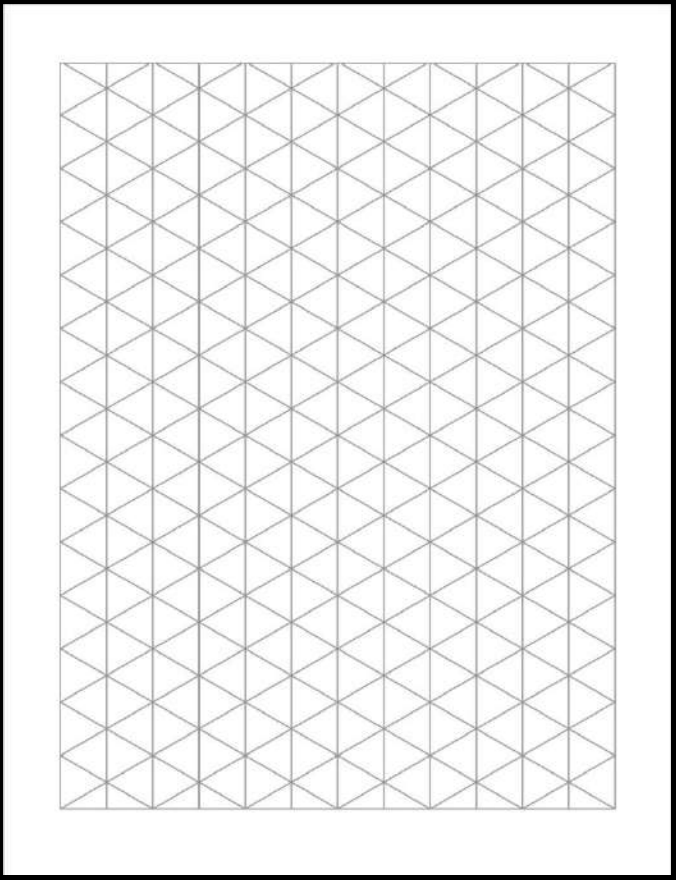


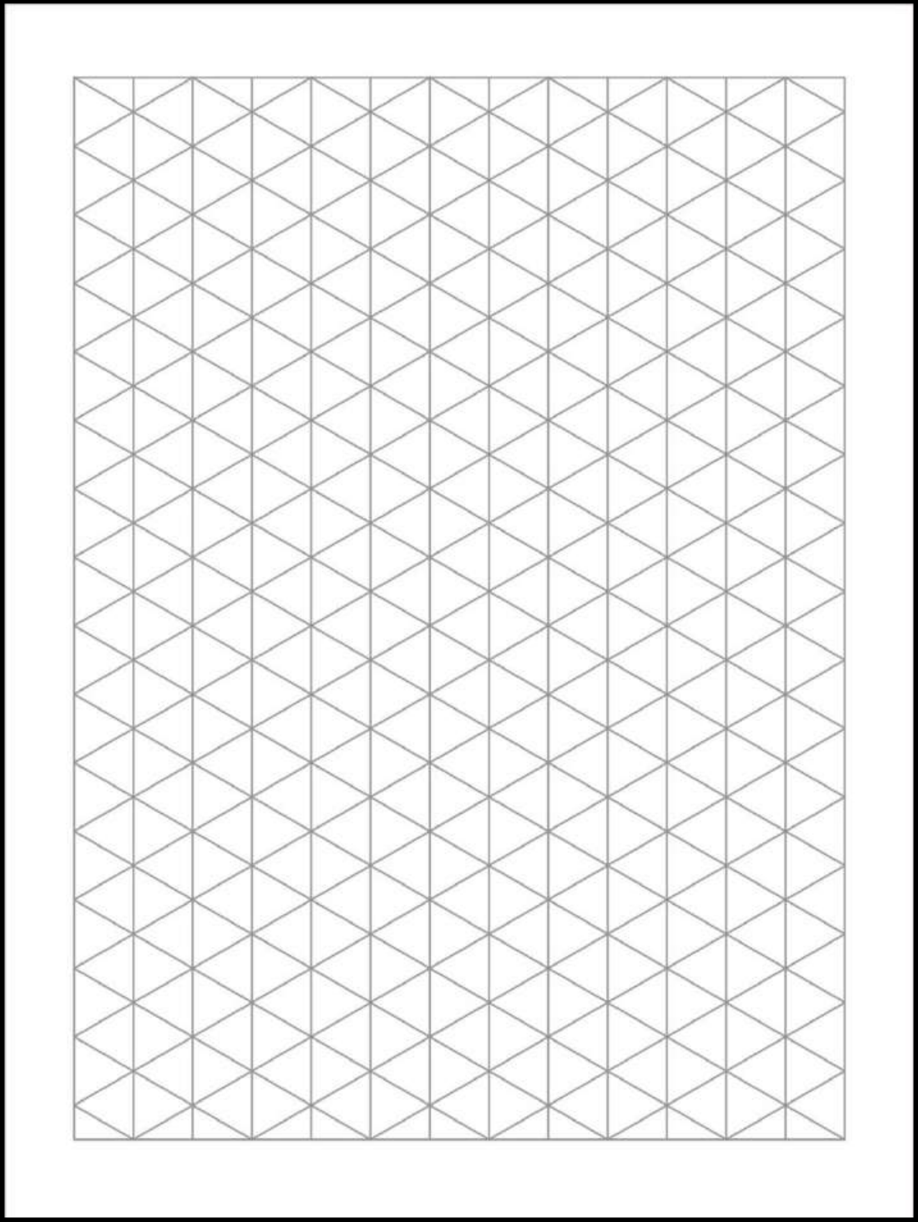


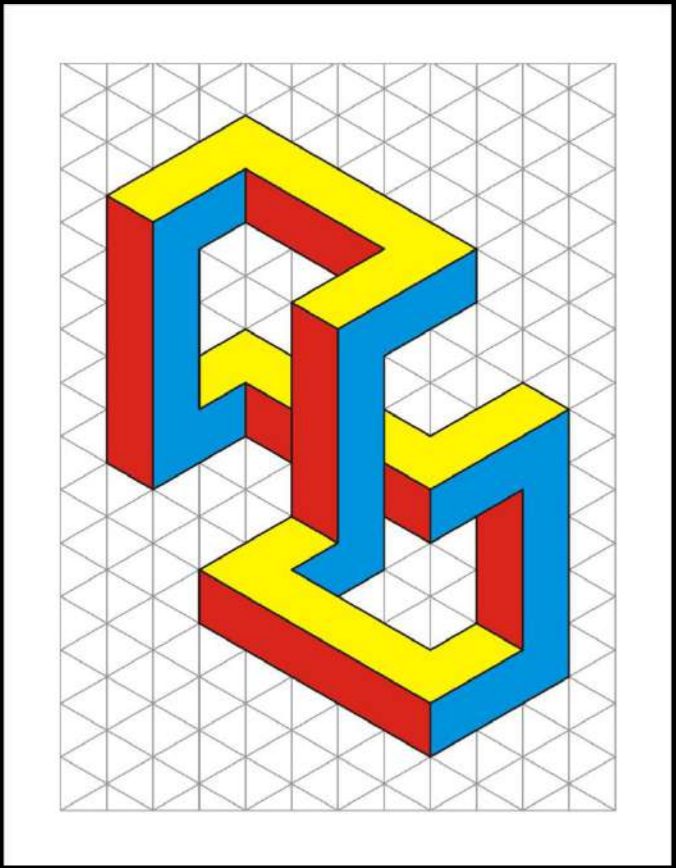


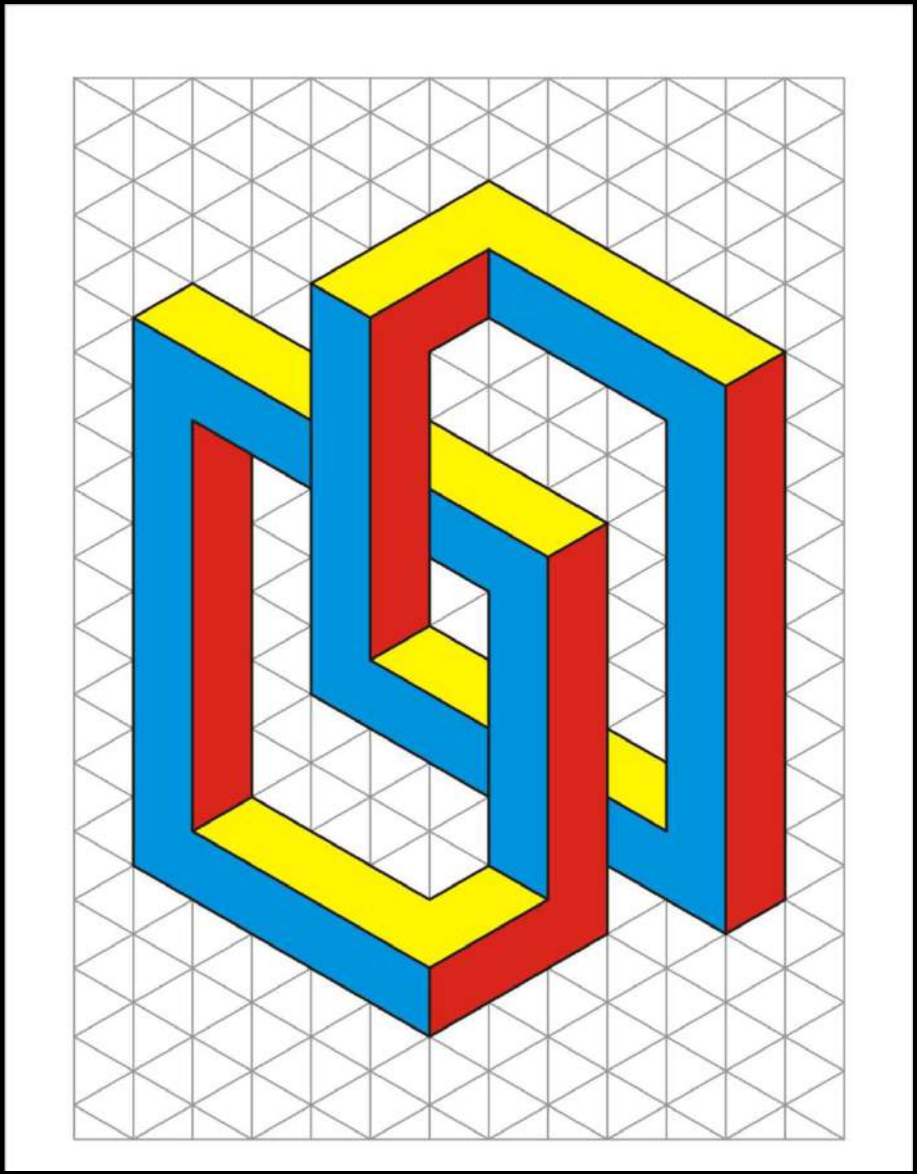


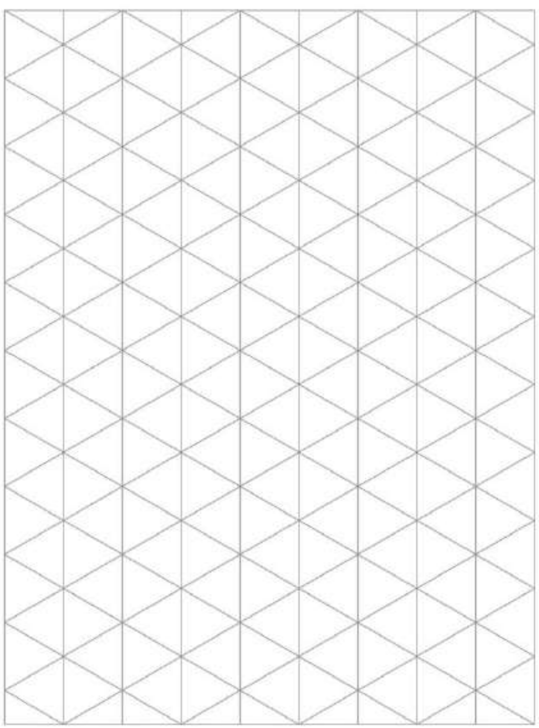





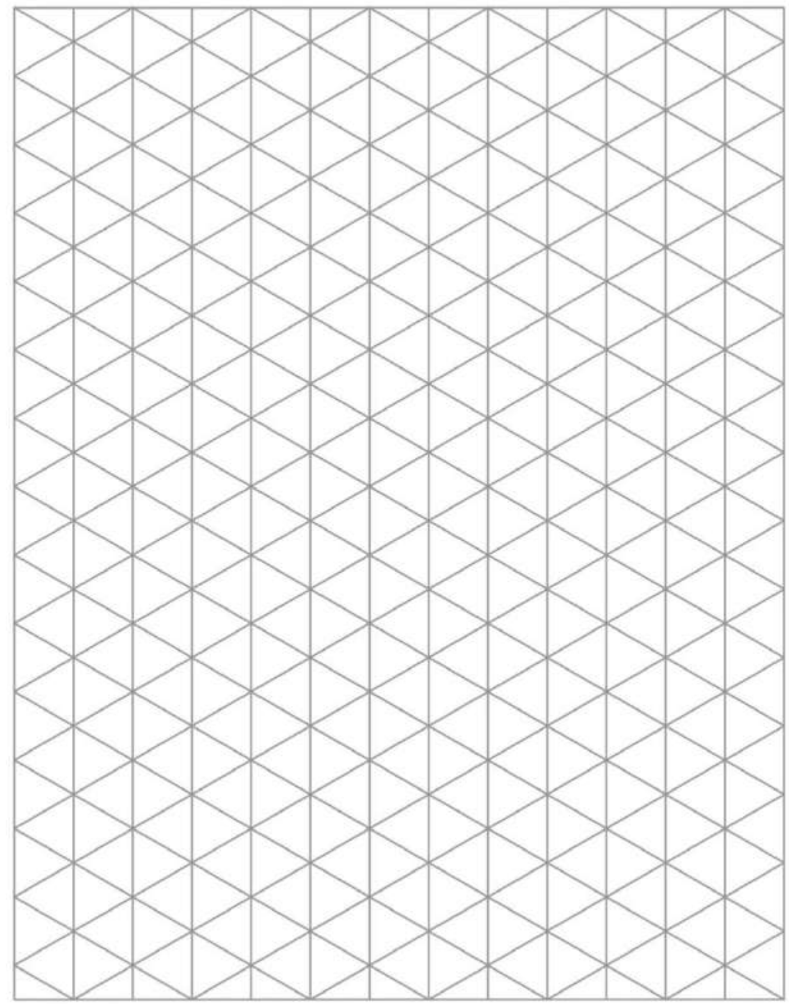




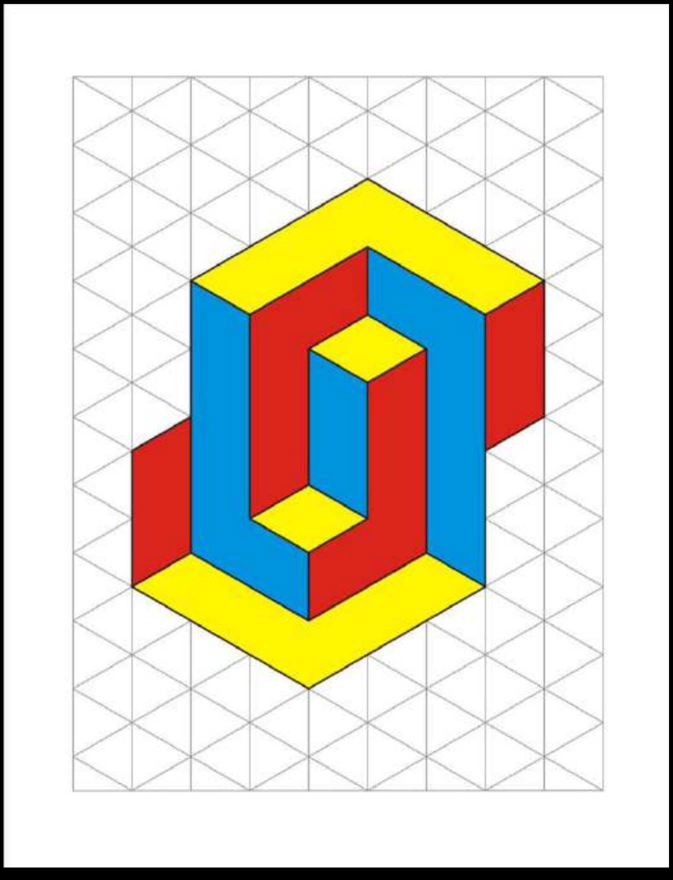


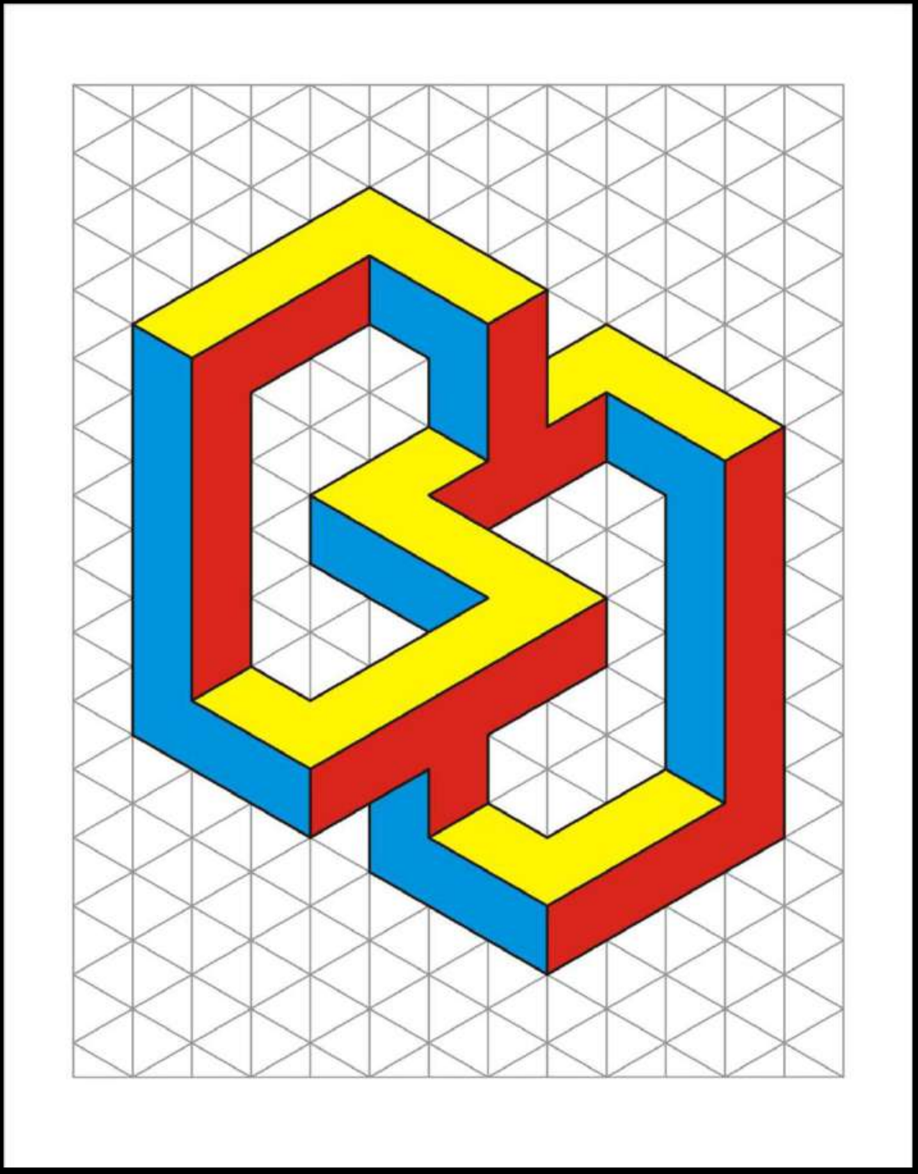


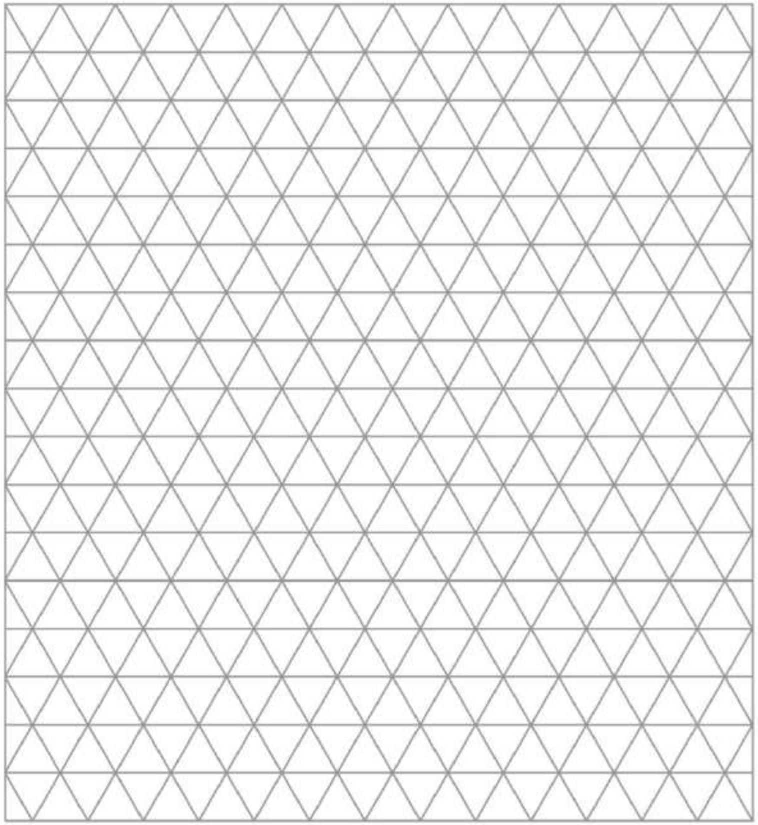
F. FARKAS TAMÁS LEHETETLEN ALAKZAT ÉLMÉNY MŰHELY 2014

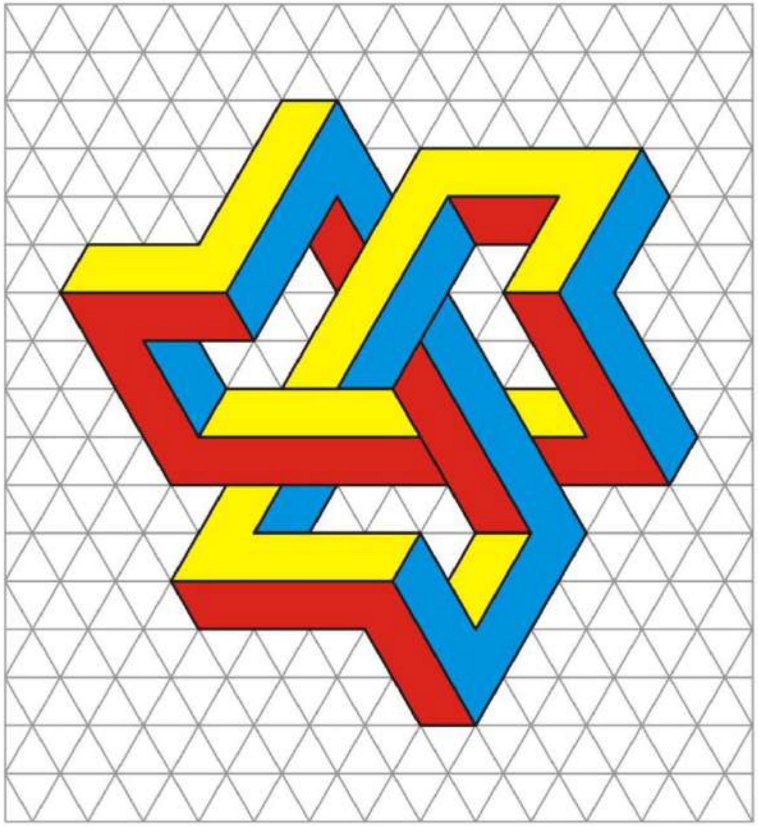


F. FARKAS TAMÁS PARADOX FORMAKAPCSOLAT II. ÉLMÉNY MŰHELY 2014









STEAMTeach

STEAM Education for Teaching Professionalism

Dr. Kristof Fenyvesi
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STUDENT-GENERATED MICROGAMES

STEAMTEACH AUSTRIA PDF

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	Draft
DATE	15.11.2021
MAIN AUTHORS' NAME AND EMAIL ADDRESS	Imam Fitri Rahmadi (imam.rahmadi@jku.at) Tony Houghton (ajh249@gmail.com)
CONTRIBUTING INSTITUTIONS	Johannes Kepler Universität Linz
REVIEWED BY	
STATUS	

TABLE OF CONTENTS

1 PROJECT JUSTIFICATION

Educational games enable students to learn in more meaningful manners. Those games may offer a rich field for a risk-free, active exploration of serious intellectual and social problems (Abt, 1970: 13). Furthermore, serious games could provide users with fun and meaningful experiences reaching up to the emotional level as well as offer immediate feedback and adaptability (Dörner et al., 2016). Games can be integrated for supporting learning in two different ways, to play games or to create games (Rieber et al., 2009; Siko & Barbour, 2012). The first strategy is by far the most common ones. Teachers use games for teaching while students playing games for the means of learning. Creating games as media for learning and instruction is the more advance level and this looks potential to support integrated learning such as for science, technology, engineering, arts and mathematics (STEAM) education. Games act as the arts to bridge connection among other STEM subjects (G.A.STEM, 2019). By developing games, students learn interdisciplinary about science, technology, engineering, arts and mathematics.

