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# Mathematics workshops in prison: Design and practice

Sofia Galli<sup>1</sup>, Giulia Bernardi<sup>1</sup>, Domenico Brunetto<sup>1</sup>, Helena Dell'Anna<sup>1</sup> and Francesco Nappo<sup>1</sup>

<sup>1</sup>Politecnico di Milano, Mathematics Department, Milan, Italy; [sofia.galli@polimi.it](mailto:sofia.galli@polimi.it)

*This paper presents the design and results of an informal mathematics education project for young adults in an Italian prison. The workshops were designed to emphasize problem-solving with the aim to provide inmates with skills transferable from mathematics to daily life. To overcome language barriers and different levels of schooling, a learning-by-doing approach was adopted. Participants' feedback indicate success in fostering mathematical and psychological empowerment: inmates reported increased patience, greater self-esteem, and improved mental engagement. Furthermore, the workshops promoted social inclusion by encouraging collaborative problem-solving among inmates, prison officers, and staff, highlighting the potential of mathematics to empower marginalized individuals and strengthen social bonds in fragile communities.*

*Keywords: Informal mathematics education, empowerment, problem solving, experiential learning, adult education.*

## Introduction

Prison education plays an important role in the successful integration of incarcerated individuals and in their social inclusion upon release (Manger et al., 2010; Ferrarello & Mammana, 2022). Mathematics education can be a powerful agency in these contexts due to its capacity to bridge educational gaps and empower marginalized individuals. In this regard, Byrne and Carr (2015) highlight the connection between perceived competencies in mathematics and improved social status. Andrà and Brunetto (2020) discuss how mathematics can trigger psychological empowerment. Here, we refer to it as longitudinal dynamic of development and attainment of a set of insights, and abilities best characterized as participatory competence (Kieffer, 1984). Roughly speaking, psychological empowerment is the process which turns a person from an object (passive and powerless) to a subject who acts on the world (Andrà & Brunetto, 2020). Moreover, as noted by Brunetto et al. (2021), developing problem-solving skills in the “safe space” of mathematics can be useful to gain confidence in daily life problem resolution, fostering mathematical empowerment. Mathematical empowerment is the development of mathematical skills and the ability of applying them both within formal context (e.g. school) and informal one (Andrà & Brunetto, 2020).

However, implementing a mathematics education experience in prison poses immense practical challenges (Byrne & Carr, 2015; Byrne & Harrison, 2022). Inmates typically have different levels of education and speak different languages, and attendance can be sporadic. Learning may also be interrupted because prison officers recall inmates during activities for various reasons, such as meeting with attorneys or communicating with other officers.

Last year, a collaboration between Politecnico di Milano (henceforth: PoliMi) and Casa Circondariale San Vittore di Milano (henceforth: San Vittore) gave our research group the opportunity to design and test an informal mathematics education program in a high-turnover prison context. The aim of our research was to identify suitable designs and practices that would make the program accessible to everyone, despite the aforementioned obstacles, and trigger empowerment. Moreover, we

wondered how mathematics could be used to foster a wider network of social relations within the prison context, reaching not only inmates, but also prison workers.

In this paper, we present design and findings from our workshops, highlighting the potential of mathematics education to enhance inmates' empowerment and promote socialization and collaboration, overcoming social barriers, in the prison context as a starting point for a social inclusion upon release. In this paper, we mean social inclusion as the equitable participation of individuals in social, economic, and political aspects of life (Rawal, 2008).

## **Methods**

### **Research context**

The collaboration between PoliMi and San Vittore started in 2021. The people housed in San Vittore are awaiting trial, after which they are either released or transferred to a permanent prison. The jail section we worked at hosts male adults between 18 and 30 years of age. Due to current policies, inmates remain locked in their cells for most of the day. This condition leads to a strong sense of powerlessness and self-deprecation among inmates (Brown, 2020). Since 2021, San Vittore hosts a PoliMi office (called "Off Campus") inside its premises, where researchers and students involved in prison projects can stay and work during working days. The PoliMi Departments that have so far been involved in this collaboration with San Vittore are Architecture, Design, ICT and Mathematics. Last year, all four of them jointly contributed to a project named "METHEXIS: Mathematics, narratives and generative spaces for extremely fragile contexts", funded by the 2023 Polisocial Award, whose overarching objective was to foster greater participation of inmates and workers in the young adult section in forms of social life and mutual support. As part of the METHEXIS project, an informal mathematics experience was designed to provide a neutral space where people with different backgrounds and with different roles in prison (e.g. inmates and officers) could work together to solve puzzles, setting aside the role barriers of prison life.

