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Critical thinking and learning of mathematics in incoming college students

Pensamiento crítico y el aprendizaje de la matemática en estudiantes ingresantes a la universidad

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Abstract

The 21st century requires people to make good decisions based on thoughtful and reasoned thinking. It is the task of the university teacher to provide the necessary conditions to develop critical thinking by using strategies that place the student as the basis of teaching work. The objective of the research was to determine the relationship between the level of critical thinking and the level of learning of mathematics of students entering university. The research is based on the quantitative correlational scope approach with transectional, correlational design. The sample was 115 students belonging to two universities, one private and the other public, located in Lima, Peru. For data collection, two tests were administered: one to assess the level of critical thinking, and the other to assess the level of learning in mathematics. The results show that critical thinking and learning of mathematics are significantly correlated. Likewise, each dimension of mathematics learning is significantly correlated with critical thinking. It is concluded that critical thinking favors the learning of mathematics in students entering university. This research serves as an indicator for mathematics teachers to use teaching strategies that develop critical thinking at the university level to obtain better results in learning mathematics.

Keywords: Critical thinking; math; real variable functions; significant learning.

Resumen

El siglo XXI requiere de personas que tomen buenas decisiones en base a un pensamiento reflexivo y razonado. Es tarea del docente universitario brindar las condiciones necesarias para desarrollar el pensamiento crítico y utilizar estrategias que sitúen al estudiante como centro de la labor de enseñanza. El objetivo de la investigación fue determinar qué relación existe entre el nivel de pensamiento crítico y el nivel de aprendizaje de la matemática en estudiantes ingresantes a la universidad. La investigación se basa en el enfoque cuantitativo de alcance correlacional y diseño transeccional-correlacional. La muestra fue de 115 estudiantes pertenecientes a dos universidades, una privada y otra pública situadas en Lima, Perú. Para la recolección de datos se administraron dos test: uno para evaluar el nivel de pensamiento crítico, otro para evaluar el nivel de aprendizaje de la matemática. Los resultados evidencian que el pensamiento crítico y aprendizaje de la matemática se correlacionan significativamente. Así mismo, cada dimensión del aprendizaje de la matemática se correlaciona significativamente con el pensamiento crítico. Se concluyó que el pensamiento crítico favorece el aprendizaje de la matemática en estudiantes ingresantes a la universidad. Esta investigación sirve como indicador para que los docentes de matemática en el nivel universitario utilicen estrategias de enseñanza que desarrollen el pensamiento crítico para obtener mejores resultados en el aprendizaje de la matemática.

Palabras clave: Aprendizaje significativo; funciones de variable real; matemática; pensamiento crítico.

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I. Introduction.

Thought is inherent in the person, but sometimes, it could be said, many times: “much of our thinking can be arbitrary, distorted, biased, misinformed or prejudiced, affecting our quality of life” (Elder & Paul, 2003, p.4). It is common to see people who make decisions or support their positions based on beliefs, sayings, judgments, phrases and others who do not have theoretical support. In educational institutions, basic education, or higher level, the task of developing high-quality reflective thinking must be accomplished.

The person's thinking can affect learning ability, speed, and effectiveness. Consequently, thinking ability is associated with the learning process. Students who are trained to think demonstrate the positive impact on the development of their education (Yee et al., 2011). Critical thinking and creative thinking are indicators of higher order thinking skills (Tanujaya, 2014), which are fundamental in the educational process. Critical thinking is considered "a liberating force in education and a powerful resource in the personal and civic life of each one" (Facione, 2007, p.21).

From the above, it is inferred that critical thinking favors learning, but what will be the impact of the level of critical thinking on learning mathematics at the university level? When students enter university they face mathematical problems framed in a context of their specialty in which interpretation, analysis and argumentation are prioritized. This is new for them, because in the school stage, the learning of mathematics, for the most part, was focused on the calculation and resolution of problems based on arithmetic or algebraic algorithms, many times outside of a real context. Currently, there is a need to improve mathematics learning at both the school and university levels. The different evaluations of Peruvian students in this area show us that learning is not as expected.

