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Developing design principles for adults' learning mathematics in the prison context

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Abstract

This paper presents the Learning Math in Prison (LeMP) project, an Educational Design Research (EDR) initiative that explores how mathematics education can support adults' mathematics learning within the Italian prison system. The project investigates the complexity of teaching mathematics in correctional settings—contexts marked by strong heterogeneity, discontinuity, and organisational constraints—and seeks to identify context-sensitive design principles to guide teaching practice. Through iterative cycles of analysis, design, implementation, and reflection, the project brings together teachers and researchers to co-develop and test learning units in real prison classrooms. The findings highlight how mathematics can serve both as a cognitive and a social resource, fostering reasoning, motivation, and agency. The paper contributes to the theoretical understanding of mathematics education by developing research-informed approaches for inclusive adult numeracy.

Key words: Adults' learning mathematics; prison context; education in prison; design principles.

Introduction

Education has long been recognised as one of the most powerful means of rehabilitation and social reintegration within correctional systems. According to Article 27 of the Italian Constitution, imprisonment must aim at the re-education of inmates, which implies ensuring access to meaningful learning opportunities and the right to personal development. From this perspective, schooling in prison is not only a legal obligation but also an ethical and pedagogical commitment to upholding human dignity and promoting inclusion.

Within this broader mission, mathematics plays a distinctive role. Beyond its cognitive and disciplinary value, mathematics can support adults in developing reasoning, creativity, and problem-solving skills that strengthen self-efficacy and autonomy. For many incarcerated learners, who often associate their previous schooling with failure or exclusion, engaging with mathematics anew can become a way to rebuild confidence in their intellectual abilities and to reclaim a positive learner identity (Ahl & Helenius, 2021; Decembrotto & Maffia, 2024). Mathematics thus becomes not merely a subject to be taught, but a medium through which adults can exercise agency, structure thought, and imagine new forms of participation in society.

Despite this potential, research on mathematics education in prison remains limited, and teachers often lack discipline-specific guidelines to support their practice. The challenges they face—instability of classes, heterogeneity of learners, time constraints, and emotional complexity—require approaches that go beyond traditional instructional models. The Learning Math in Prison (LeMP) project was conceived to address this gap.

Understanding the Multi-Complexity of the Prison Education Context

Teaching and learning mathematics in prison takes place within a profoundly complex and dynamic environment, shaped by social, institutional, and emotional dimensions that interact continuously. Italian prison schools operate within correctional institutions that host individuals with very different legal statuses, cultural backgrounds, and educational histories. These differences, combined with the strict routines and regulations of prison life, produce conditions that make educational continuity extremely fragile. Additionally, students may be transferred to another facility, released unexpectedly, or be unable to attend classes due to administrative or disciplinary reasons. Classes are often short, as movements between cells and classrooms require time and coordination. Other activities, such as family calls, medical visits, or work duties, frequently interrupt school attendance. Teachers, therefore, face a situation where class composition and learning rhythms change unpredictably.

From a pedagogical perspective, heterogeneity is also striking. Many inmates have experienced fragmented schooling or early school leaving; others are foreign-born and must cope with the additional challenge of learning mathematics in Italian, which is not their first language. Emotional factors, such as anxiety, frustration, or a history of struggling with mathematics, significantly impact engagement and persistence. Yet, in this challenging environment, mathematics can also become a space for intellectual freedom, creativity, and renewed confidence in one's cognitive potential. To capture this layered reality, we refer to the concept of multi-complexity (Maffia & Decembrotto, 2022). Borrowed from medical research, the term describes contexts in which multiple interdependent conditions interact so closely that they cannot be analysed or addressed separately.

Methodology: The Educational Design Research Approach

The LeMP project is grounded in the methodological framework of Educational Design Research (EDR), which combines the systematic study of educational practice with the iterative design of learning interventions (McKenney & Reeves, 2018). This approach is particularly suited to complex, authentic settings—such as prison schools—where controlled experimentation is not possible and where research must adapt to evolving constraints while producing actionable knowledge. More precisely, the LeMP project aims to develop design principles for creating teaching materials for Italian prison schools to enhance adult numeracy, taking into account the multifaceted complexity of the context. The LeMP project involves different Italian prisons, including juvenile detention centres and prisons for adults with long and/or short detention. The entire project is conceived as a macro-cycle, composed of multiple meso-cycles, each of which includes one or more micro-cycles. Within each micro-cycle, the classical phases of analysis, exploration, design, construction, evaluation, and reflection take place (McKenney & Reeves, 2018). Each phase is followed by a continuous analysis of the needs that emerge in the field, ensuring that the materials designed are flexible and adaptable to the specific characteristics of each institution. The first meso-cycle was primarily descriptive and explanatory, aimed at understanding the contexts of the prison schools involved in the study. The second meso-cycle focused on the collaborative design of mathematics learning units together with a group of teachers from three prison schools. The design process was guided by teachers' practical experience and by the design requirements and propositions derived from the previous phase. The third meso-cycle began with a redesign of the learning units (the first micro-cycle), informed by evidence and reflections from the previous meso-cycle. The revised materials were then implemented in classrooms and field-tested. Teachers' journals, students' logbooks, and ethnographic observations constituted the main sources of data for evaluation.

