Promoting creative insubordination using Escape Games in mathematics



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# Promoting creative insubordination using Escape Games in mathematics

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## Disclosure statement

One of the authors is also author of Escape Books, then his perception of the utility of these means of education may be influenced by that. Along the article, we have tried to remain as impartial as possible, stressing limits and opportunities. Other than that, the authors report there are no competing interests to declare.

# Promoting creative insubordination using Escape Games in mathematics

While the development of creativity, or creative thinking, in mathematics is considered as important by many researchers, there are several difficulties in implementing creative tasks, especially before secondary school. Within the original context of a mathematical escape game, this paper reports about two episodes exemplifying the difficulties met by sixth graders in abandoning stereotyped habits and acting with creative insubordination. While in the first episode, the puzzling task does not suffice to prompt creativity, in a second episode we show that an original solution may prompt unexpected mathematical contents. As a conclusion, escape games could be useful to prompt creativity even in lower grades than it is now shown in literature, but attention should be paid to the teachers' role in sustaining such creative activities.

Keywords: creativity, creative insubordination, escape game

## Educating creativity

The world we live in presents us with new challenges; we are facing a rapid cultural evolution in which the speed of change is the master (Gabora 2011). In this situation, having flexibility of thought is very important: creativity is crucial, not only during the problem-solving process, but above all to ensure that people maintain fluidity and flexibility in both behaviour and thought (Mumford et al., 1991; Torrance, 1971).

The use of creative thinking allows to counterbalance the rigidity of thinking of many adult people, meaning the use of rigid procedures and thinking patterns (Rubenson & Runco, 1995). Therefore, it is very important to improve the development of creativity from childhood and, for this aim, schooling has a crucial role. Educating creativity helps students to stimulate the ability to make decisions that are not only rational but also unpredictable and imaginative, that permits them to achieve their goals (Mumford et al., 1991). Creativity can be improved by designing, for instance, educational interventions aimed at developing attitudes and thinking patterns rarely used; in this way it is possible to create new and original ideas through the breaking of constraints of thought and the linking of the different elements to obtain new and unusual mental associations (Antoninetti, 2011).

Since Aristotle, logic was the only instrument that deals with structure of reasoning and for this reason it is object of every discipline; but new ideas, for their unpredictable characteristic, indicate that they are not always the results of a logical reasoning. Therefore, it is noted the existence of a different intellectual process emerging in the creation of new and simple ideas that appear obvious only after their creation. In literature, the expression *convergent thinking* often represents logical method, instead *lateral* or *divergent thinking* refers to the use of creativity (Antoninetti, 2011). Divergent thinking is a transversal competence taking part to social and cognitive development of students; abilities that are acquired in this way can be used in different contexts of daily life. Lateral thinking represents the ability to generate different and ingenious solutions for a problem; it is a spontaneous, fluid, and nonlinear reasoning that leads to consider a problem from different points of view (Antoninetti, 2011).

According to Löwenfeld and Brittain (1984), creativity and intelligence are often confused; they are not synonymous; schooling usually emphasize intelligence, the convergent thinking that leads students to think to a single correct answer or solution that is generally acceptable. By contrast, creative activities encourage and stimulate divergent thinking in which there is not only one correct answer, but there are situations that allow more ways of development (Löwenfeld & Brittain, 1984; Levenson, 2022), like open-ended tasks (Molad et al., 2020).

Recent studies have focused on analysis of brain areas that are activated during the use of divergent thinking. Xin and colleagues (2015) used an activation likelihood estimation (ALE) meta-analysis to conduct a quantitative investigation of neuroimaging studies on divergent thinking. The functional magnetic resonance imaging studies showed that distributed brain regions were more active under divergent thinking tasks than those under control tasks, but a large portion of the brain regions were deactivated.

**Creativity and mathematics**

Educational literature about creativity in mathematics has been growing during the last years. Several authors have claimed for the necessity of shifting from the association of creativity to some sort of innate ability characterising only gifted students, to the idea that each and every one of us can manifest creativity in everyday situations – ordinary creativity (e.g. Craft, 2001; Feldhusen, 2006; Kynigos & Diamantidis, 2021).