According to the Peruvian Ministry of Education (Minedu, 2016), the National Student Census Assessment (ECE) shows that 25.2 % of students in the fourth grade are at the satisfactory level, 41.6 % in process and 33.2 % at start or before start. Whereas only 11.5% of second-year high school students are at the satisfactory level, 16.9% at the process level and 71.6% at the beginning and pre-initiation level. Also, the Program for International Student Assessment (PISA) for 15-year-old students (Minedu, 2017) shows that, of the six levels of performance in mathematics, level 6 being the highest performing, 66.1% of Peruvian students are located at level 1 and below 1, which means that the majority of students “are able to identify information and carry out routine procedures by following direct instructions in explicit situations. They carry out obvious actions that are immediately deduced from the stimuli presented” (Minedu, 2017, p. 79). According to these results, Peruvian students do not achieve the expected learning in the school stage and this low performance continues to the higher level.

For all of the above, the question arises: is there a significant relationship between critical thinking and learning mathematics in students entering university?

Some of the antecedents that precede this research are: Tanujaya et al. (2017) who carried out a correlational investigation whose design was non-experimental. The research findings indicate that there is a significant relationship between higher-level thinking skills and student academic performance in teaching mathematics at the University of Papua, Indonesia. Likewise, Belecina & Ocampo (2018) carried out an experimental investigation whose objective was to analyze the effects of problem situations to develop critical thinking in solving problems. Graduate students

enrolled in a statistics course participated in the study. Conclusions show that problem situations promote efficient critical thinking in problem solving. Furthermore, they develop students' capacity for reflection and metacognition, especially in problem analysis. In the Peruvian context, Mendoza (2015) investigated the level of critical thinking in students from two universities in Chiclayo, the conclusions indicate that in the university where it is taught under the methodology aimed at the development of research work, students obtain a higher development of Critical Thinking, in addition to increasing it progressively. Macedo (2018) conducted a study with incoming students at the University of Engineering (UNI), after evaluating the five dimensions of critical thinking: inference, recognition of assumptions, deduction, interpretation and evaluation of arguments, found that 60.5 % of students is at a medium-high level of critical thinking. But, only the relationship between performance and argument evaluation dimension was demonstrated

Critical thinking.

It has a long history in philosophy, psychology and the social sciences and is currently a central theme in education and pedagogy (Tamayo et al., 2015). Etymologically, it refers to the ability to think (Roca, 2013). In ancient Greece, Socrates proved that society and its contemporaries had little chance of justifying their claims on the basis of knowledge, rather they did so on the basis of beliefs, confusing definitions or insufficient evidence (Campos, 2007; Mesones, 2016).

Critical thinking is the ability to actively examine, analyze, and evaluate the thinking process in order to improve it. The latter involves the development of metacognitive skills (Villarini, 2003; Elder and Paul, 2005; Roca, 2013; Morales, 2014). It has also been considered as reasoned and reflective thinking when deciding what to do or believe and involves skills such as: decision making and problem solving (Saiz & Rivas, 2012; Ennis, 2005). For Facione (2007) critical thinking aims to solve a problem, for this two components are necessary: cognitive and dispositional (attitudinal). He points out that there are six cognitive skills of critical thinking: interpretation, analysis, evaluation, inference, explanation and self-regulation. Likewise, he points out that a critical thinker is: systematic, analytical, inquisitive, open-minded, judicious, truth-seeking and trusting in reasoning.

For their part, Watson & Glaser (1980) point out that critical thinking is made up of three components: attitudes, knowledge and skills. Being the attitude the capacity to recognize problems and need of proof in support of what is affirmed as true. Knowledge of concepts, generalizations, abstractions and inferences to know the evidence logically. Ability, understood as the ability to make use of the attitudes and knowledge mentioned in the previous two points. In addition, they evaluated critical thinking through five dimensions: 1) Inference, is the conclusion obtained from observed or assumed facts, after discriminating the validity of immediate inferences, 2) the recognition of implicit assumptions or statements in the information provided , 3) the deduction of conclusions from given premises, 4) interpretation of the data to establish whether the proposed generalizations are obtained from the data provided, 5) evaluation of "strong" or "weak" arguments based on their relevance to a matter under discussion. According to what has been exposed, critical thinking is understood as reflective and reasoned reasoning that leads us to make decisions in order to solve problems efficiently. Furthermore, it has a positive impact on learning

Learning of mathematics.

