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Development of Critical Thinking in the Construction of Conclusions in Academic Work

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Abstract—This paper presents an intervention carried out with students in the last grade of a bachelor's degree program in education, in whom Critical Thinking limitations were identified when drawing up the conclusions of their degree work. The objective of this intervention was to evaluate the effectiveness of a program to strengthen the critical thinking of these students. This program was integrated with two strategies: the permanent analysis of cognitive fallacies, in addition to a table to guide the analysis of arguments. This intervention was applied to a group of students, whose results were compared with a control group, validated by a homoscedasticity test. To analyze the data on the potential efficacy of the program, a quantitative method with a quasi-experimental design was followed, using Wilcoxon tests to compare the internal measurements of each group, and subsequently, the Mann Whitney U test was administered to compare the results of the experimental group, versus the results of the control group. At the end of the data analysis, a significant difference was found in favor of the experimental group, with a medium effect size, establishing the hypothetical efficacy of the intervention.

Index Terms— Critical Thinking, Cognitive Fallacies, Quadruple Table of Life, Non-parametric Tests.

I. INTRODUCTION

In a higher education institution, it was identified that students in the last professional degree of the bachelor's degree in primary education had difficulties in constructing relevant conclusions in their degree work; for example, there were statements with characteristics typical of a Result, instead of being conclusive constructions, derived from the analysis of the information accumulated in documentary and field work: broad statements about the value of education in general were also identified, which while declaring a welcome enthusiasm for the profession, were not directly related to the degree work. On the other hand, assertions were also found that were related to the topic of study addressed, but that did not find supporting data in the content of the work, so their validity was reduced to logical inferences that, to be postulated, could dispense with the preparation of the degree work. Finally, the repetition of ideas differentiated only by paraphrase also occurred.

These situations were studied systematically in the institution since 2015 [1], [2], and persisted until the 2019 - 2022 school year, so it was considered that they converged into a problem rooted in the training of students, referring to its Critical Thinking.

Critical Thinking can be defined as that form of cognitive processing that allows - among other functions - to analyze one's own thinking (metacognition) and be based on reason to reduce emotional biases as much as possible, and with this, “be sure not to jump to conclusions without sufficient foundation” [3].

Thinking critically involves reflecting on and rationalizing information, evaluating it considering the evidence, and, in its absence, based on available objective experience.

All these encompasses specific cognitive skills, such as interpreting, analyzing, comparing, or inferring, but it also requires dispositions or attitudes that enable its sustainment, given that it is a complex process. Among the attitudes that facilitate the development of Critical Thinking are a commitment to truth, confidence in reasoning, open-mindedness, maturity of judgment, and resilience to face of frustration, among others specific skills [4].

The foundation of Critical Thinking lies in arguments; however, a critical thinker can construct these arguments by performing mental operations that are developed through the experience of facing various types of situations.

However, a critical thinker can construct these arguments by performing mental operations that develop through the experience of facing various types of situations. Therefore, the development of this type of thinking is not about accumulating strategies or principles that are memorized and then applied to a critical exercise, but rather about generating the skills to create reasoning that specifically addresses each problematic situation. This does not exclude the possibility of generating or adopting general principles of thought, but their application will be a unique combination for each situation.

The spectrum of situations were critical thinking can be used includes, at least: seemingly simple or logical situations, which must be reviewed to ensure they align with sensory experience or the apparently consensual reality; complex situations where two or more rational or logical positions exist independently but cannot logically coexist and even "strange" situations that occur in the tangible or sensory reality, challenging, at least initially, some logical, theoretical, or even scientific principle [5].

As can be seen, Critical Thinking is a highly complex cognitive skill that requires strategic and sustained effort to develop.

Therefore, its development does not occur simply with the passage of time, that is, through chronological maturation, nor through prolonged exposure to situations where arguments are learned but not constructed, as can happen in school environments where students spend long hours reading reasoning that they have not constructed themselves, but rather are contained in weighty texts they encounter at a literal level due to their teachers' assignments.

While it is not a mechanical process that benefits from mere repetition, it is important to continually practice this type of thinking to deepen its analytical capacity and to expand its repertoire of responses to the countless situations in which it may be tested.