Developing educational microgames – very short and small games, instead of games in general, appears to be more suitable for school curriculum and resources. The present activity promotes students and teachers to be able to develop microgames on the GeoGebra platform. The activity could empower them to explore arts in connection to science, technology, engineering, and mathematics. Students and teachers could start expressing their creativity by designing a very short and small game with mathematical contents. This process is followed by constructing the design on GeoGebra so that they can apply science, technology, and engineering during the game developments. The process of designing and developing microgames can be done individually or in collaboration with peers. They may also share the created games to their peers for testing.

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

1.1 Project Overview

Participant age: 15 - 45	***No. of participants:*** Groups of 3 - 5	***Duration:*** 5 hours
Level of knowledge: Basic of GeoGebra, computer, and programming	***No. of teachers:*** 2 - 3	***Type of venue:*** Regular classroom Computer laboratory
Learning methodologies: Project-based learning Collaborative learning	***Involved disciplines:*** Science Technology Engineering Arts Mathematics	***Technological needs:*** Paper and pencil Computer Internet
Most emphasised learning methodology: Project-based learning Collaborative learning	***Main addressed topics:*** Mathematical games	***Estimated project cost:*** 500 €

2 CURRICULAR CONTEXT

2.1 Key competences

The present activity develops students and teachers competences on digital literacy and STEAM.

2.2 Content

The content of this activity is described in the following table.

DISCIPLINE	CURRICULAR CONTENT ADDRESSED
Science	Proof of game concept
Technology	Computer and programming
Engineering	Coding and programming
Arts	Design and visualisation
Mathematics	Mathematical contents

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2.3 Expected learning results

Students and teachers are expected to learn arts that are integrated with science, technology, engineering, and mathematics (STEM).

3 STEPS TO BE EXECUTED

3.1 Step 1: Identify a unique challenge or problem

Duration: 30 minutes

Identifying mathematical concepts or problems for microgames content

3.2 Step 2: Investigate the challenge using the inquiry process & apply ideas

Duration: 30 minutes

Designing a microgame with paper and pencil as the basic concept

3.3 Step 3: Explore the ideas through collaborative activities

Duration: 2 hours

Developing the microgame design on GeoGebra

3.4 Step 4: Utilize the inquiry process to refine products

Duration: 30 minutes

Testing and refining the created microgames

3.5 Step 5: Develop the summative product and share publically

Duration: 30 minutes

Developing the final version of microgames and share it to their peers

4 PROJECT EVALUATION

At the end of the activity, students and teachers are asked to fill out a questionnaire about their experiences in integrated teaching and learning by developing microgames.

5 MATERIALS AND ROOMS

The activity would need papers, pencils, and computers with good Internet connection.

6 INSTRUCTIONS ABOUT THE CONSTRUCTION OF PROTOTYPE/SOFTWARE/OTHER

Learning resources for this activity would be provided on a GeoGebra book.

7 CONCLUSIONS

The activity has been planed and would be evaluated after the training.

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

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June 2023

PROBLEM-BASED LEARNING: DIDACTICAL AID IN THE EXAMPLE OF TEACHING "MASS, WEIGHT AND GRAVITY" IN A STEAM APPROACH

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

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

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Problem-Based Learning

Didactical Aid in the example of teaching "Mass, weight and gravity" in a STEAM Approach

Author	Csilla Fülöp, Ph.D.
STEAM areas	physics, mathematics, languages, technology, history, IT, integrated science, biology, health studies, astronomy, metrology, engineering, PE, astronautics

Summary

Subject	Physics
Topic	Mass, weight, gravity
Age of students	14–19-year-old
Project time	7 x 45 classes (for 8-12 students)
Number of participants	3-30 (preferably 8-12) students
Online teaching material	The links are all listed in the related content of the programme
Offline teaching material	All are listed in the related content
21st century skills	• Innovation • Creativity

- Problem solving
- Active learning
- Critical thinking
- Decision making
- Improving skills in presentation
- Evaluating content
- Discussion

Learning objectives

The students can get familiar with the latest results in physics:

- Classical mechanics
- Modern physics
- Contemporary research projects and results

They take great advantage of the use of classical secondary physics

Project Plan

Name of activity Mass, weight, gravity

	Procedure	Time
 Questioning	What is the history of the topic? Who are the researchers of the topic? Are there any scientists in our nation? What is the main idea of the topic? Can we observe gravitational and inertial phenomena? What is the connection between simulation and real-life phenomena?	1st class
	What do we already know about the topic? What subtopics can be the focus of our interest?	1st class

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Brainstorming

Prepare

What topics do we revisit?

What topics do we investigate?

What online/offline information can we use?

What tools do we need?

2nd class

Predict

There are some in situ experiments we can make or do.

We can learn about proven science and the cutting edge of contemporary science investigations.

2nd class

Plan

What content can we learn?

How can we find relations to our everyday life and experience?

Can we make any product like

- In-situ experiments
- A collection of online materials
- An artistic interpretation of what we have learned
- Any crafts
- Demonstration

2nd class

Explore

Investigating the aspects of the appointed topic on a wide range of scales.

3rd & 4th class

Record

Record what material you met.

Evaluate them.

Suggest for others interested in the topic.

3rd & 4th class

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Also record if you found them useful or not.

Note why.

Some areas that can be great examples:

5th & 6th class

Area 1. History

Demonstrate

Some students find understanding concepts easier when familiar with the historical background. It is worth it for all to find out what questions arose and when, how scientists made efforts to figure out science. Main steps of science at the international level:

- Aristotle
- Newton
- Cavendish
- Eötvös
- Einstein
- the SI system, standards
- the LIGO experiment

Area 2. Basic notions in science

There are some basic notions that appear in most secondary curricula, yet very important in our topic.

We should study or revise these:

a) secondary level
   - Mass
   - Density
   - Force
   - Weight
   - Gravity
   - Weightlessness
   - Types of fields: homogenous and radial

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- Pendulum

b) applied level

- Inertia
- Particle physics
- The standard model
- The higgs boson
- Error propagation
- Pendula
- Gravito-magnetism

Area 3. Mathematics in use

The great book of nature is written in mathematical language.' wrote Galileo Galilei We still believe that mathematical relationships reflect real aspects of the physical world. Science declares we live in an ordered Universe, and also that it is a subject to mathematics.

- scalars and vectors
- solving equations
- calculating the volume and surface
- inverse square laws
- direct proportionality
- algebra with the normal form of numbers
- maxima and minima of functions

Area 4. "In-situ" experiments

- making a cylinder
- making a sphere
- demonstrating the curved space-time
- mathematical pendulum
- the Párkányi machine

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- use of PC to measure gravitational field strength
- tearing a thread with a mass slowly or rapidly

Area 5. IT

- searching for and evaluating materials
- making a list of recommended materials

Area 6. Artistic creativity in action

- jewellery set
- poems
- essays
- jokes
- fashion

Reflect

What material was useless for you? Why?

What did you learn?

What did you find interesting?

What ideas were reinforced?

What ideas had been overridden?

5th & 6th class

Presentation

Present the result of your investigation. It can be

- a game,
- an artistic activity,
- a presentation,
- a crossword,
- an experiment,
- a video, etc.

5th & 6th class

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Product

- ppt
- video
- hand-out
- poem
- essay

5th & 6th class

Re-design

Overview of the notions and methods that we used. Evaluate them.

Suggest or substitute

7th class

Stations

Science station

- measuring mass
- demonstrating inertia
- measuring weight
- demonstrating gravity

Research station

- Problems in science history
- problems and results of contemporary research
- astronomy and physics
- engineering and physics
- metrology

Technology station

We highlight active pedagogy, and promote hands-on, minds-on didactics also in problem-based learning.

There are a number of possible solutions also in this very field, like

IT-related	Others
• PC	• Scissors
• Smartphones	• Ruler
• Digital camera	• Glue
• Internet	• Blank paper

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- YouTube

- Calculator
- Plasticine
- Rubber sheet
- Heavy loads
- Small balls
- Wrap paper
- Markers
- Pendulum
- Párkányi machine

Engineering station

- Pendula
- Fishing scales
- Scales

Tools and materials

- Calculator
- Pc
- Internet
- Cardboard paper, ruler, pencil

Art and Design station

- Poems, novels, jokes, anecdotes, etc.
- Fashion
- Jewellery
- Farewell and retirement cards

Tools and materials

- Paper and pen
- Video recorder
- Plasticine
- Scissors
- Cloths, thread, buttons, etc.

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Math station	• Hand-out • Maps • Calculator • Pc, laptop or smart phone • Paper, markers
Recording station	• Paper, pen or pencils (different colours) • Digital camera • Pc or laptop • Smart phone
Experiences	Students can recognize the difference and relation among the notions of mass, weight, gravity Students can learn about facts and models relating natural phenomena Students can reflect and show how the results and methods of science can reflect their conceptions regarding the topic
Annexes	**In Hungarian:** - A tömeg és a súly, mint különböző fogalmak - YouTube - 4 ProFizika A tömeg fogalma és mérése - YouTube - 6 ProFizika A gravitációs erő, a súlyerő és a tömeg - YouTube - A Gravitáció Lenyűgöző Világa - Az Életünket Formáló Erő - [HD 720p] - YouTube - LIGO – Wikipédia (wikipedia.org) - Gravitációs hullámot észlelt a LIGO | WIGNER Fizikai Kutatóközpont - Kibble-mérleg – Wikipédia (wikipedia.org) - Itt a legújabb gravitációshullám-hegy! | csillagaszat.hu - Mi a gravitációs hullám? | magyar felirattal - YouTube - Dálya Gergely: Csillagászat gravitációs hullámokkal (2019.10.10.) - YouTube - Raffai Péter: Csillagászat gravitációs hullámokkal (Atomcsill, 2017.04.06.) - YouTube - Mik is azok a gravitációs hullámok és hogyan fedezték fel őket? - YouTube - Frei Zsolt - A gravitációs hullámok felfedezése (Mindenki Akadémiája) - YouTube

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- veto_b.pdf (elte.hu)

In English:

- What is Mass? (eschooltoday.com)
- Your Weight on Other Worlds | Exploratorium
- Are Mass and Weight the same thing? | Physics | Don't Memorise - YouTube
- What is Gravity? | Physics | Gravitation | Don't Memorise - YouTube
- Mass and weight clarification (video) | Khan Academy
- Mass vs Weight - The Difference Between Mass and Weight (sciencenotes.org)
- Why Are Astronauts Weightless? - YouTube
- RIP 'Grand K' - YouTube
- Gravity - Wikipedia
- LIGO Lab | Caltech | MIT
- The Kilogram Is Dead. Long Live the Kilogram! - The New York Times (nytimes.com)
- Kibble Balance I How we re-defined Kg? - YouTube
- Gravitational wave - Wikipedia
- What Is a Gravitational Wave? | NASA Space Place – NASA Science for Kids
- Sources and Types of Gravitational Waves | LIGO Lab | Caltech
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+ many pictures, videos from the internet

June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

Problem-Based Learning: Chaos Theory

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

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

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Problem-Based Learning

Chaos Theory

Author	FÜLÖP Csilla Ph.D.
STEAM areas	Physics, math, languages, cuisine, technology, history, meteorology, IT, biology, geography, integrated science, chemistry
Cross-cultural connections:	Cuisine, origami, language skills, games, peonza game, fractals in nature, phenomena

Summary

Subject	Physics
Topic	Chaos theory
Age of students	Age 14–19 years
Project time	7 x 45 minutes
Number of participants	3-30 (preferably 8-12) students
Online teaching material	All the links are under the related content of the programme
Offline teaching material	All the links are under the related content of the programme
21st-century competences	Innovation, creativity, problem-solving, active learning, critical thinking, decision-making, presentation skills, content evaluation, discussion

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Learning objectives

Students can recognise chaotic phenomena in their everyday life and surroundings: food, flows, games, weather, biology, medical studies, etc.

They become familiar with the latest results of physics: methods of classical mechanics in a modern mathematical setting: the role of simulation, and the exponential nature of error propagation.

They will be able to rely on and use classical secondary physics: Atwood machine, pendulum

Students meet the basic notions of chaos theory and are introduced into

advanced mathematics and science: phase diagrams, simulation, use of IT, exponents, error propagation, etc.

Project Plan

	Procedure	Time
Discussion questions	The history of chaos theory. Who studied chaos theory? Do we know any chaos theory scientists in our country? What is the central idea in chaos theory? Can we observe chaotic phenomena? What is the butterfly effect? Are there any chaotic games? Is chaos theory present in art (poems/novels/movies/visual arts, etc.)? Is chaos theory modern physics at all? Or is it classical physics? If it is classical physics, why is it physics of our age, then?	45 minutes

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	Chaos or instability? Which sciences use chaos theory? What is the connection between simulation and real-life phenomena?	
 Brainstorming	What do we know about chaos theory? What are chaotic phenomena?	
 Prepare	What topics do we revisit? What topics do we investigate? What online/offline information can we use? What tools do we need?	45 minutes
 Predict	There are experiments we can do. We can learn about the gist of chaos. …..	
 Plan	What content do we use to understand and what can we learn from chaos theory?	
 Explore	Investigating the aspects of chaos theory on a wide range of scales. Classical mechanics is about the special, rarely observable cases of motions. In-class science experiments of motions are not easy to demonstrate, they can go chaotic.	2 x 45 minutes

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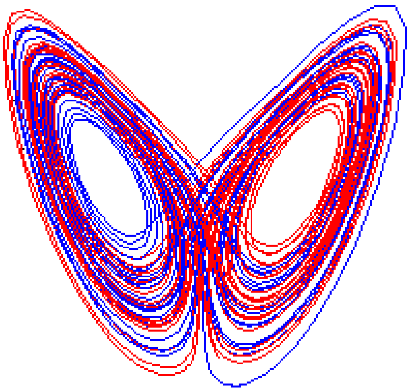
 Record	Record what material you worked with. Evaluate them. Give suggestions to other students interested in the topic. Also record if you found them useful or not. Note why.	
 Demonstrate	Prepare a chaotic tea! Practical exercises with plasticine. Have fun with chaotic games Lace and fractals (phase diagrams) Hand-made fractals and fractals in nature. Some areas that can be great examples:	2 x 45 minutes

Area 1. History

There are some students who find it easier to understand concepts if they are familiar with the historical background. It is worthy for all to find out what questions arose and when, how scientists made efforts to figure out the science behind phenomena.

Main steps of science towards chaos theory:

a) International level:
- Weierstrass
- Kovalevszkaja
- Carlwrigt & Littlewood
- Kolmogorov
- Lorentz



b) Hungarian aspects:

- KöMAL
- Vermes Miklós
- Szépfalussy Péter
- Vicsek Tamás
- Gruiz Márton
- Tél Tamás

Chaos theory - Wikipedia

What is chaos theory? | Britannica

Area 2. Basic notions

There are some basic notions that appear in most secondary curricula, yet very important in chaos theory.

We should study or revise these:

- Equilibrium (notion and types)

https://www.space.com/chaos-theory-explainer-unpredictable-systems.html

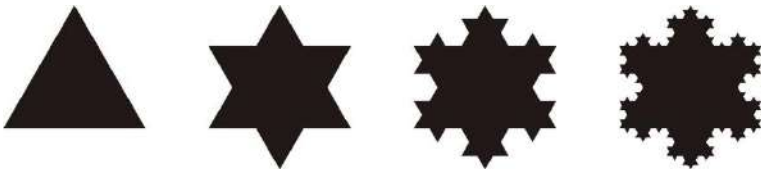
- Is a phenomenon a sequence of instabilities or a chaotic one?

[Life comes at u fast commercials 3 - YouTube]

- the laws of classical physics
- error, error propagation

Area 3. (Applied) mathematics

-Fractals: the Mandelbrot set, the Carnot set, the Koch snowflake, the Sierpinsky mesh, the Menger sponge



Fun with Fractals - YouTube

Fractal - Wikipedia

Fractals are typically not self-similar - YouTube

- Fractals in nature: biology-flora, biology-fauna, geography, meteorology, etc.

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 -

[How Chaos Theory Unravels the Mysteries of Nature - YouTube]

[Fractals in Nature - YouTube]

Art: Origami: creating a fractal

[Origami Fractal - Andrea's Rose Tutorial - YouTube]

- The dimension of the fractal: 1D, 2D, 3D, $\log_a b$, factors, definition of quotient dimension, Poincare map

Area 4. Chaotic experiments

- “Similabda”, the Hungarian yo-yo
- yoyo
- pendula
- chaotic sculptures

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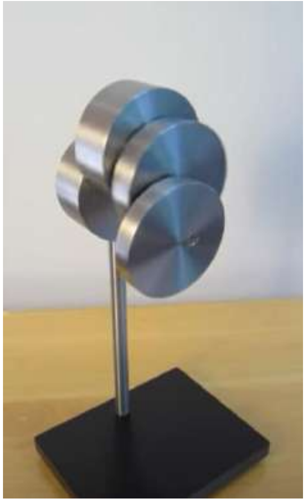

- The magnetic pendulum
- Chaotic watch
- Non-harmonic oscillator
- Smoke
- Chaotic water mill
- Induced oscillation

Triple Pendulum Chaotic Acrobatics - YouTube

Rott's Chaos Pendulum - YouTube

3A95.50 Double Pendulum Ring and Bar - YouTube

PH ME DY DEMO 70045A V0521 Triple Pendulum Some Chaotic Behaviour - YouTube

3D Triple Pendulum - YouTube

Ferrocumulus Chaotic Pendulum - YouTube

ROMP: Randomly Oscillating Magnetic Pendulum - YouTube

Gentry Stein - 1st Place - 1A Final - 2019 US Nationals - YouTube

[Double Pendulum Chaos Light Writing (computer simulation) 1 - YouTube]

[Chaotic Lorenz Water Wheel - YouTube]

[Chaotic Pendulum with Magnets - YouTube]

Area 5. Chaotic activities

Chaotic tea:

marble cake & coffee with cream

Chaotic activities:

- Plasticine
- Rubber ball in a bowl
- The Ebru technique

[How to paint on Water for Paper Marbling and Ebru Art. - YouTube]

[Water Marble Nail tutorial (for beginners) - YouTube]

[Tırnağa Ebru Sanatı Nasıl yapılır - YouTube]

Area 6. The wide palette of uses

- The solar system

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- Meteorology
- Flow
- Drift
- Self-oscillation
- Feedback in electric circuits
- Biochemical processes
- The operation of the heart
- The operation of the brain
- Dynamics of population
- Random number generation
- Encryption
- Ball games
- Modelling economic processes
- The operation of the mixer
- The process of kneading dough

Area 7. IT

- The Atwood machine
- The mathematical pendulum
- The polar coordinate system
- Simulation
- Dynamics Solver
- Different solutions: chaotic & periodic ones

[Trajectories of the Swinging Atwood's Machine - YouTube]

Reflect

What material was useless for you? Why?

What did you learn?

What did you find interesting?

What ideas were reinforced?

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What ideas had to be overridden?

Presentation

Present the result of your investigation.

It can be a game, an artistic activity, a presentation, a crossword, an experiment, a video, etc.

Product

- Marble cake with coffee
- Yoyo
- Ppt
- Video
- Hand-out
- Poem
- Origami
- Nail polish
- Painting with ebru technique
- Origami fractal
- Sponge

Re-design

Overview the notions and methods that we used. Evaluate them. Suggest or substitute.

45 minutes

Stations

Science station

- Solar system
- Hydrodynamics
- Gyroscope
- Experiment
- Error and error propagation
- Phase diagram, ljapunov exponent
- Fractals

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- Equilibriums: stable, neutral, instable, chaotic
- Magnetic pendulum
- Swinging atwood machine
- Ball in a bowl

Research station

- Problems to investigate in science history: Poincare, Kovalevskaya, Kolmogorov, Lorentz, etc.
- Map the fields in which chaos is used (astronomy, meteorology, drift, flow, vibration, swelling of electric circuits, brain and heart phenomena, chemical and biochemical processes, population dynamics, encryption, random and accidental phenomena, economics, ball games, etc.
- Modern mathematics, numerical methods, fractals, dimension
- Order in chaos
- Chaos in art: movies, videos, promotional clips and articles

Technology station

We highlight active pedagogy, and promote hands-on, minds-on didactics in problem-based learning as well.

There are a number of possible solutions in this field, too, such as pendula, toys, manicure, yoyo, food, origami, graphs, tools for experiments, etc.

IT-related	Other
• PC	• Scissors
• Smartphones	• Rulers
• Digital cameras	• Blank paper
• Internet	• Graph paper
• Dynamics Solver	• (coloured) pencils
• YouTube	• Markers

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

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- Yo-yos
- “similabda”
- Baby bouncers
- Cigarettes
- Matches
- Bowls
- Rubber balls

Engineering station

- Radio locator
- Chaotic watch
- Pendula: magnetic, double

Tools and materials

- Calculators
- PC
- Internet
- Graph paper
- Rulers
- Pencils
- Magnetic pendulum: button magnets, wooden rod and slab, glue, markers

Art and Design station

- Poems, novels, jokes, anecdotes, etc.
- Ebru technique
- Melange
- Origami
- Manicure
- Fractal art

Tools and materials

- Paper and pen or video recorder
- Water, bowls, paint, cloth or wooden yo-yos
- Plasticine

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- Origami paper
- Scissors
- Nail polish, nail polish remover, cotton wool, small bowls, water

Math station

- Hand-outs
- Maps
- Calculator
- PC, laptop, or smart phone
- Paper, markers

Recording station

- Paper, pens or pencils (different colours)
- Digital cameras
- PC or laptop
- Smartphones

Experiences

Chaotic phenomena can be observed in our everyday life.

