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Variational thinking in the academic performance of High School students

Patricio Xavier Giler-Medina
Maestría en educación básica, Universidad Laica "Eloy Alfaro" de Manabí, Extensión Chone, Manabí, Ecuador
patricio.giler@pg.uleam.edu.ec
https://orcid.org/0000-0001-9276-4638

Eddie José Alcívar-Castro
eddie.alcivar@uleam.edu.ec
http://orcid.org/0000-0002-6213-1978
Maestría en educación básica, Universidad Laica "Eloy Alfaro" de Manabí, Extensión Chone, Manabí, Ecuador

***Abstract*---**The research was based on inquiring about the knowledge acquired in variational thinking and its relationship with the academic performance of Higher Basic students of the Private Educational Unit "El Oasis" of the Chone canton in the period 2021-2022. The results of the research developed through a structured base test are shown, as a way of schematizing the educational reality in mathematical thinking in its various forms. The problem of the teaching-learning process of variational thinking presents various deficiencies that lead to poor academic performance. A categorization of topics on knowledge achieved in the block of algebra and mathematical functions was developed. The objective was to determine variational thinking in the academic performance of students regarding algebraic learning and functions. Qualitative, quantitative, and bibliographic analysis was applied; in addition to the inductive-deductive and analytical-synthetic method. The applied technique was a structured base test to perform the analysis and interpretation of the results obtained from the students, on the knowledge of the variational thought of the upper basic. The result was that the inadequate development of mathematical exercises in variational thinking affects the academic performance of this, the need to improve the strategies applied by teachers and apply methodological strategies in the teaching-learning process through ICTs was observed.

***Keywords*---**Variational thinking, academic performance, teaching-learning, algebra and functions

Introduction

The research was based on contributing to the teaching-learning processes of variational thinking in higher basic education, to promote a significant improvement in academic performance in the math area. Variational thinking is not only the ability to represent reality through models or formulas, but it is an orderly, progressive, and continuous process of acquisition and assimilation of mathematical skills for life and that conditions interpretive and reflection skills in situations. of change (Parada, 2018, p.15).

Academic performance is usually associated with processes of mastery of skills, degree of skill in developing skills, self-esteem, the ability to integrate **and** demonstrate the knowledge acquired (Mello & Hernández, 2019). Within the context of the mathematics subject, regarding variational thinking, it corresponds to the results of the development and evaluation of the variational skills contained in the Algebra and Functions block, which in turn integrates the topics of real functions, polynomials, equations, and inequalities.

In Ecuador, students entering the Baccalaureate level have difficulty in achieving the content established in the national curriculum; their ability to interpret, model, represent, analyze every day and simulated phenomena is reflected in the national score of the PISA-D test, of 377 points, corresponding to Level 2 in Mathematics (INEVAL & OCDE, 2018).

In the curriculum of compulsory education levels, in the introduction to mathematics (MINEDUC, 2016), it is established that "*the teaching of this has as its fundamental purpose to develop the ability to think, reason, communicate, apply and assess the relationships between ideas and real phenomena*" (p. 50); and in it, according to the contribution of the area of mathematics to the exit profile of the Ecuadorian high school, it indicates that "*the area is focused on the development of logical and critical thinking to interpret and solve problems of everyday life*" (p. 51) .

The learning process is a planned act with clear goals, but its application is presented in stages and depends on each student, regarding their prior knowledge, motivation, and complexity of the content to be learned. Academic performance is interpreted as the result of the learning process that can be influenced by multiple factors, which is how, in variational thinking, it is related to both the classroom climate and teacher strategies (Corredor & Bailey, 2020, p. 139), the commitment to school activities, the motivation of the students to meet the proposed objectives and the processes of academic reinforcement.

The socio-affective processes of motivation, extrinsic and intrinsic, directly influence the "*personal and academic development*" of the students (Usán & Salavera, 2018, p. 105) and must be considered in relation to workspaces and relevant evaluations that allow reducing the anxiety in the face of misunderstanding and improve long-term performance in mathematics (Villamizar, Araujo, & Trujillo, 2020, p. 10).

It is evident that the complexity in the acquisition of variational skills is conditioned by the previous knowledge of the students and the systematic use of strategies in meaningful learning, currently mediated by information technology and telecommunications (ICT) in the school environment (Martínez & Gualdrón, 2018); but also, in the strengthening from the progressive increase of knowledge in different scenarios, through the orientation of activities, the execution of active strategies and the control of the resources to be used, which allow variables and variation to be recognized through graphs and models (Doylet & Villamar, 2018), in addition to the didactic proposal based on "*cognitive visual perception*", as a methodological axis for learning basic concepts (Jiménez, 2021, p. 71-72).