This problem became relevant for the institution, considering that the development of Critical Thinking is a training expectation of primary importance in the career profile: for example, in the Pedagogical Approach of the official curriculum, it is explicitly declared that all content of the curricular mesh constitutes a means for the gradual formation of the critical (and reflective) thinking of the students, and this is ratified in all the subject programs. Likewise, it is expected that this thinking will be developed as a Generic Competence that allows the student and future teacher to solve problems and make professional decisions [6].

Specifically, authors such as Huang and Sang [7] have studied the importance of Critical Thinking in students preparing to become teachers. These researchers have conducted systematic analyses of research reports addressing this topic and have concluded that a significant proportion of the studies reveal a limited and unsystematic treatment of Critical Thinking. Even though there is a clear awareness that this cognitive skill is crucial for the quality of thinking, and it is recognized that it is the responsibility of teachers to promote it in their students, it is not strategically practiced and is instead encouraged through common sense to tackle academic tasks that later cannot be transferred to professional situations.

Furthermore, Critical Thinking is constituted as a fundamental tool for the intellectual development of the individual, which is a desirable achievement, but in addition, it is a tool to substantially raise the quality of learning in the school environment, in the work environment and daily life [8], [9], [10].

On the other hand, the Conclusions of an academic work represent the concretion of the learning and achievements when addressing the problem of interest: they are interpretive syntheses that must configure a coherent and integrated whole that clarifies doubts, resolves practical problems, or stimulates the desire for delve into the topic [11] therefore, they are a fundamental part that determines and demonstrates the quality and impact of a research process or an applied project.

An academic conclusion is a reflective assertion fully supported by the systematic analysis of the available valid theoretical framework or the empirical findings from systematically conducted fieldwork to address an objective and well-defined topic. It can be said that the comparison between the theoretical reference framework and the results obtained in a content analysis, or an intervention creates a discussion from which the author can objectively derive a proposition strictly related to the work’s objective; when questioned on its foundation, this proposition should be able to find documented support in the work conducted.

This represents a learning event that allows the student to translate their mental productions into a concrete and communicable language, primarily to verify the value of its content and its communicative effectiveness

Thus, crafting a conclusion is not a mechanical procedure either. Fundamentally, the person constructing conclusions must understand that a conclusion is different from a result, and that the two broader goals of this exercise are to convince the reader that these ideas have a robust foundation in the presented work, and that these conclusions have fully addressed the intentions of the same work, as stated in the objective outlined in the introduction [12].

However, in practice, most higher education students confuse the two, and in their academic work, different sections often contain the same content, leading to a repetitive, confusing, and diminished reading experience [1].

As mentioned, a conclusion must be clearly distinguished from a results report: while a result is a statement that simply reports or describes what was found by analyzing data collected through a predetermined method, a conclusion allows for the author's personal but reflective intervention. In the conclusion, the author generates an assertion that results from critically analyzing the available theory, the specific conditions of the context in which the work was conducted, and the descriptive results obtained; based on this contrast, the author can make an objective and well-founded personal assertion: this idea will be original and unique in its content and morphological construction.

In close relation to the above, another challenge faced when constructing academic conclusions is to limit oneself to the theoretical information and fieldwork data contained within the completed project, using them as inputs to derive conclusive ideas. In practice, students often exceed this limitation, and they tend to develop general conclusions related to their topic, which they generate in the very moment when finalizing the report, invoking all the irrefutable ideas or principles they have learned from their sources or instructors, hoping to enrich the content and the professional image of their work.

Another severe complication in drafting appropriate conclusions is avoiding unsupported transitions from the results to statements or assertions. This may be the most complicated difficulty to face in this topic.

It is in this case that errors or weaknesses in critical thinking can occur, allowing for hasty leaps to assertions based on data without sufficient support or, worse, without a clear connection to what is being claimed [13].

This is why critical thinking must be approached through concrete, methodical, and mindful actions within the everyday intellectual work that is supposed to be developed in the classroom. This approach is necessary to overcome its complex challenges and to ensure that its development offers a substantial improvement in students' academic, personal, and professional performance.

In addition to demonstrating the student's intellectual or professional abilities, another primary purpose of crafting conclusions in an academic paper at the higher education level is to communicate the significant results and ideas that the author developed while conducting their task or learning project.