### **Conceptual framework**

The research was conducted in accordance with the principles of Design-Based Research (DBR), defined by Wang and Hannafin (2005) as a methodology aimed to improve educational practices through systematic and iterative processes of analysis, design, development and implementation. Findings are based upon collaboration among researchers and practitioners in real-world settings, leading to the formulation of principles or theories. Based on this methodology, we designed a workshop, implemented it (May-June 2024), and collected data that served our analysis. Our subsequent evaluation led to a refinement of the initial workshop design, the implementation of a second version (July-August 2024), and a new analysis of the results.

The initial workshop design was based on previous experiences of mathematical instruction in immigrant communities (Brunetto et al., 2021) as well as existing literature about the teaching of mathematics in prison (Byrne & Carr, 2015; Maffia & Decembrotto, 2022). Furthermore, we considered experiential learning theory and informal mathematics education, where student learning is attained through personal experience and involvement (Kolb, 1984) also out-of-school (Kuş, 2024). In line with Manger (2010) we conjectured that experiential learning activities assume an even more

important role in prison. Indeed, convicted people are often relieved of any work responsibilities. Therefore, having a space where they can learn by doing can be an important incentive. We were also inspired by Maffia and Decembrotto's (2022) recent work, where the utility of assigning tasks with multiple levels of difficulty is highlighted. Finally, both in the way of conducting the meetings and in some of the proposed contents we took some hints from Liljedahl's (2021) thinking classroom.

### Design and first implementation

Considering the above-mentioned studies as a conceptual framework, we proposed an informal mathematics workshop based on learning-by-doing principles (Kolb, 1984), with a focus on problem-solving. Our purpose was both offering stimuli to be active thinking about and doing mathematics and opportunities to cooperate regardless of culture, nationality, religion and so on. High turnover, sporadic attendance and differences in languages and mathematical knowledge (average schooling age being around 13) led us to design a short-length workshop consisting of six meetings that were not preparatory to one another and did not require fluency in Italian or previous mathematical instruction. The maximum number of participants was 15 and at least two tutors were always present.

Each meeting was structured into three parts. The first one served as an introduction to buy some time while waiting for all the people to arrive. We proposed intriguing challenges, preferably preparatory or at least related to the next parts. The second part was the core of the workshop: a problem-solving activity, possibly with several steps of increasing difficulty, according with the "flow" theorized by Liljedahl (2021), and following experiential learning principles (Kolb, 1984). In accordance with the experiential learning cycle, the main activity presented a problem in a concrete way (concrete experience) and allowed ample time for participants to reflect on the problem (reflective observation) and to devise solution strategies (abstract conceptualization); once the solution strategy had been identified, participants were presented with further instances of the problem to test their full grasp of the solution strategy (active experimentation). Both in the first and in the second part we invited participants to work in pairs or small groups standing in front of a vertical blackboard, as suggested in the "thinking classroom" by Liljedahl (2021). In Table 1, introductory quizzes and core activities of the first workshop are summarized. The third part was dedicated to a metacognition activity: we will return to this in the section about data gathering. During the final greetings, attendants were given a take-away puzzle that they could try to solve on their own over the following days. We handed over the puzzles also to the prison officers, hoping to create a connection between them and the prisoners.

**Table 1: The activities proposed in the 1<sup>st</sup> edition of the workshop**

Day	Introduction	Main activity
Day 1: The desk calendar	Some matches are displayed to form a number as in a digital screen. Moving only 2 matches, what is the highest/lowest number you can get?	Which digits must you write on each face of the cubes to build one of those desk calendars where the date is displayed on the faces of 2 cubes?
Day 2: Symmetry puzzles	Having several cutouts of shapes consisting of 6 squares joined together, identify which of these are developments of the cube and which are not.	Given a square sheet with some dots on it, you can fold it, as many times as you like, so that if you make only one hole, it is at all and only the dots.

Day 3: Points of view	Two players have the same number and type of cubes. One makes a construction, then gives instructions to the other to reproduce it without looking at it.	Solve different skyscrapers grids.
Day 4: Eulerian Graphs	Draw a small house without ever taking the pen off the paper and without going over an already drawn line.	Analyze several graphs to find the criterion for which it does or does not admit a Eulerian path.
Day 5: Eulerian Graphs	Explanation of the historical background of graph theory and the Seven Bridges of Königsberg problem.	Same as in Day 4.
Day 6: Strategy games	Play tic-tac-toe in one of the grids attached to the wall.	Find a winning strategy for the <i>nim game</i> starting with 7 bricks, in which players, in turn, can take 1 or 2 bricks. The winner is the last player to move.

