International Conference
The Future of Education
Edição 15

# Critical and Creative Thinking in a Cooperative Learning Context with Emerging Technologies in Maths A

Maria da Graça Magalhães (500gmagalhaes@eshm.edu.pt)

Helena Santos Silva (helsilva@utad.pt)

José Pinto Lopes (jlopes@utad.pt)

University of Trás-os-Montes and Alto Douro (UTAD) and Centre for Educational Research and Intervention of the University of Porto (CIIE), Portugal

# Introduction

- This communication is part of a doctoral project whose main objective is to understand the effects of Cooperative Learning on the development of Critical and Creative Thinking in STEAM students, with the aim of providing evidence to support pedagogical approaches in line with the Profile of Students Leaving Compulsory Schooling in 21st century.

In this study the aim is to **report one of the cooperative activities implemented as part of this project, with the collaborative method Pairs Think Aloud to Solve Problems.**

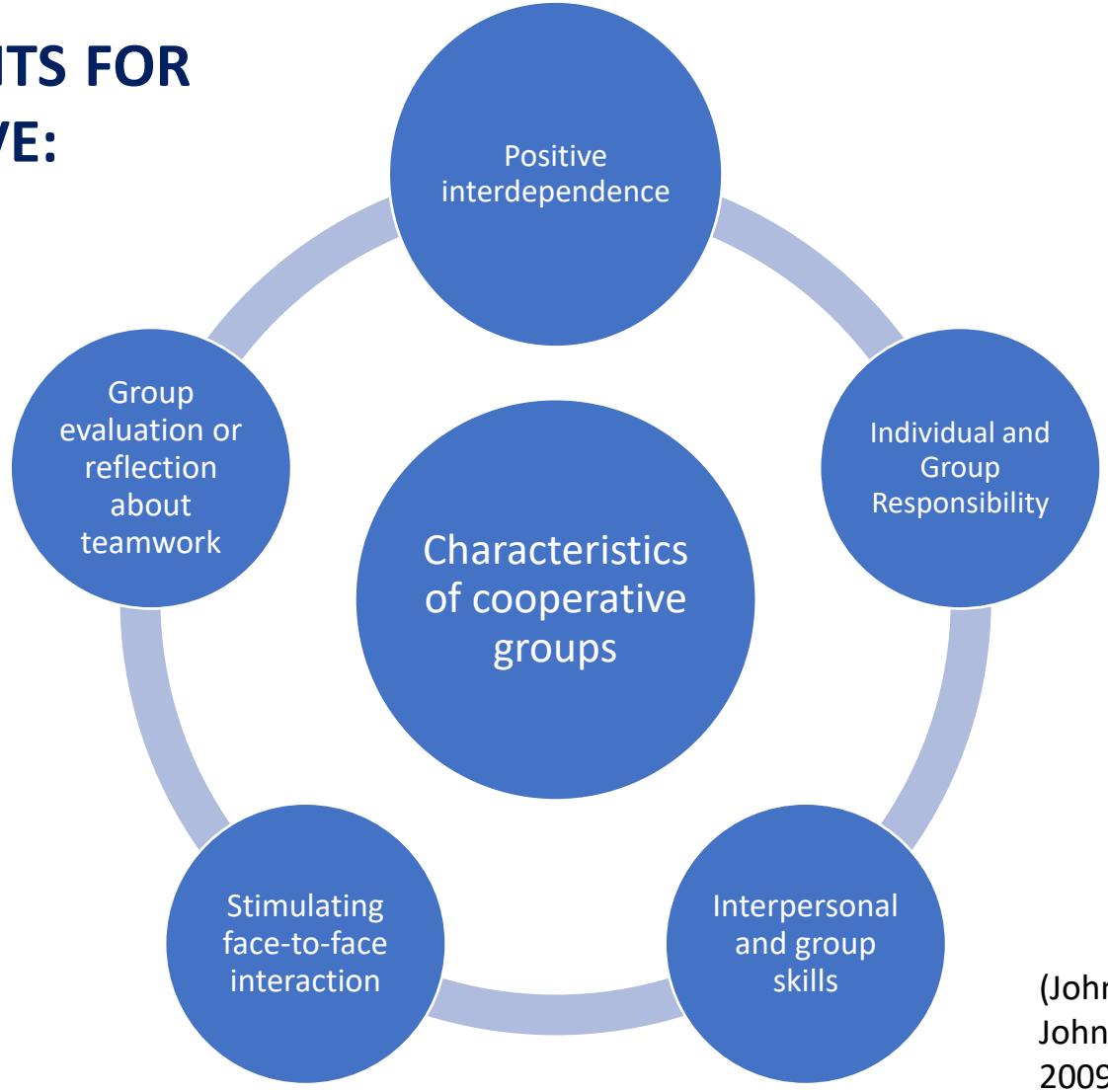
- Developing critical and creative thinking is a key priority in 21st century education (OECD, 2019).
- Cooperative learning and emerging technologies enhance student engagement, reasoning, and creativity (Gillies, 2016; Voogt et al., 2022).
- In Maths A, students face complex tasks that require logical precision and imaginative problem solving.
- This study explores how structured cooperation, and digital tools promote higher-order thinking in secondary mathematics.