These have not been scientifically described until the 20^{th} century.

Chaos theory is based on classical physics but is a present-day topic for investigation.

Chaos is used in a very wide range of scientific and artistic fields.

Appendix

1 Káoszelmélet (fizikashow.hu)

2 Az osztályozás és a káoszelmélet (oszk.hu)

3 A káosz természetrajza (termeszetvilaga.hu)

4 Pillangóhatás (elmélet) – Wikipédia (wikipedia.org)

5 Káoszelmélet – Wikipédia (wikipedia.org)

6 meszena_magyar.pdf (elte.hu)

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

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

7 DOKTORI ÉRTKEZÉS TÉZISEI (elte.hu)

8 DOKTORI ÉRTKEZÉS TÉZISEI (elte.hu)

9 Szegedi matematikusok rendet tesznek a káoszban | National Geographic (24.hu)

10 Microsoft Word - Szatmary-Bajko (atw.hu)

11 Szatmáry-Bajkó Ildikó: „Káoszt”? – Azt! – Káoszelmélet a középiskolában, Fizikai Szemle, LVI, 376, 2006/11.

12 Gruiz Márton: A kaotikus mechanika kapcsolata Platónnal és a levelestésztával, Természet Világa, 129, 389,1998.

13 Fraktál – Wikipédia (wikipedia.org)

14 Fraktálművészet – Wikipédia (wikipedia.org)

15 Mandelbrot TDK - Mi a fraktál? (fizikashow.hu)

16 Index - Tudomány - Káoszelmélet fejti meg a változócsillagok évszázados titkát

17 http://fiztan.phd.elte.hu/letolt/fraktalok_vilaga_nagy.pdf

18 leave two empty, 16 pt single lines (elte.hu)

English sources:

1 Chaos theory - Wikipedia

2 Chaos: The Science of the Butterfly Effect - YouTube

3 How Chaos Theory Unravels the Mysteries of Nature - YouTube

4 An Unpredictable Universe: A Deep Dive Into Chaos Theory | Space

5 What is chaos theory? | Britannica

6 Fun with Fractals - YouTube

7 Fractal - Wikipedia

8 Fractals are typically not self-similar - YouTube

9 What is a Fractal? - The Ultimate Guide to Understanding Fractals (iternal.us)

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10 ED413289.pdf

+ variety of pictures, videos from the Internet

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June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

PROJECT-BASED LEARNING: A DIDACTIC GUIDE IN THE EXAMPLE OF TEACHING THE GOLDEN RATIO IN THE STEAM APPROACH

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

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

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

STEAMTeach

Project-Based Learning

A didactic guide in the example of teaching the golden ratio in the STEAM approach

Authors	Dr. STONAWSKI Tamás
STEAM areas	Math, physics, art
Cross-cultural connections	Golden ratio, the unique and inspiring proportion. Different cultures have different ideas about beauty and the right proportions. How beautiful and proportional are we?

Summary

Subject	Mathematics
Topic	Quadratic equation Ratios Averaging
Age of students	14-20 years
Project time	8 x 45 minutes
Number of participants	8-10 students
Online teaching material	• Rectangle pageant – judging and ranking rectangle contestants • Rectangle reconstruction (extending rectangles until they become golden rectangles) • Measuring the ration of the height of the naval and other body parts to the height of the body

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- Measuring proportions of the face and works of art, assessing results

Offline teaching material	Stonawski, Tamás Az aranymetszés az európai festészetben In: Juhász, András; Tél, Tamás (szerk.) A fizika, matematika és művészet találkozása az oktatásban, kutatásban : Nemzetközi konferencia magyarul tanító tanárok számára Budapest, Magyarország : ELTE TTK (2013) 351 p. pp. 89-96. , 8 p. Stonawski, Tamás Az aranymetszés és más arányok: a tudomány és a művészet kölcsönhatása FIZIKAI SZEMLE 71 : 7-8 pp. 262-266. , 5 p. (2021)
21st century competences	• Innovation • Creativity • Problem-solving • Analytical thinking • Active learning • Critical thinking • ICT • Cooperative skills
Learning objectives	• Acquiring discipline-related knowledge • In-depth understanding of topic • Assisting the formation of learning communities • Developing manual skills • Developing abstract thinking skills

Project Plan

	Procedure	Time
 Discuss questions	Who discovered the golden ratio and what did they use it for? Who used the same ratio in other fields later? Where does Φ come from? How is Fibonacci related to the golden ratio? Does his name have anything to do with the golden ratio? Who named this proportion golden ratio or divine proportion? Who assumed a scientific connection with aesthetics and who measured it first? What manifestations of the golden ratio can be found in nature? What is the formula for the quadratic equation? How do you calculate averages and deviation? Is there a connection between beauty and proportion? Can we assign a special proportion to beauty? If yes, how can we can reach such a decision?	35 minutes
 Brainstorming	Collecting students’ ideas	10 minutes

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Prepare	Collecting tools (rubber bands, measuring tapes, scissors, felt tip pens, cardboard, paper clip) Cutting out rectangles Cut rubber bands to size, marking φ using a felt tip pen Slipping rectangles on top of each other and fixing them with a paper clip	45 minutes
Demonstrate	Demonstrating various ways of employing golden ratio proportions Constructing a golden spiral Constructing a golden ratio-template, the significance of the golden ratio-template, see below. Finding the ideal proportion by changing the proportions of rectangles Using a rubber band to check the position of the navel and other dominant body proportions Lay a golden ratio-template over photos using Power Point.	3 x 45 minutes
Predict	There is connection between the golden ratio and aesthetics but it is not too close.	20 minutes
Plan	Applying previously acquired mathematical concepts and skills, we can investigate the connection between the golden ratio and aesthetics	40 minutes
Explore	The focus of the project is to have students chart the laws of physics. Their exploration based on hands-on, minds-on learning leads to a deeper and more lasting knowledge	30 minutes

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Record	Students compare their results with their preliminary assumptions and formulate their experience.	30 minutes
Reflect	Why do assumptions and experience differ? Is golden ratio a special proportion? How is it mathematically different from other ratios? Where can you apply this knowledge?	30 minutes
Presentation	Measurement results are recorded in a table and visualized on graphs including figures related to averages and deviation. Findings are summarized in a presentation. Results and the learning process are published in school papers or journals.	45 minutes
Product	Reconstructed rectangles, rubber bands suitable to measure various items in the future. A golden ratio-template accessible in a digital format for later use enabling students to investigate their own photos, images and works of art available on the web. PPTs Docx documents Videos	
Re-design	Give the students enough time to re-plan the processes and modify their report	

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Stations

Science station

Science includes thinking, observation and experiments. It is important to formulate assumptions and share experiences. Formulating and answering questions related to the visuality and the proportions of the world.

Collecting and recording data.

Tools

- Paper cubes
- Notepads
- Calculators
- Pens

Research station

Unguided explorations in the world of the golden ration and body proportions, e.g. Where is the body divided according to the golden ratio? Why bank cards are made in the shape of a special rectangle?

What does sense of beauty mean?

Tools

- Ipads
- Books
- Maps
- Encyclopaedias
- Tablets
- Computers
- Fiction and non-fiction books

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Technology station

Electronic technology

- Computers
- Tablets
- Smartphones
- Smartboards
- Digital camera

Non-electronic technology

- Scissors
- Paper clips
- Cardboard
- Measuring tapes
- Rubber bands
- Felt tip pens

Engineering station

Engineering tools and materials

- Paper clips
- Cardboard
- Measuring tapes
- Rubber bands
- Felt tip pens

Art and Design station

Art and design supplies

- Paint
- Scissors
- Cardboard

Maths station

Maths tools

- Calculators
- Rulers

Recording station

- Flashcards
- Pens
- Notepad

Experiences

At the end of the project, joint assessment of experience, discussion of further ideas and future plans

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Appendix

Links

https://diakoffice-my.sharepoint.com/:p:/g/personal/stonawski_sulid_hu/EaCk9TNXPdRDg4_-Pw1ZyDMB3Lcmc-22BL16lU_yoaezeA?e=YMJWrq

https://diakoffice-my.sharepoint.com/:p:/g/personal/stonawski_sulid_hu/EffjFNSvn8ZDkHP8q-BLMK4BhdgRKmu-YP3TexuPUPiRvA?e=Ll5uLl

https://diakoffice-my.sharepoint.com/:p:/g/personal/stonawski_sulid_hu/ERIbr37Wp2dLoI7-miRXmfABjwHPs5MLnfsu5nDId0Rbsg?e=mLx7DV

https://diakoffice-my.sharepoint.com/:p:/g/personal/stonawski_sulid_hu/EYI6zjhIAytFqb1XyjnmqesBKBiUaGzsKjaStJhORc6Ecg?e=lo2PBy

Videos

Mi az az aranymetszés? [What is the golden ratio?]https://www.youtube.com/watch?v=orTnieSPMIs

The Mystery of the Golden Ratio https://www.youtube.com/watch?v=CY3kr5L-Nso

The Golden Ratio (why it is so irrational) – Numberphile https://www.youtube.com/watch?v=sj8Sg8qnjOg

Discussion

- Discussion of assumptions and questions, their verification or rebuttal

Group work

- Assigning preparatory tasks to groups 2-3
- Assigning tasks to groups
- Crafting the product in small groups
- Preparing group presentations

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Experiments

- Rectangle pageant – judging and ranking rectangle contestants
- Rectangle reconstruction (extending rectangles until they become golden rectangles)
- Measuring the ration of the height of the naval and other body parts to the height of the body
- Measuring proportions of the face and works of art, assessing results

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2 Inquiry-based learning

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

STEAMTeach

How to model objects with Tracker and GeoGebra

César Llata, Zaira Ortiz-Laso and José M. Diego-Mantecón
(ortizz@unican.es)

Universidad de Cantabria

HOW TO DOWNLOAD TRACKER

Tracker (Video Analysis and Modeling Tools for Physics Education) is available in the following link

https://physlets.org/tracker/

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of the European Union

PROBLEM

"Determine the maximum height that a ball reaches when we throw it into the air"

MODELLING THE TRAJECTORY

- Recording a video of the physical phenomenon.
- Obtaining mathematical information from the video using the Tracker program.
- Finding the curve equation that describes the movement.

Thus, Tracker allows obtaining measurements and equations just with a video

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USING TRACKER

RECORDING A VIDEO WITH METRIC REFERENCES TO IMPORT IT INTO THE TRACKER

In this case, we will employ the following video that you can find in Google Drive (tallertracker2023@gmail.com; tracker2023$)

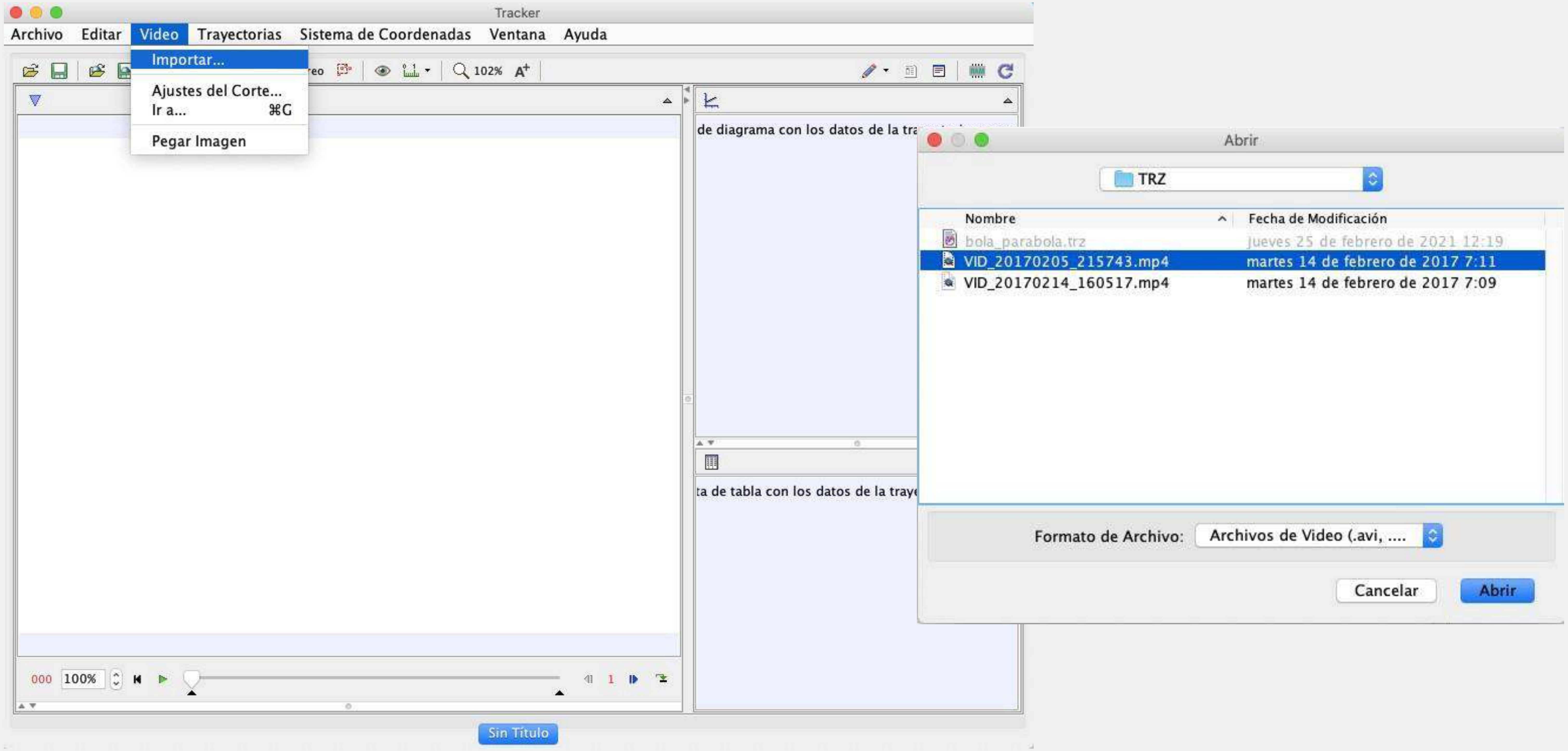
Aspects to be considered

- Record the video with good contrast and background
- Record from the parallel plane and perpendicular focus
- Have a reference object that we can measure

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

USING TRACKER

TRACKER INTERFACE AND VIDEO LOADING, ADJUSTING THE DESIRED START AND END WITH THE SLIDERS



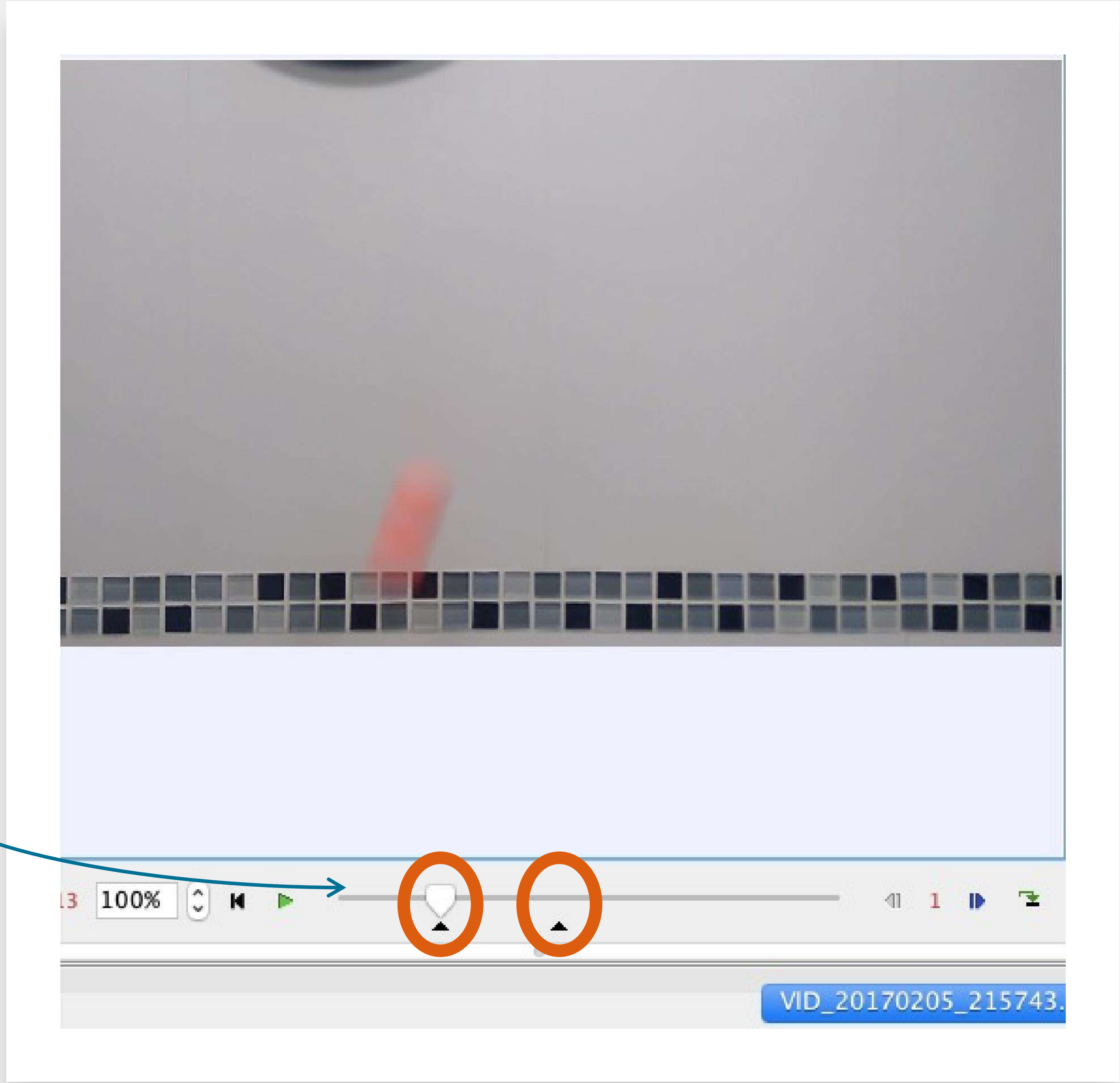
Co-funded by the Erasmus+ Programme of the European Union

