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Pedagogical Innovation and Effectiveness in Mathematics Teaching: An Analysis of Action Research in Computer Integration in Elementary Education

Pedagogical Innovation and Effectiveness in Mathematics Teaching: An Analysis of Action Research in Computer Integration in Elementary Education

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Abstract

This doctoral thesis addresses the Teaching Practice for the use of computers in the teaching-learning process of Mathematics in Elementary School.1 The research sought to analyze the discrepancy between the potential of Information and Communication Technologies (ICTs) and the actual frequency of their use in Mathematics classes at the Cecília de Godoy Camargo Jornalista State School in Campinas/SP.1 The methodology used was a mixed approach (Quali-Quantitative), of descriptive exploratory level, operationalized through the modality of Action Research.1 The diagnostic phase, which involved 4 Mathematics teachers, 2 pedagogical coordinators and 28 students, revealed that, although 100% of teachers and students recognized the value of the tool and the existence of the Computer Lab, 45% of teachers reported not using the resource and 96% of students confirmed not having contact with the computer in Mathematics classes.1 The main barriers identified were lack of preparation teacher for pedagogical use (50%) and technical-operational failures related to insufficient or inadequate equipment and support.1 The central finding of the thesis, resulting from the intervention phase (continuing training followed by practical classes), demonstrated that the use of computers streamlines the teaching process, promoting **faster and more solid learning** of the content.1 It is concluded that the computer is a possible viability for the quality of Mathematics teaching, as long as there is systematized teacher training and a functional operational environment.1 Keywords: School, Computer, Classroom, Mathematics, Learning.1

Abstract

This doctoral thesis addresses the Teaching Practice for the use of the computer in the teaching-learning process of Mathematics in Elementary School.1 The research sought to analyze the discrepancy between the potential of Information and Communication Technologies (ICTs) and the actual frequency of their use in Mathematics of the Year classes, at the Cecília de Godoy Camargo State School Journalist, in Campinas/SP. operationalized through the Action Research modality.1 The diagnostic phase, which involved 4 Mathematics teachers, 2 pedagogical coordinators and 28 students of the Year, revealed that, although 100% of the teachers and students recognized the value of the tool and the existence of the Computer Laboratory, 45% of the teachers reported not using the resource and 96% of the students confirmed that they did not have contact with the computer in Mathematics classes. for pedagogical use (50%) and the technical-operational failures related to the insufficiency or inadequacy of equipment and support.1 The central finding of the thesis, resulting from the intervention phase (continuing education followed by practical classes), demonstrated that the use of computers streamlines the teaching process, promoting faster and more solid learning of the content.1 It is concluded that the computer is a possible feasibility for the quality of Mathematics teaching, as long as there is systematized teacher training and a functional operational environment.

Keywords: school, computer, class, mathematics, learning.

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1. Introduction: The Imperative of Digital Transformation in Mathematics Education

1.1. Context and Justification

Contemporary society, marked by intense and accelerated technological evolution, demands profound transformations in the educational system, imposing the urgent need for teachers to reconfigure their practice.1 The introduction of computers, since the 1980s and 1990s, has established a new type of social relationship that is directly reflected in school dynamics.1 Mathematics, in particular, requires special attention, as it has historically been a critical point in Basic Education, generating high dropout and repetition rates.1 The use of computer resources is, therefore, essential to enhance cognitive development and stimulate logical-deductive reasoning, as recommended by the National Curricular Parameters (PCNs), which consider the discipline an essential component in the construction of citizenship.1

The Ministry of Education and Culture (MEC) in Brazil has implemented initiatives such as the Program National Institute of Informatics in Education (PROINFO) and, in the State of São Paulo — one of the most important information technology hubs in the country — the Acessa Escola Program, aiming at digital and social inclusion.1 However, the evaluation of Brazilian education, especially in science and mathematics teaching, is considered inferior to the world level.1 This situation suggests that the problem lies not in the absence of policies or the potential availability of *hardware,* but rather in the ineffectiveness of the *didactic transposition* of technology into the classroom. Large-scale projects often suffer from wasted financial contributions and equipment, since the school structure or teaching staff is not prepared to receive or operate them effectively.1

Overcoming the deficit requires sufficient "technological literacy" among teachers to keep up with the changes, transforming technology into a strategic pedagogical tool.1