# Cooperative Learning

- Cooperative learning is a model of organizing the teaching and learning process, to ensure the equal participation of all elements of the group, providing each of them with the same opportunities to participate in classroom activities, maximizing the possibilities for students to learn by working as a team(Johnson el al., 1999; Lopes & Sila, 2009, 2022; Pujolás, 2012).

**"It is a matter of cooperating to learn and learning to cooperate"**(Lopes & Silva,2022, p.3)

# THE FIVE ESSENTIAL ELEMENTS FOR A GROUP TO BE COOPERATIVE:




(Johnson et al. 1999; Johnson & Johnson, 2009; Lopes & Silva, 2009, 2022)

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**The success of the group depends on the success of each element.**

- There are several **cooperative learning methods,** which enhance the teaching and learning of STEAM subjects, namely, **method Pairs Think Aloud to Solve Problems** (Howden & Martin, 1997; Lopes & Silva, 2009, 2022).

# Critical and Creative Thinking

- Critical thinking is a type of **rational, reflective**, **intentional**, **self-directed**, and **systematic thinking** that focuses on decision-making, analyzing arguments, evaluating concepts, and creating counter-arguments, allowing each one to develop creative attitudes (Ennis, 1987).

- The **essential skills of critical thinking** (CT) are **interpretation**, **analysis**, **evaluation**, **inference**, **explanation** and **self-regulation** (Facione, 1990, 2011).

- In education, the ability to **think critically and creatively** is one of the main goals, however, it is a skill that needs to be trained so that students can work in society (Yuliati et al., 2018).

# Emerging Technologies

- The integration of emerging technologies in the teaching and learning process has been affirmed as a transformative element of educational contexts, enabling more interactive, meaningful, and student-centered practices (Voogt et al., 2018; Czerkawski & Lyman, 2015).

- In the teaching of Mathematics, tools such as programmable graphing calculators, computers, programming languages, and robotic devices have shown high potential in strengthening mathematical reasoning and understanding abstract concepts (Aldon & Trgalova, 2020; Christine, 2017).

# Methodology

## 1. Nature of Research:

**PhD project**

- **Objective:** Understand the effects of Cooperative Learning on the development of Critical and Creative Thinking in 11th grade students in the areas of STEAM.
- **Nature of the research:** **quantitative, almost experimental design with two intact groups, experimental group and control group** (Almeida & Freire, 2007; Coolican, 2018; Tuckman, 2000).