STEAMTeach

USING TRACKER

TRACKER INTERFACE AND VIDEO LOADING, ADJUSTING THE DESIRED START AND END WITH THE SLIDERS

Adjusting the beginning and the end

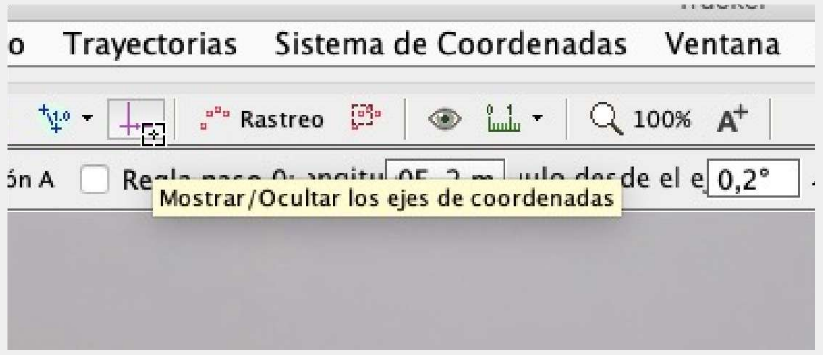


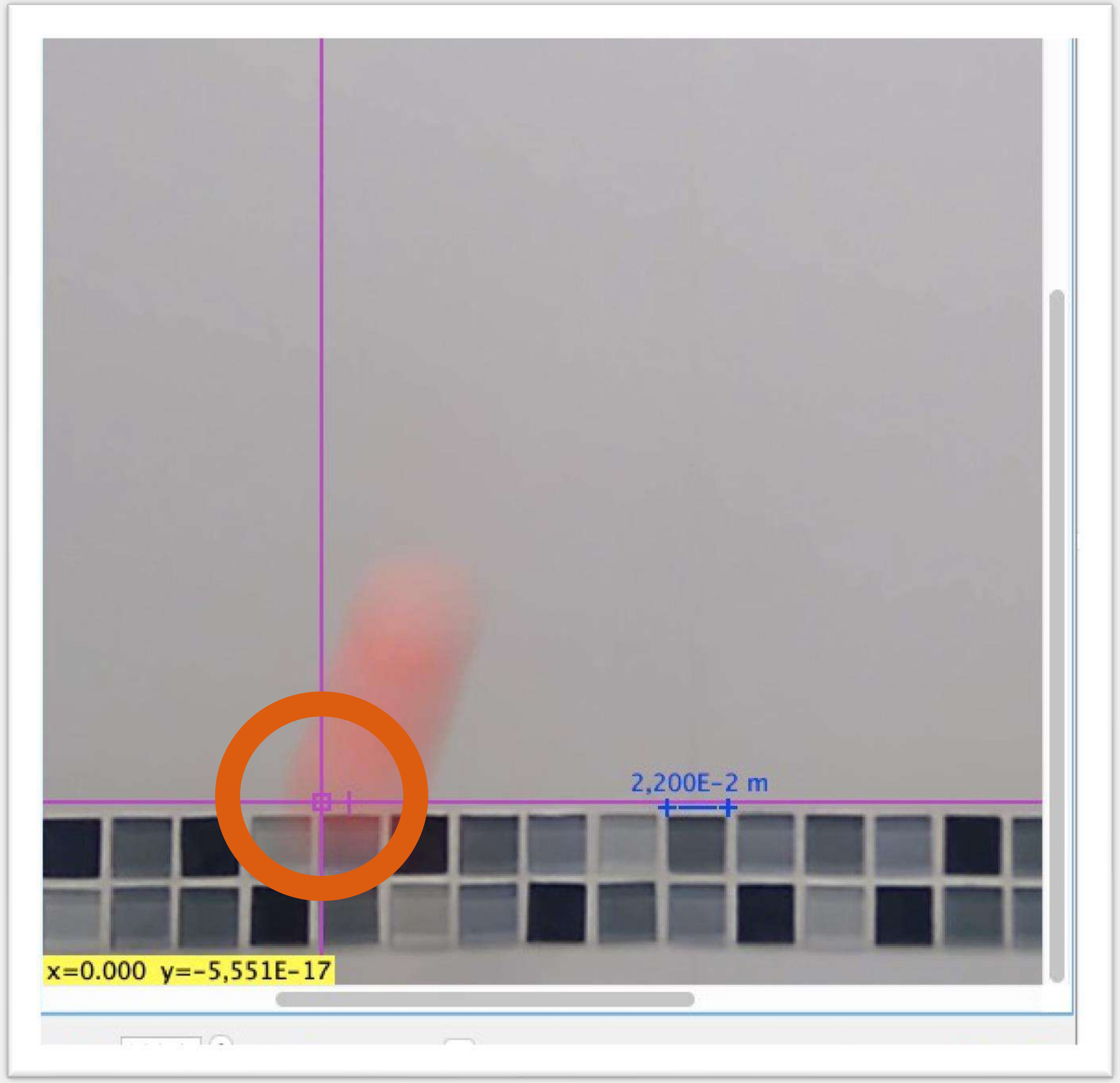
USING TRACKER

CALIBRATION ROD, TO GIVE METRIC SCALE TO THE VIDEO

USING TRACKER

COORDINATE AXES, TO LEAVE THE ORIGIN AND THE X AND Y AXES ORIENTED

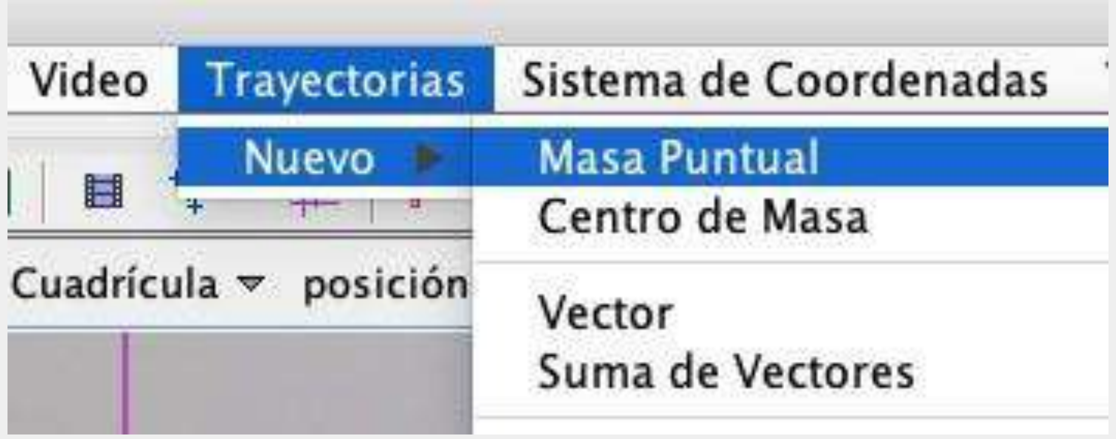




Co-funded by the Erasmus+ Programme of the European Union

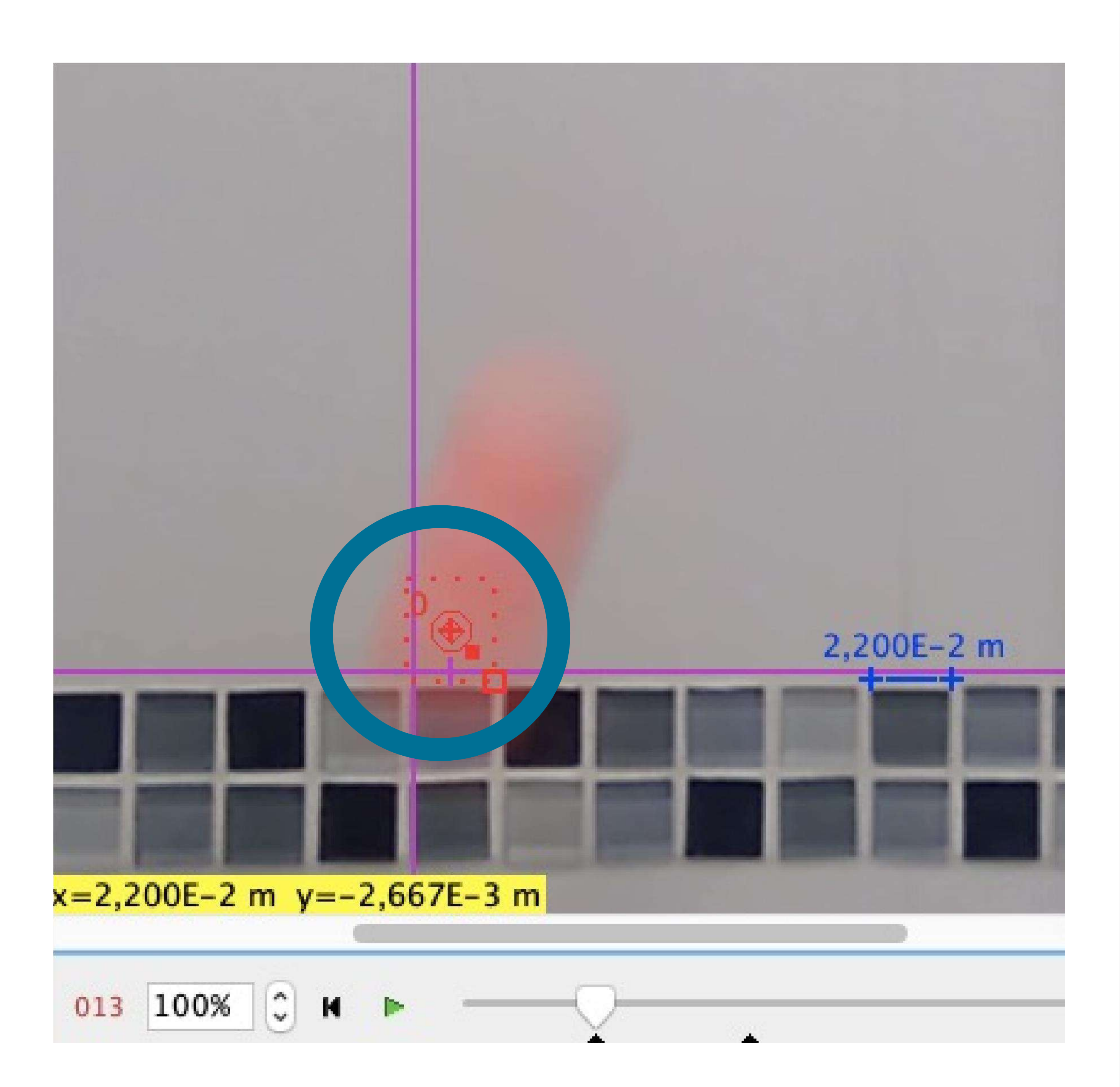
USING TRACKER

IDENTIFY THE POINT MASS OF THE MOVING OBJECT



We use the key combination:
Ctrl + Shift [⇧] + Left mouse button

- Circle: search pattern
- Square: search area



USING TRACKER

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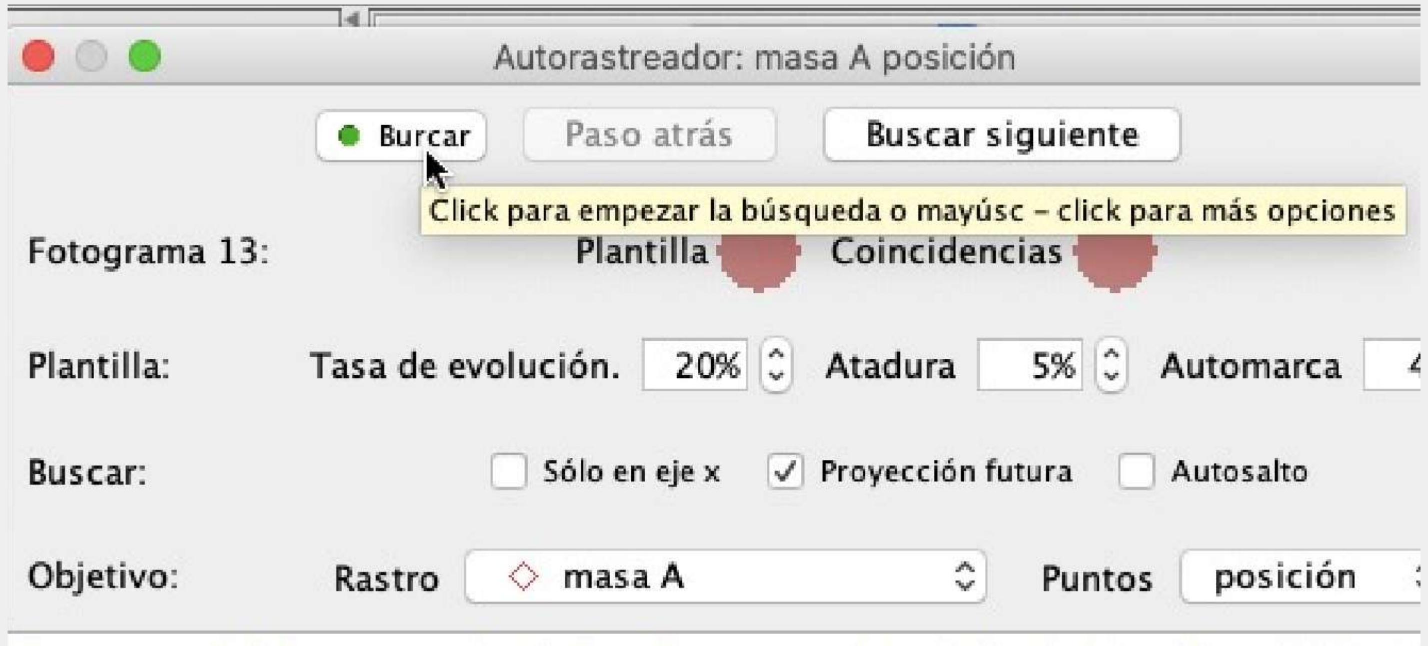
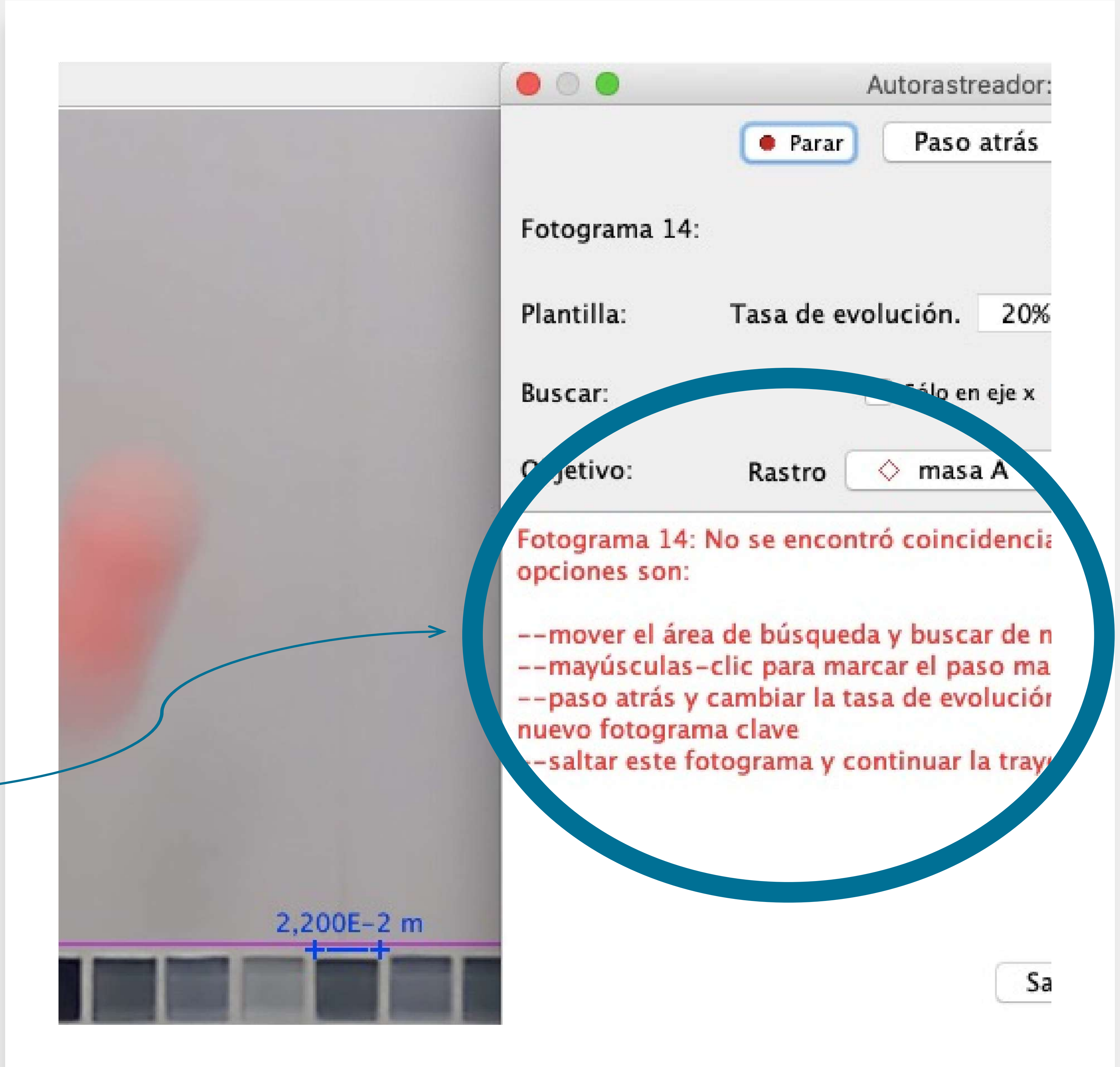
STEAMTeach

FIND THE TRAJECTORY OF POINTS



- Find the path of points [Buscar] to generate the points
- It is usually automatic, but if at any time the object is not detected, search for the trajectory with the following:

Shift [⇪] + Left mouse button



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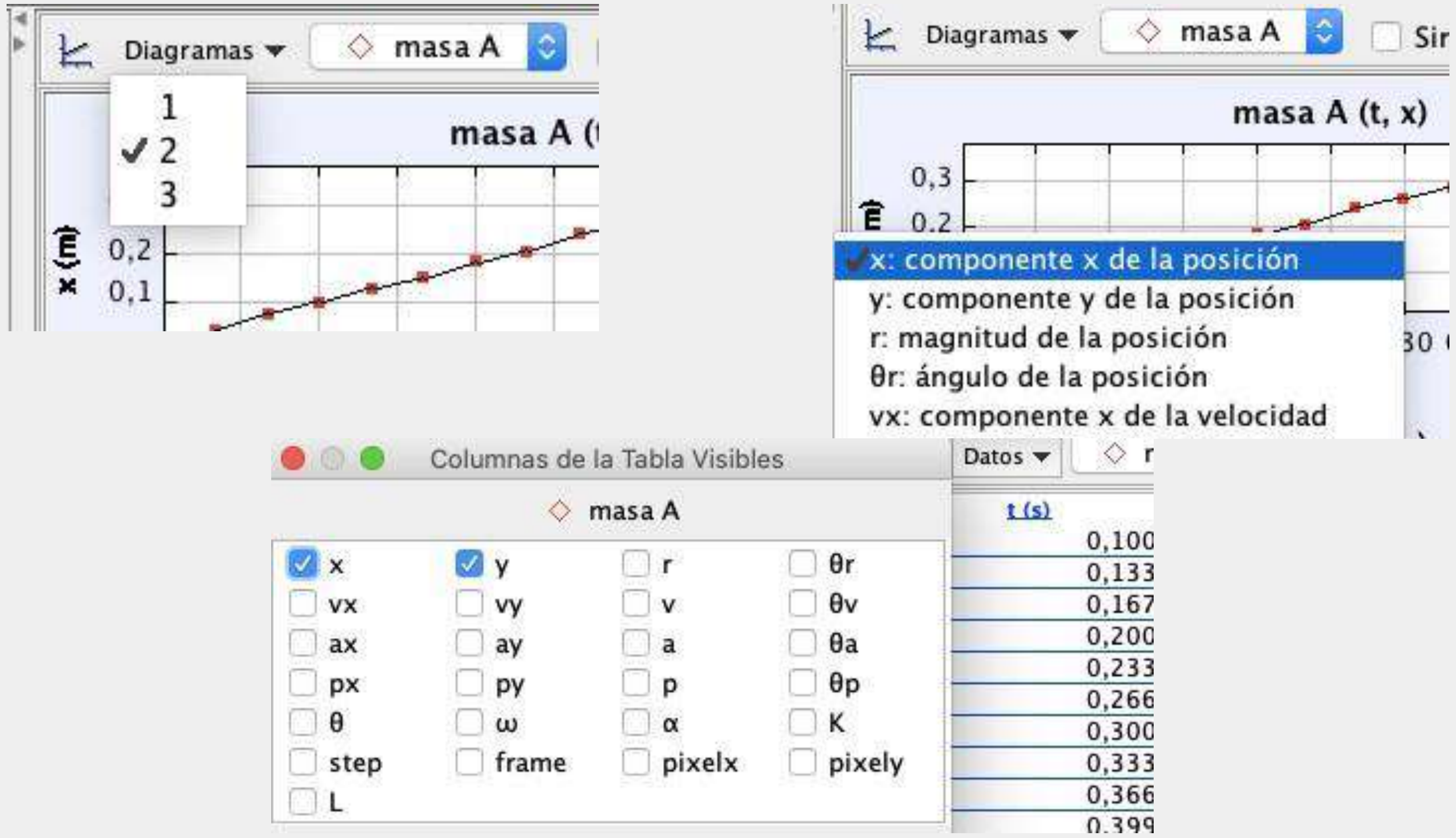
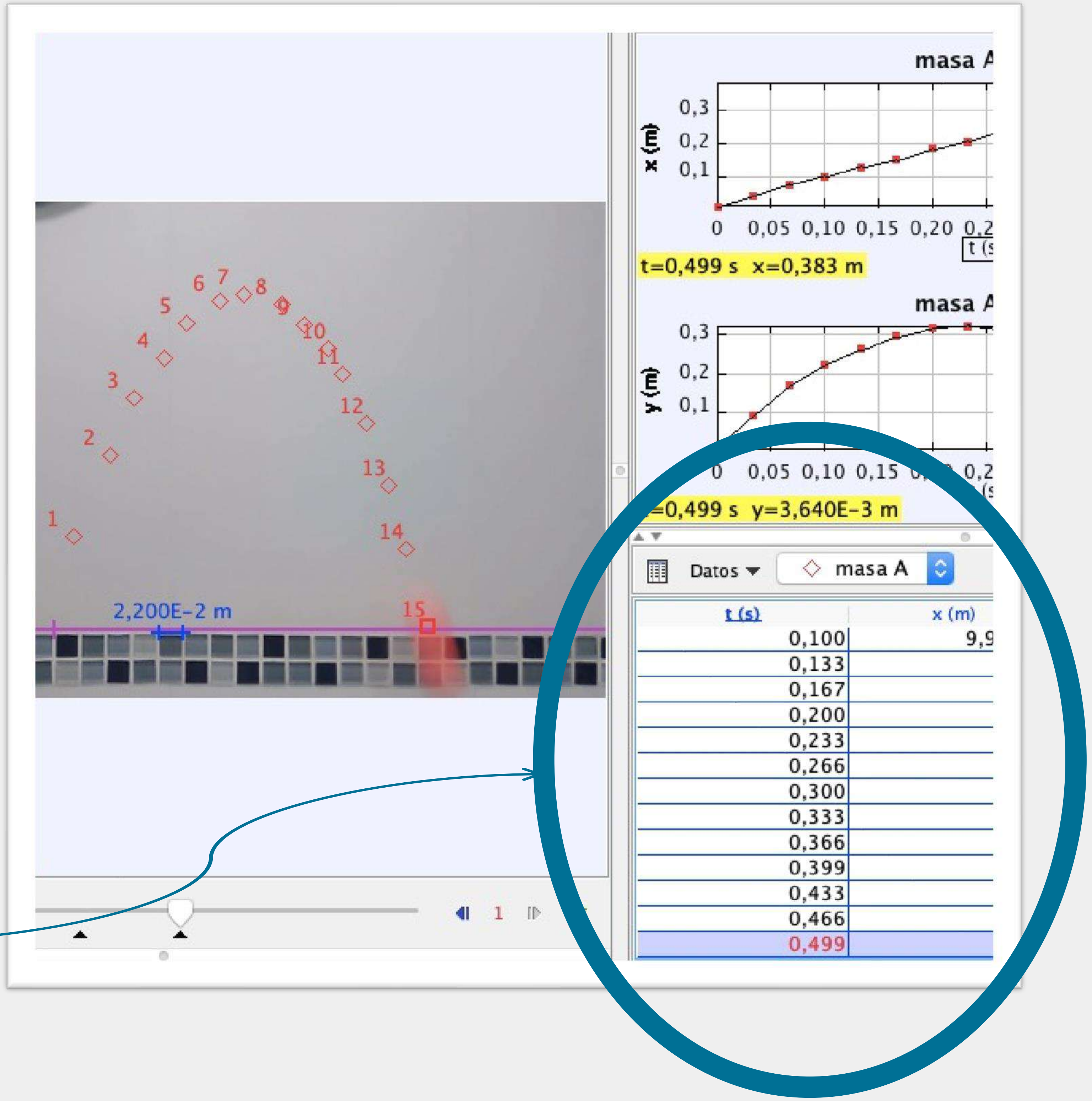
USING TRACKER

IDENTIFIED DATA





You can identify the points detected in the video frames:

- You can select which data to see
- You can choose which graphs to display

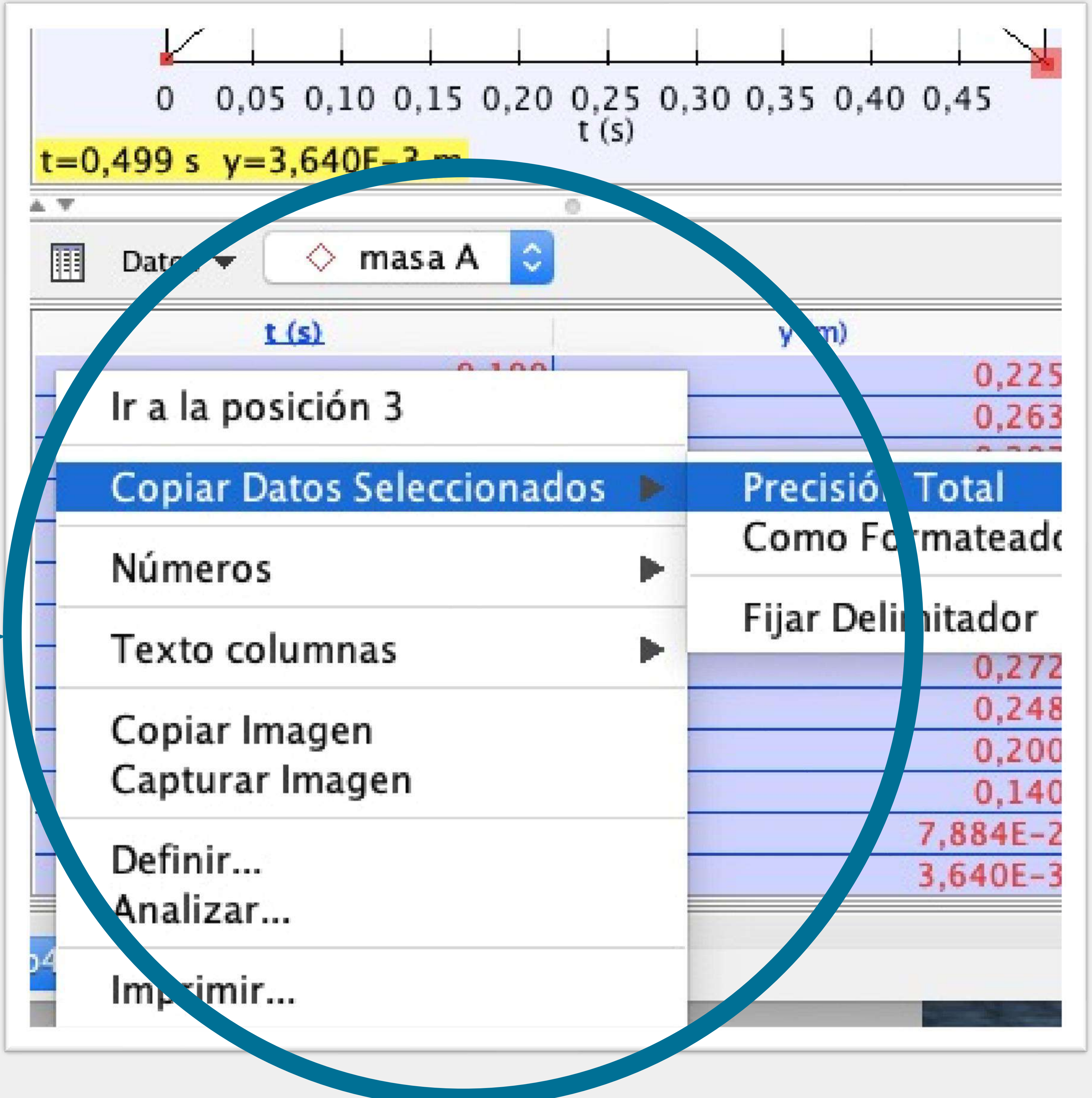
USING TRACKER

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

STEAMTeach

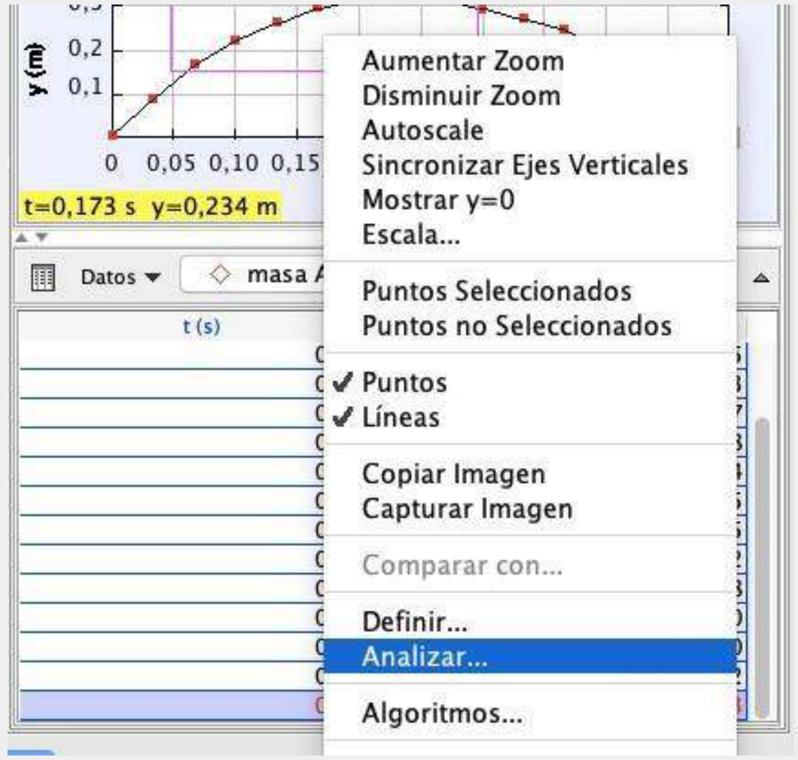
EXPORT DATA

Export the data to Excel or GeoGebra by selecting the data in the spreadsheet and, with the Right Button of the mouse, giving Copy with Total Precision:



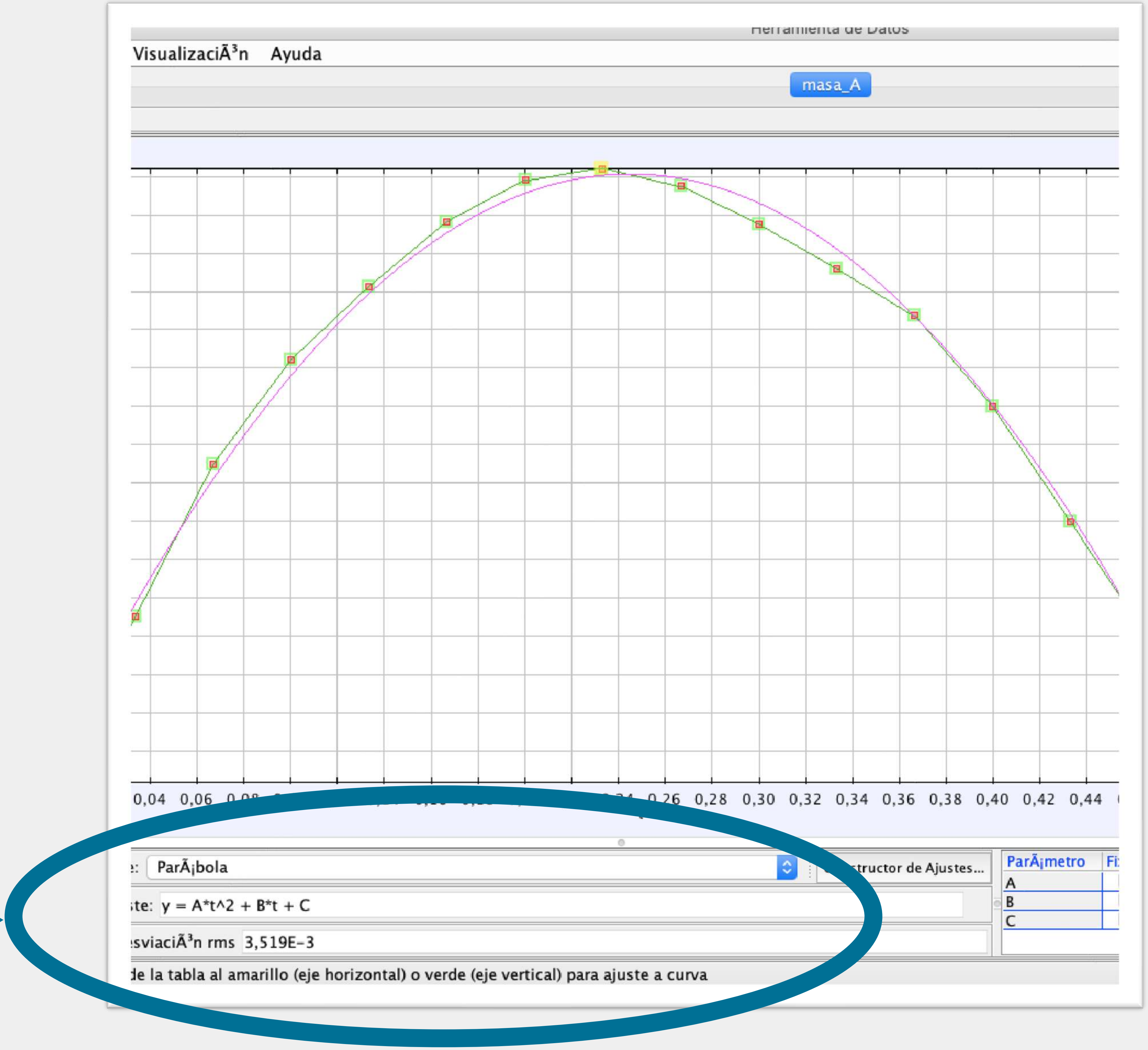
USING TRACKER

OBTAIN THE CURVE OF THE TRAJECTORY



Mathematical modelling to obtain the curve equation that best fits the trajectory of the object:

- With the right button, we click on the data or a graph and choose "Analyze", selecting the "Type of Adjustment“.



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USING TRACKER

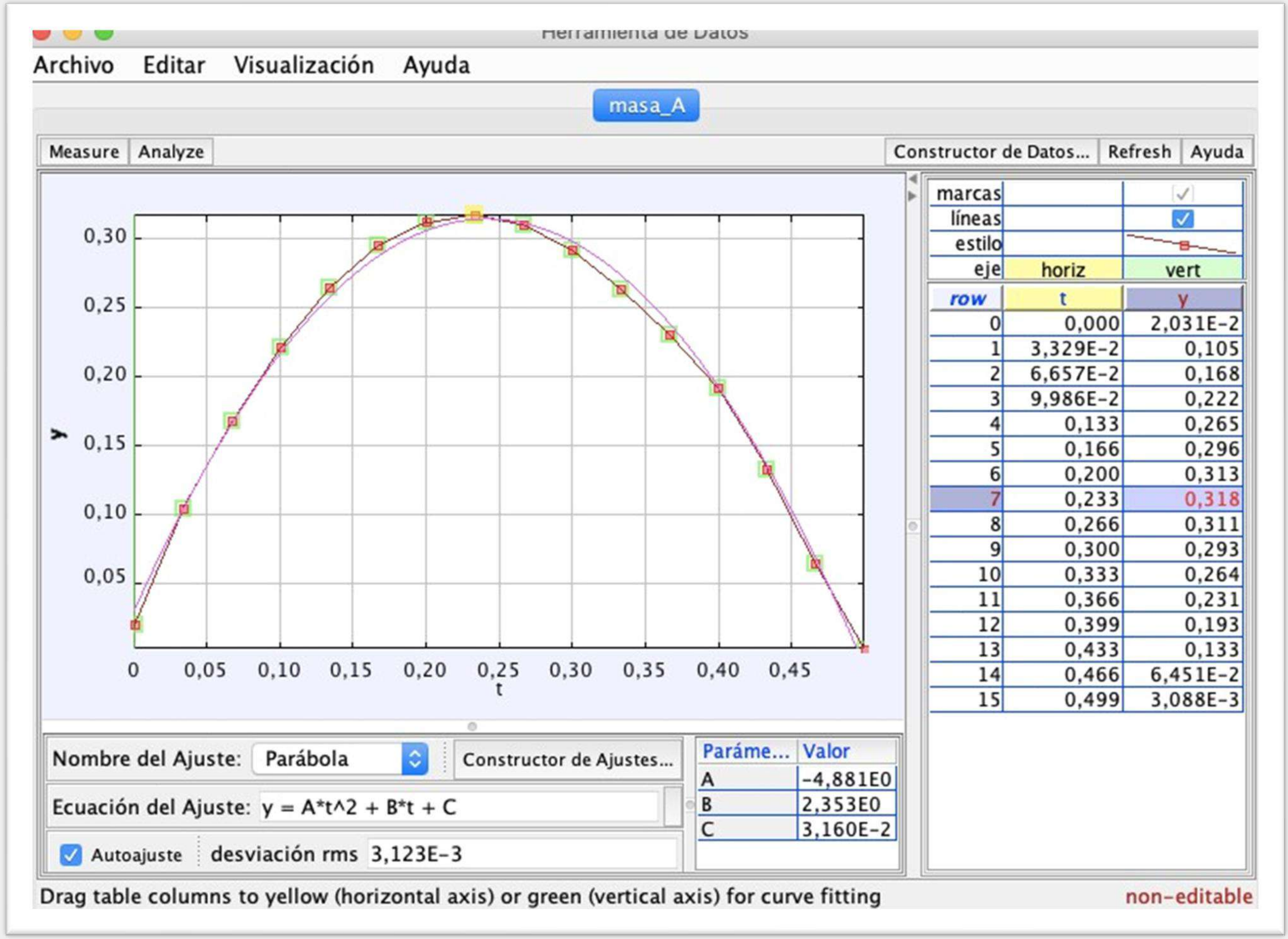
OBTAIN THE CURVE OF THE TRAJECTORY

The parabolic movement, also known as an oblique throw, consists of throwing a body with a speed that forms an angle α with the horizontal. The equation y(t) is:

$$y = y_0 + v_0 \cdot \sin(\alpha) \cdot t - \frac{1}{2} \cdot g \cdot t^2$$

As g=9.8 m/s^2, the coefficient A of the parabola is expected to be -4.9.

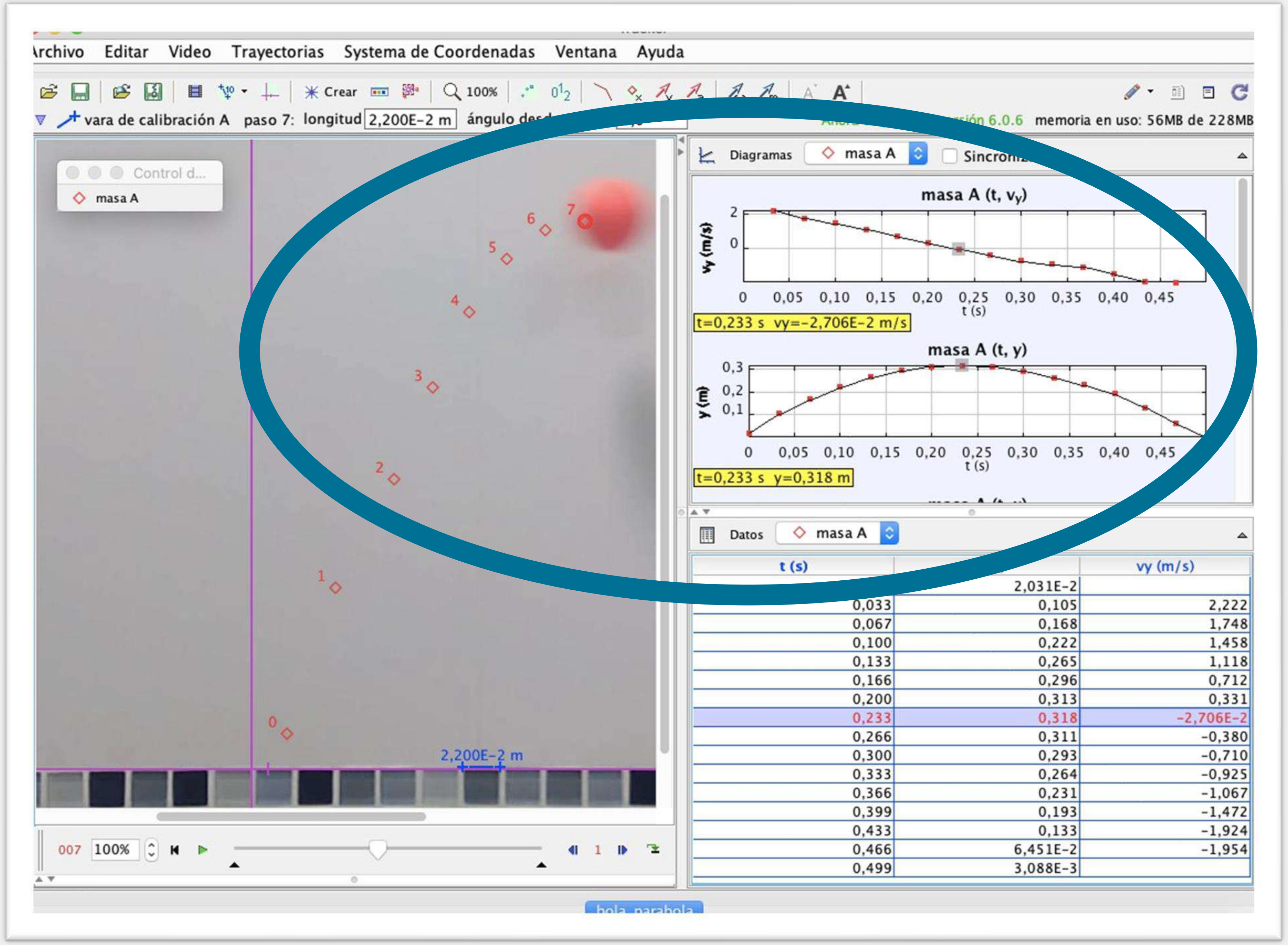
In our case, A=-4,81



USING TRACKER

SOLVING OUR INITIAL PROBLEM (OBTAINING THE MAXIMUM HEIGHT)

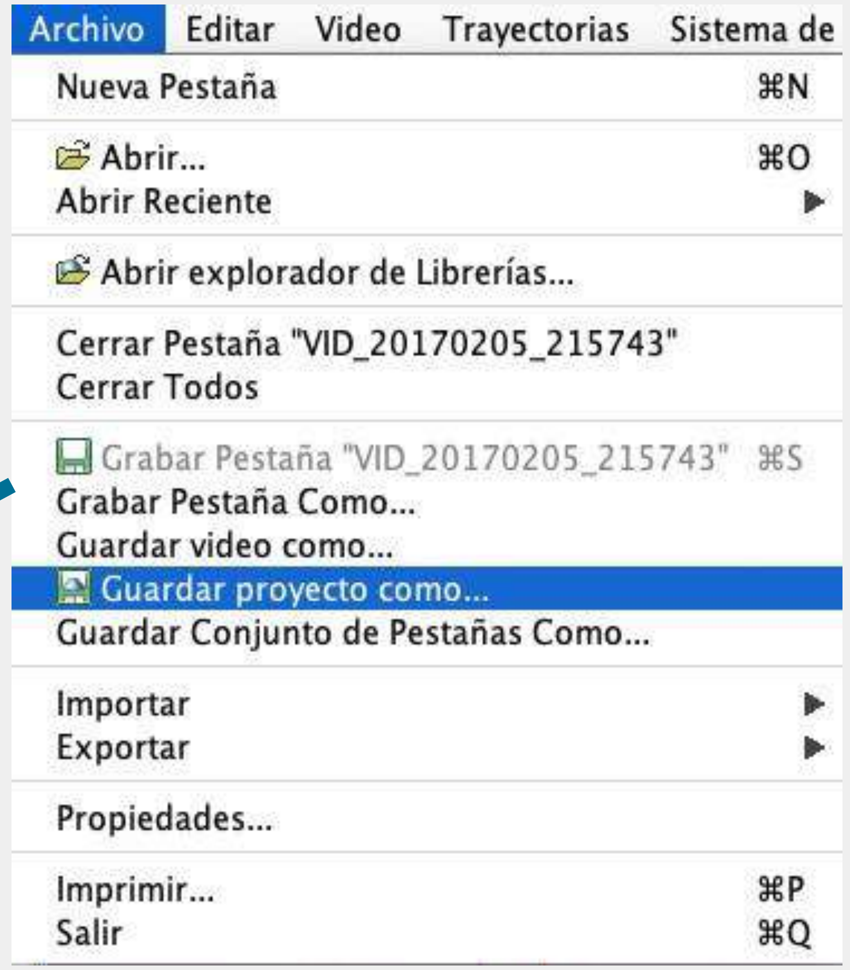
It can be seen how at the vertex of the parabola, where the maximum height is reached, the v_y component of the velocity is zero (in our case, almost zero -0.02706)

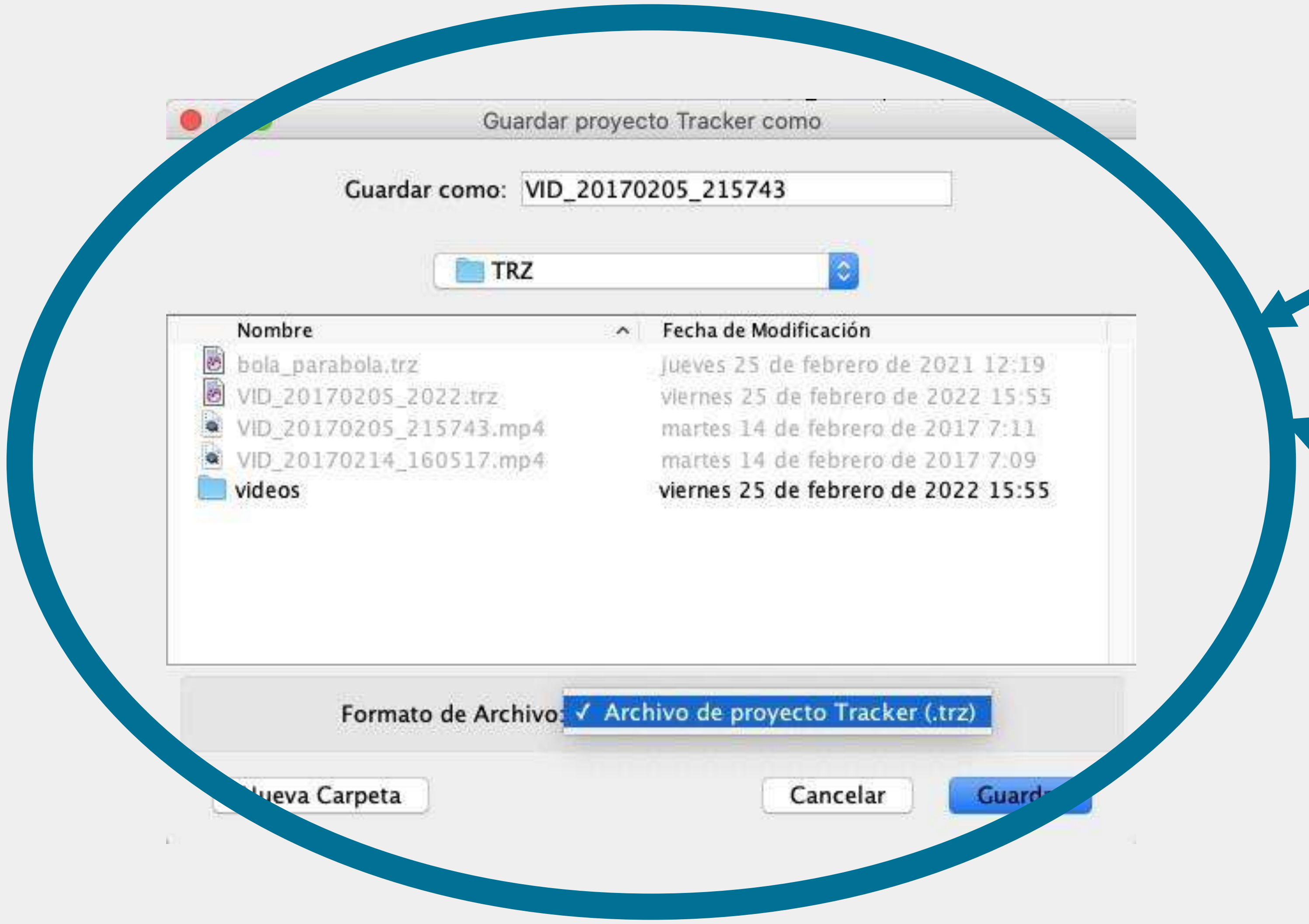


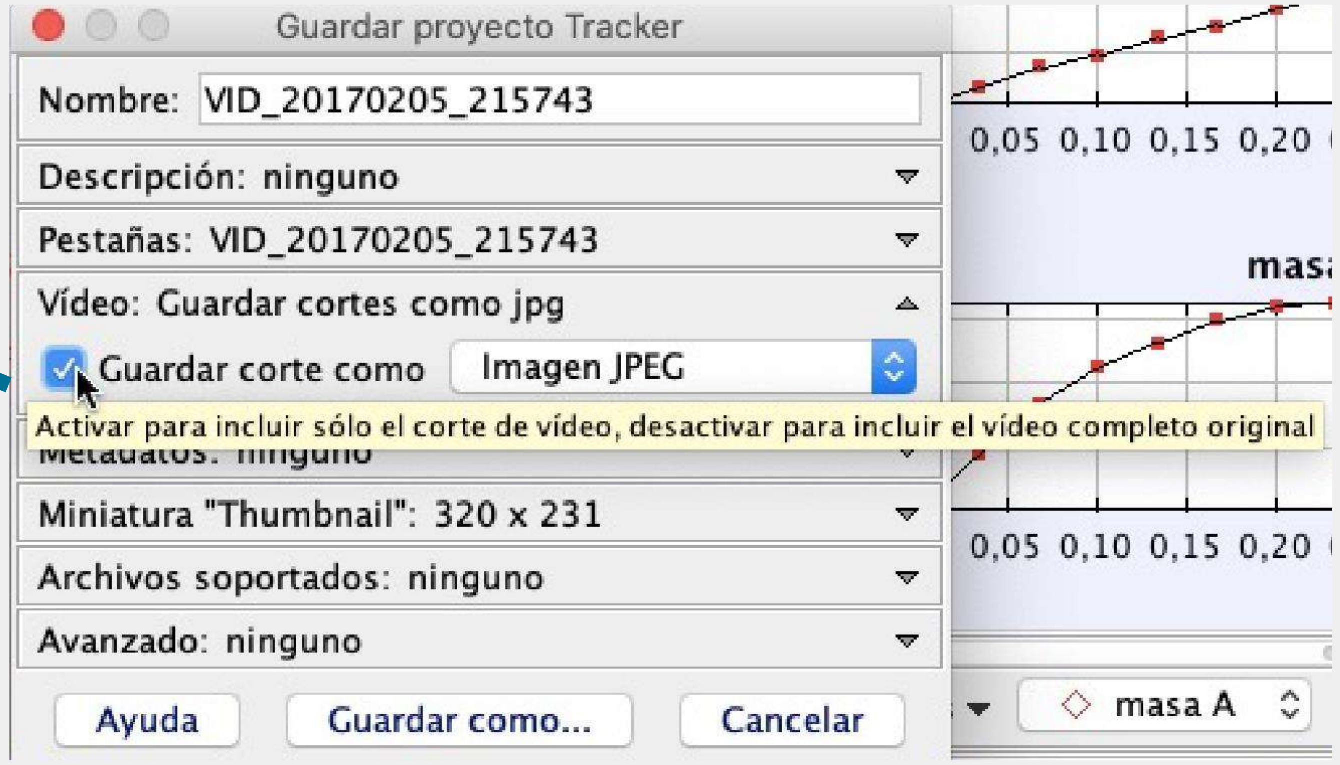
USING TRACKER

SAVE OUR PROJECT IN TRACKER: CREATION OF A .TRZ FILE

there are many options to save our project, export it, and save the video clip, among others







