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Problem solving in teaching sets in the 10th grade: contributions of didactic engineering to improving the approach in an Angolan context.

Problem solving in the teaching of sets in the 10th grade: contributions of didactic engineering to the improvement of the approach in the Angolan context

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Summary

This study seeks to understand how the teaching and learning of sets theory takes place in the daily school routine of 10th-grade students in the Physical and Biological Sciences course at the "Afonso Domingos VanDúnem Mbinda" High School No. 80M, proposing pathways for the construction of a didactic framework based on problem-solving. The concern driving this research stems from conversations with teachers and students and the analysis of curricular documents, which reveal persistent difficulties in understanding fundamental concepts of set theory and, above all, in their application to problem-solving situations. A mixed-methods approach was chosen, of a descriptive and exploratory nature, combining theoretical methods (analysis-synthesis, historical-logical, modeling), empirical methods (documentary analysis, survey of teachers and students), and statistical-mathematical methods (percentage analysis and graphical representation), in order to characterize the current state of set theory teaching and the role of problem-solving in this process. The results reveal, on the one hand, that teachers almost unanimously recognize the formative importance of problem-solving and the adequacy of the mathematics curriculum; on the other hand, they show that students face significant difficulties in interpreting statements, identifying relevant data, formulating strategies, and verifying solutions in tasks involving sets. Based on this analysis, a didactic sequence inspired by French didactic engineering and the problem-solving stages proposed by Polya is outlined, structured in four phases: problem orientation, problem work, solution, and solution evaluation. These phases are articulated with didactic functions such as ensuring the starting level, motivation, goal orientation, and treatment of new material. It is concluded that the systematic integration of problem-solving, conceived as context, capacity, and art, can make the teaching of sets more meaningful, contextualized, and coherent with the demands of a mathematics education that develops logical reasoning, critical thinking, and intellectual autonomy in students. It is recommended that the proposed sequence be implemented and subsequently validated experimentally, as well as ongoing training for teachers focused on the design, application, and analysis of problem-solving situations in the teaching of sets.

Keywords: Mathematics teaching; Set theory teaching; Didactic engineering; Problem solving.

Abstract

This study seeks to understand how the teaching and learning of the topic sets is carried out in everyday school life in the 10th grade of the Physical and Biological Sciences course at Liceu No.
80M “Afonso Domingos VanDúnem Mbinda”, and to propose pathways for building a didactic engineering grounded in problem solving. The research interest arises from conversations with teachers and students and from the analysis of curriculum documents, which reveal persistent difficulties in understanding fundamental concepts of set theory and, above all, in applying them to problem situations. The study adopts a mixed approach, descriptive and exploratory in nature, combining theoretical methods (analysis–synthesis, historical–logical, modeling), empirical methods

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(document analysis, questionnaires for teachers and students) and statistical–mathematical procedures (percentage analysis and graphical representation) to characterize the current state of the teaching of sets and the role of problem solving in this process. The results show, on the one hand, that teachers almost unanimously acknowledge the formative importance of problem solving and consider the mathematics syllabus to be adequate; on the other hand, they indicate that students face significant difficulties in interpreting problem statements, identifying relevant data, devising strategies and checking solutions in tasks involving sets. Based on this analysis, a didactic sequence is outlined, inspired by French didactic engineering and by Polya's stages of problem solving, structured in four phases: problem orientation, working with problems, solution, and evaluation of the solution. These phases are articulated with didactic functions such as ensuring the initial level, fostering motivation, guiding towards the objective and introducing new content. The study concludes that the systematic integration of problem solving, conceived as context, competence and art, can make the teaching of sets more meaningful, contextualized and coherent with the demands of a mathematics education that fosters students' logical reasoning, critical thinking and intellectual autonomy. It is recommended that the proposed sequence be implemented and experimentally validated, and that continuous teacher education actions be developed, focused on the design, implementation and analysis of problem-solving situations in the teaching of sets.

Keywords: Mathematics teaching; Teaching of sets; Didactic engineering; Problem solving.