Human beings learn mathematics when they are able to use the language and concepts of mathematics to solve problems (Godino et al., 2003). In order for students to understand mathematical objects in a meaningful way, they must be related to problems in which their need is

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evident. The learning of mathematics becomes meaningful when it is used to understand reality, in addition to being linked to everyday family, cultural and social activities (Minedu, 2015).

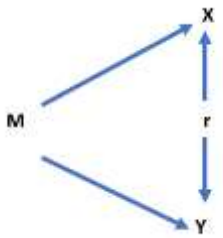
Godino et al. (2003) distinguish the dual function of language used by mathematics. This is representational, because it allows us to symbolize abstract objects that we cannot perceive with our senses; and instrumental, as a tool to do mathematical work. The instrumental value can be very different depending on whether they are words, symbols, or graphics. Consequently, it is necessary to know the different representation systems for the same mathematical object.

In view of what was previously described, the objective of this study was to determine the type of relationship between critical thinking and learning mathematics in students entering two universities in Lima.

II. Method.

Enfoque y diseño

The research was conducted in a quantitative, substantive, correlational approach, because the purpose is to observe how the variables in the sample are related. This relationship shows associations but not causality (Hernandez et al. 2014; Bernal, 2016). Composed by the correlational transectional design, because the data is collected at a given moment to then describe the variables and analyze the correlation. The research design scheme is as follows:



Where:

M: Research simple.

X: Variable Critical Thinking.

Y: Variable Learning of Mathematics.

r: Correlation.

Sample

The research was carried out with a sample of 115 students of which one part belongs to a private university and the other to a public university in Metropolitan Lima, all enrolled in the first semester of 2019. For the sample selection, the non-probabilistic technique was used, the selection criteria was the accessibility of the subjects to be investigated. When requesting authorization for the application of the instruments, only three groups of students were allowed access at each

university. Initially, the total number of participants was 180, but they withdrew to 65 because they did not complete all the questions on the test.

Table 1.

Synthesis of the characteristics of the simple

University type	M (years)	Women (%)	Mens (%)	University Careers
Public (*n*=52)	18.6	55.6	44.6	Accounting, Administration and International Business.
Private (*n*= 63)	17.7	44.3	55.7	Humanities, legal and social sciences.

Source: Research database.

Instruments.

Critical Thinking Test

To collect data on the critical thinking variable, the survey technique was used. The instrument was the Chalupa test (2006). The test has 66 items, grouped into five dimensions. The first 16 questions of the test, of the first dimension, have four alternatives; the remaining questions have only two alternatives (Table 2).

The applied test already registered a reliability with the Cronchach Alpha of 0.82 (Ossa-Cornejo et al., 2017). Tiny changes were made in the text to adapt it to the Peruvian context, for which the reliability of the test was verified again. For this, it was applied to a pilot sample of 25 students, then the internal consistency technique was used, with which a Cronbach's Alpha index of 0.63 was obtained. This confirmed the reliability of the first instrument.

Table 2.

Dimensions and evaluation of the critical thinking variable

Dimensions	Indicators	Ítems	Valuation by dimension
Inference	Evaluate, deduce and conclude correctly	1-16	Deficient: 0- 5 Low: 6-11 High: 12-16
Assumptions Recognition	Distinguish and recognize correctly	17-29	Deficient: 0- 4 Low: 5-9 High: 10-13
Deduction	Relate and determine correctly	30-42	Deficient: 0- 4 Low: 5-9 High: 10-13
Interpretation	Values, discriminates and judges correctly	43-54	Deficient: 0- 4 Low: 5-9 High: 10-13

Argument Evaluation	Differentiate and classify correctly	55-66	Deficient: 0- 4 Low: 5- 8 High: 9 - 12

Source: Research database.