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Thank you

ANALYSING SPORTING PERFORMANCE

STEAMTEACH AUSTRIA PDF

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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	0.1
DATE	01.11.2021
MAIN AUTHORS' NAME AND EMAIL ADDRESS	TONY HOUGHTON ajh249@gmail.com
CONTRIBUTING INSTITUTIONS	
REVIEWED BY	
STATUS	

TABLE OF CONTENTS

1 PROJECT JUSTIFICATION Analysing Sporting Performance

Analysing Sporting Performance movement asks students to work in groups capturing and analysing sporting performance using video capture mobile phone or camera, importing this to Tracker movement capture for display and analysis and using this real life data for GeoGebra software simulations. This offers an opportunity for students to engage in *collaborative learning and for teachers to engage in multidisciplinary, supportive, collaborative groups/networks within school and outside*. It offers a *Project and Problem based approach supported by appropriate scaffolding and best practice, proven "plug-and-play" modules, notably Tracker software and Geogebra* which can be easily inserted into the integrated STEAM approach and used in other STEAM activity, for example on-line games and flight . Above all, by looking at various sporting activities chosen by students and also real-life sporting heroes, it provides a focus on *affective factors for students and teachers* (learning that relates to the learner's interests, attitudes, and motivations)."

1.1 Project Overview

Participant age: 14-16 year-old-students	*No. of participants:* Groups of 4-6	*Duration:* 8 hours
Level of knowledge: None	*No. of teachers:* 2	*Type of venue:* Regular classroom Outdoor space
Learning methodologies: Collaborative learning Problem-based learning Project-based learning	*Involved disciplines:* Mathematics Technology Sport	*Technological needs:* Computer Mobile phones Internet Portable cameras
Most emphasised learning methodology: Collaborative learning Problem-based learning Project-based learning	*Main addressed topics:* Analysing sporting performance	*Estimated project cost:* 0 €

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2 CURRICULAR CONTEXT

2.1 Key competences

PISA and EU2020 all recommend that children's education should foster enjoyment, self-belief and the stamina to address complex problems and situations in STEAM subjects (OECD, 2018). This is also a requirement of the International Baccalaureate: "Educational approaches should feature creative problem solving challenges including societal factors/needs." and at least one interdisciplinary unit with at least two subject groups (IB, 2020). The following shows extracts from the English National Curriculum for key stage 3 (age 11-14) and stage 4 (age 15 upwards), in particular Computing, Mathematics, English, Science, Design and Technology, and Art and Design:

Computing programmes of study: key stages 3 and 4 National curriculum in England September 2013

Undertake creative projects *that involve selecting, using, and combining multiple applications, preferably across a range of devices,* ***to achieve challenging goals****, including collecting and analysing data and* ***meeting the needs of known users***

Mathematics programmes of study: key stage 3 National curriculum in England

Develop fluency; mathematical reasoning and competence in ***solving increasingly sophisticated problems****... apply their mathematical knowledge* ***in science, geography, computing and other subjects****.*

English programmes of study: key stage 3 and 4 National curriculum in England September 2013

Are competent in the arts ***of speaking and listening, making formal presentations, demonstrating to others*** *and participating in debate...speak confidently and effectively in a range of formal and informal contexts,*

*Supporting a point of view by referring to evidence...****recognising the possibility of and evaluating different responses****...* ***making an informed personal response that derives from analysis and evaluation***

Science programmes of study: key stage 3 National curriculum in England September 2013

Present reasoned explanations*, including explaining data in relation to predictions and hypotheses*

Design and technology programmes of study: key stage 3 National curriculum in England

Critique, evaluate and test their ideas *and products and the work of others,* ***take into account the views of intended users and other interested groups***

Art and design programmes of study: key stage 3 National curriculum in England

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Analyse and evaluate their own work, and that of others*, in order to strengthen the visual impact or applications of their work*

-

2.2 Content

DISCIPLINE	CURRICULAR CONTENT ADDRESSED
Science	Flight: gravity, acceleration and equations of horizontal and vertical motion of projectiles
Technology	Video capture technology, Tracker and GeoGebra software
Engineering	
Arts	Various sporting activities
Mathematics	Statistics, analysis and simulation using real-life data

2.3 Expected learning results

We expect students to develop technology, communication and collaboration skills, gain experience and confidence in technology activities that include video–capturing and movement analysis using Tracker and GeoGebra mathematical software and gain a better understanding of gravity, acceleration and equations of horizontal and vertical motion of projectiles all of which they can apply to other STEAM activities.

Above all, by looking at various sporting activities chosen by students and also real-life sporting heroes, we hope to stimulate the learner's interests, attitudes, and motivations for STEAM.

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3 STEPS TO BE EXECUTED

The generic steps can be stated: Identifying the problem, Generating ideas, Exploring the Science and Maths, Designing and Constructing the Model, Evaluating and Refining the Model, Presenting the Project.

In “Analysing Sporting Performance” this cycle is done on an iterative basis in four workshops. The main focus of the first workshop is Identifying the problem and Generating Ideas, with workshops two and three developing the solution leading to workshop four presenting the project:

<table>
<tr><td>Identifying the problem, Generating ideas</td><td>Exploring the Science & Maths, Designing & Constructing the Model</td><td>Evaluating & Refining the Model</td><td>Presenting the Project</td></tr>
<tr><td colspan="4">Workshop 1Focus ←---</td></tr>
<tr><td colspan="4">--------------------------Workshop 2 Focus←--</td></tr>
<tr><td colspan="4">--Workshop 3 Focus ←------------</td></tr>
<tr><td colspan="4">---Workshop 4←-</td></tr>
</table>

Table 1 Iterative Cycle with changing focus

Here is an example 4-workshop agenda. Note the transition from the first very structured, time-intensive teacher-led workshop to the later progressively less-structured student-driven workshops.

We set the students a very open-ended problem challenge. We 'teach' them some tools, then it's up to them to work together, project plan their activity and present. We (both students and teachers) provide iterative feedback for continuous improvement - up to presentation of their solution. Believe it or not, students find it...fun!

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Further detail can be found at:

https://sites.google.com/site/cciteasp2/resources/hothouse-challenge

Workshop 1: Identifying the problem, Generating ideas

In workshop 1, the focus is on identifying the challenge, generating ideas working in teams, receiving introductions to the technology (video capture, Tracker & Geogebra) and recording a real-life sporting activity of their choice (Netball clip reversed , Bloodhound test run 420fps ruler 1 5m1 , ballbouncecommented) culminating in group presentations 'selling the idea' , receiving feedback and discussing their experience.

10.00 – 10.10 Welcome and Objectives

10.10 – 10.20 Challenge: How can we analyse sporting performance?

10.20 – 10.40 Group work

Students split into groups of 5 to address the challenge (teachers stand back). :-)

3 minutes of discussion, then present first ideas for 60 seconds!

10.50 – 12.30 Group work

Bouncing Ball Video Capture, Tracker & GeoGebra Taster: Discussion and agreement on "who does what," research, expert interviews, development of solution and plan, practice presentation

12.30 – 12.50 Group 60–second presentations/demonstrations

Receive feedback, discuss team–working experience

12.50 – 13.00 Next Steps and Close

Workshop 2: Exploring the Science and Maths, Designing and Constructing the Mode

In workshops 2 and 3, we move to progressively less-structured student-driven workshops. Tracker movement recording (Tracker - cciteasp2) and GeoGebra simulation (GeoGebra - cciteasp2) are introduced in more depth:

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Welcome and Project Objectives

Video capture, Tracker, and GeoGebra re–cap

Discussion and play with real–life examples

"Do your own" activity—students develop their own ideas with help, as/if requested

Presentation preparation

60–seconds Presentation: YOUR activity, ideas, and next steps

Workshop 3: Evaluating and Refining the Model

Welcome and individual project presentation update—feedback and suggestions from pupils and experts

Pupils work on their individual projects and are visited by our various experts receiving support as and when needed

Tracker and GeoGebra Help in developing project—from GeoGebra experts

GeoGebra on-–line communication and collaboration including getting content on GeoGebra during the day

Individual project presentation update and agreement on next steps and meeting

Workshop 4: Presenting the Project

The final session is essentially a celebration event where students present their work, assess each others work (with or without a winner or prize). The presentation "KIKS Kids Inspiring Kids in STEAM UK" illustrates the presentation aspect (both physical and on-line) throughout the process culminating in an event engaging other children, parents, experts and community:

https://prezi.com/jnd6nez1oz11/kiks-kids-inspiring-kids-in-steam-uk/?present=1

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4 EVALUATION

This presentation features a variety of evaluation examples - these can be tailored to, or might form part of, or be in addition to, a specific organisation's assessment and evaluation requirements:

https://sites.google.com/view/tony-houghton/evaluation

Below are three examples featured in the presentation relating to:

PLTS Skills

PLTS (Personal Learning Thinking Skills) evaluations, both paper and on-line get students to THINK about their work and receive feedback from peers and teacher.

Perceptions

PISA International best practice tells us that self-belief and High PERCEPTION of the value of education is a key differentiator of the best international educational systems. Accordingly, we can measure Self Perception (eg self-esteem, aspirations and respect), and enhanced Perception of eg Education, STEM and Technology careers.

Ratings

We can also find out a lot about how students and teachers enjoyed and benefited from the activity by looking at how many completed the process and their ratings of the activity. This in turn allows us to determine cost benefits. We can mix qualitative and qualitative to evaluate the activity and also identify enhancements.

5 MATERIALS AND ROOMS

Classroom, mobile and/or mobile cameras, computers and LAN access, school playing areas

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6 CONCLUSIONS: RECAP & REFLEXION

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STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

MAKING TESSELLATIONS!

EDUCATIONAL TECHNOLOGY LAB, DEPT. OF EDUCATIONAL STUDIES, SCH. OF PHILOSOPHY, NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS

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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	20-1-22
MAIN AUTHORS' NAME AND EMAIL ADDRESS	Myrto Karavakou (karavak@eds.uoa.gr), Dimitris Diamantidis (dimitrd@eds.uoa.gr).
CONTRIBUTING INSTITUTIONS	Educational Technology Lab, Dept. of Educational Studies, Sch. Of Philosophy, National & Kapodistrian University of Athens.
REVIEWED BY	-
STATUS	Final

TABLE OF CONTENTS

1 PROJECT JUSTIFICATION

This project can be an offspring for students to express themselves aesthetically, in a learning environment, through programming, where the making of Mathematical meaning can be the key to their personal expression. To make their own creations in 3D space through logo programming in MaLT2 (http://etl.ppp.uoa.gr/malt2/), a 3D Turtle Geometry environment with dynamic manipulation affordances, they should handle mathematical concepts and properties, making new meaning in a concrete or even abstract way.

1.1 Project Overview

Participant age:13-16	*No. of participants: a classroom*	*Duration: 3-4 school hours*
Level of knowledge: Preliminary knowledge of logo programming	*No. of teachers: 1-2*	*Type of venue: PC school lab*
Learning methodologies: PBL (project-based learning) Collaborative learning Constructionism	*Involved disciplines:* Technology Arts Mathematics	*Technological needs:* Computers Internet
Most emphasized learning methodology: PBL	*Main addressed topics:* Symmetry, tiling.	*Estimated project cost:* 0 €

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2 CURRICULAR CONTEXT

2.1 Key competences

The main key competences may be developed during the project development:

- Creativity
- Computational thinking
- Collaboration skills
- Taking initiative
- Critical thinking
- Originality

2.2 Content

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

DISCIPLINE	CURRICULAR CONTENT ADDRESSED
Technology	The use of MaLT2, dynamic manipulation of 3D objects in the screen.
	Logo programming.
Engineering	Makers' culture.
	Design through experimentation.
Arts	Design and create mosaics, based on Escher's creations.
Mathematics	Geometrical figures.
	Symmetry (translation, rotation, reflection).



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The main aim is the tiling of a square frame with tiles, either using one kind of ready-made tile, or by creating a new tile, but not a square.

2.3 Expected learning outcomes.

What we expect students to achieve after their engagement with the project:

- Students make meaning on symmetry, use translation, rotation, and reflection to make figures.
- They use proportions and inverse proportions to make drawings.
- They use variables to express geometrical properties, in an algebraic way.

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3 STEPS TO BE EXECUTED

3.1 Step 1: Identifying the problem.

Duration: 0.5 SH (school hour).

The problem is the tiling of a square frame in the 3D space of MaLT2 with tiles, in a way that is aesthetically accepted and valuable for them (Figure 1). In this step, students should frame the problem, realize what they can do, and they cannot do in this learning environment, and identify its main characteristics, and constraints.

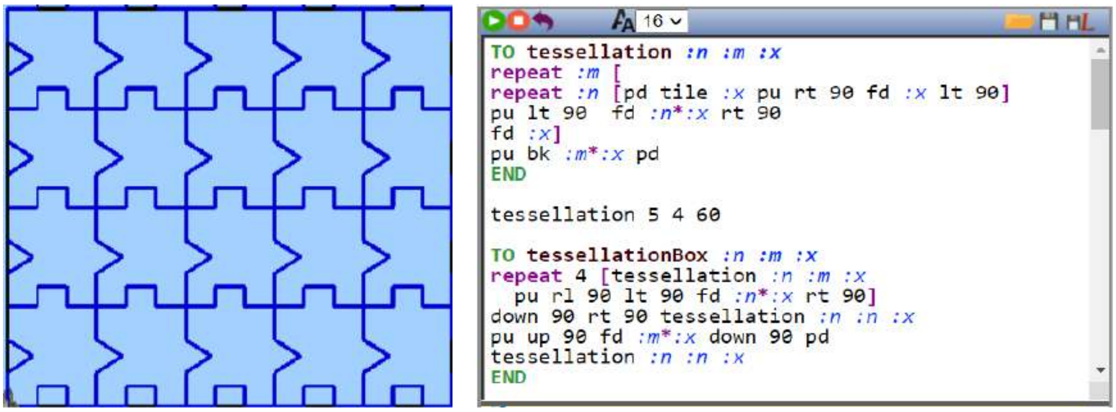

Figure 1: On the left-hand side: a case of tiling the square, in the environment of MaLT2. On the right-hand side: the logo editor containing the procedure that makes the tessellation.

3.1.1 Constraints

The only constraint is that the tile should not be a square, not only because the solution is trivial; the construction should be aesthetically valuable for the students.

It is obvious that the tiles should not overlap.

For the tiling, students may use some ready-made tiles that they are given to them as logo programs in MaLT2, or they could create their own tiles (through programming).

3.1.2 Criteria

The aesthetic result is the main criterion. We do not have to predetermine criteria of aesthetic quality, because we should let students express their understanding of it.

3.2 Step 2: Generating ideas.

Duration: 0.5 SH.

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The main objective of this step is that students introduce, discuss, and reflect on ideas about this type of tiling. Escher's paintings will be used as sparkers by the teacher, so that students recognize the three types of symmetry. The following themes could be used by the teacher as questions that will help students organize their activity:

- Brainstorming based on Escher's paintings and their relation to the project.
- Discussion and reflection on tiling based on Escher's paintings.
- Organizing the goals.
- Devising a strategy about how they will work.

As the inquiry will proceed, it is expected that the conversation and communication will be more Mathematically based.

Tip for teachers: If necessary, remind students of the criteria and constraints identified.

3.2.1 Sub-problems

Students could recognize some sub-problem, to make their own solutions.

- What types of symmetry does Escher use?
- How can we produce symmetry through programming?
- How can we avoid overlapping?

3.3 Step 3: Mathematical investigation.

Duration: 1 SH

In this step, students may try to answer the sub-problems above (or more of their own), giving provisional answers to start working. Some more specific questions to be answered are:

- How can we reproduce a tile in MaLT2 exploiting translation, rotation, or reflection?
- How can we use the given tiles to make tessellations and a mosaic in the square given?
- Will we use the given tiles, or are we going to create our own tile?

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- Are we going to use one type of symmetry or not? Will we choose this type from the beginning?

3.3.1 Experiment/task 1

The following figure (Figure 2) shows the tiling through rotation.

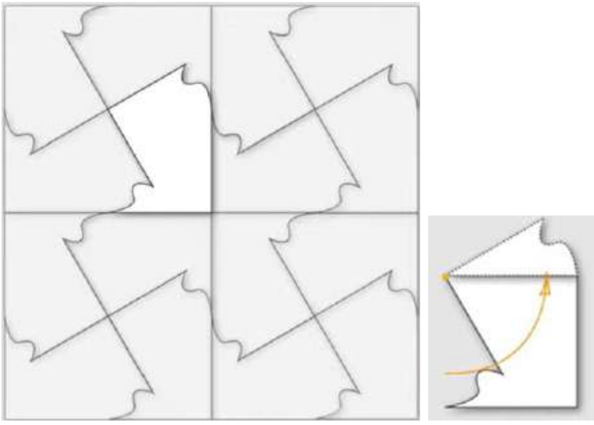

Figure 2: Experimenting with symmetry using paper and pencil.

Students may use paper and pencil to experiment with symmetry (rotation, translation, reflection) or use the program of the tile (below) and the slider on MaLT2 to change it (Figure 3) and reproduce it through translation or rotation.

```
to tile :x

setpencolor [0 0 255]
fd :x/3
right 60
fd :x/3
lt 120
fd :x/3
rt 60
fd :x/3
rt 90
fd :x/3
lt 90
fd :x/5
rt 90
fd :x/3
rt 90
fd :x/5
lt 90
fd :x/3
rt 90
```

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```
fd :x/3
left 60
fd :x/3
rt 120
fd :x/3
lt 60
fd :x/3
rt 90
fd :x/3
rt 90
fd :x/5
lt 90
fd :x/3
lt 90
fd :x/5
rt 90
fd :x/3
rt 90
end

tile 50
```

Figure 3: Using the slider, students may manipulate the value of x, changing the size of the tile.

3.3.2 Experiment/task 2

Formulate ideas through experimentation for tiling the square given with a tile of your preference and by using any of the symmetry's types?

In this task, students move forward trying to reproduce a tile, to make tessellations with no overlapping.

3.4 Step 4: Designing and Constructing the model.

Duration: 1 SH

During this step, students will generate many ways as possible to make tessellations of the square using MaLT2. They may exploit the experimentation of the previous phase, but they can construct a model based on a totally novel idea. The sub-problems they are supposed to address are:

- Implement their ideas from previous phases, to reproduce the tile in MaLT2.

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- Make the tiling fit into the square.
- Try different types of tiles.
- Try tiling using different types of symmetry.

Each group of students will suggest solutions for each sub-problem and will be a prototype of their project.

3.5 Step 5: Evaluating the model

Duration: 0.5 SH

The prototypes from the previous step will be discussed with the whole classroom and the teacher. They should be encouraged to exchange the prototypes and test them, to elaborate them after group discussion. The teachers may pose the following questions:

- Does it work?
- Does it address the problem?
- How do you like it?
- How could you improve the prototype?

3.6 Step 6: Refining the model.

Duration: 0.5 SH

After the group discussion, the exchange of the prototypes, and the reflection on them, student may refine their own prototype, based on the feedback they got.

At the end of the refining process, models could be presented to e-class.

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4 PROJECT EVALUATION

Proposing ways to evaluate the expected learning results.

To evaluate the learning process, we propose the exploitation of the learning outcomes of the lesson.

- Give the students a simple task asking them to apply symmetric transformations in a figure; assess their use of translation, rotation, and reflection.
- Ask students to write down the ratio of magnification or diminution of two given figures.
- Then ask them to make magnifications or diminutions of shapes, with given ratios.
- Give students tasks to express through formulas the relationship of lengths in given shapes.

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5 MATERIALS AND ROOMS

There is no cost since the school has a PC lab, and MaLT2 is free.

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6 INSTRUCTIONS ABOUT THE CONSTRUCTION OF PROTOTYPE/SOFTWARE/OTHER

An exemplary tile in logo is given above. You may create your own tiles. Here are some ready-made procedures in logo.

