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CHAPTER 26

MATHEMATICS EDUCATION LABORATORY: A FORMATIVE EXPERIENCE WITH MATHEMATICS TEACHERS

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ABSTRACT

This qualitative, bibliographic and descriptive study investigated the trends in continuing education for the professional development of literacy teachers, focusing on the period from 2018 to 2024. Motivated by the systematic absence of teacher training in the context of professional development, the research sought to present and discuss theoretical findings of an ongoing doctoral thesis, suggesting approaches for study groups. The central guiding question was to analyze the impact of innovations in continuing education, in the light of Imbernón, on the professional development of literacy teachers in the context studied. The relevance of the work lies in clarifying how training trends meet the needs of these teachers, contributing to the understanding of Brazilian educational reforms and offering subsidies for more effective continuing education policies. Practical implications include guiding the formulation of educational policies, improving training programs, and strengthening teacher collaboration networks. The bibliographic survey, carried out in February 2024 in the BDTD, Capes Catalog and Google Scholar databases, using the descriptors "professional development of teachers", "literacy teachers" and "continuing education", resulted in the selection of 17 works (6 theses, 5 dissertations, 1 monograph, 5 scientific articles) after applying inclusion and exclusion criteria. The analysis of these studies, compared with the theories of authors such as Imbernón, Nóvoa and Day, revealed the predominance of qualitative research, mostly from the Southeast of Brazil, addressing the impact of programs such as PNAIC and the limitations of traditional training. The study highlights the uniqueness of its focus on innovations in continuing education in Porto Velho, Rondônia, arguing that significant innovations have occurred, especially in the light of Imbernón's six propositions: treatment of problematic situations, development of collaboration, enhancement of teacher identity, creation of training communities, development of complex thinking, and development of attitudes and emotions. The research concludes that, although challenges persist, innovative approaches offer promising paths for teacher training that is more aligned with the real needs of teachers and the complexity of teaching literacy, with a potential impact on the improvement of basic education, particularly in the Amazon region.

Keywords: Literacy teacher. Training innovations. Formation communities. Collaborative Culture. Teacher identity.

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INTRODUCTION

The Mathematics Education Laboratory (LEM) plays an important role in the initial and continuing training of Mathematics teachers, by providing an environment in which teachers can experience and reflect on teaching and learning situations, analyze teaching strategies, produce didactic resources/materials aimed at assisting the teaching of mathematical contents, prepare texts aimed at the use of didactic resources in the teaching of Mathematics, among other actions (Bezerra, 2024).

The Theory of Objectification is a theory of teaching and learning in Mathematics Education, of a sociocultural and contemporary current, which can offer Mathematics teachers opportunities to think, dialogue and produce reflections on teacher training based on the principles of *Joint Work* and *Community Ethics* (Radford, 2020; Bezerra, 2021). Thus, the Theory of Objectification offers modes of human collaboration, responsibility, commitment and care for the other.

As for Recreational Mathematics, it is a methodological approach in Mathematics Education that we chose to work on in teacher training, based on the Theory of Objectification. Recreational Mathematics has connections with Problem Solving, the use of Games, the History of Mathematics, Investigations and Argumentation in Mathematics, in addition to Digital Technologies (Bezerra, 2021; 2023; 2024). Therefore, its use goes beyond playfulness and motivation, involving students through curiosity and challenge.

The elaboration of the Recreational Mathematics tasks (games, mathematical puzzles and Recreational Problems) was the responsibility of the Objectification Theory. The tasks were developed in the Mathematics Teaching Laboratory of the Mathematics Degree Course, at the Federal Institute of Rio Grande do Norte (IFRN), Ceará-Mirim Campus, with students enrolled in the disciplines of Mathematics Teaching Methodology I and II, in the periods 2023.1 and 2023.2, with the purpose of presenting Recreational Mathematics to Mathematics Degree students, aiming at the knowledge of this methodological approach and its application in the classroom.