1. Introduction

Today, more than ever, mathematics plays a strategic role in the education of citizens capable of interacting critically with a rapidly changing society, driven by scientific and technological advances. To meet this demand, it is necessary an education that goes beyond the simple transmission of formulas and procedures, prioritizing the conceptual understanding and the mobilization of knowledge in contexts that make sense to the students.

In the Angolan context, several studies report structural difficulties in the teaching of Mathematics: the predominance of traditional, transmission-based methodologies, the weak contextualization of content, the limited teaching training of some of the faculty, and the discouragement of many students, who perceive the discipline as excessively abstract and detached from everyday life.

The topic of sets, usually introduced in the 10th grade as one of the first blocks of More formal mathematics forms a foundation for the construction of later concepts in algebra. Analysis, probability, and statistics. Weaknesses in this area tend to have repercussions at various stages. subsequent to schooling. The author's school experience, supplemented by conversations Informal discussions with students and teachers revealed persistent difficulties in understanding concepts. basic set concepts, negligence in the didactic treatment of this content, and the persistence of gaps even after class progression.

Based on these empirical conversations with teachers, the analysis of normative documents, and the Through the application of surveys to teachers and students, a problematic situation was identified, characterized by... by: correction of activities focused only on the final result, devaluation of the process of students' thinking, attributing difficulties exclusively to the student, and disregarding

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A systematic approach to the prerequisites necessary for learning sets. This constellation of factors led to the formulation of the scientific problem: how to contribute to improving the teaching process and How do students learn about sets in the 10th grade?

The teaching and learning process of [the subject of study] was defined as the object of investigation. Mathematics, and as a field of action, the teaching of sets in the 10th grade of the Physical Sciences course. and Biological Sciences at the High School No. 80M "Afonso Domingos VanDúnem Mbinda". It is thus defined as The overall objective is to improve the teaching and learning process of sets in this specific context. through the development of a didactic engineering proposal that prioritizes the resolution of Problems as a central strategy.

Three scientific questions arise from this objective:

(i) What are the theoretical and methodological foundations that support a proposal for improving the Teaching and learning sets in the 10th grade?

(ii) What is the current state of the teaching and learning process for the topic of sets at the aforementioned school?

(iii) What proposal can contribute to improving students' learning in the teaching of sets? in this context?

Consequently, the following are defined as research tasks: determining the fundamentals Using relevant theoretical and methodological frameworks, empirically characterize the current state of set theory teaching. and to develop a teaching proposal based on problem-solving and educational engineering.

2. Theoretical Framework

2.1. The teaching of Mathematics: challenges and perspectives

The teaching of mathematics occupies a central place in school education, contributing to the development of logical reasoning, analytical skills, and problem-solving competence problems in diverse contexts. Authors such as Lesh and English (2005), Steen (2001) and Cumbo (2018) They argue that mathematical thinking is increasingly required in everyday life, not only because professionals in scientific fields, but also ordinary citizens. This creates a need for a Teaching with a strong focus on application, avoiding merely formalistic and repetitive practices.

From this perspective, Lima (2001) emphasizes that one of the biggest problems in teaching Mathematics resides in the absence of explicit explanation of the everyday applications of its content, which leads students perceive the subject as something eminently abstract and disconnected from reality.

The critique of traditional pedagogy, which considers the student a mere receiver of content, is... recurring in educational literature. Based on Libâneo (1990), Queiroz and Júnior (2017) Eessa The approach is characterized as being centered on the vertical transmission of knowledge, on memorization. and in algorithmic reproduction, to the detriment of problematization and critical reflection.

In contrast, a liberating pedagogy is advocated, in which the contents are articulated.

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connecting with the students' concrete reality, promoting spaces for dialogue, argumentation, and construction.
Active pursuit of knowledge. In this context, Mathematics ceases to be presented merely as a collection of...
formulas and procedures, becoming conceived as a language for understanding and intervening in
world.

