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Conceptions of Primary School Teachers about the Introduction of Early Algebra: Teaching Implications

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Abstract: Thinking about the introduction of algebra in the first years of school implies, among other aspects, a transformation of the school mathematics curriculum and a change in the limited and traditional conceptions that are held about its teaching. This article characterizes the conceptions of a group of primary school teachers from public institutions of the Buenaventura District about the introduction of algebra from an early age based on the perspective of curricular change called early algebra. The research was of a qualitative nature through the hermeneutic phenomenological approach with which the teachers' conceptions were described from their classroom and personal experiences in teaching algebra. The analysis of the teachers' conceptions provided fundamental didactic elements about the advantages of reflecting on the importance of transforming the traditional practices of algebra teaching at school. It was found that the conception that one has regarding the teaching of mathematics and the disciplinary training that teachers have play an essential role in the design and implementation of tasks that promote the development of algebraic thinking in students from the first years of school.

Keywords: conceptions, teachers, primary education, early algebra.

小学教师对早期代数入门的看法：教学启示

摘要：考虑在学校的第一年引入代数意味着学校数学课程的转变以及对其教学的有限和传统观念的改变。本文从"早期代数"课程变革的角度，描述了布埃纳文图拉区公共机构的一群小学教师对于从小就引入代数的看法。该研究通过解释学现象学方法进行定性研究，教师根据课堂教学和代数教学的个人经验来描述其概念。对教师观念的分析为反思学校代数教学传统做法的重要性提供了基本的教学要素。研究发现，教师对数学教学和学科训练的观念在设计和实施促进学生从学年开始代数思维发展的任务中发挥着至关重要的作用。

关键词：概念、教师、初等教育、早期代数。

Introduction

The teaching of algebraic processes in basic primary education plays an essential role in the cognitive and mathematical development of students. Beyond being

just a set of equations and formulas, algebra is a powerful tool that fosters critical thinking, problem solving, and logical reasoning skills. Thus, teaching algebraic processes in primary education provides students with a solid foundation for understanding more advanced mathematical concepts in later stages of their education.

In this sense, it is necessary to inquire about the conceptions that mathematics teachers in elementary school have about the beginning of algebraic work in school since they are the fundamental actors promoting this type of thinking in the classroom.

Likewise, teacher training, their experiences, and pedagogical practices are building conceptions of teaching processes, which significantly influence the type of planning and organization of activities proposed in the classroom. Because of the above, experiences in teaching practice should be explored and understood regarding the possibility of teaching or early development of algebraic thinking in the first years of school.

Consequently, this article presents the results of an investigation focused on characterizing the conceptions of a group of primary school teachers regarding the promotion of the teaching of algebra in primary education and on the analysis of how specific training of mathematics teachers for elementary school significantly influences the possibility of paving the way so that in later years of school, students have a friendlier approach to algebraic content.

1. Theoretical Framework

1.1. Early Algebra and Curricular Change Perspective

From different investigations, a new perspective of curricular change called early algebra or early algebra centered on the idea of Kaput [1] on the algebrization of the Colombian curriculum has been contemplated. This author maintains that “the key to algebra reform is to integrate algebraic reasoning in all grades and in all subjects, that is to say “algebraize” school mathematics” [2], which means not waiting until certain high school grades start work with algebra in school. Now, talking about early algebraic work does not mean putting another subject called algebra in the students’ class schedule, in addition to arithmetic, but that this is considered as "a way of thinking and acting about objects, relationships, structures and mathematical situations, as guide toward a teaching with understanding and meaning of mathematics” [3]. In general, what is sought in particular terms with this new curricular perspective is as follows:

- Incorporating into primary education classrooms activities aimed at observing patterns, relationships, and mathematical properties to develop algebra skills. As Blanton and Kaput [4] point out, these activities create a work environment in mathematics in which students explore, model situations, make predictions, discuss, argue, and check ideas, in addition to practicing calculation skills [4]. In short, it is about simultaneously developing numerical and algebraic thinking from primary education to develop learning with understanding that facilitates the subsequent study of algebra in secondary education [5].
- Covering the study and generalization of patterns, identification of numerical relationships, characterization of functional relationships, development and manipulation of symbolism with meaning, study and understanding of structures abstracted from calculations and relationships, and modeling [6].

These positions associated with early algebra will allow the primary mathematics teacher to be clear about the purpose of this curricular perspective and make practical pedagogical transformations in favor of strengthening the difficulties that students present when working with algebra, without forgetting that excellent planning, disposition, and commitment on the part of the teacher are required to achieve a significant inclusion of this proposal in their pedagogical work.