This allows readers who are interested in the same topic to have a reference point for guiding their own work or continuing the research that has already been done.

Reflecting on the relevance of this situation, the objective was proposed to evaluate the effectiveness of a program to strengthen the critical thinking in the constructions of conclusions in academic work of a group of students studying for a degree in primary education.

II. PROCEDURE

To address this objective, a quantitative design was planned. A quasi-experiment was proposed with an intervention or experimental group, and a control group; Each group was made up of 32 students from the last degree, who were carrying out their degree work, either in the form of a research thesis, or as an applied project, through their professional practices in primary education classrooms, in the that they had to address a learning problem of their students, to try to have a positive impact on it.

In a synthetic form, the entire process followed can be represented as follows:

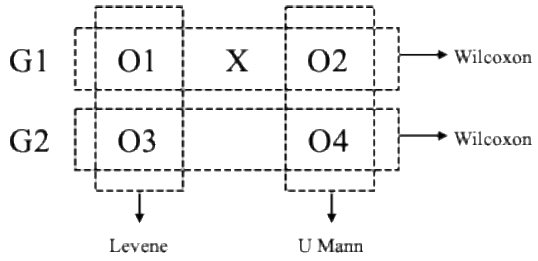

Fig. 1. Outline of the methodological process carried out

The conclusions of their degree work were evaluated for each student in two moments: first, when performing their pretest or diagnosis, and subsequently, when concluding their didactic intervention and recording the final data of their didactic intervention. In both cases, the following estimation scale was used, based on the criteria of Pimienta, De la Orden, and Estrada [14].

Table I. *Guide to qualify the relevance of conclusions in academic works*

Attributes of an academic conclusion
Clarity: the proposition or statement is understood with no difficulty.
Internal consistency: it is directly related to the objective of the work.
Synthesis: constitutes an integrative interpretation of the theoretical information and the results obtained.
Support: find data in the report that supports the claim.
Moderation: decisive or forceful causal statements are avoided.

These indicators were validated through theoretical review by seven academic peers in teachers' colleges, and the stability of their results collected over time for three consecutive semesters was reviewed using a correlation test [15] finding adequate satisfactory metric values (r = .76).

The relevance of the comparison of the two groups was corroborated by the Levene Homoscedasticity test, which found a significance of .06, which corroborated the Null Hypothesis ($p > 0.05 = H0$), which suggests the equality of the groups of scores.

Levene's test is a statistical procedure that is used to test the equality of variances (homoscedasticity) for a variable calculated for two or more groups; this is crucial to decide to compare two o more groups, because ignoring this can lead to measurement errors and to errors in the conclusions derived from those measurements.

Having verified that the two groups designated as the control group and the experimental group had approximately equivalent conditions regarding their initial state of critical thinking, the preparation and implementation of the experiment or intervention proceeded.

The intervention program that was administered to the experimental group consisted of two strategies implemented simultaneously throughout the documentary and field work that was carried out by the students.

On the one hand, each conclusive idea developed by the students was questioned, reviewing in small groups whether it avoided presenting any of the main cognitive fallacies of thought: in each case, the ideas were disaggregated into the proposition and its argument, in order to carry out this contrast, and if any logical or rational failure was identified, an attempt was made to correct or discard the idea, based on its foundation.

The reference source for this content was the work of Rodríguez and Gallardo [16].which, in addition to extensive information and examples on this topic, offers exercises to conduct the review of fallacies.

In general, it can be said that a fallacy of thinking refers to an error in reasoning that undermines the logical validity of an argument, proposition, or in the case of this work, a conclusion.

These fallacies can occur in several forms: from principles that are misunderstood or misapplied, deviations in logic, to manipulative rhetorical strategies. Fallacies often seem eloquent on the surface but fail to stand up to rigorous logical scrutiny and when they are confronted with facts of reality. They can lead to incorrect conclusions or mislead others in a debate or discussion.

Fallacies are generally categorized into two main types:

a) Formal Fallacies: these events occur when there is a defect in the structure of the argument itself. The logical form that is proposed is invalid, meaning that even if the premises are true, the conclusion derivates wrongly.

b) Informal Fallacies: these are errors in reasoning because of the content of the argument, rather than its structure. These fallacies often involve misinterpretations, irrelevant use of data or even language errors.

