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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

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PROJECT

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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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