2.2. Problem solving as a structuring axis

Problem-solving is a structuring axis of contemporary proposals for
the teaching of Mathematics. Polya (1978) highlights that the teacher who wishes to develop the "spirit
"Problem solver" should spark students' interest in problems and provide multiple opportunities.
Opportunities for practice in real or realistic situations, organizing the work in stages:
Understanding the problem, developing a plan, execution, and retrospective analysis.

Schoenfeld (1985) reinforces that the understanding and teaching of Mathematics should be conceived
as a problem-solving domain, in which students mobilize prior knowledge,
They make decisions, monitor strategies, and evaluate results. This understanding precludes resolution.
It eliminates problems from a purely evaluative status, assigning it the role of methodology.
privileged for the construction of meanings.

Recent national literature corroborates this view, showing that the methodology of
Problem-solving fosters meaningful learning and the development of skills.
superiors. Catchala, Bernardo and Damião (2021), when working with problems that lead to
In the 9th grade, students studying systems of two linear equations concluded that the systematization of fundamentals...
Theoretical and experiential knowledge about problem-solving contributes to enrichment.
epistemological and for improving the organization of the teaching process.

Catima, Tchimuku and Tchiyeka (2021) identified shortcomings in the characterization of
problem-solving and lack of methodological suggestions to support teaching work in
content related to inverse proportionality, reinforcing the need for more didactic proposals.
consistent.

Manuel (2024), when investigating logical-mathematical reasoning as a resource to improve the
In solving exponentiation problems, he emphasized that learning to solve problems is the main...
The reason for studying mathematics was highlighted, along with gaps in the understanding of specific topics, stemming from...
of methodologies that are neither inclusive nor well-informed.

Quimuanga, José and Domínguez (2023), when addressing the teaching of statistics based on
In problem-solving, they found that including practical problems increases interest and...
Student participation, by highlighting the application of mathematics in real-world contexts, including
involving the school community.

Internationally, Santos et al. (2022) argue that problem-solving is a

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an important teaching and assessment tool, as it allows the teacher to observe the knowledge mobilized by students and articulating knowledge built at different moments of school trajectory.

Almeida, Gomes and Madruga (2020) highlight the importance of understanding the dynamics internal training processes to generate data on the discursive productions of teachers and students during problem-solving, highlighting the potential of this methodology for... continuing education.

Pereira, Corrêa and Zardo (2016) conclude that, when properly planned and executed, the Problem-solving promotes better conceptual understanding and improves academic performance. contributing to demystifying mathematics as an inaccessible subject.

Along these lines, Vale, Pimentel and Barbosa (2015) argue that problem solving should to form an integral part of the curriculum, in combination with other strategies, enhancing the mathematical thinking.

2.3. Teaching sets: specificities and challenges

Specifically regarding the teaching of sets, the topic is recognized as structuring for school mathematics, since it offers language and formalism for the The organization of numerous topics, ranging from arithmetic to probability, is systematically addressed in the literature. elements such as historical overview, concept, notation, set description, axioms, types of sets, Venn diagrams, numerical sets and set operations, indicating the place The central role this content plays in the curriculum progression.

However, it is evident that, in practice, the teaching of sets tends to be developed in a way that... excessively formal, disconnected from everyday situations, and poorly explored through... contextualized problems, which makes it difficult to construct meaning and transfer it to new situations.

2.4. Didactic engineering as a methodology for research and intervention.

Didactic engineering is considered as a theoretical and methodological framework that allows for the articulation of investigation and intervention in the teaching of sets. Cumbo (2018) highlights that didactic engineering, traditionally anchored in the internal validation of the designed teaching situations, it can be challenged to incorporate external validation processes, such as the expert method (Delphi method), when one wishes to assess the reliability and robustness of the proposals that result from it.

The research in question proposes a didactic engineering approach focused on the topic of sets, in which the preliminary analysis (of the context, difficulties and objectives) and a priori analysis (of the situations)

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(of teaching methods) gain prominence, even when the stage of full experimentation is limited by institutional constraints.