When referring to academic reinforcement in mathematics, it is interpreted as the set of activities scheduled in the educational institution in order to support students in achieving knowledge and achieving the planned objectives of the area (Córdova & Barrera, 2019), where tries to establish priority care measures for educational needs and for students to be aware of the diagnosis of their errors in order to establish measures that lead to the correct understanding of skills and allow them to advance chronologically, from upper basic to high school, with optimal academic performance.

At this point, Orellana and Vilcapoma (2018), comment that the teacher should not advance in their curricular planning if there is no "*measuring process of the real development zone*" that allows with (potential) peers to reach new levels ofknowledge (next) in the integral learning of mathematics, and thus in each school grade, constituting the pedagogical justification for the establishment of academic reinforcement based on "*Vygotsky's sociocultural theory*" (p. 15-16).

With the intention of investigating and providing answers to these research problems, the objective was to determine variational thinking in the academic performance of Higher Basic students, through a structured base test with respect to real functions, operations with polynomials, equations, inequalities, and systems of equations.

Considering that the proper learning of variational skills leads to the comprehensive development of variational thinking, it is known that continuous evaluation, of a formative nature, is a fundamental process to access accompanying assessment processes (Alarcón & Sepúlveda, 2019) and in consequently improve academic performance.

Materials and methods

The applied methodology has a qualitative approach, which allows to investigate, analyze, and interpret, from a disciplinary (Mathematical) and didactic view of the acquisition of variational thinking skills and the analysis of the academic performance of students in learning variational thinking of students. students of the tenth year of higher basic education. In this category, the level of explanatory research was used, which related the causal findings associated with the independent variable (variational thinking) and how this influences the dependent variable (academic performance), in the 2021 - 2022 school period.

As an approach qualitative research in education points out (Cerrón, 2019), that the "*concrete transproduction of knowledge*" for the correct interpretation, categorization, analysis and innovation of the educational and sociocultural context, needs skills and methodological representations that allow establishing links that integrate diversity of relationships present in the educational reality (p. 167). A review of the literature contained in books and scientific databases was applied, which theoretically validated and conceptualized the research. The review of the physical and digital files that rest in the secretariat of the UEP "El Oasis" was carried out, granting clarity to the investigative process.

Some quantitative aspects were evaluated as indicated (Núñez, 2017), based on a pragmatic and statistical vision that allows the rigorous and systematic analysis of data in the social sciences, allowing the full integration of the complexity of the educational reality and the plan that leads a mixed investigation, which integrates the qualitative approach (p. 647).

According to the mixed research process, as pointed out by (Ochoa, Navia & Fusil, 2020), there are differentiating epistemological situations between both approaches that provide understanding and precision (p. 21), this is how a structured base test and analysis were used. documentary of the methodological strategies and record of qualifications, against a quantitative posture of collection, analysis and interpretation within the framework of descriptive statistics, in addition, the situation under study was characterized, applying: the observation of the phenomenon of study to recognize the aspects that influenced the acquisition of variational skills; the inductive method, in order to study the research problem that originated in the educational institution, to know the causes of poor academic performance in mathematics and to establish possible effects associated with the problem; and the analytical-synthetic method, to consolidate, in a logical and structured way, the relevant aspects, the results and the conclusions of the investigation.

The population studied was 143 upper basic students and 6 Mathematics teachers from the Private Educational Unit (UEP), of whom 37 students from the tenth year of Basic General Education (EGB) were selected by intentional sampling, as school grade and requirement. for admission to the baccalaureate level.

Analysis and discussion of results

The results obtained show the information collected from the structured base test to investigate the knowledge achieved by the students who complete the higher basic education of the Private Educational Unit "El Oasis" of the Chone canton. Through structured questions, the 37 tenth year EGB students were investigated with the intention of identifying parameters that affect academic performance in learning variational thinking.

It should be considered that the tenth year of EGB. It is the final grade of the Superior Basic sublevel, and it is where the variational skills raised at the beginning of the sublevel must be fulfilled. Variational skills raise the need to "*understand and give meaning"* to notions of variational thinking, which is

fundamentally based on "*digital artifacts*" and "*overcoming difficulties*" associated with change or variability in real or simulated situations in mathematics (Parada, 2018, p.17).