### Data gathering

In the third part of each meeting, we asked participants a metacognition effort: to fill out a journal answering the questions “What I did and what I learnt” and “What I liked and what I did not like”. The purpose was twofold: help them fix ideas in a context where everything is transient and collect feedback. Moreover, at the end of the whole workshop, they filled in a questionnaire where we asked if they liked it, which meeting they liked the most, how they found the level of problems (both in terms of understanding the task and in solving it) and their preferred mode of work (individually, in pairs or in groups). For ease of access, we wrote it in both Italian and Arabic. The Likert scale ranged from 1 to 4, to avoid the medium value, and we opted for a graphical visualization of it, using “stars” as in reviews. After each meeting, the tutors also filled in a journal with observations about the classroom setting, how the activity was conducted, participants’ attitudes, difficulties (both logistical and content-related) and interventions. These three data served us for the analysis of the first workshop, as required by the DBR.

The open-ended questions of the journals were analyzed according to the conceptual framework. In particular, the empowerment lens allows us to figure out if and what elements of the workshop trigger the empowerment, namely the participants manifest an experience of control on mathematics, on relationships, or on the future. Examples of such analysis are provided in the next sections.

### Second cycle of DBR

We report here the most relevant findings from the analysis of tutors’ journals of the workshop’s first edition and changes in light of our evaluations. In line with Liljedahl (2021), we confirm that encouraging participants to work by standing in front of a vertical blackboard was very successful both in making them feel involved and in reshuffling working groups, to encourage collaboration between all; hence, we decided to improve this working method in view of the second edition. As

indicated in the literature (Maffia & Decembrotto, 2022), it is useful to give tasks that can be tackled step by step (e.g. the skyscrapers' grids and the Eulerian graphs). We noted that when someone understands the game strategy or the solution, they are enticed to seek challengers; this being a symptom of proactivity, we took care, in the second edition, to stimulate competitiveness to an appropriate and positive extent. We also observed that participants were often not autonomous in grabbing the materials to work on and tutor guidance was necessary. Thus, in the second edition, we looked into ways to encourage participants to be more proactive (e.g. leave the material on a table so that they stand up to get it instead of us distributing it desk by desk). To encourage participants to take better care of the material and to enable them to keep track of the path they would be taking, we planned to provide participants with a cardboard folder to collect all their materials in the second edition. Moreover, since in the previous edition some inmates came to us asking for the solution of the take-away riddle, we decided to put more emphasis on them by asking, at the beginning of each meeting, if anyone has solved the riddle provided the previous time. The metacognition activity of journals turned out to be too difficult for some of them, so in the new edition we decided to ask them just to write on a sticky note a free comment about the meeting at the end of it. Regarding questionnaires, using stars in the Likert scale turned out not to be a good idea both because the language of the reviews was not familiar to everyone and because in Arabic you read from right to left. We thus kept the same questions and same answers' range from 1 to 4 but changed the answers' format into multiple choice.

Considering the findings above, we implemented a second edition of the workshop, whose introductory challenges and core problems are described in Table 2. We made only a few adjustments to the schedule after the first edition, changing the order of the activities and adding a new activity (Day 4) devoted to solving logic puzzles similar to the matches' puzzle provided at the beginning of Day 1 in the first edition, which had proved intriguing for all participants: it seemed appropriate that this activity should not only be introductory but main. We designed this with the aim of supporting a challenge dynamic among participants, that we had noticed as positive, and to stimulate their proactivity, leaving them free to engage in the puzzles that they perceived as most appealing.

Among the changes we introduced in the second edition, having people standing in front of a vertical blackboard worked well, whereas asking them to take good care of the material in the cardboard folder failed almost completely. Referring to the solution strategy of the take-away puzzles at the beginning of each new meeting highlighted continuity throughout the six meetings.

**Table 2: The activities proposed in the 2<sup>nd</sup> edition of the workshop**

Day	Introduction	Main activity
Day 1: The desk calendar	Enter the numbers 1 to 8 in a specific grid, satisfying some constraints.	As in the 1 <sup>st</sup> edition, Day 1.
Day 2: Strategy games	As in the 1 <sup>st</sup> edition, Day 6.	As in the 1 <sup>st</sup> edition, Day 6.

Day 3: Eulerian Graphs	As in the 1 <sup>st</sup> edition, Day 4.	As in the 1 <sup>st</sup> edition, Day 4.
Day 4: Mixed puzzles	Card tricks played by tutors.	Six different puzzles on the wall of the room and participants had a study card to mark their solution.
Day 5: Symmetry puzzles	Counting the numbers of triangles in symmetric figures.	As in the 1 <sup>st</sup> edition, Day 2.
Day 6: Points of view	How to fold a sheet into a square and then the square into an equilateral triangle.	As in the 1 <sup>st</sup> edition, Day 3.