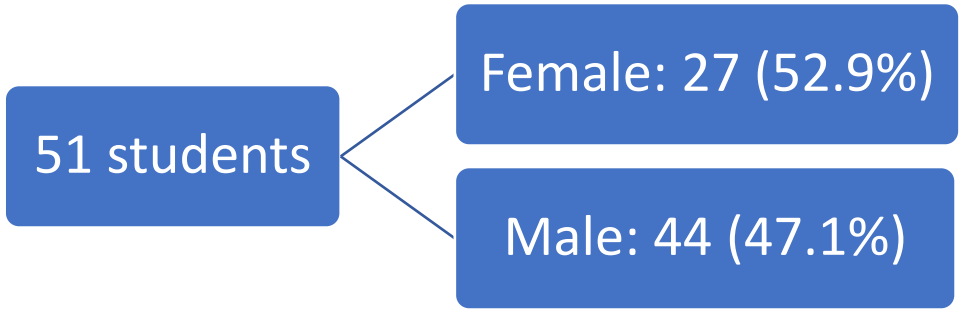
**In this paper**

Report one of the activities implemented in the experimental group, in which the method Pairs Think Aloud to Solve Problems was used.

## Objetives in the activity:

- **Analyze** the impact of cooperative learning on the development of critical and creative thinking in Maths A students.
- **Explore** how structured peer interaction and emerging technologies (Python, TI-Rover, TI-84 CE-T) foster reasoning and problem-solving skills.
- **Assess** students' ability to interpret, analyze, evaluate, and synthesize information during a geometry programming task.
- **Identify** manifestations of creative thinking through fluency, flexibility, and originality in mathematical tasks.

## 2. Participants:




## 3. Instruments:

- Direct observation;
- Individual Reflection;
- Written productions;
- Multimodal records (photographs and videos).

## 4. Data Processing:

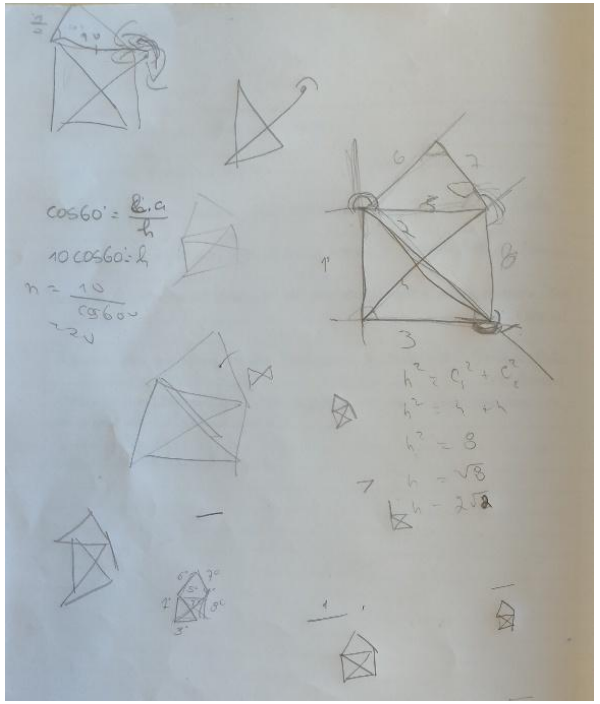
**Content Analysis** (Bardin, 2011; Krippendorff, 2018)

## 5. Study Description:

- The study was conducted in the last **academic year**;
- The teacher formed **heterogeneous groups** (3/4 elements) based on the averages of the 1st period tests;
- The students chose a **name for the group** to encourage team spirit;
- A learning activity was planned with the application of **collaborative method Pairs Think Aloud to Solve Problems;**
- The activity consisted of **programming a geometric path in the Cartesian plane, using Python and programmable robots,** to solve a mathematical challenge grounded in STEAM education and designed to foster logical reasoning, creativity, and collaboration.

# Results and discussion

## 1. Critical Thinking skills: interpretation, analysis, explanation, evaluation and synthesis



- During the work in pairs, the students performed geometric analyses, testing mentally and on paper several possibilities of vector composition (Fig. 1).
- Their notes demonstrate reasonable explanations of the choices made, namely in the selection of angles and the direction of the vectors to respect the criteria of the task.