The subsequent reflection phase, conducted collaboratively with teachers, served to determine which design propositions could evolve into design principles (McKenney & Reeves, 2018) and which should be refined or discarded. As reported in the works by van den Akker

(2010), design principles are formulated in this way: *If you want to design intervention X [for purpose/function Y in context Z] then you are best advised to give that intervention the characteristics C_1, C_2, …, C_m [substantive emphasis] and to do that via procedures P_1, P_2, …, P_n [methodological emphasis] because of theoretical arguments T_1, T_2, …, T_p and empirical arguments E_1, E_2, … E_q (van den Akker, 2010, p. 190).*

Results: Examples of Design Principles

The third meso-cycle of the LeMP project focused on the implementation and evaluation of the redesigned learning units. Data collected through classroom observations, teachers' reflective journals, and students' logbooks were analysed to identify recurring patterns connecting theoretical assumptions, design choices, and practical outcomes. The resulting principles emerged from an iterative dialogue between researchers and teachers, as well as from systematic reflection on classroom practice.

Differentiation

The present formulation of the first example of the identified design principle is: "*If you want to design a problematic situation suitable for all students, it seems appropriate to provide that the situation is presented through various assignments with multiple levels of difficulty and the possibility of generalisation*."

In prison classrooms, where student attendance is often irregular and prior knowledge varies widely, it is crucial to design problematic situations that are accessible to everybody while still offering opportunities for challenge and generalisation. From a theoretical perspective, this principle refers to the "*low threshold, high ceiling"* approach (Papert, 1993), which promotes activities that all learners can enter easily, while also allowing for deep exploration and generalisation. It also resonates with Sullivan's (2011) *enabling and extending* framework, which distinguishes between scaffolds that make tasks achievable and extensions that push learners toward richer reasoning. From the practical point of view, this principle was realised through modular and flexible learning units, sometimes referred to by teachers as "lesson pills", "tree-structured", or "accordion-like".

A significant example of this approach is the Tangram activity, developed in collaboration with teachers of CPIA of Bologna and tested in other prison schools. The choice of constructing the Tangram using different manipulative and digital tools arose from the teachers' desire to create an activity that yields a concrete/tangible result, while also allowing for activities of varying levels of difficulty. More precisely, the activity integrated manipulative, representative, and digital components, allowing differentiated engagement and progressive complexity. Students could begin with hands-on construction—cutting or folding shapes to form the Tangram—then move to representational and analytical phases using GeoGebra to explore sides, angles, perimeters, and areas.

Supporting different motivations

The present formulation of the second example of identified design principle is: "*If you want to present a motivating problem situation, it is appropriate to engage students actively and cooperatively in learning mathematics by proposing activities in appropriate contexts*."

This principle focuses on the importance of active, contextual, and cooperative engagement in sustaining motivation and understanding in mathematics learning. From the theoretical point of view, the most significant motivational factors for adult learners in prison include: (1) preparation for life after prison; (2) socialisation in prison; (3) the acquisition of formal knowledge or specific skills (Diseth et al., 2008); (4) the opportunities for redemption

from a previous unsuccessful course of study; (5) the desire to have a new chance in being able to study a subject one has always been fascinated by.

Concerning the empirical arguments, it is possible to note that the Tangram activity represents a concrete instantiation of this design principle. The entire activity was organised into manipulative, representational, and digital phases, allowing students to move from tangible exploration to abstract reasoning. Working first with manipulative tools and later with GeoGebra and, where available, Laser-Cut technology, students experienced mathematics as a process of making, verifying, and refining—one that required accuracy, collaboration, and creativity.

Discussion and conclusion

The two examples of design principles identified emerged from the dialogue between theory, classroom observation, and teachers' professional reflection. Each principle connects a specific challenge of prison education to a regulative guideline for designing inclusive mathematical experiences. The Tangram activity exemplifies how a design-based approach can transform mathematics into an opportunity for active participation, motivation, and identity reconstruction.

More broadly, the LeMP project contributes to a reflection on what it means to design for learning in spaces of restriction and vulnerability. It shows that innovation in mathematics education does not necessarily depend on new technologies or resources, but on rethinking design as an ethical and relational practice—one that enables learners to reclaim the right to think, to reason, and to project themselves into the future. In this sense, the design principles elaborated here are not final products, but living hypotheses, open to refinement through future meso- and micro-cycles of research.

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