1.2. Research Problem and Guiding Questions

This study originates from the researcher's observation and experience in the field of study, working as a Mathematics teacher at the Cecília de Godoy Camargo Journalist State School, in Campinas/SP.1 The perception of the need to combine computer knowledge with practical experience pedagogical, aiming to stimulate students and dispel the myth that "Mathematics is complicated", drove the investigation.1

The **central question** of the study sought to understand how teachers enhance the student performance in terms of teaching Mathematics using the computer in

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Year of Elementary Education at the aforementioned school.1

From this central question, the following **Specific Questions** were derived 1:

1. How does technology fit into the educational context?
2. What is the role of teachers and the use of computers in the classroom?
3. What are the difficulties and possibilities of using computers in Math classes?
4. What are the successes in teaching and learning Mathematics with the use of computers in the classroom?

classroom?

1.3. Study Objectives

The **general objective** of the thesis is to analyze how teachers enhance the use of of students regarding the teaching of Mathematics using the computer in the Year of Teaching Fundamental at Cecília de Godoy Camargo State School Journalist in the city of Campinas in Sao Paulo.1

The **Specific Objectives** defined for the methodological path are: to situate technology in the context educational, identify the performance of teachers and the use of computers in the classroom, evaluate the difficulties and possibilities of using computers in Mathematics classes, and to highlight the successes in teaching and learning Mathematics with the use of computers in the classroom.1

2. Theoretical Framework: Foundations for Teaching Practice in the Digital Ecosystem

2.1. Technology in the Educational Context: Evolution and Paradigms

Information technology and computers have entered education through a dynamic historical process, divided into six phases (waves), ranging from Logo and programming to collaborative learning and the uncertainty of the technological future.1 The school, as a social organism, responds to social, economic and cultural factors and cannot be left out of this progress.1

However, the history of ICT implementation in Brazil demonstrates a prioritization of *logistics. hardware* to the detriment of *software pedagogy.* The UCA Project (One Computer per Student), for example, it is cited as a case in which the lack of structure and qualified personnel to operate equipment led to a waste of resources, highlighting that the simple presence of technology does not ensure the quality of teaching.1 The use of technology only makes sense if it adds to and optimizes the quality of teaching, requiring the individual to be reflective and critical when using it.1

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2.2. Pedagogical Practice in the Context of ICTs and the Mediating Role

The use of ICTs promotes changes in social representations about the teacher's work.1 According to with Moscovici, social representations originate in the need to transform something strange (like technology) into something familiar, which demands adaptation and reflection on the part of the teacher.1 The role of the teacher in the digital ecosystem undergoes a paradigmatic transformation, migrating from function of information transmitter to that of **mediator** or facilitator of the knowledge appropriation process.1 Technological mediation, according to Lev Vygotsky's socio-interactionist view, facilitates the creation of pedagogical projects that respect the pace of learning, using the sign (linguistic or non-linguistic) as the core of cognitive mediation.1 The teacher, as a mediator, must guide the student in searching and filtering information, ensuring that the avalanche of data is transformed into knowledge.1

For the use of technology to be conscious and effective, it must be aligned with the principles, goals and proposals of the school's Political-Pedagogical Project (PPP).1 Technology should not be used just to maintain an "up-to-date teacher" *status* , but rather as a support for achieving effective educational goals.1

2.3. Teacher Training and Technological Instrumentation

The appreciation of the education professional is a principle established in the LDBEN (Law , Art.).1 No. However, initial training often presents weaknesses in preparing for the use of new technologies.1

Training is generally restricted to an **instrumental** nature — teaching technical handling —, without providing reflection on the pedagogical possibilities.1 Using the theory of Rabardel's instrumentation, it is crucial to differentiate the use of the computer as *an artifact* (mere machine) and as an *instrument* (machine integrated into pedagogical practice with effective meaning).1 Often, teachers end up adapting computational resources to obsolete methodologies, using the computer merely as a "digital notebook", instead of innovating their practice.1
Continuing education needs to go beyond technical instruction and develop meta-skills. cognitive and strategic learning skills, including technological fluency, the ability to problem solving and the three "C"s – Communication, Creativity and Collaboration.1 The investment in training must be a commitment that enables reflexivity and change in teaching practices, helping teachers to overcome their difficulties and insecurities.1

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2.4. Contents and Methodologies in Mathematics with ICTs