Understanding and identifying fallacies of thinking is crucial in academic discourse, as it allows individuals to engage in critical analysis, avoid deceptive reasoning, and construct sound arguments.

The following table shows the main cases that were reviewed in the work that is presented here, in addition to their explanation, and an example applied in the primary education teacher career.

Table II. *Fallacies reviewed in intervention*

Fallacie	Explanation and example
Composition	Attribute to a set the characteristics of one of its members. E. g.: “Elementary students are disrespectful (since students in one group showed this behavior”).
Division	Attribute to an element the characteristics of a membership set. E. g.: “That child must be conflictive, since his two older brothers have been”.

Table II. *Fallacies reviewed in intervention (Continue)*

Fallacie	Explanation and example
Ad Hominem	Transfer a characteristic of a person to other areas of their personality. E. g.: “He is a very unpunctual student; He must be a bad student".
Ad Verecundiam	Accepting someone's ideas because of their recognition or social acceptability. E. g.: “That thesis topic is irrelevant, because Dr. X said he was not interested”.
Appeal to ignorance	Dismiss or approve a conclusion, given that there is a lack of evidence for or against it, respectively. E. g.: “I will implement this idea in my classroom, since there is no evidence that it is counterproductive”.
Begging the question	Repeat a conclusion as an argument. E. g.: “The intervention was successful: all its activities were appropriate”.

Likewise, a table was used to analyze ideas or hypotheses, proposed by Lilienfeld, Lynn, Ruscio and Beyerstein [17] to organize arguments and opposite arguments that help reverse the effect of Naive Realism, that is, the assumption that what can be observed with the naked eye is reliable evidence of reality, and of Selective Perception, which inclines us to Let us look more closely at what could corroborate our own ideas.

This table, called by its authors as “The great quadruple table of life”, guides the review of ideas or information collected, through the analysis of the possibilities involved in them, to avoid, as mentioned, concentration on those data. that are favorable or that are directly related to the approval of the proposed hypotheses (or to the refutation of the null hypotheses). The table is reproduced below:

Table III: *Great quadruple table of life*

	Data in favor of the hypothesis	Data contrary to the hypothesis
Event that confirms an idea or hypothesis	A	B
Event that refutes the idea or hypothesis	C	D

For example, if a teacher found that, after carrying out any dynamic, his students showed an improvement in a desirable skill, one might be tempted to infer that his dynamic was responsible for said improvement, given that it preceded it: this seems to be a clear common-sense inference, but critical thinking requires a broader analysis, before jumping to the seemingly logical and obvious conclusion.

As can be seen, the intention of the table is to avoid overlooking possible alternative explanations or those different from those identified by a particular line of reasoning. It thus aids in the search and review of other possibilities that could explain an event, allowing for appropriate considerations to be made. Therefore, it is not a vicious attack on ideas, but rather a critical exercise that brings caution and prudence to the assertions

Thus, the analysis could be carried out with the following substitution of information in the quadruple table:

Table IV. *Example of using the Quadruple Table of Life, (Op cit.)*

	Implementation of dynamic X	Implementation of a different dynamic to X (Y)
Skill improved	A	B
Skill did not improve	C	D

With this guide, the student must analyze each proposition raised by the conjunction of cells corresponding to each letter: for example, cell A involves analyzing the conditions of the case, or the cases in which "The skill improved with the Implementation of the dynamics X", which constitutes evidence in favor of the hypothesis or work proposal; Subsequently, it is necessary to review the conjunction raised in cell B, and recognize if there are cases in which "The ability improved, with a dynamic different from the improvement attributed to dynamic X, since dynamic Y could also be related to an improvement in skill.

Likewise, conjunction C must be reviewed, which raises cases in which "The skill did not improve, even with the Implementation of dynamic D implies reviewing whether cases are found in which "The skill did not improve with the Implementation of dynamic Y", which could pose a conflict in the arguments, if cases referring to column B had also been found, where dynamic Y would have been related to an improvement.

The purpose of this exercise, then, is to increase the rigor of the analysis of the ideas or conclusions emanating from preliminary results, to avoid incurring the commonsense fallacy called Post hoc ergo propter hoc, that is, if an event that occurred after; on the other hand, it must be the result of that immediate previous event, which is not necessarily correct.