Thus, considering the arguments presented, the guiding question of our investigation is: *what contributions does the Mathematics Education Laboratory, through the use of Recreational Mathematics tasks from the perspective of the Objectification Theory, to the training of Mathematics teachers?* In this context, the main objective of the research was *to investigate the contributions of the Mathematics Education Laboratory, through the use of Recreational Mathematics tasks, from the perspective of the Objectification Theory, for the initial training of Mathematics teachers.*

LABORATORY OF MATHEMATICS EDUCATION, OBJECTIFICATION THEORY AND RECREATIONAL MATHEMATICS

In this section, we will deepen the discussion on three fundamental axes for understanding innovative practices in teacher training and mathematics teaching: the Mathematics Education Laboratory, the Theory of Objectification and Recreational Mathematics.

In the Brazilian context, Júlio César de Mello e Souza (1895 –1974), known as Malba Tahan, stands out as one of the pioneers in the dissemination, conception and implementation of the Mathematics Education Laboratories (LEM). These spaces are conceived as environments conducive to reflection, the formulation of conjectures and pedagogical practice centered on creativity, playfulness and the manipulation of teaching resources/materials. Through these approaches, it seeks to make the abstract concepts of Mathematics more accessible, favoring the understanding and development of mathematical thinking in a significant way.

As Lorenzato (2012) argues, the LEM is a favorable environment not only for structuring, organizing and planning mathematical thinking, but also as a space that facilitates, both students and teachers, the practice of questioning, conjecturing, experimenting, analyzing and concluding, thus promoting learning, especially the development of the ability to learn how to learn.

The LEM in the training of Mathematics teachers is understood, according to Bezerra *et al.* (2023), as a space for learning, research, production and experimentation of didactic materials. It is also an environment that favors cooperation and dialogue between teacher-students and student-students. Therefore, LEM goes beyond the physical space and the teaching process, involving an active posture of questioning, experimentation and analysis.

In teacher training, LEM offers a privileged space for the elaboration of teaching strategies, the construction of didactic sequences and critical reflection on the educational process. In addition, it enables in-depth discussions about different methodological approaches in Mathematics Education, for example, Recreational Mathematics, Games, Problem Solving, Ethnomathematics, History of Mathematics and the use of Digital Technologies. In this environment, the articulation between teaching, research and extension is also promoted, favoring the development of investigative practices in the classroom, supported by a consistent theoretical and practical training.

For Kaleff and Rosa (2020), the Mathematics Education Laboratory is an environment conducive to the development of critical learning. Based on their experiences

as Mathematics teachers working in the initial and continuing education of teachers, the authors highlight that the use of didactic materials in the LEM contributes to break with the traditional teaching model, based on the sequence of definition, exercise and application of mathematical concepts. In this sense, the LEM emerges as an alternative, which values the construction of knowledge in an active, reflective and contextualized way.

The research developed by Cavalcanti (2014), Santos (2021), Bezerra and Silva (2024), highlights some contributions of the Mathematics Education Laboratory in the training of Mathematics teachers. Among them, the stimulation of creativity, the enrichment of teaching and learning activities, and the promotion of discussions on different teaching methodologies stand out. According to the authors, the LEM is configured as a privileged space to articulate mathematical thinking and doing, favoring the construction of concepts. In addition, it constitutes a favorable environment for critical reflection on the teaching of Mathematics in the teaching degree, by allowing the analysis of mathematical knowledge from a didactic-pedagogical perspective.

In this way, we defend an emancipatory education, in which teachers are understood as unfinished human beings, in movement and in constant evolution. For this, we rely on the assumptions of the Theory of Objectification. Why the Theory of Objectification? Because it is a theory of teaching and learning in Mathematics Education, of a sociocultural, contemporary current, inspired by the philosophical works of Hegel (1770 – 1831), Marx (1818 – 1883), contemporary philosophers such as Ilyenkov (1924 – 1979), Freire's concept of education (1921 – 1997), and Vygotsky's school of thought (1896 – 1934), the Theory of Objectification was developed by researcher Luis Radford.