Traditional Mathematics, based on the memorization of formulas and decontextualized content, is identified as the main cause of disinterest and school failure.1 To reverse this situation, Innovative methodologies, such as Mathematical Modeling, Ethnomathematics and the use of educational games, seek to contextualize the content and develop logical reasoning.1

The computer acts as a powerful ally, especially for the subject of Mathematics, which deals with abstract content.1 Educational software , which can be classified into Exercise and Practice, Tutorials, Simulation, Reference and Educational Game, must be carefully selected by the teacher, who needs to be proficient in choosing the right program according to the objectives and contents.1

Among the elements that facilitate learning provided by the computer, the following stand out: **interactivity,** which acts on different sensory channels of the operator (touch, vision, audio); **memory capacity** (data storage and processing); the potential for **repetition** mechanized; the **ability to adapt** (through programs that adapt to the needs individual); and **audiovisual capacity** (multi-representation of phenomena, crucial for the visualization of concepts of geometry and shapes).1 These resources allow teaching to become more dynamic and effective, escaping the rigidity of traditional teaching.1

3. Methodological Approach: The Action Research Design

3.1. Focus, Design and Level

The research adopted a **Mixed Approach,** combining qualitative and quantitative approaches.1 The qualitative approach sought to describe the complexity of the problem and the subjects' perception (teachers, coordinators and students), while the quantitative approach classified and analyzed the data through statistical techniques and percentages.1

The **Research Design** was classified as Non-Experimental, suitable for the analysis of social phenomena without the need for manipulation of variables, and at the Explanatory Level, seeking to bring the researcher closer to the object to better understand the occurrence of the phenomenon.1 The research was carried out as a Field Study at the Cecília de Godoy Camargo Jornalista State School.1

3.2. Modality: Action Research (Action Research)

The **Action Research** (Action Research) modality was chosen because it is intrinsically linked to

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nature of the problem. Given that the central challenge was to change *teaching practice* (an action), the methodology could not be merely observational, but rather active and interventive.1 This modality serves two basic purposes: the **practical** (solving the problem of ineffective use) and the **knowledge** (theorizing from the solution).1 The researcher gets involved in the problem, working cooperatively with stakeholders to optimize practice, which is essential to ensure that the proposed solution is contextualized and effective.1

3.3. Population and Sample

The research was carried out at the Cecília de Godoy Camargo Jornalista State School, which offers Education Fundamental I, II, High School and EJA, with 1,386 students.1

The **population** investigated comprised 112 elementary school students, 4 mathematics teachers and 4 pedagogical coordinators.1 The **sample** was composed of all 4 mathematics teachers, 2 pedagogical coordinators and 28 students.1 The inclusion criteria were strict, limited to mathematics teachers and students with regular attendance.1

3.4. Collection and Analysis Instruments

Primary data were collected through questionnaires administered to teachers and students, and unstructured interviews administered to pedagogical coordinators.1

For data analysis, the results were organized into categories, to analyze the aspects qualitative, and in graphs and tables, for the analysis of quantitative aspects, ensuring the clarity and objectivity necessary to illustrate the phenomenon investigated.1

4. Diagnostic Results (Analytical Framework): The Mismatch between Intention and Action

The initial phase of the research revealed a significant paradox: the high perception of the value of ICT contrasts with the very low frequency of its practical application in the classroom.1

4.1. Mathematics Teachers' Perception

All Mathematics teachers investigated (100%) confirmed the existence of the Laboratory of Computer Science at school and recognized the computer as a pedagogical tool differentiated, essential and indispensable for teaching.1 Furthermore, 82% of teachers stated that they had sought or be seeking specialization courses in computer use, indicating a desire

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update.1

However, this positive perception does not translate into practice: 45% of teachers reported not use the computer in their classes, and 40% use it infrequently (only 1 to 2 times a month).1 Only 20% use it weekly.1

The main barriers that prevent effective use were detailed: 50% of teachers pointed out the **lack of preparation for pedagogical use;** 30% cited the **lack of computers in the school;** and 46% of teachers do not know about mathematics *software* that could be used.1 The fact that there is a high demand for training (82%) against a high rate of perceived unpreparedness (50%) suggests that the problem lies in the quality of the training offered, which is predominantly instrumental, failing to provide the didactic knowledge and pedagogical resources necessary to that the artifact becomes an instrument.1

Below, Table 1 summarizes the mismatch between intention and action:

Table 1: Summary of Initial Diagnosis: Barriers and Frequency of Use

Investigated Group	**Perception on ICTs**	**Main Barriers (Percentage)**	**Frequency of Use in Mathematics**
Teachers (N=4)	Important, useful, enriching (100% Yes) [1]	Unpreparedness (50%); Lack of computers (30%); Lack of *software* (46%) [1]	45% do not use it; 40% use 1-2 times/month [1]
Coordinators (N=2)	Essential for making classes attractive; New language [1]	Teaching resistance (Generation X); Technical-operational problems (Internet/broken) [1]	N/A
Students (N=28)	Help with classes, entertainment, advancement (93% yes) [1]	Lack of computers at school (64%); Teachers never used in Mathematics (96%) [1]	96% do not use [1]

4.2. Pedagogical Coordination Approach

The pedagogical coordinators corroborated the operational difficulties and human resistance. They reported that the biggest difficulty is **"discomforting the teacher"** and taking him out of his comfort zone, especially those of previous generations who manifest resistance or great difficulty in to update themselves (what the literature defines as Generation X resistance).1

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In terms of planning, coordination encourages the use of the computer room for research and games.1 However, execution is often limited by technical-operational issues, such as unstable internet access, broken equipment, and insufficient quantities.1 Although the coordination acts in the right direction, the functional ineffectiveness of the infrastructure and teaching inertia paralyze action.1

4.3. Student Perception of the Year

The students, classified as digital natives (Generation Y), showed great openness to technology: 100% confirmed the existence of the Laboratory, and 93% stated that the computer can be a differentiated and useful tool in teaching Mathematics.1

The most critical piece of data from the diagnosis lies in the extremely low use: **96% of students responded that they do not use** computers in Math classes in Elementary School.1 Of these, 75% reported that the frequency of use is non-existent, and only 4% use them.1

Regarding barriers, 64% of students pointed to the **lack of computers at school** as the main impediment.1 This perception among students that "there is a lack of computers", even with the The existing laboratory complements teachers' complaints about broken equipment and inadequate support.1 The laboratory, although physically present, is functionally limited. a class of 112 students, the ICT fleet is insufficient or inoperative, reinforcing the digital exclusion precisely for the low-income population that depends on public schools for this inclusion.1

5. Intervention in Action Research: Training and New Teaching Practice (Thesis Proof)

The Action Research methodology required an intervention phase (Stages 2 and 3) that addressed directly address the problems identified in the diagnosis, notably the lack of pedagogical preparation and the low frequency of use.1

5.1. Structure and Thematic Axes of Teacher Training (Appendix 4)

Based on the diagnosis of unpreparedness (50%) and lack of knowledge of *software* (46%), a project systematized continuing education was developed and applied to Mathematics teachers.1 The The general objective was to continuously train teachers to use computers as a learning tool.1

Teacher Training followed a progression structure, with an emphasis on practice, not just theory, contradicting the previously flawed instrumental model.1

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Table 2: Structure of Mathematics Teacher Education (Appendix 4)

Project Stage Training	**Workload / Nature**	**Contents Approached**	**Central Objectives**
Awareness and Discussion	4 hours	Explanation of the thesis and acceptance of the challenge 1	Raise awareness of the use of computers as a relevant tool for improving excellence 1
Lecture and Debate	2 hours	Importance and diverse forms of ICTs; Programs Existing mathematics; Practice teaching and challenges 1	Reflect on teaching practices and encourage the use methodological strategies 1
Workshop Practice (Simulation)	2 hours	Practical use of platform *software ;* and Class simulation 1	Establish teaching practices, going beyond training 1 instrumental

The format of the practical workshop was essential so that teachers could actually use the computers in simulations of mathematics classes. This active and contextualized approach represents a direct and immediate response to the "unpreparedness for use" barrier, catalyzing the changing the mentality from artifact to pedagogical instrument.1

5.2. Planning the Practice: Applying the Digital Lesson Plan (Appendix 5)

After the training, the teachers implemented a Lesson Plan (50 minutes) in the Action Research modality, focusing on content that benefits from visualization and play.1

The **Selected Contents** were Logical Reasoning through Calculation and the Content of Geometric Shapes and Logical Reasoning.1 These were chosen because they are aligned with the annual planning of the Year and allow the use of specific online games for cognitive development.1

The **Methodology** included:

1. A dialogued lecture for initial guidance on computer use.
2. The use of the computer with the support of relevant programs and *online* games (citing specifically educational game sites).1
3. The development of activities with immediate assistance from teachers and researchers.1
4. An assessment based on the public sharing of results (in full screen) and the sending of activities for correction, allowing immediate intervention by the teacher and self-assessment by the student.1

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6. Analysis of Teaching Practice and Proof of the Thesis

The implementation of Mathematics classes using computers, mediated by teachers who went through the training, produced notable results in the teaching-learning process.1

The main evidence of success was **student engagement and participation.** They reported that the development of Mathematics activities with the computer was more enjoyable, dynamic and innovative.1 The students reported that they learned the content (logical reasoning and geometry) in a "different and faster" way.1

This result indicates that computer use has overcome the disinterest often associated with abstract and decontextualized mathematics.1 The use of *software* and games to approach forms geometric, for example, has proven to be a fundamental resource, as audiovisual capacity of the computer allows the multi-representation of phenomena and concepts, facilitating the construction of mental images and spatial vision, which are challenges in the traditional blackboard methodology.1 The the inclusion of playfulness in games acted as a strong agent of intrinsic motivation, breaking inertia of Generation Y in the classroom.

In terms of teaching performance, the presence of the researcher to provide immediate assistance, both technical and pedagogical, was vital.1 The practice reinforced the new role of the teacher as mediator and intervener, focused on helping students solve problems and manage the tool.1 The Action Research cycle, by providing reflective training followed by assisted practice, broke the cycle vicious underutilization (Unpreparedness, Fear , Low Frequency), restoring confidence and teaching autonomy necessary for mediation in the digital environment.

The **thesis** was proven in practical terms: the use of computers in Mathematics classes, when planned and with engaged teachers after training, it transforms the reality of the process teaching-learning, making it more dynamic, effective and solid in the absorption of content.1

7. Final Considerations and Implications for Educational Policies

7.1. Research Conclusion

The present study fully achieved its objective by confirming that teaching practice for the use of computer is a possible and effective way to improve the quality of Mathematics teaching in Elementary Education.1 The computer is a process enhancer, but its effectiveness is directly proportional to the teacher's pedagogical preparation and the functionality of the environment school.1

Research has shown that technology underutilization is a "domino effect" that starts with

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the lack of resources and inadequate training, generating demotivation and perpetuating obsolete methodologies.1 The training received by teachers at EE Cecília de Godoy Camargo was insufficient, instrumental and not contextualized, which explains the high level of perceived unpreparedness in diagnosis.1

The intervention carried out, based on the Action Research model, proved that continuing education, focused on practical workshops and reflection on the pedagogical use of *software,* is the catalyst necessary for changing practices. The computer, when inserted into the routine, was able to reverse the perception of Mathematics as "boring" to a pleasant and enjoyable subject, contextualizing learning in the digital reality of students.1

7.2. Implications for Quality and Digital Exclusion

The implications of the research point to the need for investments in ICTs transcend the mere acquisition of *hardware.* The majority of students' complaints (64%) are about the lack of computers [1], added to the technical-operational difficulties reported by the coordinators (internet, broken equipment) [1], demonstrates that access is illusory without **functional infrastructure and constant maintenance.**

To ensure academic success and combat digital exclusion, schools must be spaces where access to technology is guaranteed and functional.1

7.3. Policy Recommendations

Based on the results and evidence of the effectiveness of Action Research in transforming practice teacher, the following recommendations are presented:

1. **To the São Paulo State Department of Education (SEESP):** It is essential to create and implementation of specific and mandatory continuing education programs, focused on teaching Mathematics with ICTs (exploration of *software,* games and simulations). This training should adopt practical and reflective models, such as Action Research, to ensure that technical knowledge is translated into effective pedagogical innovation.1
2. **To the Cecília de Godoy Camargo State School Journalist:** It is recommended that the school internalize and carry out periodic workshops on the use of computers in Mathematics classes, replicating the successful intervention model. Such actions would sustain innovation and mitigate possible recurrence of teaching resistance.1
3. **Implementing Dedicated Technical Support:** It is crucial to establish a dedicated program monitoring and maintenance of Computer Laboratories, with the presence of technical personnel

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during school hours, to ensure functionality and immediate access to equipment, overcoming the main operational barrier that currently prevents high frequency of use.1

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