**Fig. 1.** Vector plane with students' justification notes, demonstrating geometric analysis and argumentation.

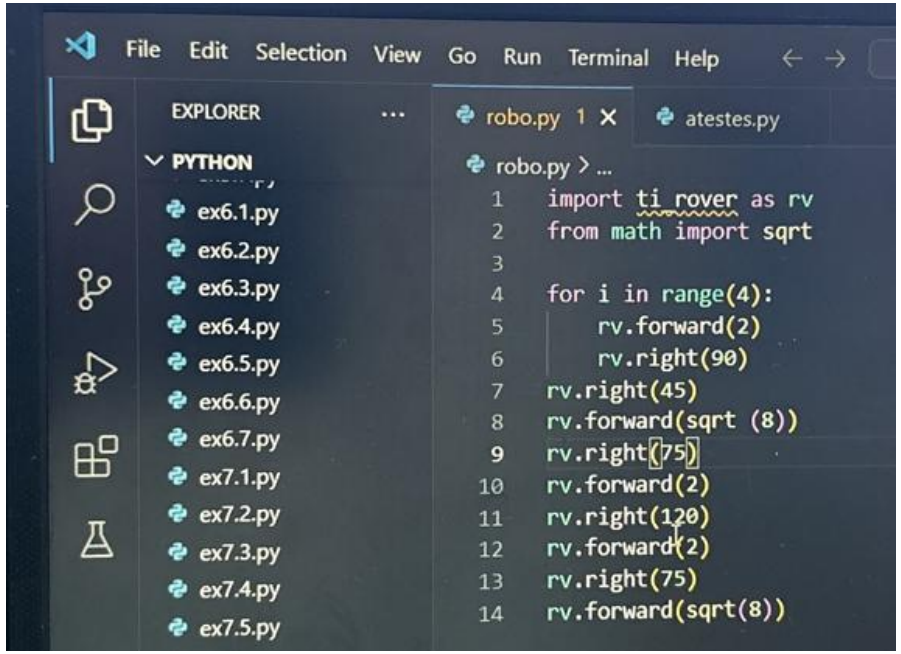



**Fig. 2.** Python code with rephrasing annotations made after incorrect execution.

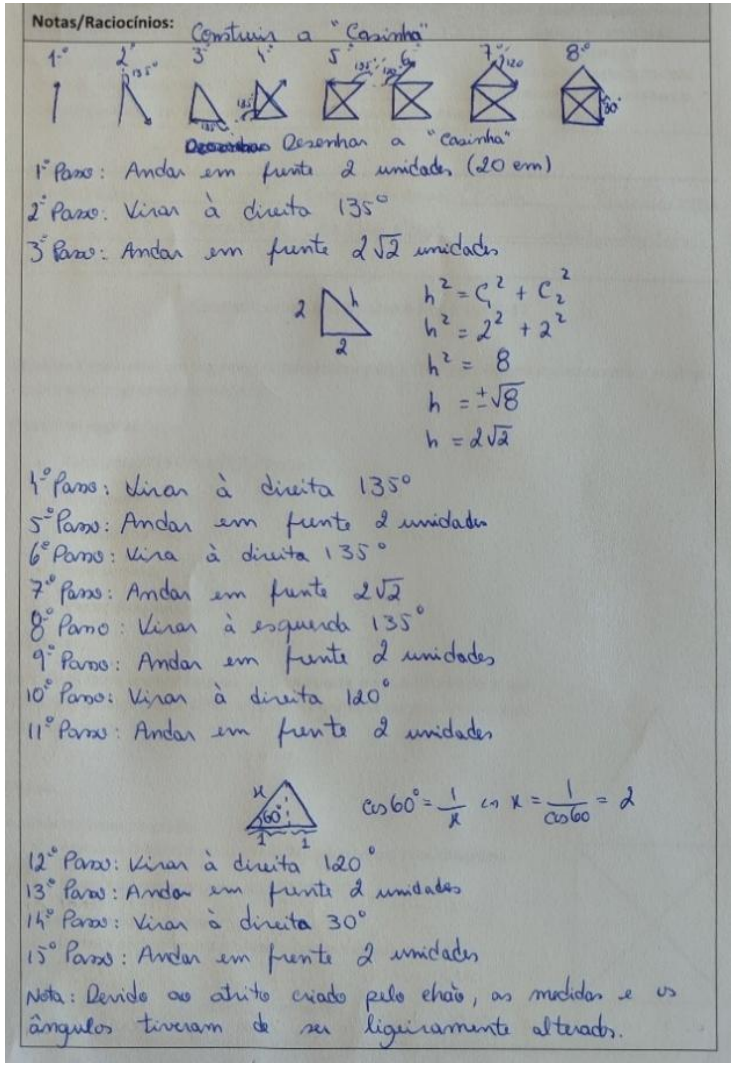



**Fig. 3.** Collective record resulting from the intra-group discussion, evidencing the process of synthesis of strategies and the consolidation of the final solution.