1.2. Early Algebraic Thinking

Introducing the teaching of algebra in primary education encourages the development of algebraic thinking in its different forms of representation, especially if it is not reduced to the manipulation of symbols, that is, if it is done from a broader perspective through the observation of regularities, patterns, building relationships, understanding properties, among others. Considering the importance of these processes, the teacher’s idea about the forms of introduction and work toward the construction of algebraic thought and belief about a methodological order to lead students to understand these processes influence what they propose for such developments. Thus, one of the deep-rooted ideas of teachers is associated with the fact that algebraic thinking underlies arithmetic thinking, that is, without one, the other could not be worked on.

However, it is necessary to distinguish between these two thoughts in such a way that it allows the teacher to elucidate what is sought when working in each of the two fields and determine which characteristics unite them and which ones make them “different”. What distinguishes arithmetic from algebraic thinking is the fact that in the latter, indeterminate quantities are treated analytically [7]. In other words, indeterminate quantities (unknowns or variables) are considered as if they were known, and we perform calculations with them as with known numbers. It follows, then, that the difference between arithmetic and algebra cannot be given in terms of notations, as is often thought. This author maintains that the alphanumeric algebraic symbolism that we know today is in fact a recent invention, so we can affirm that "the birth of algebra is not the birth of its

modern symbolism" [8].

In short, developing early algebraic thinking, according to research results, will make it possible to close gaps in relation to the difficulties that students present when they go from arithmetic to algebraic work and mitigate the fear, rejection, and frustration that are generated. in school when it starts "formally" with more advanced algebra courses in high school, precisely because an early approach to it was made.

1.3. Conceptions and Training of Elementary School Mathematics Teachers in the Introduction of Early Algebra at School

The term "conceptions" can be identified with the perception or vision of the nature of a discipline [9]. From this perspective, teachers' conceptions are considered an important element in the teaching and learning process at school insofar as they condition the educator's pedagogical practices. Therefore, within this research, it is considered a fundamental element to know what conceptions teachers have regarding the teaching of algebra in primary school and how much they are rooted in their pedagogical practices.

In this sense, in terms of mobilizing the conceptions of primary school teachers in the development of algebraic thinking in the Londoño School [10], the following conclusions were drawn:

The elementary school teachers participating in the research have the conception that it is necessary to form solid arithmetic foundations in students so that from the notion of number, counting, basic operations, and problem-solving, the student can move on to knowledge of other concepts such as algebraic.

However, it is essential to recognize that many of the inappropriate conceptions of primary school teachers about the teaching of algebra are due to their unpreparedness and lack of disciplinary knowledge that is required for the design of tasks and activities oriented to the development of early algebraic thinking.

As expressed in [4], the incorporation of algebra in basic primary education is not a trivial matter, considering that, generally, teachers at these levels do not have exclusive initial training in mathematics [12], and that this could lead to their knowledge lacking disciplinary depth, making it impossible for them to understand the how and why of algebra in primary school.

2. Method

To understand and characterize the conceptions of the teachers from their pedagogical experiences, the phenomenological hermeneutic (FH) method was used, which is oriented to describe and interpret the fundamental structures of the lived experiences of the agents of the educational community, to the recognition of the meaning of the pedagogical value of these experiences, as well as their understanding, meaning and sense [14] and for this, four research phases are proposed in Table 1.

Table 1 Description of the research phases [15]

Fase	Contenido	Actividad
I (+Description)	Collect the experiences lived (directly)	• Anecdotal personal descriptions • Protocols of personal experience of teachers (anecdotes)-
II (+Interpretation)	Gather lived experience (indirectly)	• Conversational interviews- • Autobiography-Documentary film-Conversational interviews
	Reflect on the lived experience.	• Thematic analysis and use of various writing methods. • Writing of linguistic transformations.
III (Description + interpretation)	Write-reflect on the lived experience.	• Elaboration of phenomenological text. • Review of phenomenological documentation.

The fourth phase is connected with the third, in which all the individual physiognomies of all the subjects studied are integrated into a single description, which will be carried out in the final analysis described in the investigation. In short, the methodological process developed in the investigation is presented in Fig. 1.

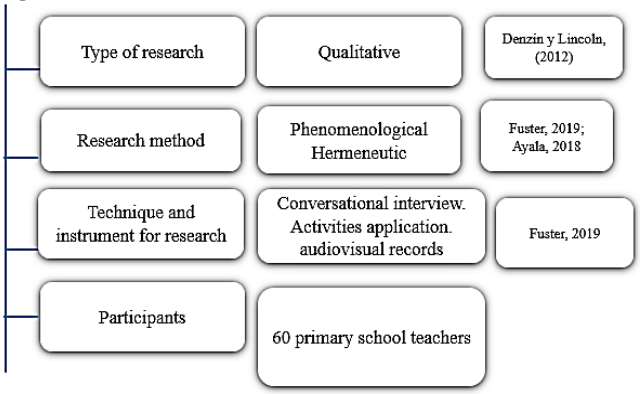

Fig. 1 General elements of the methodological design (Developed by the authors)

3. Results

The results of the investigation are presented in three moments, and in each of them, specific instruments were applied for their respective analysis according to the objective of the investigation. According to the purpose of this article, only the results of two of the moments will be presented.