Thus, the theoretical framework outlined here converges on the idea that the teaching of Mathematics, and in particular the topic of sets, requires overcoming traditional pedagogy and adopting... of active methodologies, with problem-solving as the structuring axis and engineering Didactics as a support for the design, analysis, and improvement of classroom practices.

3. Methodology

The study falls within a mixed-methods research paradigm, of a descriptive and... exploratory, combining qualitative and quantitative procedures with a view to understanding comprehensive of the phenomenon investigated.

3.1. Theoretical methods

From a theoretical point of view, analysis and synthesis methods were used to identify, to organize and articulate the main problems affecting the teaching and learning of Mathematics, in particularly in the segment related to the teaching of sets. The historical-logical method allowed reconstructing the evolution of the notion of set and methodological approaches in didactics of Mathematics. Modeling was used to outline a theoretical-methodological model for intervention. compatible with the principles of educational engineering.

3.2. Empirical methods

On an empirical level, documentary analysis of official programs and other documents was used. normative documents that regulate the teaching of ensembles in the 10th grade, and the survey by questionnaire aimed at mathematics teachers and students of the Physical Sciences course and Biological Sciences, with the aim of capturing teaching practices, perceptions about the discipline and the theme. sets, and specific difficulties in working with problems.

The bibliographic analysis was based on books, articles, reports, and other scientific materials. which address the teaching of mathematics, problem solving, the teaching of sets, and engineering. didactics, forming the basis for the theoretical and conceptual framework of the research.

3.3. Statistical-mathematical methods

Regarding information processing techniques, statistical methods were used. mathematicians, in particular percentage analysis for quantifying the collected data and The use of tables and graphs for their presentation and comparison allows inferences to be made about them. of trends and patterns in the responses of teachers and students.

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3.4. Population and sample

The study population comprised 14 classes from the 10th grade of the Physical Sciences course and Biological Sciences, totaling 490 enrolled students, and 11 Mathematics teachers from High School No. 80M. "Afonso Domingos Pedro VanDúnem Mbinda", totaling 501 individuals.

The sample consisted of 4 mathematics teachers selected randomly from among 120 of the 123 students, corresponding to approximately 25% of the population, this provides a snapshot. representative of current perceptions and practices. In the case of teachers, all respondents They have higher education, which is a positive indicator of their potential for appropriation. of innovative methodological proposals.

3.5. Phases of didactic engineering

From a methodological point of view, the research engages with the perspective of engineering. The teaching methodology developed from French mathematics didactics, organized in four stages: analysis Preliminary, conception and a priori analysis of teaching situations, experimentation and a posteriori analysis. and validation.

Taking into account time and school organizational constraints, the study focused on- If it is in the preliminary analysis, in the conception and a priori analysis, it does not reach the experimentation phase.

4. Results

An analysis of the results, in light of the theoretical framework, reveals a strong coherence between the... empirical difficulties encountered and criticisms directed at the traditional teaching of Mathematics and to a rather simplistic treatment of the topic of sets.

4.1. Teachers: aligned discourse, still traditional practice

The data shows that teachers explicitly recognize the importance of resolution. of problems for the development of critical thinking, logical reasoning, and comprehension. A deep understanding of concepts, creativity, motivation, and planning skills. This attitude It converges with Polya (1978), Schoenfeld (1985), Santos et al. (2022) and Vale, Pimentel and Barbosa (2015), who advocate the centrality of problem-solving as the structuring axis of teaching Mathematics, and not just as an assessment tool.

However, the responses themselves and the analysis of the context reveal that this theoretical agreement This does not translate systematically into classroom practices, especially in the teaching of sets, which It continues to be characterized by lectures, a focus on formal definitions, and mechanical exercises. The discrepancy confirms the criticisms of Libâneo (1990) and Queiroz and Júnior (2017) regarding traditional pedagogy. and illustrates the gap between pedagogical discourse and effective practice, justifying the need for a framework.

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How didactic engineering can support the design and implementation of teaching sequences.
consistent with active learning methodologies.