Following Riling's (2020) work, Kynigos and Diamantidis claim that "it is hard to look for creativity in formalist mathematical contexts since creativity emerges from agency, the capacity to act independently" (Kynigos & Diamantidis, 2021, p.1). Along the school years, students can develop habits-of-mind that are all but mathematical (Gordon, 2011). There is a vast amount of literature showing that students act following norms that they derived (implicitly or explicitly) from the experienced classroom practice (e.g. Riling, 2020). The collection of the mainly implicit rules which influence the work of both students and teachers could be so strong that it has been called 'didactical contract' (Brousseau, 2006). We consider the act of breaking the rules prescribed by this contract as a creative act; in particular, stretching the original definition of the construct, we adopt the following definition of *creative insubordination*: "creatively insubordinate actions are based on the knowledge of when, how, and why individuals act against established procedures and directives" (Grando &

Lopes, 2020, p. 622). We consider this definition as equivalent to Kynigos and Diamantidis reference to “students’ own undisciplined decisions while engaged in disciplined structured activity in a mathematical classroom context” (Kynigos & Diamantidis, 2021, p. 3)

The aim of this paper is to contribute to the literature by providing additional anecdotical evidence of the fact that creative insubordination against the norms imposed by the didactic contract established among several years of schooling is difficult, but possible. Drawing on an experiment realised in an Italian lower secondary school (grade 6) using an escape game, we will show difficulties experienced by students in not surrendering to the implicit norms, and their successes in taking agency in mathematical problem solving. Prior to that, we will better describe the context by introducing what mathematical escape games are.

**Mathematical escape games**

The concept of ‘escape game’ is derived by recreational *escape rooms*. An escape room is a collaborative game in which a group of players must exit from a room by solving a series of puzzle in a limited time (Nicholson, 2018). “Within an escape room, all activities are called puzzles and they use a simple game loop: a challenge to overcome, a solution and a reward (e.g. a code for a lock, or information needed in the next puzzle)” (Vedlkamp et al., 2020). Games preserving the same mechanics, but with different goals than escaping a room, are generally called *escape games*. An escape game is usually set in a narrative (escaping from a prison, finding a treasure, …) which may take place in realistic, historical, or phantasy settings.

The popularity of escape games in education has increased in the last years as a bottom-up process, meaning that the phenomenon started from passionate teachers and then captured the interest of researchers (Vedlkamp et al., 2020). There are more and more examples of use of escape games for the teaching of curricular material such as history (Rouse, 2017), chemistry (Dietrich, 2018), and physics (Vörös & Sárközi, 2017). When escape games are used for educational purpose in the classroom, students usually work on one puzzle individually or in small groups. Afterwards, their solutions are discussed during a collective discussion, or a small group debrief (Vedlkamp et al., 2020). The role of the teacher during an escape game consists in monitoring, providing hints, and debriefing. This last role is particularly relevant to connect the activity realized within the game with the learning goals. Studies have shown that escape games may result effective in assessing and enhancing teamwork and communication skills; studies related to the fostering of content knowledge related skills are still missing (Vedlkamp et al., 2020).

While mathematical puzzles are quite common in recreational escape games, the literature about mathematical escape games is scarce. The few available research studies refer to preservice teachers (Arnal Palaciàn, 2019) or to secondary school contents (Fuentes-Cabrera, 2020; Jimenez et al., 2020). In several cases, the puzzles are detached from the narrative, appearing more as sugar-coated (in the sense of Di Salvo, 2016) math exercises rather than part of a game. On the contrary, we conjecture that puzzles in escape games may provide a context in which the mathematics to be used is not already explicated to pupils, then letting them exploit their own creativity to find solutions. However, it is well known that students are so used to didactical situations that their behaviour may be guided more by the implicit norms of the didactical contract rather than by their creativity (e.g. Brousseau, 2006).

With the aim of stimulating students to transfer their mathematical knowledge to unknown contexts by exploiting their creativity, we proposed an escape game to six-graders. Puzzles were taken from the Italian book (Maffia, 2020), an educational mathematical escape-book. In the story presented in the book, the students are intergalactic policemen and policewomen whose mission is to bring back a spaceship to the solar system of Bellatrix. In the following section, we present two examples from the classroom activity to show difficulties and opportunities met by students. Each episode is related to a puzzle from the book.

The English translation of the puzzle of the first episode is shown in figure 1. A monitor shows the route of the spaceship as a list with the names of the stars to be reached (Dubhe, Phecda, Alnitak, Betelgeuse, Bellatrix). The computer asks to insert the total duration of the trip including a 10-minutes break for each hour of flight. The time needed to go from one star to another is shown in a table. The total amount of time provides a three digit-number and, according to the rules of this escape-book, a three-digit number corresponds to the code of the next puzzle (shown on the upper-right corner of the page, figg. 1 and 2). Then, the escape game consists of a string of tasks, each one yielding a key to enter the next task.