## 2. Creative Thinking: fluency, flexibility and originality

Creative thinking was evidenced in the diversity of strategies proposed for the route layout (Fig. 4).

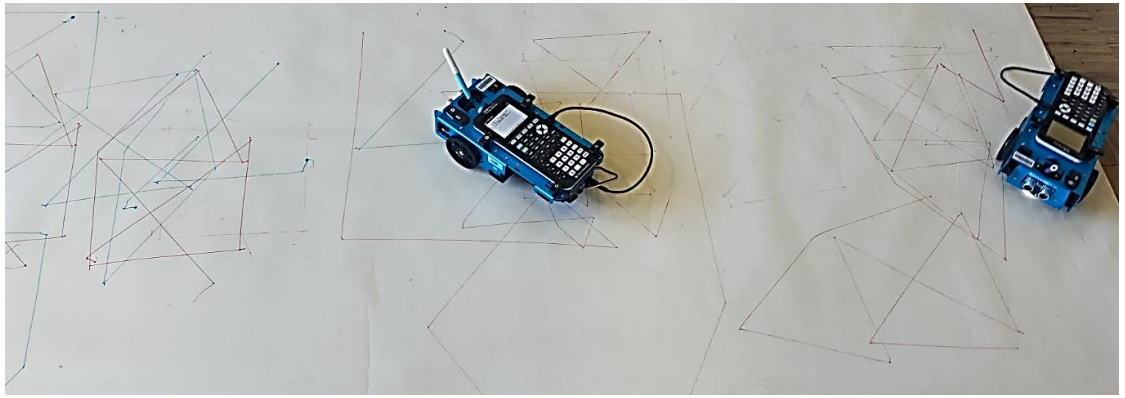


**Fig. 4.** Different proposals for geometric layouts elaborated by the cooperative groups.

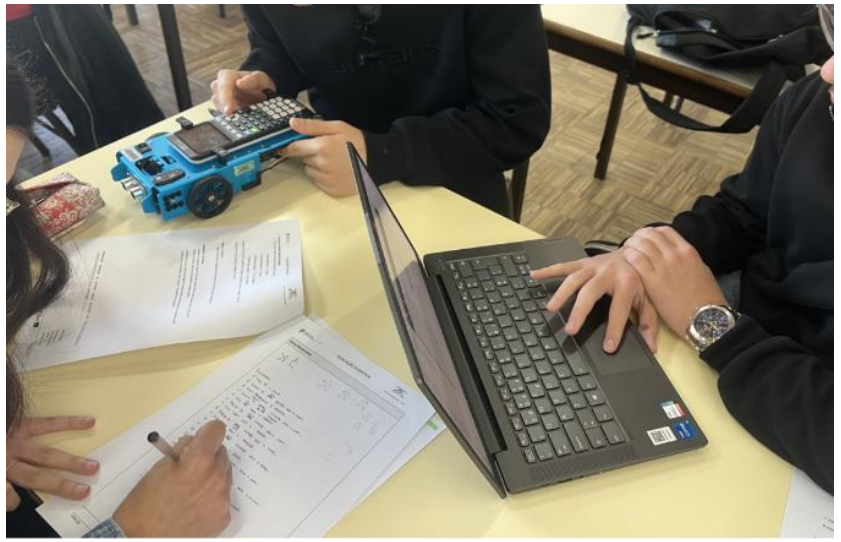


***Fig. 5.*** *Cooperative group reformulating Python code after incorrect execution, illustrating cognitive flexibility in reformulating strategies.*