According to Radford (2021, p. 40), the Theory of Objectification is part of the growing set of contemporary educational sociocultural approaches.

> [...] whose common denominator is the assertion that human beings are consubstantial with the culture or cultures in which they live their lives. Consubstantiality here means that there is a deep intertwining of cultures with what their individuals think, do, feel, imagine, hope for, and dream.

The Theory of Objectification brings contributions to the organization of teaching practice in Mathematics Education, being applicable, in general, to Education. The theory understands learning as a simultaneous and collective process, in which teachers and students work collectively – *Joint Labor* (Radford, 2020).

As Radford (2023) argues, the Theory of Objectification focuses on how students construct their own knowledge, but also on how, through *joint work* in the classroom, teachers and students produce knowledge anchored in their histories and cultures.

Simultaneously, the theory focuses on the process by which teachers and students co-produce each other as subjects, reaffirming the formative and relational character of the educational act.

Activity, for the Theory of Objectification, is a way of life. Activity is understood as the process through which knowledge is concretized and transformed into knowledge. It is this activity that updates knowledge and makes it come alive in the context of the classroom (Radford, 2020). Thus, what makes learning possible is human and practical activity. The activity "[...] it is a dynamic system in which individuals interact collectively with a strong social sense, which makes the products of the activity also collective" (Radford, 2021, p. 53).

Learning occurs in human activity: sensitive, bodily, affective, material and symbolic. In this activity, teachers and students participate, expresses the idea of a collective of individuals who work together, in harmony, with the aim of achieving an object of common satisfaction (Radford, 2023; P; Bezerra, 2024). It is usually an object of historical-cultural interest, for example, a way of thinking about the world: scientific, artistic, mathematical, among others. It is a way of thinking and questioning the world in which teachers and students find space to express themselves subjectively as human beings.

The activity in the Theory of Objectification is called *Joint Labor*, which is the main ontological category of the theory (Radford, 2021). Joint *work* involves the activity of teachers and students in a dialectical way, being understood as the teacher-student activity. In this way, teachers and students work together during the objectification process, which culminates in learning. In joint *work*, language, sensations, emotions, tensions, contradictions, movements, signs, artifacts, among others, are involved.

Community Ethics, according to Radford (2023), is based on three vectors: responsibility, commitment, and care for others. Responsibility is understood as the starting point from which we emerge as ever-changing, flowing, and transforming subjectivities. Commitment refers to engaging with what we are accomplishing together—a common mathematical work that is political, ethical, and aesthetic (Radford, 2023). Care for the other is manifested in the actions we perform (verbal or non-verbal) so that the other feels our presence, support, solidarity and respect.

In addition to the Objectification Theory, we rely on Recreational Mathematics, which is a methodological approach in Mathematics Education in which it can be seen as a playful way of presenting Recreational Problems, mathematical games and puzzles, in addition to other tasks of a playful-pedagogical nature. Its objective goes beyond fun: it seeks to

arouse curiosity and a sense of challenge, favoring the development of logical-mathematical reasoning (Bezerra, 2021; 2023).

To understand Recreational Mathematics, Bártlová (2016) highlights four fundamental aspects – *scientific-popular*, *fun* (*entertainment*), *pedagogical* and *historical*. “[…] that are interconnected and influence each other. The four aspects overlap considerably, so that there are no clear boundaries between them and serious mathematics" (Bezerra, 2021, p. 67).

Recreational Mathematics, under the *scientific-popular aspect*, is the part of Mathematics that is fun and popular. The *fun aspect* (*entertainment*) is seen as a Mathematics that is used as a deviation from serious Mathematics, that is, used for fun.

In the *pedagogical aspect*, there is the possibility of using Recreational Mathematics in the classroom as a methodological approach. This approach can provide a variety of problems for investigations in teacher training and in the classroom in Basic Education. Finally, in the *historical aspect*, Recreational Mathematics has always played an important role in the History of Mathematics, being responsible for the origin of mathematical theories and concepts that would not exist without Recreational Mathematics (Bezerra, 2021). Therefore, another meaning that we can attribute to the historical aspect is the possibility of being able to use Recreational Mathematics tasks to study the History of Mathematics.