The puzzle faced in the second episode is shown in figure 2. The text says: “The door opens and you enter in a mirror-covered room. Here you can see the image of the room from above. You can see three laser emitters. When a ray hits the wall, the angle between the incoming ray and the wall is the same as the angle between the reflected ray and the wall. When a ray hits a receiver, it lights up. One emitter is already turned on and the laser ray is reflected on the mirror walls. There are switchers to turn on the other two emitters”. The numbers indicated on the three lit receivers provides the three-digit code indicating which is the next puzzle.

**Examples from classes**

Puzzles from the book (Maffia, 2020) have been proposed weekly, during usual mathematics classes taught by the first author of this contribution. A total of 20 puzzles was presented during the whole school year. The intervention was addressed to students of a first class of lower secondary school (grade 6) of the Comprehensive School of Rivanazzano Terme, a village near Pavia, situated in Staffora Valley, in Northern Italy. The class consists of 25 students, 14 males and 11 females; among them there are two students with disability (since in Italy there are not special classes), two students with special educational needs and one with dyscalculia.

In the following, we present data from two episodes, each corresponding to a different puzzle from the book. In particular, episode 1 refers to the puzzle shown in figure 1, while episode 2 refers to the puzzle in figure 2. The first episode shows a case in which students were not able to resort to creative thinking because of the didactic contract. In the second episode, an example of creative insubordination is presented.

***Episode 1: surrendering to the didactical contract***

The teacher proposed to the students to work individually on the puzzle shown in figure 1. When all the students found a solution, a collective discussion was initiated to share and evaluate the proposed solutions (debrief phase), before moving to the next puzzle. This situation has a unique solution, but several different numbers were proposed for the duration of the trip. While we could expect some difficulties due to the addition of the 10-minutes breaks, a widespread difficulty in understanding the task was unanticipated. In the following, we report the transcript of a part of the discussion: Camille (names are pseudonyms) is presenting her process of solution:

| | |
|---|---|
| Teacher | Any new idea? Tell me Camille. |
| Camille | First, I found… |
| Teacher | Wait, I will write it. |
| Camille | I got 595. |
| Teacher | You did this one? 165+169? No, sorry: 199. Plus… 186+45. |

| | |
|---|---|
| Camille | I got 595. 595 minus 10... |
| Teacher | 595? |
| Camille | Minus 10, it is 585 |
| Teacher | 595–10 is 585. But why minus 10? |
| Camille | Because it stops 10 minutes per hour. |
| Teacher | 10 minutes per hour, ok. Minus 10. |
| Camille | Then I did 98+173+101+45-10 and it is... |
| Teacher | Wait Camille. I don't understand. Then you took 98 plus? |
| Camille | I took 98+173+155. |
| Teacher | Then the column… the row of Phecda? Isn't it? Ok, then you did 98+173+101+45, how much is it? |
| Camille | 417. |
| Teacher | 417? |
| Camille | Yes, and then I did minus 10 as well, it is 407. |
| Teacher | 407. |
| Camille | Then I summed all the rows... |
| Teacher | You did all the rows by summing. |
| Camille | Then I did minus 10. |
| Teacher | Minus 10. |
| Camille | I did subtraction at the end, and it comes out... |
| Teacher | How much does it come out? |
| Camille | 336. |
| Teacher | Three, Three, six. You did each row, you summed it, you summed all the values in each row. |
| Camille | And then minus 10. |

Quite surprisingly, Camille summed all the values in each of the rows of the table. This behaviour was common among several students; some of them did the sum of all the values in one row, some of them summed all the values in the table. This procedure may be the result of a difficulty in understanding the task, and a possible cause for that difficulty is expressed by Gabriel when he is justifying his own solution:

| | |
|---|---|
| Gabriel | I did differently, I did not follow the itinerary, I did directly 88 plus 0, which doesn’t count, then 88+73+199+173. |
| Teacher | I didn’t understand, sorry. |
| Gabriel | I summed all the row of Bellatrix. |
| Teacher | 73+73+186+101? |
| Gabriel | No. I did 88+73, the row of Bellatrix. |
| Teacher | Ah! Sorry, I was reading the other one. |
| Gabriel | 73+199+173, summed is 533 |
| Teacher | 88+73+199+173. Ok. |
| Gabriel | Summed is 533. It is 533, and then I divided by 60 and I got 8 with a reminder of 53, then 8 hours and 53 minutes. But, to these hours, I have to add always 10 minutes and so I did… Let’s say… I got a total of 613 minutes. |
| Teacher | Because you added 80 minutes... |
| Gabriel | Then I divided by 60, I got 10 hours and 13 minutes in total. |
| Teacher | Ok […] I didn’t get why you decided to sum the various… the times in the row of Bellatrix. |
| Gabriel | Because it is the final destination. |
| Teacher | It’s the destination. But which is the route that I follow? […] That is not the route. |

Gabriel I thought it was… Because I didn't even look at the route. I just looked at the table.

Apparently, Gabriel does not even consider necessary to look at the whole puzzle once he has detected the data and the operations to be done. We may interpret this behaviour as similar to the well renowned "Age of Captain" effect, which is the result of the didactical contract (Brousseau, 2006). In the presented excerpts we can see that the teacher appears surprised since the students' behaviour may be the result of the didactical contract slowly built with the teachers of the previous years (more or less explicitly). This interpretation is reinforced by observation realised during discussions of other puzzles. For instance, when one of the first puzzles was presented, several students had difficulty in finding a solution. The puzzle contained a table as well, with some missing items, but completing them was just part of the task.

Teacher Ok, then, what did you do after calculating the multiplications??

Camille I didn't do anything, because I just thought we had to fill the table.

It seems that some students simply surrender to the didactical contract; they are completely unable to insubordinate to that. There is not any instance of creativity in their processes, which consist mainly in rote calculation and there is not any interpretation of the information and/or the solution in the context of the puzzle.

***Episode 2: unexpected insubordination***

In the second puzzle, there is a room completely covered with mirrors; three laser emitters are installed on the right wall and on the other walls there are six receivers (figure 2). Every emitter emits a beam and when the ray hits the wall it is reflected; if a receiver is hit, it lights up. The aim of this activity was to trace paths of the rays and observe which receivers would be switched on. An anticipated difficulty was in measuring and drawing angles using a protractor, even if this tool was already introduced in previous grades.

The teacher gave students a printed copy of the puzzle and proposed to them to face the activity individually in 20 minutes; each student had a personal protractor. Few students showed some difficulties immediately, some of them did not remember how to use the protractor; others, even if they were able to measure the angle with the instrument, did not know how to draw the angle of the reflected ray. However, most students solved the puzzle without any problem, using the protractor in the correct way (figure 3).

Surprisingly, one student, found the solution using the ruler instead of the protractor. He used a different tool than anybody else, a tool that was not anticipated by the authors. We consider this as an act of creative insubordination. The teacher asked the student to explain his approach: he said he had taken some landmarks in the figure and had measured horizontally the distance between the landmark and the point where the laser ray hit the wall. He later measured horizontally the same distance on the opposite side and, trying to keep the same inclination of the incident ray, he drew the reflected ray (figure 4); in this way, the student introduced (intuitively) the notion of slope of a line, even if it was not completely correct.

The teacher took this chance to introduce to the class the notion of slope of a line, as ratio between vertical and horizontal displacement, that is the ratio between vertical and horizontal variation that separates two different points of the line. The introduction of this mathematical content was not anticipated, and it is not usually part of the sixth-grade curriculum in Italy.

After the teacher's explanation, the student corrected his work, looking at both horizontal and vertical distance between the point where laser ray hit the wall, and the selected landmark, finally reporting the two measures on the opposite side appropriately.

Within the discussion about this puzzle, students were able to experience that the same issue can be solved in two different ways, the first using the protractor and the second, thinking about the concept of slope of a line, using the ruler.

## Conclusion

Educational escape games are becoming more and more widespread in the last years, as result of a bottom-up process started from the personal interest of some teachers and then captured by researchers as well (Vedlkamp et al., 2020). Using a series of puzzles to encourage students to find creative solutions to mathematical tasks appear sounding, but in this paper we have shown that, sometimes, insubordinate to the didactical contract is far from easy for them. For instance, finding the route for a spaceship may result too similar to a usual mathematical tasks and prompt stereotyped behaviours.