4.2. Students: low achievement and structural difficulties

Students' self-assessments on subtopics such as set union and set disjunction and negation reveal a low level of achievement, with significant percentages of "bad" responses and "Very bad," as well as significant abstention rates.

In the case of group meetings, although 52% rate themselves positively, there are 20% who... 28% rate it negatively and 28% abstain, which indicates a weak grasp of the content and, possibly due to demotivation or lack of confidence to respond.

In set disjunction analysis, 47% rate themselves well or excellently, but 24% rate themselves poorly. and 29% abstain, reinforcing the idea that a significant portion of the class does not consolidate the content. in a satisfactory manner.

In the negative category, 44% rate themselves positively, 23% negatively, and 33% abstain. maintaining the pattern of low performance and high indecision.

This configuration of results is directly linked to the framework of Lima (2001) and Cumbo (2018), who denounce the lack of contextualization and connection of Mathematics to daily life as a factor of distancing and failure, as well as with national studies (Catchala et al., 2021; Catima et al., 2021; Manuel, 2024; Quimuanga et al., 2023), who identify recurring shortcomings in learning content that is taught without an approach systematic problem-solving.

The high abstention rate on several issues can be critically interpreted as an indicator of Cognitive and affective disengagement, consistent with a practice that, by not mobilizing situations Significant, it does not encourage the active participation advocated by liberating pedagogy.

4.3. Difficulties in problem-solving skills

Students' difficulties in interpreting problems, identifying and extracting data, and transforming Expressing statements in mathematical expressions, establishing relationships between data, formulating strategies. Resolution efforts and verifying solutions reveal gaps that go beyond the technique of manipulating... sets. Such difficulties fall precisely on the stages described by Polya (understanding, planning, execution and retrospect), confirming that the central problem is not just "knowing "Sets," but rather "knowing how to think with sets" in problematic contexts.

In light of Schoenfeld (1985), this means that students are not being trained for the metacognitive regulation of the problem-solving process itself, remaining stuck to typical algorithmic routines of what the literature calls exercises, not problems. Reading

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Criticism suggests that the difficulties diagnosed are consistent with a teaching model that does not consciously develops the competence of reading, modeling and monitoring strategies, confirming the findings of Pereira, Corrêa and Zardo (2016) on the direct relationship between Inappropriate use of problem-solving methodology and poor academic performance.

4.4. Consistency with the need for didactic engineering

The empirical results, when compared with the theoretical framework, legitimize the bet. in a didactic engineering approach specifically designed for the topic of sets, which addresses the problems not as an appendix to the lesson, but as a structuring element of the teaching sequence. The analysis Preliminary findings in the study clearly identify: the effects of current teaching methods (shy students, students' conceptions (Mathematics as a subject) distant from reality), specific obstacles (interpretation of statements) and contextual restrictions (time, number of topics).

This identification is in line with the function of didactic engineering described by Cumbo. (2018), which starts from real problems to conceive and analyze, a priori, didactic devices suitable, possibly validated by experts.

Thus, a critical reading of the results reveals that:

- They empirically confirm the criticisms of the theoretical framework regarding traditional pedagogy and teaching. out of context with Mathematics.
- They make it clear that students' difficulties in ensembles are closely linked to the absence from a systematic problem-solving practice, as advocated by Polya, Schoenfeld, Santos et al., among others.
- They robustly support the relevance of a didactic engineering proposal that reorganizes teaching set theory around contextualized problems, linking preliminary analysis, analysis a priori and, when possible, internal and external validation of teaching situations.

In summary, the results not only describe a picture of low utilization, but They corroborate the central thesis of the manuscript: without a methodological change based on resolution of Problems and supported by consistent didactic engineering, the teaching of sets in the 10th grade It tends to reproduce historical difficulties and keep mathematics detached from concrete experience. of the students.

5. Discussion

The results highlight a tension between, on the one hand, a teaching discourse that is favorable to active methodologies — particularly in problem-solving — and, on the other hand, still practices strongly marked by traditional, transmission-based approaches, centered on solving exercises.