3.1. Moment I: Characterization of A Priori Conceptions about Teaching Algebra

The accounts of the teachers underlying the application of a questionnaire in the form of a conversational interview were analyzed in detail, with which a first approach to the ideas of the participants on the teaching of mathematics in primary education and algebra in particular was obtained. Tables 2 and 3 show the categories and subcategories of the analysis, and Tables 4-7 show the responses to them.

Table 2 Description of the first category and subcategory of the analysis (Developed by the authors)

Teaching mathematics in primary school (EMP)	
Subcategory	**Description**
Training of	Knowledge that teachers need to

mathematics teachers	promote the development of mathematical thinking
Disciplinary contents and processes relevant to teaching mathematics	It refers to the selection of content that teachers prioritize during the teaching of mathematics and the strategies they use to develop it in the classroom.

Table 3 Description of the second category and subcategory (Developed by the authors)

Introduction of Algebra in Primary Education	
Subcategory	**Description**
General conceptions of teachers about algebra	Ideas that teachers carry with them from their experiences about what school algebra is
Relevance of the development of algebraic thinking in primary school	It refers to disciplinary and curricular knowledge in relation to the importance of starting the development of algebraic thinking in school.

Table 4 Results of the first subcategory (Developed by the authors)

Training	**Number of teachers**	**Percentages**
Normalist	12	20%
Bachelor of Preschool Education	12	20%
Bachelor of Pedagogy	18	30%
Bachelor of Social Sciences	12	20%
Master of Education with an emphasis on mathematics education	6	10%
Total	60	100%

Table 5 Results of the second subcategory (Developed by the authors)

Prioritized Math Content	**Response rate**
Positional number system (reading and writing numbers)	80%
Natural numbers and their basic operations	100%
Recognition of geometric figures and angles	20%
Number sequences, equivalences, patterns, and generalizations	20%
Clearance of formulas	10%
Bar charts and probability	20%

Table 6 Response to the first subcategory (Developed by the authors)

What is algebra?	**Response rate**
Does not answer	20%
Development of complex operations based on a formula, i.e., advanced mathematics	40%
I never understood it.	10%
Combination of numbers and letters to find the unknown	20%
Mathematical aspects that address variation and change based on patterns and regularities	10%

Table 7 Response to the second subcategory (Developed by the authors)

Can you teach algebra in elementary school?	**Response rate**
Yes	30%
No	70%

From the above answers, it follows that:

- 90% of the teachers do not have disciplinary training in mathematics but in other areas of knowledge, and only 10% represented by a teacher have specialized knowledge in mathematics in their training; however, all of them at some point in their experience have dealt with its teaching. This panorama provides an important element in this analysis because their perceptions of the development of algebraic thinking in the first years of school will be closely linked, in addition to their years of experience and academic training.
- 100% affirm that one of the most important topics that children should learn is operations with natural numbers. In fact, one of the teachers in her intervention stated that: "if a child manages to learn basic operations in primary school, in high school, they will have fewer difficulties; other topics can be deepened in high school." In this sense, it is not possible to appreciate concern in the work with early algebraic thinking since according to their answers, only 20% of the teachers mention the work with sequences, patterns, and generalizations, a fundamental element to bring students closer to the PAT.
- The classroom practices of mathematics teachers are oriented according to how they conceive mathematics, conceptions that are linked to the training they received and their experience with them, following the same patterns received to be transmitted [3].

According to the answers of the teachers to the questions raised in the subcategories, the following can be deduced:

- 90% of the teachers have a traditional idea regarding what school algebra is, since they state that algebra "is a complex subject where its emphasis is work with numbers and letters where techniques are learned to find the value of an unknown; a subject that, due to its complexity, could never be understood." This traditional conception of algebra by teachers is perceived in both teaching and learning. For the vast majority, their teaching must be given in high school, precisely because of the rigor that their learning brings with it (this is based on their personal experiences).
- The ideas described by the teachers previously show that the experience they had when they studied was not the best since traditionally, the teaching of algebra focused on presenting students with prefabricated symbolizations called meaningless algebraic expressions, that is, a subject focused on the combination of letters and numbers that must be taught in secondary school and that to understand it, it is strictly necessary to have a solid arithmetic foundation [16, 17].