Recreational Mathematics is an important methodological approach for the training of Mathematics teachers, as it can be used as a playful way to present mathematical games and puzzles, Recreational Problems, stories, legends, divinations, riddles, topological curiosities, magic, art, origami, among others, making classes more dynamic and attractive to students (Bezerra, 2021; 2022; 2023). In this sense, it is essential that teachers know Recreational Mathematics, its conceptual and didactic-pedagogical aspects, so that they can understand it and take a critical position on how and why this approach should be present in Mathematics classes.

The Theory of Objectification, combined with the practices developed in a Mathematics Education Laboratory, contributes to the materialization of Recreational Mathematics in the classroom, as the Recreational Mathematics tasks are, in general, open, which favors the deepening of mathematical thinking around certain contents (Bezerra, 2024). In addition, the tasks stimulate collective discussion, promoting the active participation of students in the learning process, as well as interaction with knowledge, with students and the teacher.

Another relevant aspect is that Recreational Mathematics can incorporate elements of a historical and social nature, expanding the space for ethical and reflective debates,

which enriches the educational process and contributes to the integral formation of students.

We conclude this section by emphasizing the importance of the Mathematics Education Laboratory, the principles of *Joint Labor* and *Community Ethics* of the Theory of Objectification and Recreational Mathematics, as they are articulated to sustain a more critical, creative and collaborative formative proposal for Mathematics teachers.

METHODOLOGY

The discussions we present about the Mathematics Education Laboratory, the Theory of Objectification and Recreational Mathematics in the training of Mathematics teachers are based on a study with a qualitative approach , of an exploratory nature. According to Gil (2008), exploratory research aims to provide greater familiarity with the problem and explain it through bibliographic surveys, interviews, among other instruments.

The research was developed in 2023, with undergraduates of the Mathematics Teaching Degree Course at IFRN, Ceará-Mirim Campus, enrolled in the disciplines of Mathematics Teaching Methodology I and II, taught in the fifth and sixth periods by the teacher-researcher. Data collection took place throughout the 2023.1 and 2023.2 academic periods, within these disciplines. The analysis of the results produced during the research was conducted in the light of the principles of Joint Labor and Community Ethics of the Theory of Objectification,

Thus, considering the elements previously presented, we developed our investigation according to the following steps.

- Theoretical studies on the Theory of Objectification, the Mathematics Teaching Laboratory and Recreational Mathematics.
- Task of reading articles on the Theory of Objectification, with the objective of offering undergraduates a notion of what this theory is.
- Construction of Recreational Mathematics tasks from the perspective of the Objectification Theory, to be used in the disciplines of Mathematics Teaching Methodology I and II.
- Elaboration and realization of mini-courses involving Recreational Problems extracted from works: *Problems to stimulate young people* by Alcuin of York (735 – 804); *De Viribus Quantitatis* by Luca Pacioli (1445 – 1517); the *Liber Abaci* by Leonardo Fibonacci (1170 – 1250); and *The Man Who Calculated*, by Mello e Souza (1895 – 1974), the Malba Tahan. The mini-courses were held at the I Mathematics Week and at the II EXPOTEC of IFRN, Ceará-Mirim Campus.

- Publication of articles in Education and Mathematics Education events.

In the next section, we will present the results and discussions.

RESULTS AND DISCUSSIONS

In this section, we present the results of some practices developed in the Mathematics Education Laboratory, through the use of Recreational Mathematics tasks, from the perspective of the Objectification Theory, in the Mathematics Degree Course, IFRN, Ceará-Mirim Campus, in the initial training of Mathematics teachers.

In the 2023.1 and 2023.2 periods, the teacher-researcher used the LEM space to teach the disciplines of Mathematics Teaching Methodology I and II, promoting readings on the Theory of Objectification, the Mathematics Education Laboratory and Recreational Mathematics, in addition to guiding the production and implementation of Recreational Mathematics tasks.