Math Learning Test

To measure the learning of the mathematics course, an ad hoc test was developed, considering the common themes of the syllables of the mathematics courses of both universities. The topics that were evaluated were: equations, inequalities and functions. The first five cognitive processes of Bloom's taxonomy, reviewed by Anderson and Krathwohl (2001), and the different registers of representation of the mathematical objects mentioned in Duval (2004), such as: figural, algebraic and graphic, were taken into account. In accordance with these elements, the following scheme was followed.

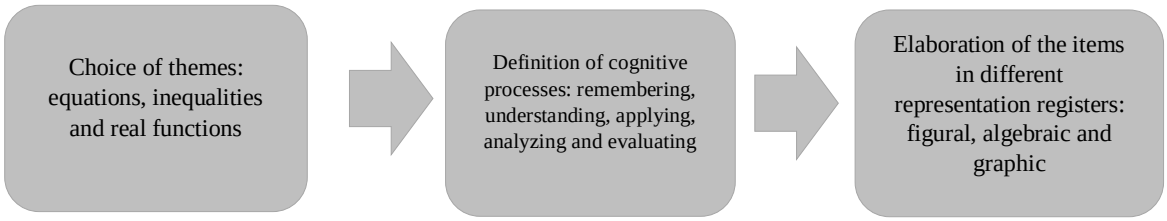


Figure 1. Steps in preparing the math learning test.

The learning test of the mathematics course consists of 16 items with four options each, of which only one was correct. Table 3 shows the dimensions and scales of the variable learning of mathematics.

Table 3.

Dimension and evaluation of the variable learning of mathematics

Dimensions	Contenidos	Ítems	Valoración por cada dimensión	Valoración de la variable
Equations	First degree algebraic equation	1-2	Deficient: 0- 1,6 Low :1,7-3,3 High : 3,4-5	Deficient:0- 5 Low :6-11 High :12-16
	Quadratic equation	3-5		
Inequations	Intervals	6	Deficient: 0- 1,6 Low : 1,7-3,3 High : 3,4-5	
	Quadratic inequality	7-9		
	Linear inequality	10		

Functions	Graph of functions Numerical value Lineal funtion Domain of a function Quadratic function	11-12 13 14 15 16	Deficient: 0- 2 Low : 3-4 High : 5-6

Source: Research database.

To establish the validity, the instrument was submitted to the judgment of experts, who gave their evaluations according to the following criteria: intentionality, sufficiency, consistency and coherence. Of the 4 experts, two suggested making changes to the wording of some items. After making the changes, the expert judges assigned a rate of 75 %, that is, the instrument was considered appropriate. Therefore, it can be affirmed that the items of the instrument are valid.

Regarding the reliability of the test, the test was applied to a pilot sample of 25 students. After statistical analysis, a Cronbach's Alpha index of 0.63 was obtained. With both results it can be affirmed that the instrument has validity and reliability.

Procedure.

After obtaining permission to apply the instruments, he coordinated with the teachers of the mathematics courses at both universities. The critical thinking test was administered on the first day of school, during the last 45 minutes of the first class session. At the private university classes started a week earlier than at the public university. Before administering the *test*, the intention of the research, voluntary participation and anonymity of the information collected were explained to the students.

The mathematics learning test was applied after ten weeks of starting classes at both universities. One day and one hour was coordinated with the teachers of each university in their class sessions. The instrument was administered for thirty minutes in one session.

The statistical software SPSS 23 was used for data analysis. It started with descriptive statistics for the variables critical thinking and learning of mathematics. Bar graphs were constructed and a brief description was given for a better understanding of the results. Inferential analysis was also performed, for which the Spearman non-parametric correlation test was chosen, appropriate to determine the relationship between the quantitative data of two variables.

III. Results.

Descriptive results

Regarding the levels of critical thinking, Figure 2 shows that the highest percentage of students, from both universities, has a low level of critical thinking. It is also evident that students entering public universities have a higher level of critical thinking compared to those entering private universities, due to the fact that they do not present students at the deficient level and 100% are located at the low and good levels.