Difficulties in variational thinking

The authors (Alarcón, García & Sepúlveda, 2019) indicate that the applications of variational thinking, in mathematics, are very broad and require "*modeling processes*" (p. 468), highlighting that formative evaluation favors the assimilation of processes, which allows a positive rapprochement between students and the object of study (curricular planning), which encompasses four main branches in secondary education: equations, relations, functions and calculation. At the upper basic level, variational skills have emerged from the implementation of a national curriculum in 2016, which established a separation into blocks of the mathematical subject, from which Algebra and Functions were studied due to its relationship with the phenomenon studied. (MINEDUC, 2016, p.56).

The difficulties of learning variational thinking in mathematics were raised by Parada (2018), in figure 1, these are shown.

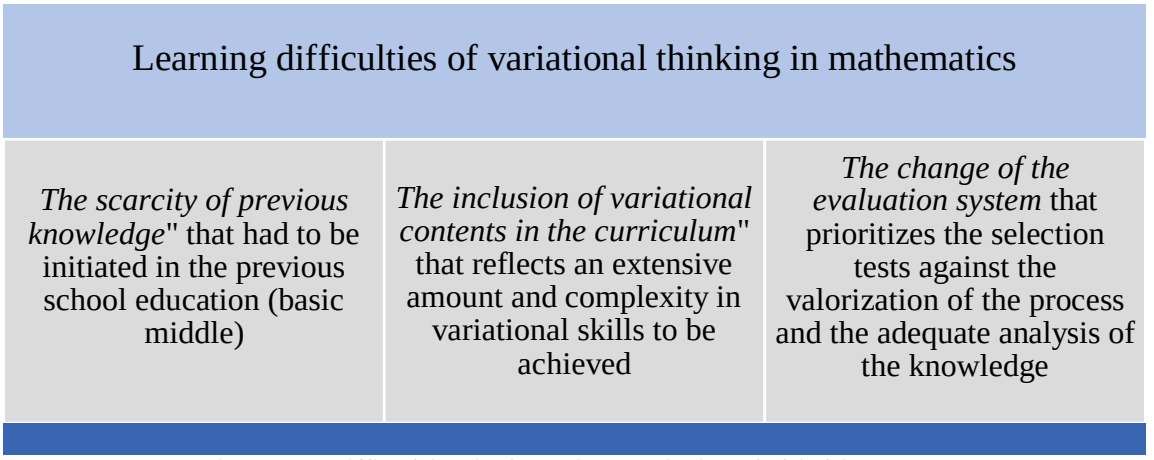

Figure 1. Difficulties in learning variational thinking
Source: (Parada, 2018)

Among other associated difficulties, there are those raised by (Usán & Salavera, 2018), who suggest the need for "*longitudinal models*" and not "*sectional*" teaching that allow to know the periodic progress of the academic performance of mathematics between the sublevels and educational levels (p. 107), (Mello & Hernández, 2019) point out the importance of the assessment and confidence processes that students develop compared to what they learn with their parents and teachers (p. 8), in addition to the difficulty that the subject represents by not implementing "*habits of thought*" as school progresses (Martínez & Gualdrón, 2018, p. 100).

Difficulties in learning variational thinking do not occur in isolation, their impact on poor academic performance is related to the correct application of teaching strategies and methodologies in mathematics and the receptivity of the applied

educational models. In relation to the above, (Ramos, Casas & Torres, 2018), they emphasize that teachers can present: erroneous perception of the complexity of the skills and the cognitive level of the students; inappropriate use and lack of resources in the classroom; and lack of interest in what is taught (p. 556). The motivation for learning is then conditioned to all the difficulties raised and implies the need for changes for good school performance, especially in interpersonal relationships between parents (Corredor & Bailey, 2020).

Academic performance in mathematics

Problem solving in mathematics, which involves variational thinking, is based on a series of algorithms ordered and characteristic of each topic; Some authors comment that the development of variational skills require different domains of creativity and intuition, but that these must be developed from the interpretation of the data, the understanding of the rules to follow and deepening of the solutions in diverse scenarios (Mariño, Hernandez, 2021). Academic reinforcement, then, is interpreted as the route necessary to achieve said exposed skills system, in the face of the educational needs of those who do not understand or are unable to satisfactorily achieve knowledge, expressed in poor performance.

It is possible that the academic performance of the students is significantly improved, thus avoiding substitution processes in the sublevel of study, if the academic reinforcement is applied according to a defined institutional planning, the results of the diagnostic tests and the formative evaluation in each school cycle, including the implementation of virtual learning environments in conjunction with permanent and personalized reinforcements as proposed (Vallejo, 2020, p. 147) and applications within the classroom that enhance the cognitive, creative and participatory development of basic skills, especially adaptive ones against the variational miscompensation (Carrillo, et al, 2020).