## Results

According to the student log, the average number of participants and the number of them attending at least 66% of the workshop were respectively 10 and 4 in the first one, 8 and 7 in the second one.

In the final questionnaires the most highly ranked meeting in the first edition was the one about Eulerian graphs, while in the second edition was that on skyscrapers grids. One participant reported the following motivation for enjoying the workshop on graphs the most: “because now I know the street rule”, referring to his having found the criterion for a graph to be Eulerian in his own words. Such a statement is evidence of perceived control on mathematics, at least temporarily. Considering the answers to the second questionnaire only (being it more reliable), the level of problems was judged fair (not too easy nor too difficult) by 87%, and 74% of participants always understood the task (37% at the very beginning, 37% after a while).

The qualitative data collected via journals and sticky notes highlight some notable findings. The role of patience in facing problems (“I confronted my patience and myself by doing these exercises”), participants’ perception of using mind and time well (“I enjoyed pushing myself more and more into more difficult exercises and challenging myself”; “It was stimulating for the mind”), increasing self-esteem (“I found out that I am smarter than I thought”). Such statements refer to controlling themselves: patience, challenging, and feeling smarter. There were also some comments on the opportunity that mathematics gives you in escaping from the vicious circle of everyday thoughts (“There was less noise and more concentration”; “I detached my mind a little, re-entering my logical world”) and some others on purely mathematical topics (“I saw new geometric shapes”; “Mathematical tricks. I learnt the binary system, winning at tic-tac-toe, winning at cubes”). Those are evidence of acting on mathematics, either thinking about or doing. Finally, some wrote about mathematical skills that can be transferred to daily life, such as “I learnt that to everything there is a reason and to everything there is a solution”; “I have learnt not to take anything for granted”; “I learnt to look outside the box” and the utility of mathematical instruction for their future, noting a link between the activities completed in the workshop and problems encountered in real life (“They are useful for our future, even outside [prison]”). Those manifest the control of using mathematics outside the specific context.

As mentioned before, one of the aims of our project METHEXIS was to offer opportunities for social life and mutual support. In this regard, we report the following comments: “I met new people”; “[I spent] a beautiful afternoon with a beautiful family”. Moreover, in both the final questionnaires, all participants indicated they preferred to work in pairs or in groups. Other feedback we had concerns the involvement of other prison stakeholders. As mentioned earlier, the take-away riddles had a twofold purpose: firstly, to give prisoners something to think about to kill time in the cells and, secondly, by also distributing them to prison officers, educators and healthcare staff, to create an invisible network of connections among minds all thinking about the same mathematical riddle. At first, we expected them to maintain a form of detachment and to not put themselves on the same level as the inmates. Over time, however, by making ourselves known as “the mathematicians of PoliMi” and establishing a riddle delivery as a ritual, their attitude changed. Seeing their growing interest, we started hanging a weekly riddle outside our office and left copies in small format to be taken freely by anyone interested. To our surprise, soon after that we observed inmates and police officers solving riddles together. This is evidence of the large potential of mathematics to create a neutral space where to free one’s mind and get involved and it seems to indicate very interesting possibilities.

## **Discussion and conclusion**

In this paper, we presented an experience of informal mathematics education designed for young adults in a high-turnover jail in Italy. Different linguistic and mathematical backgrounds and discontinuous participation have represented crucial challenges for designing a successful workshop and, indeed, have had a strong impact on the way the meetings were conducted. Recalling the aim of our research to find an appropriate design and practice for an informal mathematics educational experience in prison, tutors’ observations and participants’ feedback suggest that, even in extreme conditions of low literacy and high turnover of inmates, there is considerable potential for mathematics activities based on problem solving and learning-by-doing principles to be empowering for them. We observe an important interplay between mathematical and psychological empowerment mediated by experiential learning activities: the comment “I learnt to draw possible and impossible roads, like life” is symptomatic of this. In drawing graphical patterns and identifying rules behind them, the inmate was appropriating a theorem. This could be an indicator of mathematical empowerment. This research indicates that psychological empowerment came from exploiting mathematics, reflecting upon roads which are not only graphical patterns but signify real life.

Researchers’ observation on the dynamics between inmates, prison officers, health workers and educators indicate that mathematics can offer a neutral ground for overall networking within the prison. This was made possible by devising take-away riddles that were accessible to anyone, but at the same time engaging. Further studies on mathematics education through experiential learning can help support its important role in creating a positive and inclusive social fabric in socially marginal and difficult contexts.

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