It is important to highlight that the LEM is a space available to other undergraduates and teachers who are interested in handling teaching materials for study and research purposes.

At the IFRN LEM, Ceará-Mirim Campus (2023.1), theoretical tasks were developed for the presentation of the principles of *Joint Labor* and *Community Ethics* of the Theory of Objectification[2], in addition to readings about the Mathematics Education Laboratory and Recreational Mathematics.

The objective of the tasks was to exercise the ability to read and interpret texts, as well as to offer Mathematics students a notion of what Objectification Theory, LEM and Recreational Mathematics are.

The reading tasks were developed in small groups. The texts were read after granting a specific time for the students to carry out the collective reading between the groups. Then, all participants were invited to participate in the debates, with the teacher-researcher encouraging collaborative work and mutual help. According to Radford (2021), it is in *joint labor* that students and professors engage with each other, work cooperatively, and commit responsibly.

The students stated that they had never heard about the Objectification Theory and Recreational Mathematics. They stated that they knew the LEM space at IFRN, but that they had not read on the subject. In this sense, the reading tasks were important for the undergraduates to know a theory of teaching and learning in Mathematics Education with a

[2] If you are interested, seek more information via the link: https://luisradford.ca/publications/.

sociocultural and contemporary basis, in addition to getting closer to Recreational Mathematics, a methodological approach to the teaching of Mathematics. The readings contributed to the understanding of the importance of the LEM in the training of the Mathematics teacher.

During this period, there was a greater participation of undergraduates in the laboratory. Thus, the LEM is configured as an environment that can provide opportunities for theoretical and practical discussions pertinent to the process of initial training of students of the Mathematics Degree Course (Bezerra *et al.*, 2023). These data show the importance of LEM in the training of Mathematics teachers.

In 2023.1, part of our teaching and research experience was socialized through the production of the article *"The Mathematics Teaching Laboratory and its contributions to Teacher Training",* published at the IV Education Symposium, promoted by the Public Education Observatory Research Group (GRUPOEP) of IFRN – Ipanguaçu Campus, held on April 19 and 20, 2023, in the city of Natal/RN.

At the end of the period (2023.1), we participated, as organizers of the event, in the I Mathematics Week of IFRN – Campus Ceará-Mirim, in which we taught the mini-course, entitled "Recreational Mathematics", held from May 2nd to 4th, 2023 and promoted by the Mathematics Degree Course. The objective of the mini-course was to introduce the students of the course to the conceptions and aspects of Recreational Mathematics, in addition to proposing the resolution of Recreational Problems extracted from *the work The Man Who Calculated*, by Mello e Souza – the Malba Tahan.

During the mini-course, the students worked through *joint labor*, in a collaborative and engaged way, with the aim of building a common work (Radford, 2023). In this way, it was possible to present Recreational Mathematics in the training process of Mathematics teachers, based on the principles of *Joint Labor* and *Community Ethics*.

This experience shows how Mathematics Education Laboratories can play a fundamental role in this training process. In addition to encouraging the improvement of the training of Mathematics teachers, by promoting the integration of teaching, research, and extension actions, these spaces also make it possible to stimulate the practice of research in the classroom (Bezerra *et al.,* 2023; Santos, 2021).

Other actions developed at the LEM of IFRN – Campus Ceará-Mirim, in the 2023.2 period, included the construction of the game *Cover 12* and reflections on the production processes, reading the rules, development and evaluation of teaching materials for the teaching of Mathematics. Discussions were also held about the correct and appropriate use of the game in the classroom, considering that future teachers need to live experiences that

lead them to perceive the possibility of changes in the strategies and methods of intervention, cooperation and analysis of the ways of teaching and learning.

The task with the game *Cover 12* was carried out from the perspective of *joint work*, with the members of the groups discussing questions such as: what challenges does the teacher face when using Recreational Mathematics tasks? How does the use of these tasks favor more inclusive learning? Are we, in fact, training autonomous and creative teachers through Recreational Mathematics?