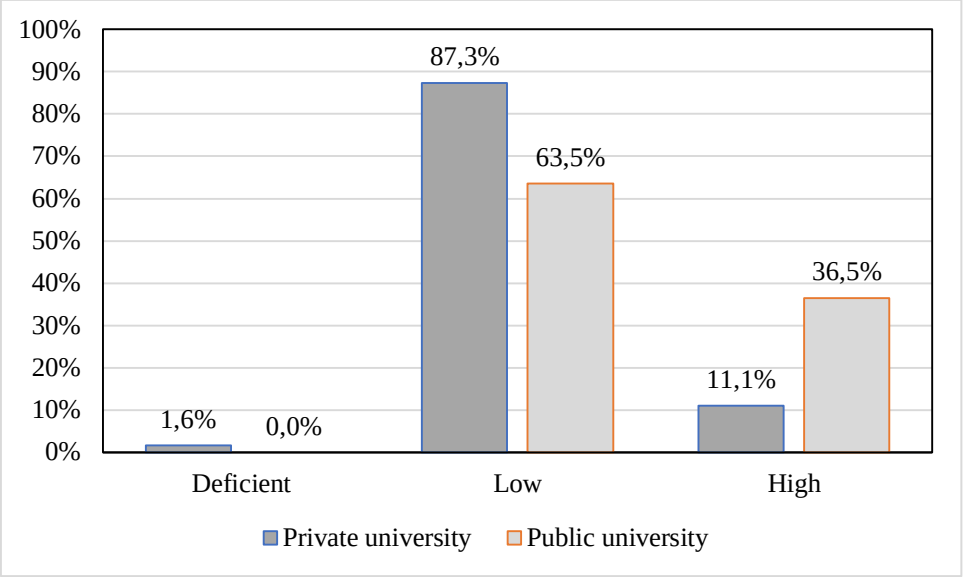


Figure 2. Level of Critical Thinking.

Figure 3 shows the results of the second variable, learning mathematics. It is evident that the highest percentage of students has a low level of learning. It can also be observed that both the students of the public university and the private university are located in the low and regular levels, with an accumulated percentage of 82.7 % and 87.3 % respectively.

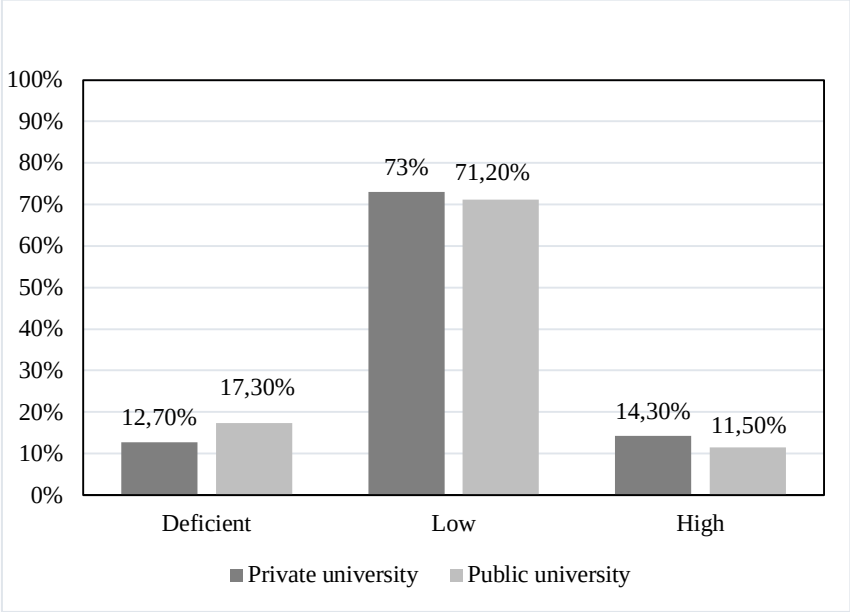


Figure 3. Level of learning of mathematics.

Table 4 reveals the level of learning achieved by students from both universities in: equations, inequalities and functions of real variables. The table reflects that the highest percentage of students is at the low level. On average, only 22% of students have a good level of learning.