This intervention was administered for four months, after having carried out an initial measurement (Pretest) of the quality of the conclusions that the students drew up in the diagnosis of their own work; for this purpose, the Guide to qualify the relevance of conclusions in academic works, shown above, was used. After the intervention was completed, a second review of the students' final conclusions was carried out (Posttest).

III. FINDINGS

To analyze the data collected from this design, a homoscedasticity test was first carried out, using Levene test, to ensure that the Experimental and Control groups were comparable to each other [18].

It should be noted that a specialized software was used to carry out all the analysis done in this work (Statistical Package for Social Sciences).

From this procedure, a significance of .895 was found, which rejects H0, and proposes the hypothetical equality of the variances of the scores of the two groups to be compared. The above is reproduced in the following:

Table V. *Levene tests report of results*

Pretest of both groups	Levene's test	
	F	Sig
Equal variances are assumed	.018	.895
Equal variances are not assumed		

Once the homoscedasticity of the groups was corroborated, a comparison of the initial and final data of each group was carried out, to estimate the record of any statistically significant change: for this, the Wilcoxon test was used, given the ordinal measurement of the variables [19], [20].

This decision also corroborated the distribution of the difference in scores of each group, using the Kolmogorov-Smirnov test, of which a non-parametric distribution was found in the first case.

Table VI. *Normality test results*

Normal parameters	Average	-1.0350
	TD	.46550
Maximum extreme differences	Absolute	.239
	Positive	.239
	Negative	-.149
Test statistic		.239
Sig. (Two tailed)		.112

In the difference test of the intervention group, a significance of .005 was found, which rejects the null hypothesis; in the case of the control group, a value of .011 was found, which also suggests a difference, although with a smaller deviation or shift in the tail.

Table VII. *Results of Wilcoxon difference tests*

Wilcoxon signed rank test	Groups
	Experimental Group, Postest. – Experimental Group, Pretest
Z	2.805
Sig. (Two tailed)	.005
	Control Group, Postest. - Control Group, Pretest.
Z	2.536
Sig. (Two tailed)	.011

The effect size of each case was reviewed, in which a coefficient of 2.4 was found for the experimental group, which, according to the criteria of Morales and Landívar [21] corresponds to a medium size effect; meanwhile, the size corresponding to the control group was 0.4, which corresponds to a small effect size. Below is the calculation of these coefficients:

Cohen's d = (3.265 - 2.23)/0.419077 = 2.46971.

Cohen's d = (2.295 - 2.17)/0.252567 = 0.494918.

Finally, a contrast was carried out between the results (Posttest) of both groups, using the Mann Whitney U test, given the nature of the measurement scale and the distribution of the variables [22].

From this exercise, a significance of .001 was found, which supports the hypothesis of difference between the scores of the groups [23].

Table VIII. *Difference test for unrelated data, by Mann Whitney U*

Posttest of both groups	
U by Mann-Whitney	5.000
W by Wilcoxon	60.000
Z	3.411

Sig. (bilateral)	.001
Signification [2*(sig. one tailed)]	.000

Finally, the result found in the differentiation of the scores is shown graphically:

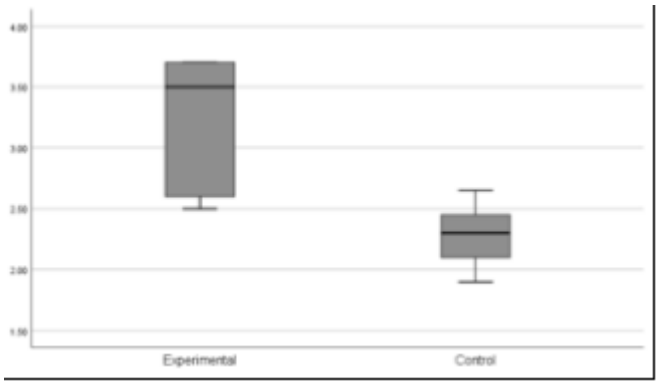

Fig. 2. *Comparison graph of experimental and control groups*

Based on it, an improvement is evident in the intervention group, when compared to the Control group. However, in this case, the scores are more compact and balanced with respect to the median.

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