The Theory of Objectification and Recreational Mathematics offer contributions to the training of Mathematics teachers, for example: the expansion of the understanding, by future teachers, of the foundations of the Theory of Objectification and Recreational Mathematics; the strengthening of a more critical, reflective and ethical education, with positive impacts on the quality of teaching and learning of Mathematics; and the valorization of diversified pedagogical methods, especially in public schools. In addition, the proposal includes working with recreational, historical, and pedagogical aspects of Recreational Mathematics, as well as exploring possibilities for inserting these tasks from the perspective of the Theory of Objectification, as part of the teachers' training process (Bezerra, 2021; 2024).

Another action developed within the scope of LEM was our participation and the offer of a mini-course on *Historical-Recreational Problems* during the II Scientific, Technological and Cultural Exhibition (EXPOTEC) of the Ceará-Mirim Campus, held from November 20 to 24, 2023. The objective of the mini-course was to work with Historical-Recreational Problems of the work *Liber Abaci*, by Leonardo Fibonacci, with the target audience being Mathematics undergraduates.

During the development of the mini-courses on Recreational Mathematics, it was possible to observe potentialities that this approach promotes: joy, pleasure, motivation, enthusiasm, entertainment and fun. It is a fun that favors the experience of cooperation between students of the Degree in Mathematics and teachers, facilitating awareness of the mathematical elements mobilized in the context of *joint work* (Bezerra, 2021).

Another result was socialized through the production of the article *"Some actions in the Mathematics Teaching Laboratory of IFRN – Ceará-Mirim",* published in the annals of the XII EPBEM, held at the Federal University of Paraíba (UFPB) – João Pessoa Campus, on November 27 and 28, 2023, in the city of João Pessoa.

During the actions developed in the LEM, we observed that the Mathematics undergraduates acted based on *the shoulder to shoulder* activity (*Joint Labor*), with commitment, responsibility and care for the other. This commitment was manifested in the

fulfillment of tasks, mutual respect, and responsibility understood as an ethical response to the other – a concept that Radford (2021; 2023) calls *Community Ethics*.

Therefore, the experience lived in the Mathematics Education Laboratory of the IFRN, Ceará-Mirim Campus, through the development of Recreational Mathematics tasks from the perspective of the Objectification Theory, contributed to the critical-reflective training of the undergraduate students in Mathematics.

As a result, in the light of the Theory of Objectification, the undergraduates carried out a work based on human cooperation, characterized by a collective effort sustained by an ethics of respect, dialogue, commitment and mutual care.

CONCLUSION

In this work, we seek to broaden the reflection on the following question: *what contributions does the Mathematics Education Laboratory, through the use of Recreational Mathematics tasks from the perspective of the Objectification Theory, to the training of Mathematics teachers?* To answer it, we defined as a research objective: *to investigate contributions of the Mathematics Education Laboratory, through the use of Recreational Mathematics tasks, from the perspective of the Objectification Theory, for the initial training of Mathematics teachers.*

The Mathematics Education Laboratory can contribute to the training of Mathematics teachers and Basic Education students, by promoting a continuous and argumentative dialogue between those involved. In addition, its effects can extend, generating positive impacts both in the school environment and in society.

The Theory of Objectification can offer Mathematics teachers spaces for critical and reflective reflection through *joint work*, enabling the overcoming of limiting conceptions that reduce the school and the Mathematics classroom to simple replicas of society. Thus, the theory contributes to the construction of human relationships based on respect, dialogue, responsibility, commitment, care for others and solidarity.

Recreational Mathematics, in turn, encourages teachers to explore problems in an unconventional way, stimulating critical thinking and problem-solving skills. This practice contributes to the formation of Mathematics teachers capable of teaching students to approach mathematical situations in a creative, reflective and ethical way.

Therefore, we hope that this study on the Mathematics Education Laboratory, the Theory of Objectification and Recreational Mathematics, will contribute to students of the Mathematics Teaching Degree Course, teachers, researchers and other people interested in teacher training.

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