Table 4.

Learning levels in equations, inequalities and functions

Levels	Equations		Inequalities		Functions	
	Private	Public	Private	Public	Private	Public
Deficient	20.6 %	23.1 %	25.4 %	32.7 %	19.0 %	28.8 %
Low	47.6 %	57.7 %	65.1 %	40.4 %	46.0 %	59.6 %
High	31.7 %	19.2 %	8.5 %	26.9 %	34.9 %	11.5 %

Source: Research database.

Inferential results

Table 5 shows that the correlation value between the variable: critical thinking and the variable: learning mathematics is equivalent to Spearman's rho coefficient of 0.263, significant at the p-value of 0.05. This result indicates that there is a significant relationship between the variables.

Table 5.

Spearman's rank correlation for the relationship between critical thinking and mathematics learning

Variables	Critical thinking	
Learning the math	Rho	0.263*
	Sig.	0.004

Source: Research database.

Table 6 shows that there is a significant correlation between critical thinking and each of the dimensions of mathematics learning. It is evident that there is a greater correlation with the learning dimension of equations and a lower correlation with learning functions. This is because the correlations obtained are positive, it can be inferred that critical thinking favors learning the mathematics course of the first semester of study at the university.

Table 6.

Spearman's rank correlation for the relationship between critical thinking and the dimensions of mathematics learning

Dimensions of learning mathematics	Critical thinking	
Equation learning	Rho	0.207
	Sig.	0.027

Learning of inequalities	Rho	0.217
	Sig.	0.020
Learning of algebraic functions	Rho	0.113
	Sig.	0.035

Source: Research database.

IV. Discusión.

The results of the descriptive statistics show that the students entering the university, both private and public, have a low level of critical thinking (75.4 %) in the five dimensions analyzed: Inference, recognition of assumptions, deduction, interpretation and evaluation of arguments, although a slight advantage of the students entering the national university is evident over the students of the private university. This difference can be explained by the years of additional preparation, after the school stage, that students must follow to take a rigorous public university entrance examination. Which is the opposite in the private university. This result confirms what was found by Macedo (2018) who concluded that university students enrolled in a statistics course present a level far from the optimal level of critical thinking.

Descriptive statistics also indicate that the learning level of the evaluated students is mostly at the low level, more than 70 % is at this level. There were no differences in the level of learning between students belonging to the private and public universities. From the data obtained by the Sperman correlation, it can be established that the level of critical thinking is significantly related to the learning of mathematics and also to its three dimensions: equations, inequalities and functions of real variables. In other words, a student who has a higher level of critical thinking will achieve better learning in this area. This result is similar with Tanujaya et al. (2017) who concluded that there is a significant relationship between higher-level thinking skills such as: critical and reflective thinking, and performance in a mathematics course. For this reason, active teaching strategies such as the ABP, case studies, project-based learning, research projects among others should be used, which help develop the level of reflection and reasoning as mentioned by Roca (2013) and Mendoza (2015). Problem situations in problem solving also promote better critical thinking, as pointed out by Belecina & Ocampo (2018).

V. Conclusions.

There is a significant correlation between the level of critical thinking and the learning of the mathematics course in students entering a private and public university. In other words, the best level of critical thinking favors the learning of mathematics for students entering the university.

There is a positive relationship between critical thinking and the dimensions of learning mathematics, registering a greater relationship with learning equations. Based on the results, it is necessary to implement strategies that develop critical thinking in university students because it will improve the learning of mathematics and probably in other subjects.

The research results can be replicated in other science courses, such as statistics, chemistry, physics, and their relationship to critical thinking. In addition, the relationship between variables in students enrolled in higher cycles could be evaluated. It is recommended to carry out the research with a greater number of students, in this study only three groups of students were accessed.

Accessing the largest number of students was a limitation in applying the measuring instruments to more students. Three sections out of a total of approximately 50 sections were accessed at each University, which prevented the study sample from expanding in size. Another limitation was the time assigned for the application of the instruments, for this reason several students left questions blank and were withdrawn from the initial sample, which comprised a greater number of students.

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