While researchers agree on the importance of promoting creativity among students (Craft, 2001; Feldhusen, 2006; Kynigos & Diamantidis, 2021; Levenson, 2022; Molad et al., 2020), instances of creative insubordination (Grando & Lopes, 2020) might be rare but, when the task is finally conceived more as a puzzle than a formal school exercise (Brousseau, 2006, would say when 'devolution' takes place), then it is possible that students invent original solutions that could not be anticipated by the teacher. That was the case in the second presented episode, where a new mathematical concept was introduced in the class discourse because of a solution proposed by a student. This suggests that puzzling tasks inserted in a narrative (like those typical of escape games) have the potential to prompt students' creativity even quite early in mathematical education – sixth grade in our case, prior to what has been documented till now in literature. We wonder if this would be possible even earlier. Also, we presented a case where students' agency is still limited, and the teachers' guidance plays an important role in the discussion. We wonder if letting more agency to student (for instance letting them decide when to move to the next puzzle) would provide a more playful environment which may lead to more creativity (Bateson, 2015).

While considering the interesting result obtained in the second episode, despite the difficulty that were shown in the first one, we must acknowledge that the creative solution proposed by the student was fruitful for the classroom discussion because the teacher was creative as well, meaning that he decided to introduce a topic that is not usually taught in sixth grade. This observation remarks how important teachers' ability of noticing and responding to contingency (e.g. Rowland & Zazkis, 2013) is fundamental to sustain students' creative behaviours. Concluding, we agree with Levenson (2022) that it appears more and more important to have further research about teachers' implementation of tasks for occasioning mathematical creativity.

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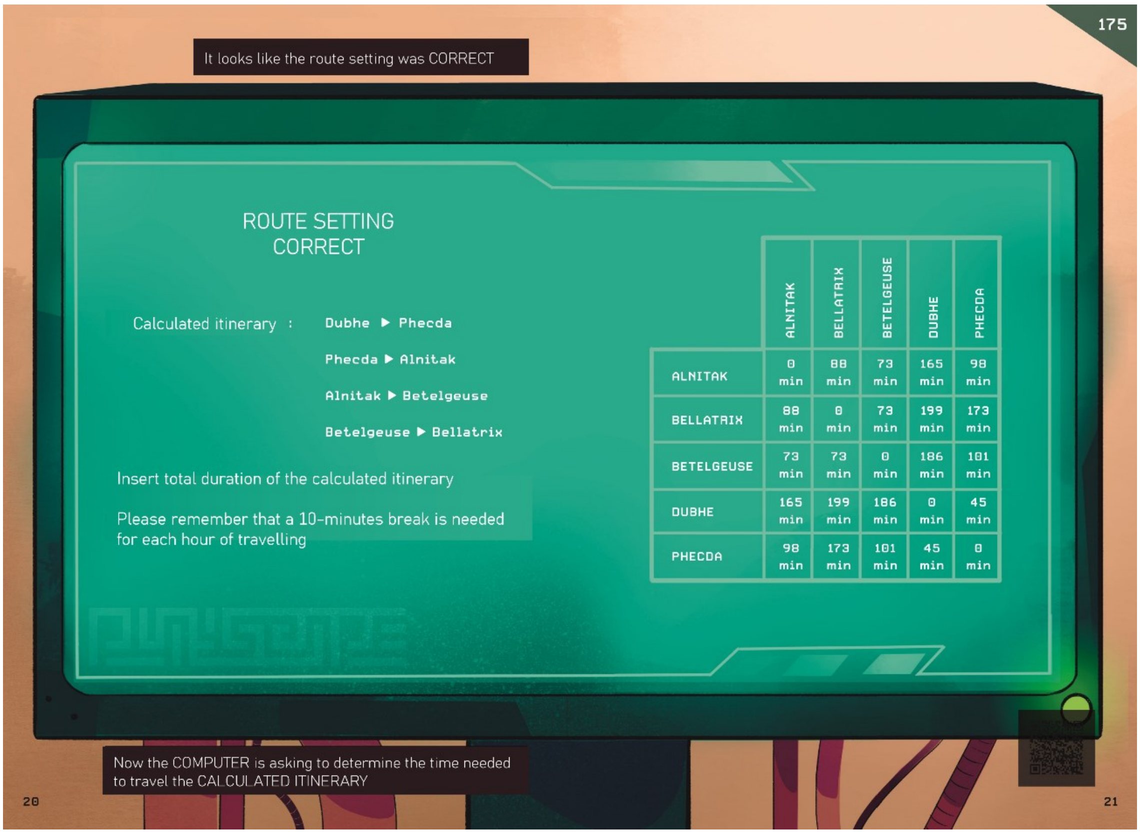


Figure 1. Puzzle of the first episode (Maffia, 2020).