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and in the memorization of algorithms. This discrepancy is consistent with broader analyses of teaching.
from Mathematics, which denounce the predominance of a banking pedagogy, in which the student is conceived
as a passive recipient of content, to the detriment of a liberating, dialogical pedagogy and
problematizing.

The theoretical framework employed in the investigation highlights problem-solving as
A teaching strategy with the potential to develop logical reasoning and thinking skills.
critical thinking, autonomy, and the ability to transfer knowledge to new contexts are highlighted.
by several authors as a central component of mathematical proficiency. However, the analysis
Empirical research shows that, in the context studied, problem-solving is not yet fully integrated into the curriculum.
this place, being used in a punctual way and, often, disconnected from didactic engineering.
that ensures consistency between objectives, content, tasks, and assessment.

Set theory, as it constitutes the basic language of much of mathematics...
modernity requires didactic work that favors the transition from the concrete to the abstract, from
from the classification of everyday objects to symbolic formalization and the manipulation of diagrams and
expressions. The proposed approach, by anchoring the learning of sets in problems
Contextualized, it responds to the need to overcome a merely definitional and abstract presentation.
of the concepts, frequently identified as one of the causes of students' difficulties.

From an educational engineering perspective, the research fulfilled the analysis stages.
preliminary and conceptual and a priori analysis of teaching situations, but did not advance to the
experimentation and post-hoc analysis, due to time constraints and rigid schedules.
Schoolchildren. This limitation prevents, for now, the empirical validation of the proposal, although the theoretical analysis...
and the comparison with the diagnosis made allows one to infer its relevance and potential. A
The future adoption of the expert method (Delphi) is suggested as a strategy for external validation.
preliminary, in line with Cumbo's recommendations regarding the need to expand the use
didactic engineering as a methodology for investigation and intervention in mathematics education.

The implications of the results point to the need to invest in initial training and
continuous training of mathematics teachers, with emphasis on the design, implementation and analysis of
Teaching sequences based on problem-solving and contextualization of content. A
The existence of a faculty with higher education constitutes an important asset, but not
sufficient, if not accompanied by systematic opportunities for professional development.
focused on active methodologies and critical reflection on one's own practice.

6. Conclusion

The study allowed for an in-depth characterization of the current state of set theory teaching in
10th grade of the Physical and Biological Sciences course at High School No. 80M "Afonso Domingos VanDúnem

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Mbinda" and highlight the centrality of problem-solving as a structuring axis of a
Proposal for improving the teaching-learning process.

It was found that, although the Mathematics program is positively evaluated by
teachers, in terms of structure, clarity, and comprehensiveness, still face significant difficulties because
part of the students in the conceptual domain of sets and, above all, in solving problems that
They involve the interpretation, modeling, and verification of solutions.

The investigation systematized theoretical and methodological foundations related to the teaching of
Mathematics, from various teaching approaches to problem-solving and set theory,
as well as the principles of didactic engineering, which underpin the development of a proposal for
A teaching sequence based on contextualized problems and Polya's stages.

This proposal, organized in four stages (problem orientation, problem work,
(solution and solution evaluation), offers a roadmap for the planning, implementation and analysis of
Teaching activities involving sets that value reasoning, autonomy, and connection with the...
students' daily lives.

Among the study's main contributions, the most notable is the clarification of subsidies for a
didactic engineering of set theory teaching using problem-solving, the clarification of
specific difficulties students face in this area and suggestions for addressing them.
teachers are oriented towards active methodologies. However, the absence of empirical experimentation of
The proposed sequence currently limits the possibility of generalizing the results.
establishing a significant limitation of the work.

Recommendations:

For future investigations, controlled implementation of the proposal is recommended in
10th grade classes, with systematic data collection (student work, classroom observations,
(video recordings) that allow for post-hoc analysis and validation, or reformulation, of the
hypotheses and didactic decisions assumed.

It is also suggested that further research be conducted on the use of problem-solving.
in other areas of school mathematics and the connection between educational engineering and other
research methodologies in mathematics education.

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