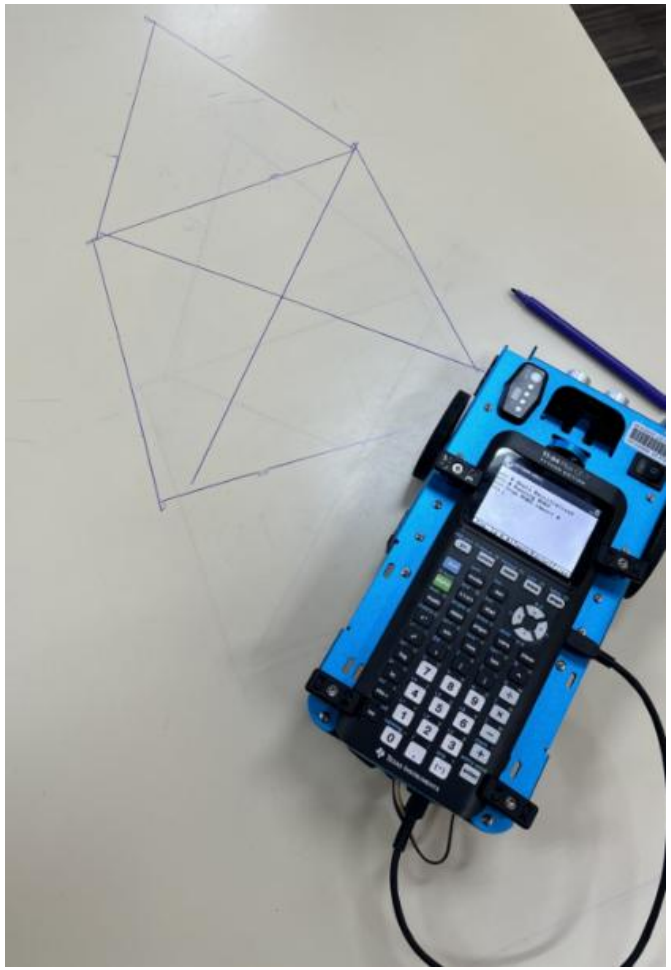


***Fig. 6.*** *Route prepared by a cooperative group with a creative and efficient structure*

- The graphic productions prepared by each cooperative group revealed a creative mastery of the mathematical tools and concepts involved, while allowing students to visualize and adjust their reasoning in real time.
- The originality of the solutions was also observed in the way the groups attributed aesthetic or symbolic meaning to the routes, giving identity to the final product.

## 3. Individual Reflections

- *"The most positive aspect is the support regarding the difficulties, because when I have any doubts, my colleagues help and try to explain in the best possible way and, sometimes, they even do it in a more simplified language."*
- *"The mutual help between group colleagues to complete the activity with the best possible results" and "the fact that I work in a group I think helps people a lot, both to work as a team and to discuss the different ways to solve the various challenges.“*
- *"The most positive aspects of our group are cooperation, respect for everyone's ideas and responsibility. We worked well together, listened to each other and each member fulfilled their part of the task."*

# Conclusions

- The pedagogical experience confirmed the relevance of integrating critical and creative thinking into Mathematics A, as supported by international frameworks (OECD, 2019; Facione, 2011).
- The cooperative method Peers Think Aloud to Solve Problems, combined with emerging technologies (Python, graphing calculators, robotics), effectively promoted deep cognitive engagement, logical reasoning, and collaborative knowledge construction (Johnson & Johnson, 2018; Voogt et al., 2018). Students demonstrated consistent progress in:
  - ✓ Critical Thinking: interpretation, analysis, explanation, evaluation, synthesis.
  - ✓ Creative Thinking: fluency, flexibility, originality.

# Thank vou for your attention.