The investigation began by delimiting the variational skills considered in the algebra block and functions of the mathematical subject of the curriculum of the compulsory education levels of Ecuador (MINEDUC, 2016, p. 71). The knowledge associated with the Higher sublevel is shown in Figure 2.

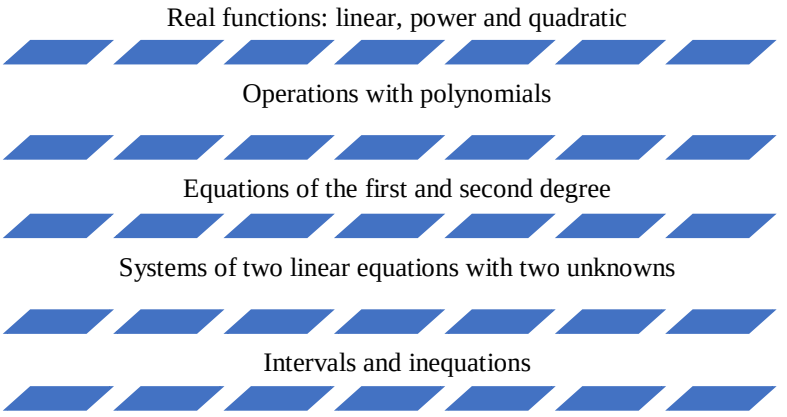

Figure 2. Knowledge associated with the Higher sublevel

With the objective of determining variational thinking in academic performance, the first question was related to situations that cause low academic performance in the previously detailed knowledge, showing the results in table 1.

Table 1. Situations that affect the academic performance of learning variational skills

Alternatives	Frequencies	Percentage (%)
A. Anxiety in the face of misunderstanding.	9	24.3
B. Temporary personal conditions.	4	10.8
C. State of health.	4	10.8
D. Lack of motivation.	11	29.7
E. Family situations.	2	5.5
F. Complexity in knowledge.	3	8.1
G. None of the above.	4	10.8

As can be seen, the students surveyed mainly relate poor academic performance to lack of motivation (29.7%) and anxiety in the face of misunderstanding (24.3%) in learning variational skills. This is related to the institutional processes of reinforcement and pedagogical accompaniment, to improve the academic performance of variational thinking, where it was shown that 50% of teachers carry out daily academic reinforcement of at least half an hour. Regarding the second result, (Villamizar, Araujo & Trujillo, 2020), they point out that emotional responses (anxiety) influence active learning of mathematics, determining that the higher the anxiety, the lower the academic performance.

In the case of the second question, it was related to the development of variational skills regarding mathematical valuation problems (table of values) in real functions of linear and quadratic type, for the values {0, 1, 2, 3}. The results of the development of the functions are shown in table 2.

Table 2. Valuation of real linear and quadratic functions.

Alternatives	Frequencies	Percentage (%)
A. Linear function: f(x) = 4x – 12		
a. Develop correctly.	33	89.2
b. Does not develop correctly.	4	10.8
B. Power function: f(x) = -3x^2 Expand		
a. correctly.	30	81.1
b. Does not develop correctly.	7	18.9
C. Quadratic function: f(x) = 5x^2 – 1		
a. Expand correctly.	31	83.8
b. Does not develop correctly.	6	16.2

As can be seen, most of the students correctly develop the processes of valuation or assignment of natural values to the unknown and elaboration of the table of values in each case. It is evident in the group that, in the valuation of real functions, students in 10.8% of linear functions, in 18.9% of power functions, and in 16.2% of quadratic functions, do not have an analysis and understanding concept, obtaining that the main drawbacks are presented in the 18.9% approach and the 27.0% resolution.

Table 3 lists the result of the development of variational skills regarding operations with polynomials and integer coefficients in situations of addition, subtraction, product, and quotient, given the polynomials A = x^2 – 12x + 20, and B = x – 2

Table 3. Resolution of operations with polynomials.

Alternatives	Frequencies	Percentage (%)
A. Addition of polynomials: A + B		
a. Develop correctly.	35	94.6
b. Does not develop correctly.	2	5.4
B. Subtraction of polynomials: A – B		
a. Expand correctly.	33	89.2
b. Does not develop correctly.	4	10.8

C. Product of polynomials: A x B		
a. Expand correctly.	31	83.8
b. Does not develop correctly.	6	16.2
D. Quotient of polynomials: A / B		
a. Develop correctly.	29	78.4
b. Does not develop correctly.	8	21.6

As you can see, most of the group performs operations with polynomials correctly. It is evident that 5.4% in addition, 10.8% in subtraction, 16.2% in product, and 21.6% in quotient of polynomials, does not correctly perform the resolution algorithms of each specific operation, manifesting the greatest inconveniences in the division or quotient of polynomials.