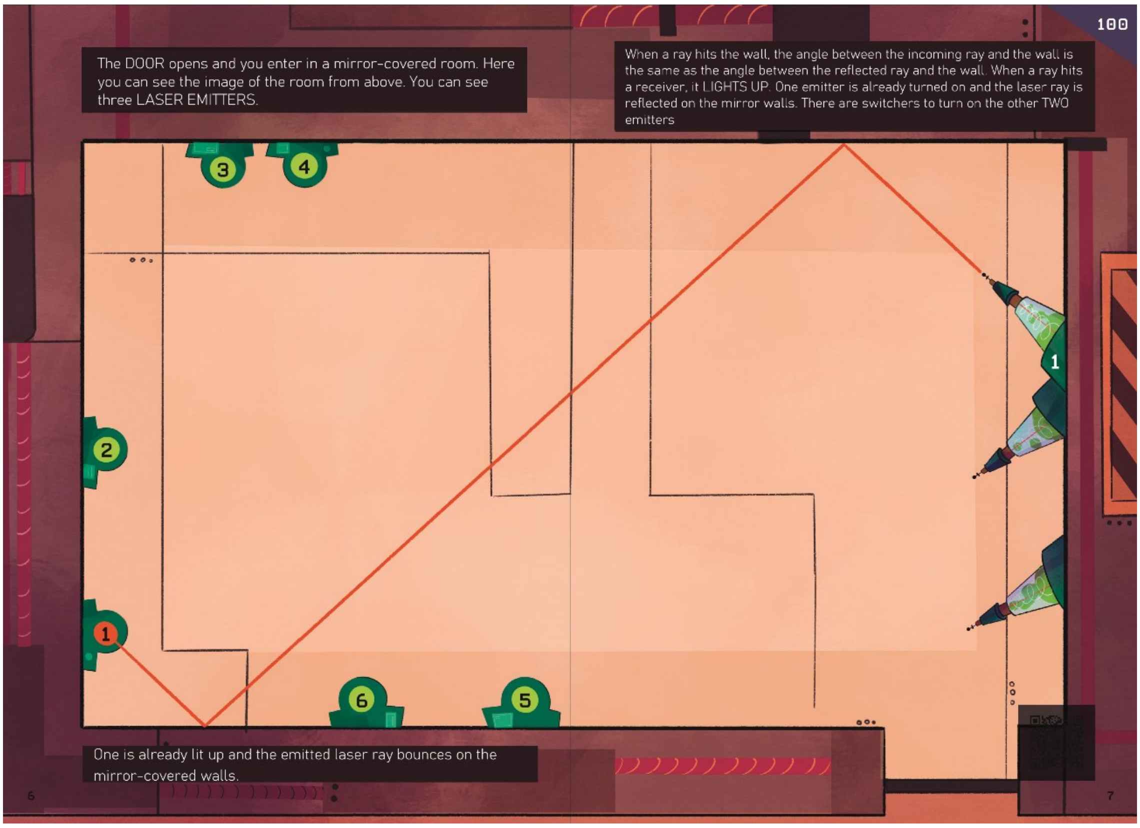


Figure 2. Puzzle of the second episode (Maffia, 2020).