```
To tile1 :a
setpencolor [102 0 255]
fd :a/3 rt 60
fd :x/3 lt 120
fd :x/3 rt 60
fd :x/3 rt 90
fd :x/3 lt 90
fd :x/5 rt 90
fd :x/3 rt 90
fd :x/5 lt 90
fd :x/3 rt 90
fd :x/3 lt 60
fd :x/3 rt 120
fd :x/3 lt 60
fd :x/3 rt 90
fd :x/3 rt 90
fd :x/5 lt 90
fd :x/3 lt 90
fd :x/5 lt 90
fd :x/3 rt 90
```

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```
END

To tile2 :x
setpencolor [5 118 84]
rt 60 fd 2*:x/3
lt 120 fd 2*:x/3
rt 60 fd :x/3
rt 90 fd :x/3
lt 60 fd 2*:x/3
rt 120 fd 2*:x/3
rt 30 fd :α
rt 90 fd :x rt 90
END

To tile3 :x
setpencolor [255 123 0]
rt 60 fd 2*:x/3
lt 120 fd 2*:x/3
rt 60 fd :x/3
rt 90 fd :x
rt 30 fd 2*:x/3
rt 120 fd 2*:x/3
lt 60
fd :x/3
```

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```
rt 90 fd :x

rt 90

END



To frame

setpencolor [0 0 0]

repeat 2 [fd 200 rt 90 fd 250 rt 90]