Table 4 shows the result of the development of variational skills regarding the resolution of first- and second-degree equations, with a variable and integer coefficients.

Table 4. Resolution of first- and second-degree equations.

Alternatives	Frequencies	Percentage (%)
A. First degree equation: 2x – 5 = 4x + 18		
a. Develop correctly.	30	81.1
b. Does not develop correctly.	7	18.9
B. Second degree equation: 10x – 24 = x^2		
a. Develop correctly.	24	64.9
b. Does not develop correctly.	13	35.1

As can be seen, 8 out of 10 students correctly solve a first-degree equation with 81.1%, but only 6 out of 10 students correctly solve a second degree equation with 64.9%. The biggest drawbacks at the time of developing an equation until obtaining the solution were: ordering 23.1% and application of resolution rules 30.8%. Regarding the question, related to the development of variational skills regarding systems of two linear equations with two unknowns, the results are presented in table 5.

Table 5. Solving systems of two linear equations with two unknowns.

Alternatives	Frequencies	Percentage (%)
A. System of two linear equations with two unknowns: 5x + 2y = 12; 7x – 3y = 11		
a. Find two unknowns.	22	59.5

b. Find an unknown.	6	16.2
c. It does not find any unknowns.	9	24.3

As seen in the results, 59.5% of the students were able to solve the system of two linear equations with two unknowns (X; Y) by finding the two variables, 16.2% only found one variable and 24.3% could not find any variable. The most frequent drawbacks when developing the variational skill were establishing the appropriate method of resolution 27.0% and analyzing the answers for verification 16.2%.
As a last approach, related to the development of variational skills regarding linear inequalities, the results are detailed in table 6.

Table 6. Resolution of linear inequalities.

Alternatives	Frequencies	Percentage (%)
A. Linear inequality: $12x + 9 < 7x - 11$		
a. Find the solution interval.	27	73.0
b. Does not find the solution interval.	10	27.0

As shown in the results, 73.0% of students in the group were able to solve the inequality and establish the solution interval. 27.0% of the group could not establish the solution interval, commenting mostly that they could not relate the answer to the number line 46.2%.

In recent decades, various investigations have been carried out on variational thinking in the mathematical subject, this current of research seeks to enhance the competencies related to the acquisition of variational skills and the application of constructivist methodologies focused on the use of ICTs. Its importance is emphasized with the implementation of these in the curriculum, prioritized with an emphasis on communication, mathematics, digital and socio-emotional skills in Ecuador, indicating that the acquisition process occurs throughout life and must respond to situations of daily life.

It was found in the institutional records of the UEP. The Oasis that the general average of academic performance in Mathematics is 8.1 points out of 10 (ten), which consequently reflects the need for a methodological change in the application of teaching strategies - learning and school motivation processes. The structured base test applied to the 37 students of the tenth year of Basic General Education shows that a considerable percentage of the students are not clear about the processes of solving operations with polynomials, equations, inequalities, and systems of equations, affecting academic performance. of the mathematical subject in the block of algebra and functions.

The contextualized and progressive development of variational thinking, as a basis for the adequate learning of knowledge in mathematics, is feasible and can be achieved through methodological and motivational strategies focused on the

student and his integral development, in the possibilities of cooperative learning and mediated by ICTs, and the establishment of permanent accompaniment programs in the school environment.

Conclusions

The results of the research demonstrate the need to review and improve the methodological strategies of teaching - learning of variational thinking and motivation processes against active learning in students, taking into consideration, the previous knowledge existing in the group of students to adequate achievement of variational skills. It was possible to demonstrate that the inadequate acquisition of processes and resolution methods in mathematical exercises, associated with variational thinking, affect academic performance and the need to implement institutional plans for pedagogical reinforcement is observed.

With the application of the structured base test, it was possible to verify the existence of a cognitive level of achievement of a satisfactory type that requires strengthening the acquired variational skills, to achieve full mastery of these, essentially in the resolution of equations and inequations as previous processes. in the learning of functions, the use of formulas and differential and integral calculus in the subjects of Mathematics, Physics and Chemistry in high school, considering that the tenth year is the school grade in which it is planned to achieve the essential skills established at the beginning of the upper basic sublevel.

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