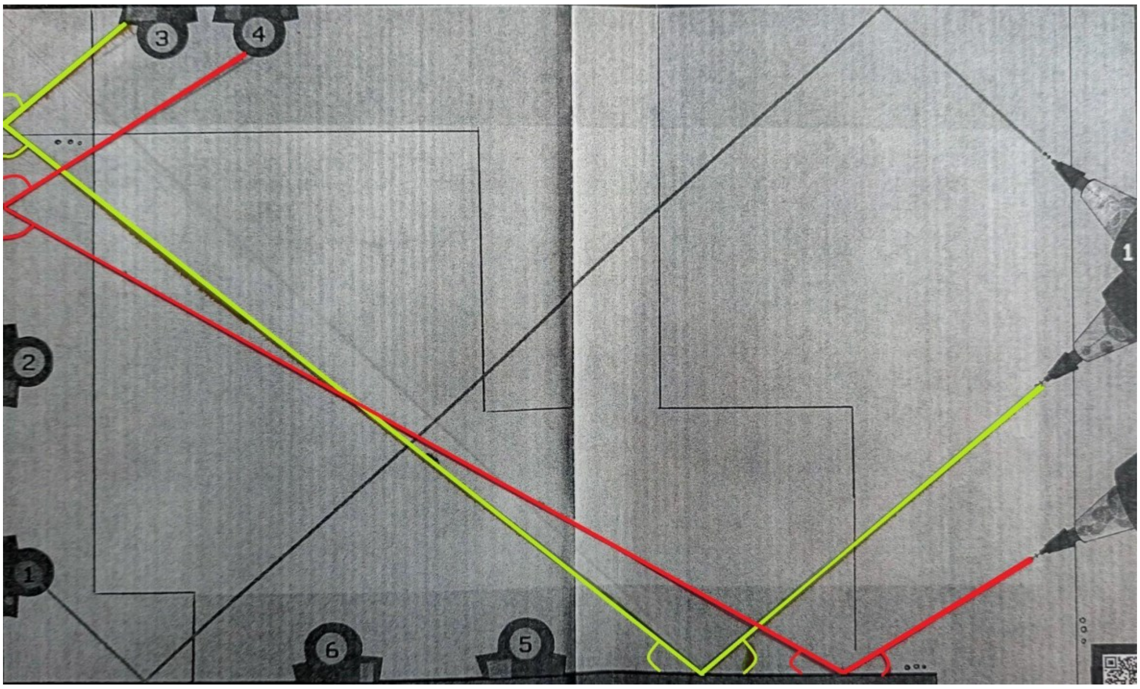


Figure 3. Solution of the puzzle using the protractor.

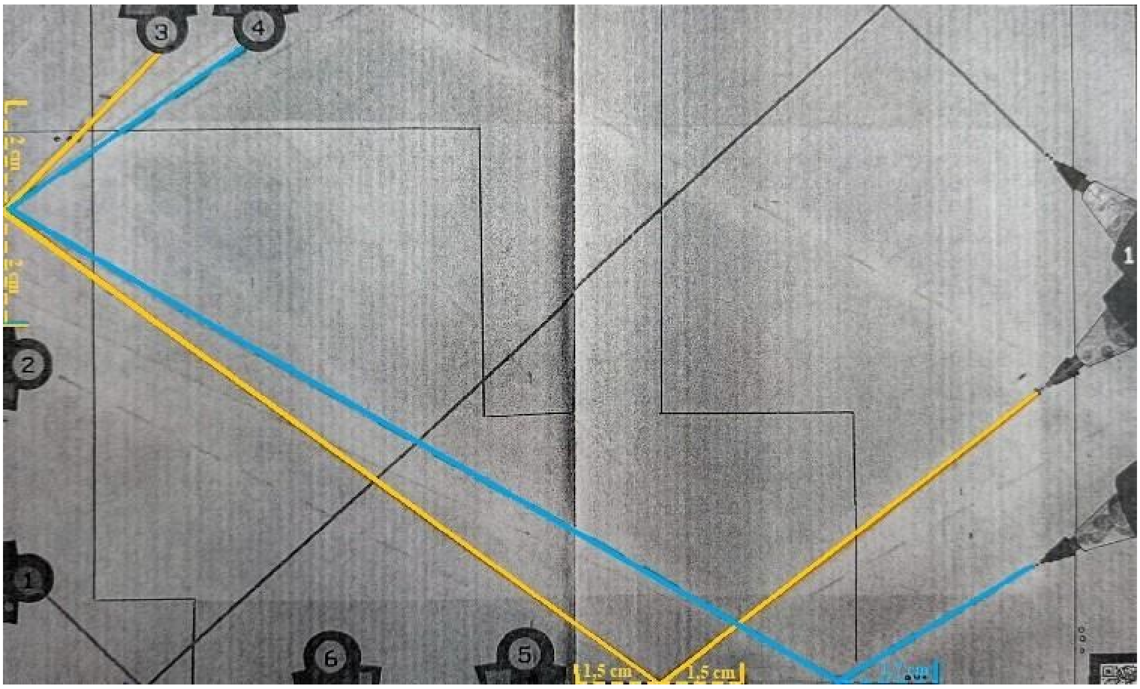


Figure 4. Solution of the puzzle using the ruler.