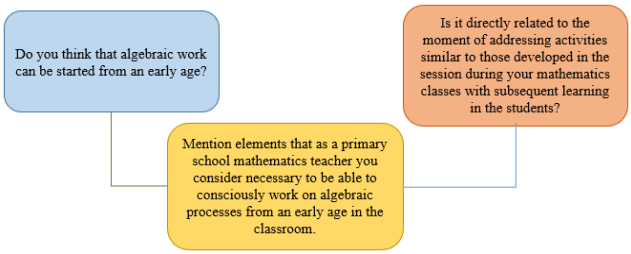

Fig. 2 Guiding questions: Moment II (Developed by the authors)

It is important to point out that the answers to these questions are after Moment II, when the research participants jointly developed activities with algebraic components that were proposed during the meeting. The responses are presented below:

100% of the teachers answered that it is possible. In other words, the perception of the 70% who initially believed that it was not possible managed to change their perception. However, teachers specify the following:

P1*: I had never visualized it that way, but now I consider it a fundamental pillar to prepare students for higher grades. The concept I had about algebra transformed me.*

P2*: With the activities carried out today, I think that they can be carried out; however, the guidance of a person proficient in mathematics is needed for the teaching-learning process to be correct.*

P3*: I think it is important and fundamental to open that "world" that is the mind of children. It would be beneficial to have more training in this (practical) sense to improve our mathematical skills.*

P4: *It is pertinent because it provides tools for developing other thoughts.*

P5: *It would be important to apply this process in primary school.*

Faced with the question relating to the contents, 80% of the teachers answered no; they generally follow the plan drawn up for the grade in which they are. There is no recognition of subsequent mathematical content or processes for students, perhaps because there is no appropriation of the horizontal and vertical organization that the Basic Competency Standards maintain for teaching mathematics at school. The foregoing means that the teaching and learning process is done in isolation and, therefore, difficulties continue to be generated in the learning of mathematics. In addition, according to their responses, their teaching is focused on the learning content rather than the development of mathematical thinking. Let us look at some of the teachers' responses.

P1: *It is simply worked on in class because it corresponds to the program, and suddenly, it is thought of as a basis to deepen in the next grade.*

P2: *Before, I have not done it; today I recognize that it is necessary that everything that is done in the classroom must have projection.*

Finally, regarding the last question to mention aspects that primary mathematics teachers should consider when working on algebraic processes at school, their answers were closely related to the experience they had during the training meeting. In general, the teachers focus on three elements that they consider essential:

- Strengthening their abilities in mathematics (disciplinary knowledge);
- Type of activities presented to the students (sequences, patterns, generalization);
- Type of resource or didactic material that allows mediating the process.

These three elements highlighted by the teachers are precisely considered in [11] for beginning algebraic work in primary school. For this, it is necessary, as already mentioned, that teachers receive training in this process where they can continue to develop algebraic thinking skills that allow them to effectively mediate the approach to algebraic work in their students.

In general, the results of Moment II are summarized in Fig. 3.

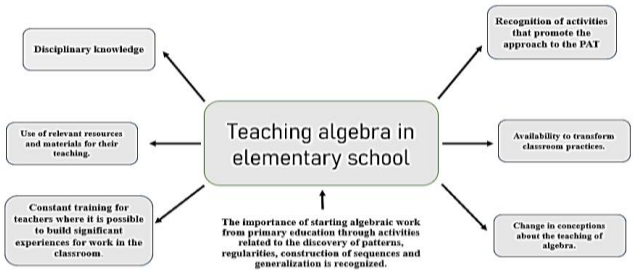

Fig. 3 General summary of Moment II results (Developed by the authors)

4. Conclusions

Initially, the teachers' perceptions of the development of algebraic thinking in primary school were negative. For them, hearing the word "algebra" immediately took them to secondary school. It brought back negative memories from their experiences when they studied. They described it as a negative, complex subject, whose learning lay in combining numbers and letters to solve equations. Of course, this conception of a traditional curriculum for the teaching of algebra did not allow them to think about the possibility of initiating an early approach to algebra in primary education [16, 17].

100% of the teachers focus on students in the first grades having a mastery of basic operations with which they can function in their daily lives. Therefore, they emphasize the recognition of a set of natural numbers and the decimal numeral system (reading and writing numbers). Obviously, numerical thinking is promoted more than other types of thinking. In other words, mathematics is presented as an activity of following procedural instructions where an approach focused on transmission and repetition is favored without achieving meaningful learning [13].

During the interaction and development of the activities, the teachers managed to recognize the importance of starting algebraic thinking from an early

age, understanding that starting algebraic work in these grades does not mean that students have to have a subject called algebra in their schedule and that they have to solve complex situations using algebraic expressions, but the challenge focuses on the relevant selection and implementation of tasks that gradually and systematically promote algebraic thinking in their students, which requires the teachers' planning of and reflection on what they want to achieve in the classroom.

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