END
```

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

3 Design-based learning

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

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

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

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

DR. KRISTÓF FENYVESI, UNIVERSITY OF JYVÄSKYLÄ, FINLAND - CONTACT: KRISTOF.FENYVESI@JYU.FI

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
MAIN AUTHORS' NAME AND EMAIL ADDRESS	Dr. Kristof Fenyvesi, kristof.fenyvesi@jyu.fi
CONTRIBUTING INSTITUTIONS	University of Jyväskylä (JYU)
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TABLE OF CONTENTS

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

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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 the model 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.

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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

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Experience STEAM from Finland: Synergies in Action!

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

STEAMTeach
STEAM Education for Teaching Professionalism

Kristóf Fenyvesi, Ph.D.

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- STEAM (Science, Technology, Engineering, Arts and Mathematics), Trans- and Multidisciplinary Learning
- Contemporary Cultural Studies

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

Innovative Learning Environments

Finnish Institute For Educational Research

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

ILE is a research and education group that focuses on the advancement of children's and young people's 21st Century Skills. The field includes especially user-driven design and study of learning technologies and spaces for enhancement of learning and wellbeing, analyses of innovative teaching and learning practices, technology-enhanced learning, and evaluation and comparison of ICT use in education. When applicable, the research can also be directed to other phases of human life for the study of citizen's knowledge society capabilities.

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Saana Mehtälä · Mikko Muilu · Mimmu Alanko · Matias Mäki-Kuutti · Takumi Yada

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STEAM UPGRADE
Upgrading pre- and in-service teachers' digital skills with online STEAM hands-on training modules

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STEAM BOX

JYULearn

"Co-designing learning environments with teachers and learners"

Ministry of Education and Culture

"Assessment of transversal skills in formal and informal learning environments"

kaks.fi
KUNNALLISALAN KEHITTÄMISSÄÄTIÖ

Digiloping Teachers:
Digital competences development and mentoring for teachers

https://www.jyu.fi/it/en/research/research-areas/cognitive-science-and-educational-technology/ile

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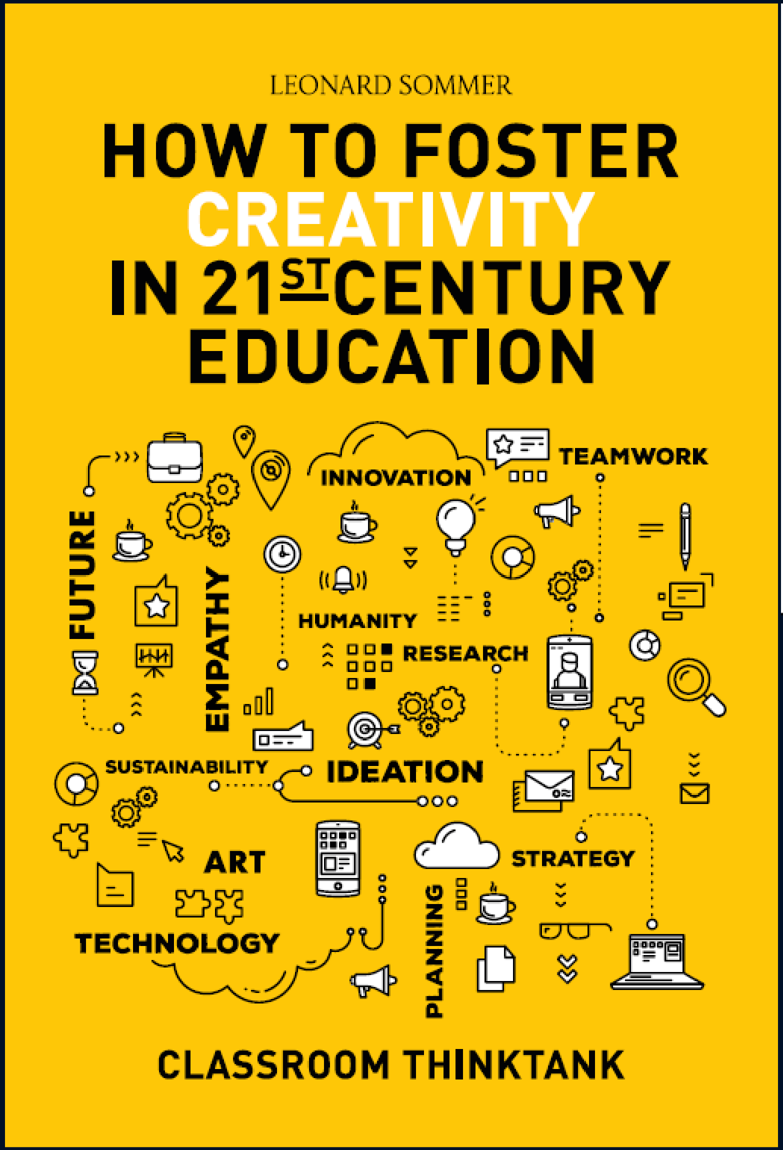
STEAM:

integration between subjects of Science, Technology, Engineering, Arts and Mathematics



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Volume of water stored [Giga-litres]
1000
750
500
250
0
2013
2014
2015
2016
2017
2018
unavailable storage (13.5% of total)
unavailable storage (10% of total)
Jul 2013
Jan 2014
Jul 2014
Jan 2015
Jul 2015
Jan 2016
Jul 2016
Jan 2017
Jul 2017
Jan 2018


Cape Town, South Africa
https://youtu.be/THJVuinPbc0
https://youtu.be/kdSUivEdlN0
EXPERIENCE WORKSHOP
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Cape Town's largest water reservoir, Theewaterskloof,
was at 11% capacity in March 2018

LEARNING FROM NATURE – Biomimetics

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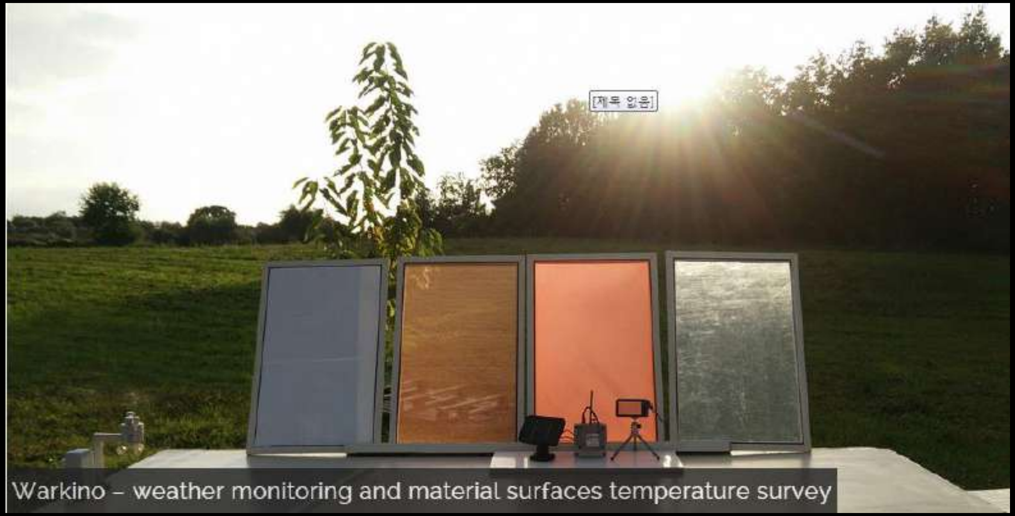
안개 수확

이슬 맺힘



ARTURO VITTORI

Founder – Bomarzo – Italy

Italian Artist, Architect, and Industrial Designer. He is the co-founder and Director of the design studio Architecture and Vision.

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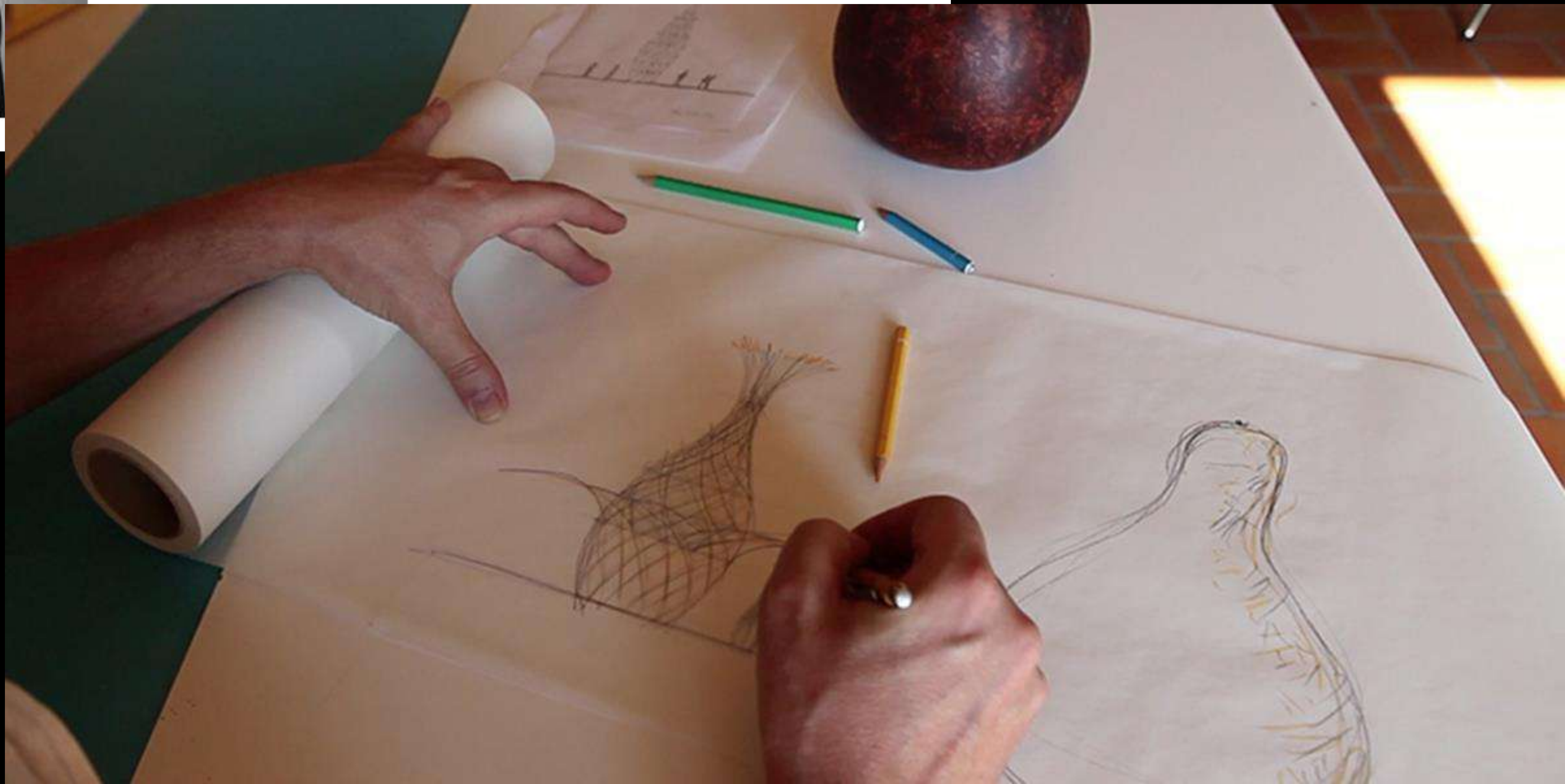
WARKA WATER TOWER for HARVESTING WATER FROM THE AIR



(Evolution)

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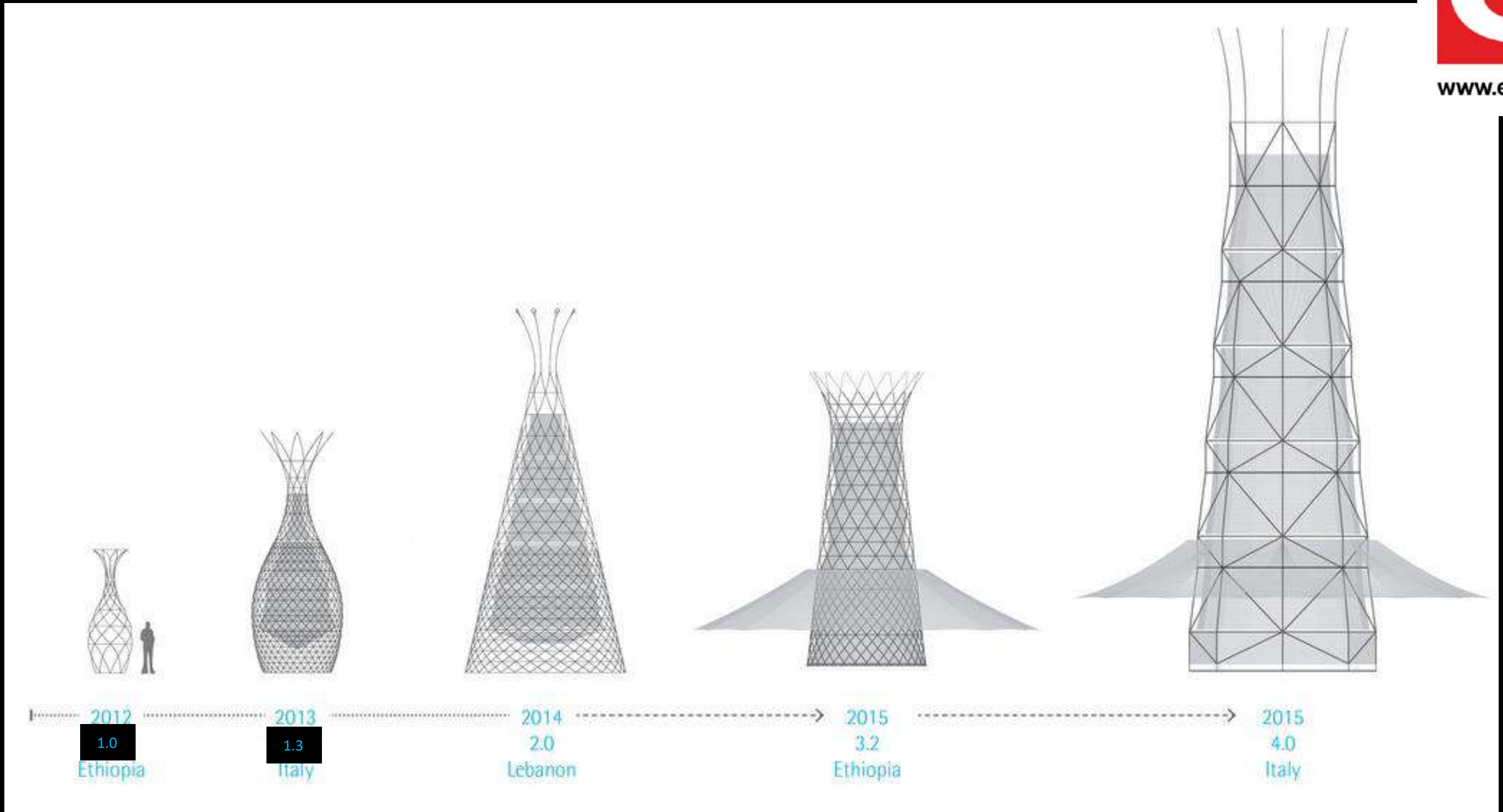
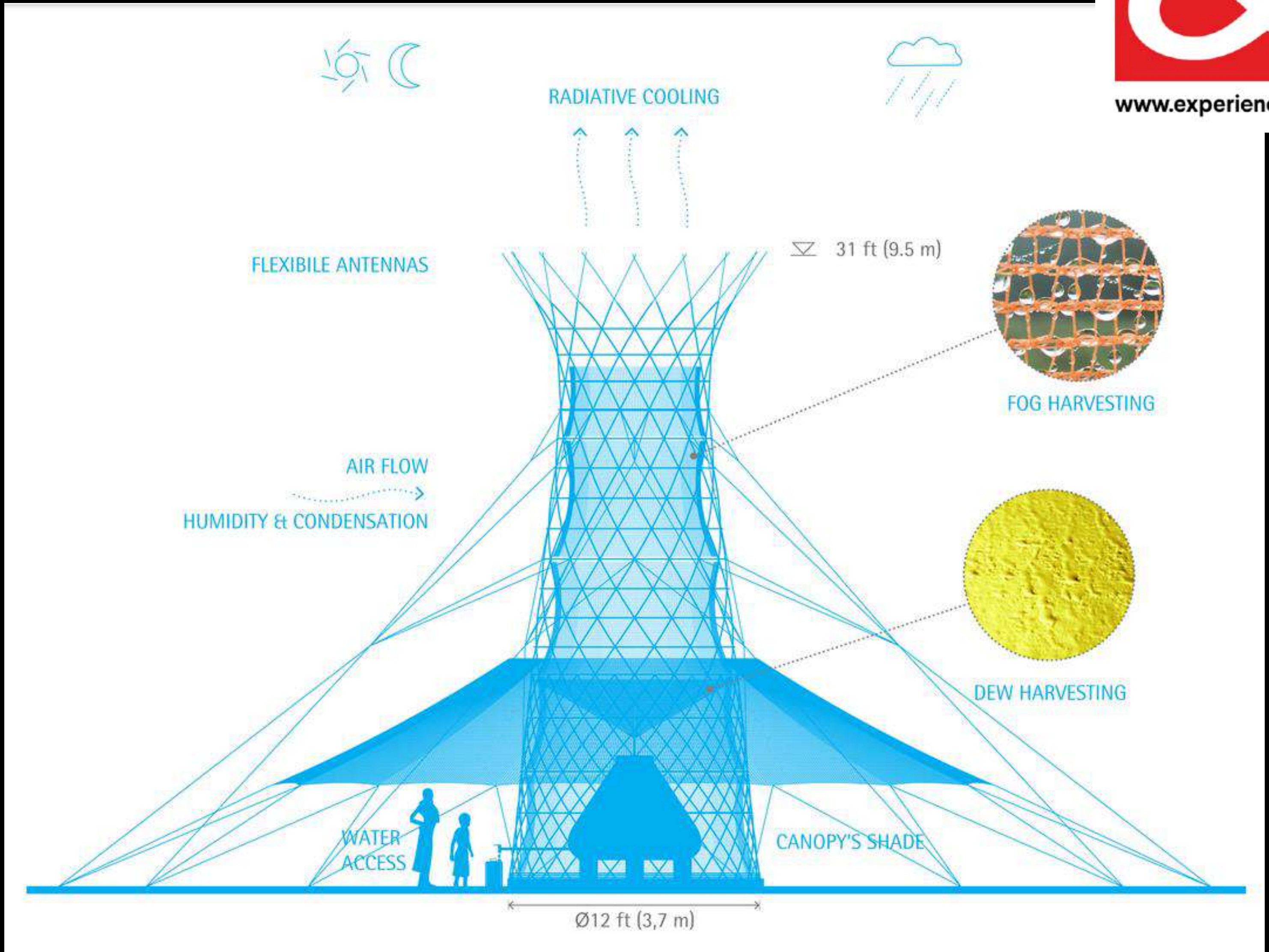


http://www.warkawater.org/evolution



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Warka Water 1 – Version 1.1

Warka Water 3 – Version 3.2

Hogul Park

- Inventor of 4Dframe
- 4Dframe Creativity Educational Program developer
- Architecture Model Expert with 30 years of experience
- Ph.D. Candidate in Science-gifted education, Korea National University of Education
- Associated degree in Architecture, Dong Seoul University
- Director of 4D Mathematical Science & Creativity Research Institute

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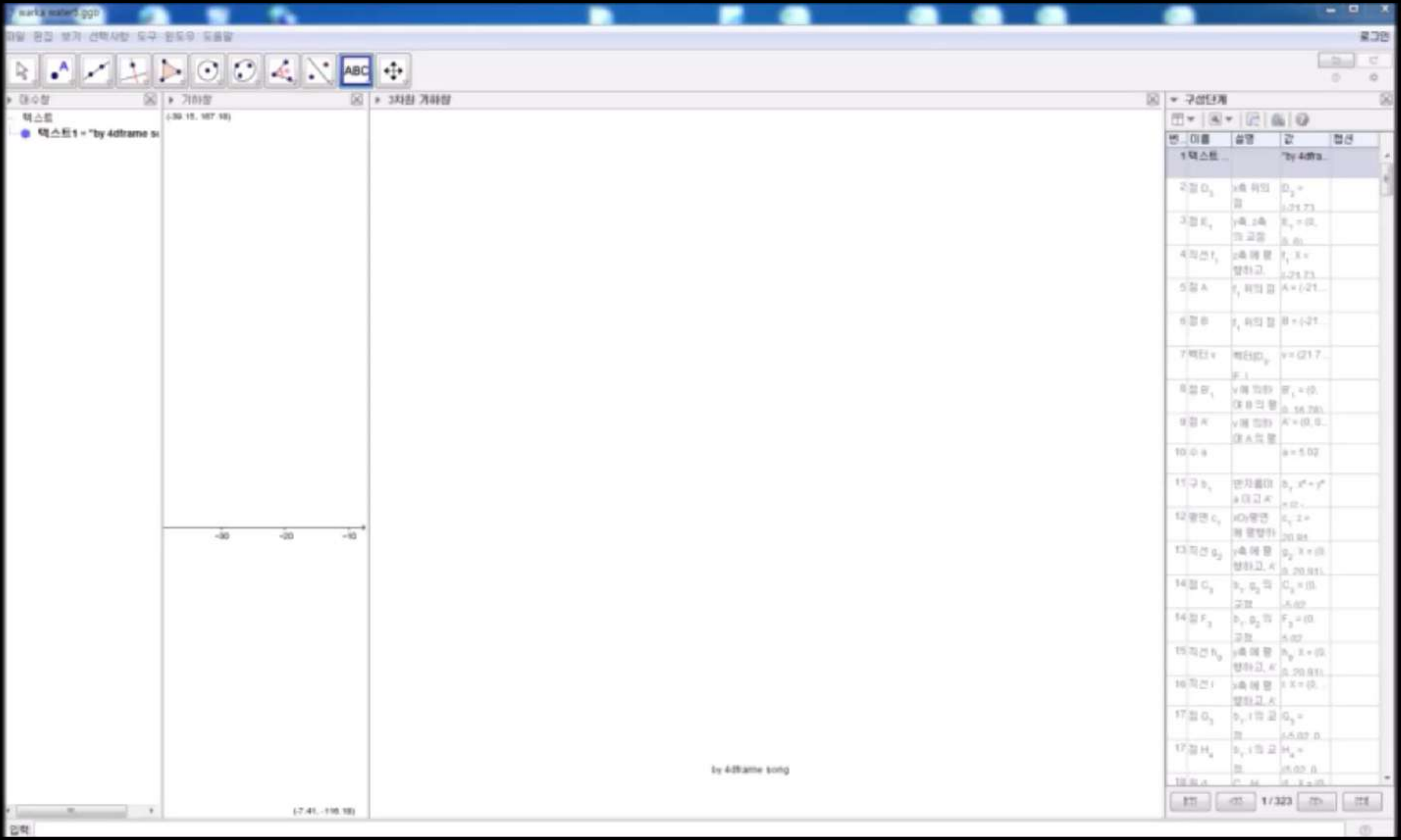

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June 2023

PROJECT-BASED LEARNING: PHYSICS AND MUSIC

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

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

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

Project-Based Learning: Physics and Music	
Author	Dr. OLÁH Éva Mária
STEAM areas	Physics, math, design, music, biology, technology
Cross-cultural connections	Musical styles, crafting and playing musical instruments, affinity for music
Summary	
Subject	Physics
Topic	Acoustics, astronomy, particle physics
Age of students	Age 6-20 years
Project time	8 x 45 minutes
Number of participants	15-20 students
Online teaching material	Oláh Éva Mária: A mikrovilág zenéje [1] Oláh Éva: Zenéljünk fizikául vagy fizikázzunk zenéül [2] Kepler: Harmonices mundi [3] 1 Kepler and the Music of the Spheres [4]
Offline teaching material	Oláh Éva, A mikrovilág zenéje, avagy játék a húrokkal, Juhász A., Tél T. (szerk.), A fizika, matematika és művészet találkozása az oktatásban, kutatásban, Budapest (2013), ISBN 978963-284-346-9, pp. 141-146. Részecskefizika tanítása középiskolában, Disszertáció benyújtásának az éve: 2018, Védés éve: 2018. Megjelenés, fokozatszerzés éve: 2018. DOI: 10. 15476/ELTE.2018.127 (PhD), III. rész (A mikrovilág megismertetése zenei analógiákkal)

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

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

	Dr. Nagy Anett, hangszerek a „semmiből”, NUKLEON, III. évf. (2010) 56	
21st-century competences	• Critical thinking • Creativity • Collaboration • Communication • Technology literacy • Flexibility • Leadership • Initiative • Productivity	
Learning objectives	Acquiring discipline-related knowledge, in-depth understanding of topic (acoustics, astronomy), assisting the formation of learning communities, developing manual skills, developing abstract thinking skills, playful learning	
Project Plan		
	Procedure	**Time**
Discuss questions	What does the term music of the spheres mean? How old are the earliest musical instruments? Do you need to understand basic mathematics to play music? Why some people have an ear for music while others do not? Which organs assist hearing? Can physicists play musical instruments? What are high and low sounds? Which animals have the best hearing? Does our hearing range change with age? What is music? How do celestial bodies move? Particle physics or string theory? What are the so-called standing waves?	35 minutes

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	What is the difference between the so-called geocentric and heliocentric model of the universe? Do planets produce sound while they are moving? If they did, would it be possible to hear that sound in space? Does pitch depend on the distance from the Sun? Does frequency range depend on the shape of the elliptic orbit?	
 Brainstorming	Collecting students' ideas Whole-class discussion following group work. Incorporating ideas and innovations into the project.	10 minutes
 Prepare	Collecting tools (straws, pliers, paperboard cores, jars, Coke bottles, wine glasses, plastic tubes, PET bottles, coloured paper sheets, scissors, glue, coloured felt tip pens, rulers, strings, wooden spoons, balloons, tins, wooden laths, drain hoses) Crafting "instruments" Drawing rainbow sheets Selecting musical pieces	45 minutes
 Demonstrate	• Sound generator for "audiometry" • Kepler: The Harmony of the Worlds • Kepler's laws • Solar system model • Relationship between speed and frequency Doppler effect • Musical drain hoses By using musical analogies, this section aims to demonstrate that the planets of the Solar System move according to Kepler's laws. The planets' distance from the Sun, the size of their orbit, their eccentricity and the	3 x 45 minutes

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	resulting change in speed all define what sounds may be assigned to their movement. Thus, familiarity with acoustics helps one better understand and discover the amazing system to which our planet belongs. As a starting point, we take a drain hose, a common household fitting to demonstrate how pitch changes depending on how fast or slow we turn it around manually. Higher speed comes with a higher frequency, which, in turn, produces a higher sound. The planets of the Solar System, except for Venus, directly revolve around the same focus i.e. the Sun moving around elliptical orbits, each of which deviates from a perfect circle to a different extent, thus their distance from the Sun varies. At the same time, the gravitational force planets are exposed to also varies which is compensated by their higher or lower speed. This causes our planets to make different "sounds" while orbiting the Sun. Students verify the correlations between frequency and pitch by playing the various musical instruments they craft. Soda bottles filled with varying amounts of water and plastic tubes of differing length can make a sound when we blow into them or hit them respectively while measuring the length of the water and air columns we can determine wavelength and frequency. These art-related activities that are directly performed by students offer them an experimental and more enjoyable learning process and thus they leave class having a longer lasting knowledge. • **Introduction of elementary particles, supersymmetric strings** Watch a video and have a follow-up discussion.	

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	• **Demonstration of differences between longitudinal and transverse waves using a "straw" wave machine** Place straws at right angles on a duct tape at equal distance from each other. For better results, attach balls made of dough to the tips of the straws to make the cyclic process last longer. • **Wavelengths and frequency of musical instruments** $c = \lambda \cdot f$ (where „c" is the speed of the sound wave within a given medium, „λ" is the length of the sound wave and „f" denotes frequency. Even relying on only basic mathematical skills, one can recognize that wavelength is inversely proportional to frequency. In practice, this means that the longer the wavelength (longer columns of water and air) the lower sound it makes. • **Demonstration of standing waves on a guitar** Demonstration of standing waves on a guitar producing partials and overtones. In the case of wind instruments, we can change soundwaves and thus frequency by closing the holes on the instrument. • **Musical tubes** Saw plastic tubes at various points to get pieces of differing length according to figures in the attached table. Chisel the ends for a smooth surface. Then mark each tube with the same colour as the colour of its corresponding note in the so-called rainbow sheet. By slapping the tubes to your palms, produce sounds of music caused by the vibration of the air columns in the tubes. • **Xylophone made of paperboard cores**	

	Cut paperboard cores of tinfoil rolls into pieces of varying length. Then attach them to each other with a string, Use wooden spoons as drum sticks to hit them to see how we make them produce sounds by vibrating air columns. • **Jar instrument** Collect jars of various sizes though the most suitable are the ones with a cubic capacity of 1 litre. Use a digital tuner to mark the height of water column in each jar with a coloured stripe according to the colour code for notes used in the previous task. Then use a wooden spoon to vibrate the water columns and thus produce a sound by hitting the jar. • **PET bottle instrument** Produce sounds of music by hitting bottles that contain water columns of different length. Again, hitting them causes the water to vibrate and thus makes a sound. • **Musical Coke bottle** Fill traditional plastic Coke bottles with water. Based on the given colour code, mark the top of the water column with slips of coloured paper. The bottles thus marked may be emptied and used again to make tuning easier. • **Pipe organ from glasses** Choose appropriate wine glasses of different sizes and shapes. Fill the glasses with water up to a given height. Determine the height of the water column in each glass by using an online tuner to denote various sounds. Wet your finger and gently rub it around along the top of the glass. From time to time, you finger gets stuck a bit or slips creating uneven friction which causes the water column to vibrate.	

	• **Straw whistle** Flatten plastic straws with pliers to make a whistle. Shape the ends of the straws as demonstrated in the video specified in the Appendix. Blow the whistle and then start cutting pieces off with a pair of scissors to hear the different sounds you get depending the length of the straw. Once again, you produce sound by vibrating the air and observe the shorter the straw (decreasing soundwave), the higher the pitch (higher frequency). • **Tin drums** Cut off the top of a can, chisel it for a smooth surface and attach a rubber sheet cut out from a balloon on the hole with a string. Use a wooden stick to vibrate the "membrane" which in turn vibrates the air and thus a sound is produced. This tin drum cannot be tuned but it can be used a rhythm instrument accompanying the rest of the instruments.	
 Predict	We cannot hear in vacuum Waves: reflection and interference Planets do not make sounds due to the lack of atmosphere Difference between the revolution and rotation of celestial bodies	15 minutes
 Plan	Using household waste, students make their own instruments. Playing these instruments they explore specific areas of physics in a more relevant and expressive way	30 minutes
 Explore	The focus of the project is to have students chart the laws of physics. Their exploration based on hands-on, minds-on learning leads to a deeper and more lasting knowledge.	15 minutes
	Students compare their results with their preliminary assumptions and formulate their experience.	15 minutes

Record		
Reflect	Why do assumptions and experience differ? Why don’t your instruments make a sound? What could you make a better instrument?	15 minutes
Presentation	Students perform simple musical pieces playing the instruments they have crafted, they explain their principles of operation.	45 minutes
Product	Various musical instruments Rainbow sheets Docx Videos	
Re-design	Find the faults in design that hinder your instrument to make a (proper) sound	
Stations		
Science station	Science includes thinking, observation and experiments. It is important to voice assumptions and then share experience. Matching sounds and the movement of planets. Tools Musical instruments, tablets, PC, notebooks, pens	
Research station	**Physics** Introduction into and understanding of Kepler’ laws of planetary motion. Becoming familiar with the dynamics of circular motion and the force of gravitation. The essence of gravitation.	

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<table>
<tr>
<td></td>
<td colspan="2">Discovering the basic principles of acoustics, defining the correlation between frequency and wavelength.
Exploring correlations through independent experiments
Making sounds, observing tones and pitch
Becoming familiar with specific concepts relating to the science of waves
Tools
Instruments, books, tablets, computers, waves-model</td>
<td></td>
</tr>
<tr>
<td>
Technology station</td>
<td>Electronic technology
• Computers
• Tablets
• Smartphones
• Smartboards
• Digital camera</td>
<td>Non-electronic technology
• Straws
• Pliers
• Paperboard cores
• Various bottled
• Glasses
• Plastic tubes
• PET bottled
• Dough
• Coloured paper sheets
• Scissors
• Glue
• Coloured felt tip pens
• Rulers
• String
• Wooden spoons
• Balloons
• Tins
• Wooden laths
• Drain hose</td>
<td></td>
</tr>
</table>

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<table>
<tr><td>Engineering station</td><td>Engineering tools and materials
Pliers
saw
Markers, pens
Ruler
Scissors
File</td><td></td></tr>
<tr><td>Art and Design station</td><td>Art and design supplies
Music
Recording sounds on staves
Recognizing intervals
Playing instruments
Tools
Glue
Scissors
Coloured paper sheets</td><td></td></tr>
<tr><td>Maths station</td><td>Maths tools
Introduction into fractions, dividing length into equal parts, calculating amounts based on direct and inverse proportionality.
Tools
Calculators
Rulers</td><td></td></tr>
<tr><td>Recording station</td><td>pens
notebooks</td><td></td></tr>
</table>

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Experiences	At the end of the project, joint assessment of experience, discussion of further ideas and future plans Recognizing links between specific disciplines, formulating correlations.	
Appendix	Video [1] https://www.youtube.com/watch?v=Sn9UtxpMZcA&t=1260s [2] https://www.youtube.com/watch?v=g0t0ZPIyv5g&t=3s [3] https://www.youtube.com/watch?v=WihmsRinpQU [4] Kepler and the Music of the Spheres - YouTube [5] Street artist playing Hallelujah with crystal glasses Street artist playing Hallelujah with crystal glasses - YouTube 2 [6] The straw trick - How to make a whistle straw The straw trick - How to make a whistle straw - Easy and simple - YouTube Links [7] https://nuklearis.hu/sites/default/files/nukleon/Nukleon_3_1_56_Nagy.pdf **Discussion** Discussion of assumptions and questions, their verification or rebuttal **Group work** Assigning preparatory tasks to groups 2-3 Assigning individual tasks to group members	

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	Crafting the product in small groups (instrument, word document, PPT, etc.) **Experiments** Higher speed results in higher pitch By vibrating the air, we can make a sound Sounds are produced according to the laws of mathematics.

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3D Modelling and Printing

STEAMTeach Austria PDF

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	Draft
DATE	15.11.2021
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REVIEWED BY	
STATUS	

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1 PROJECT JUSTIFICATION

Trends predict that more and more consumer goods will be produced locally and additive manufacturing reaches many aspects of our lives from producing small items such as replacement parts or jewellery up to large objects such as houses. The ING DIBA Analysis 2017 predicts that this technology will reduce global trading by about 40% in the upcoming future and 50% of produced goods could be 3D printed within the next 20 years. This analysis also shows that teaching and education are among the three most used applications of this technology. Creating useful objects using this technology requires skills from fields from STEAM as materials, forms, machines, and software are involved in the 3D modelling and the production of the model. The European Union developed eight core competencies that should be fostered in education and renewed them in 2018 focusing on basic, entrepreneurial and digital skills as well as languages aiming to enable everyone to participate actively in society. Within these core competencies, especially science, technology, engineering and mathematics (STEM) related skills are emphasized to lead people into careers in STEM fields.

Teachers who want to train their students in these skills need knowledge and tools to do that. However, not only the tools are required but also the motivation, knowledge and skills to use provided tools are required. 3D printing is currently not part of every school's equipment, this technology is rarely found in schools. Not always do teachers possess the intrinsic motivation to find ressources and the courage to master the basics on their own. Apart from the costs of machines, the slow adaptation of such technologies in schools suggests that teachers need support. This course concept investigates which benefits STEAM teachers can expect if they learn about and use 3D modelling and 3D printing and looks at which attributes courses and workshops have that helps them learn about and use this technology in their lessons.

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1.1 Project Overview

Participant age: From 20 to 65	***No. of participants:*** Groups of 10 to 20 people	***Duration:*** 5 to 6 hours, 2 parts
Level of knowledge: Basic Knowledge of GeoGebra, PC user, owner and user of a smartphone	***No. of teachers:*** 2 to 3 people would be perfect, one is the minimum	***Type of venue:*** A mix between a computer classroom and a makerspace with 3D printers
Learning methodologies: Collaboratively working on problems, task based	***Involved disciplines:*** all STEAM disciplines are involved	***Technological needs:*** Computers, two tablets, internet, 3D printers
Most emphasised learning methodology: Collaboration and problem based learning, modelling	***Main addressed topics:*** 3D thinking, mathematical modelling	***Estimated project cost:*** 1500 €

2 CURRICULAR CONTEXT

2.1 Key competences

The developed competencies touch literacy, need and use digital skills, foster STEAM skills, require social interaction and communication in a group, and help develop entrepreneurial thinking and can express one's inner thoughts, ideas and culture.

2.2 Content

DISCIPLINE	CURRICULAR CONTENT ADDRESSED
Science	Temperatures, slopes, shrinking of material, chemical components of materials, glass and melting points, ...
Technology	The use computers and CAD programs that are easy to use from 10 years and above
Engineering	The use 3D printers and create models that can be created in the real world
Arts	design objects that not only fulfill a purpose but that also express one's inner world
Mathematics	mathematical modelling, geometry, vertices, calculus, mirroring, scaling, ...

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2.3 Expected learning results

Pre-service teachers should understand that there is a discrepancy between 2D representations of real world objects and the actual 3D object and it is hard work to understand the projection of a 3D object to 2D and of 2D representations and 3D objects. In addition, they should understand and be able to find and/or alter and/or create 3D models that can solve real world problems or visualize a concept that they want to teach their students.

The ultimate goal is that they know how to motivate and enable their students to use this technology to create their own models. This will help their students to develop and use STEAM skills and also understand the importance of STEAM for their future lives.

3 STEPS TO BE EXECUTED

3.1 Step 1: Presenting needs of students and opportunities of the technology

60 minutes are dedicated to showing teachers what benefits they can expect for their students when doing this workshop and learning about 3D modelling and 3D printing.

A general basis of understanding the technology and what benefits in which lesson and to solve which problems will be shown. Teachers will be asked to play with games in groups of 3 that require STEAM to be created and they will learn that by creating resources they can also teach concepts of their subject. Afterwards, they receive more input about the technology and finally get the task to browse a page filled with examples in their groups to get inspiration. They should then present one example and explain why it can be beneficial to their lessons.

10 minutes break.

3.2 Step 2: Basics of 3D Modelling, Developing their First Idea

The next 50 minutes revolve around participants learning and understanding more about what attributes a 3D printable model has, get a repetition on why it can be beneficial for their lessons and their students and create their first models. Introductions into modelling using GeoGebra and TinkerCAD where participants need to create simple objects such as prisms should help them understand representations in 3D.

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They develop their own ideas in groups of 3 and create a GeoGebra book documenting their individual project ideas. Each project must be 3D printable, beneficial to their personal subject and should be producible within 10 minutes of printing time.

10 minutes break.

3.3 Step 3: Software more In Depth

The next 50 minutes should be dedicated to project ideas and more in depth modelling as well as basics of 3D printing. All ideas should be briefly presented and 2 other groups have to give feedback to a presentation so everyone gets feedback.

After the presentations, modelling something more complex and modifying the 3D model in Meshmixer and Repetierhost should help to understand how to refine one's model. Basics of which software is responsible for what in the production process will be presented.

20 minutes break, end of part 1

3.4 Step 4: Designing and Refining the 3D Model, first Print

Groups will have time of 40 minutes to refine their modelling ideas or start to alter simple models they found. All participants will be able to observe a 3D printer in action and get a presentation of an entire process from a 3D model download to the creation of the model with the 3D printing machine with a repetition of all steps of the software.

One group will get a special introduction on how to handle a 3D printer so they can operate the machine in the next step in 10 Minutes. The other groups can commence working on their models.

10 minutes break.

3.5 Step 5: Creating and Evaluating the 3D Object

The last hour of the workshop is dedicated to printing out all developed 3D models. If a group feels ready, they are invited to approach one of the dedicated 3D printing group members and try their print.

They then should evaluate in their group whether the print went fine or if there could be some improvement and then show their solution to another group for feedback.

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4 PROJECT EVALUATION

Ask participants to fill out open questions about 3 days later

5 MATERIALS AND ROOMS

One room as described, enough electricity, W-LAN, about 4 3D printers

6 INSTRUCTIONS ABOUT THE CONSTRUCTION OF PROTOTYPE/SOFTWARE/OTHER

Instructions are provided and collected in GeoGebra books.

7 CONCLUSIONS RECAP & REFLECTION

A recap and a reflection would be nice. I can not draw conclusions now.

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4 Collaborative learning

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June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

COOPERATIVE LEARNING: WATER

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

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

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Cooperative Learning: Water

Author	Dr. KOPASZ Katalin
STEAM areas	Physics, earth science, chemistry, design, technology
Cross-cultural connections	Water is essential for life (biology, physics, chemistry; history & society). Scarcity of freshwater is a key global issue.

Summary

Subject	Science
Topic	Water
Age of students	Age 10-18 years
Project time	4 x 45 minutes
Number of participants	Max. 30 students
Online teaching material	Materials are listed under each station offering specific examples of possible activities.
Offline teaching material	Materials are listed under each station offering specific examples of possible activities.
21st-century competences	• Innovation • Creativity • Problem-solving • Analytical thinking • Active learning • Critical thinking • ICT • Cooperative skills
Learning objectives	• Acquiring discipline-related knowledge • Assisting the formation of learning communities

- Developing manual skills
- Developing abstract thinking skills

Project Plan

	Procedure	Time
Discussion questions	• Is the pencil broken? • Can we walk on water? • Can we blow out a candle with bubbles? • Why are films of oil coloured? • How can we colour a white flower? • What does pH5.5 mean? • What is corrosion? • What is hard water? • Can we make puddle water drinkable? • Tap water or mineral water? • Still waters run deep – The role of water in erosion. • Water scarcity – How can we help?	45 minutes
Brainstorming	Forming groups, assigning topics, collecting the ideas of the students	
Prepare Demonstrate	Collecting necessary tools for individual experiments, arranging experiments, preparing descriptions and manuals. Each group prepares a station of an interactive exhibition. There should be descriptions and interactive elements at each station (if possible).	2 x 45 minutes
Predict	Becoming familiar with the versatility and interesting properties of water and its scarcity, students are becoming more eco-conscious.	

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Explore	Each group prepares its own station as part of an interactive exhibition in a cooperative way. Once they have finished, each station is visited by the members of the other groups to try the exhibits and learn about the results.	
Record	Students easily acquire knowledge while attending the exhibition and playing at the stations.	45 minutes
Reflect	Why do hypotheses and experiences agree/disagree?	45 minutes
Presentation	Students make an interactive science fair. Everyone can look at and test the exhibits.	
Product	Experimental sets	
Re-design	Experiments and/or descriptions may be modified after the first tests.	

Stations

Below there are some ideas on how/what to prepare for the stations below. Each of the events will result in a novel collection of experiments.

Optical illusions with water (refraction)

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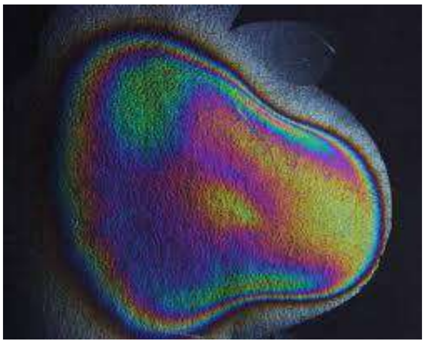
	Find interesting optical phenomena connected to water, e.g. 'broken pencil' Online materials: https://metaphysicsofphysics.com/episode-sixteen-optical-illusions-proof-of-the-validity-of-the-senses/2/ https://www.youtube.com/watch?v=G303o8pJzls
Thin film interference	Why are films of oil coloured? It is due to the phenomenon of thin-film interference. Find an explanation! Create a model with the help of nail polish and paper sheets.  Thin film interference with nail polish: https://www.nisenet.org/sites/default/files/catalog/uploads/MaterialsFilm_guide_5oct14.pdf Background: https://en.wikipedia.org/wiki/Thin-film_interference https://www.youtube.com/watch?v=4I34jA1fDp4
Surface tension of water	Upside down bottle or Can you carry water in a sieve?

	 https://blog.doublehelix.csiro.au/upside-down-bottle/
Curvature pressure:	Can we blow out a candle with bubbles? 
Capillarity and flowers	Colour changing flower experiment:  https://taminglittlemonsters.com/color-changing-flower-experiment-for-kids/

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Acids and bases:	The Red Cabbage pH Test: https://scienceexplorers.com/teaching-children-about-acids-and-bases/
Is water hard?	Hard water experiment: https://layers-of-learning.com/hard-water-experiment/
Water cleaning	Make a water filter: https://kids.nationalgeographic.com/books/article/water-wonders https://raisinglifelonglearners.com/sand-filter-activity/ https://study.com/academy/lesson/water-filtration-science-project.html
Still waters run deep – The role of water in erosion Weathering, Erosion, and Deposition	Weathering, Erosion, and Deposition: https://www.youtube.com/watch?v=-MFLgtti51I
Water scarcity	The water crisis - Lesson Plans for All Grades: https://thewaterproject.org/resources/lesson-plans/ Note: the topic may be assigned to several stations. For the Hungarian version: http://edu.u-szeged.hu/ttkcs/kezikonyvek (Komplex, p. 132.)
Tap water or bottled water	Are there significant differences between the tap and bottled water? https://www.education.com/science-fair/article/bottled-water-impurities/
Research into a nail - Corrosion	What Is Corrosion? https://studynlearn.com/blog/what-is-corrosion/ https://www.youtube.com/watch?v=Y0s44Wcrwak
Experiences	• Preparation of stations in a cooperative way is an important experience.

- Acquiring knowledge is an important learning step, just as creating didactic and well-usable station elements

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