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The "MITSSP" Strategy and its Impact on the Development of Critical Thinking: A Study Based on Neutrosophic Statistics

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Abstract. Nowadays, with the massive use of Information and Communication Technologies and social networks, it is more necessary than ever for citizens to develop critical thinking. Information media such as the Internet are flooded with false ideas, totally or partially. That is why it is necessary to provide young people with critical thinking that allows them to differentiate what is true from what is false, or even to identify dubious information. Based on the scientific method and under the protection of the educational research methodology, this article aims to demonstrate the effectiveness of the MITSSP strategy for the development of critical thinking in secondary school students at the Educational Institution "Héroes de Jactay" located in Huánuco, Peru. We conducted the study with the help of the Mann-Whitney Test in addition to the Neutrosophic Contingency Tables and the calculation of independence. This is because incomplete data were considered when comparing the results of the experimental group and the control group of students from the institution. The incomplete data is because some students did not finish the study, others joined late, and others had a question canceled on the questionnaire, among other cases.

Keywords: Strategy didactics, critical thought, comprehensive training, Neutrosophic Statistics, Neutrosophic Contingency Table, Neutrosophic Chi-square test, Neutrosophic Mann-Whitney test.

1 Introduction

Critical thinking is one of the most frequently mentioned and present forms of thinking in the literature, especially in the field of pedagogy, because it aims to form people with a reflective sense, capable of judging reasonably. This can also be achieved with a critical thinking process that involves a series of interconnected stages. Thus, critical thinking, although it is not synonymous with good thinking, is an essential human phenomenon that allows self-rectification. It is primarily associated with the form of self-evaluation, to then take corrective measures. It is already part of human nature; we all have this critical capacity developed at different levels or degrees. Therefore, these critical thinking skills constitute a current challenge for the educational system and higher education.

Today, university students need the tools and critical vision to face their circumstances, and to question and transform the society in which they live. According to reviews of the state of the art, the acquisition of these tools is still incipient at the university level in Latin American countries.

The above definitions describe critical thinking and competency; however, studies are required to identify strategies that favor its development. In this sense, it is important that teaching integrates instructional designs that foster in students the characteristics of a critical thinker. That is, with an open mind, flexible, prudent, and tolerant; as well as in the analysis of the issue to be debated and the management of arguments in a short and fast time from the points of view for and against. These are the aspects that together favor the development of critical thinking and the management of argumentation from this construct.

Defining critical thinking is complex, as there is no consensus in the academic community about its conceptualization or the skills involved in its development. Today's social and cultural changes require citizens trained with a critical, open, and flexible mindset in the face of change. Some of the skills that are desired to be achieved are classroom observation, individual interviews, and analysis of student productions.

“Critical Thinking” is therefore a polysemic concept. The plurality of its meanings is directly related to the disciplinary contexts from which it emerges. This is evident in the various nuances and academic communities that promote one or another meaning. Furthermore, the traditions and trajectories from which it emerges are also diverse.

As far as women and their development of critical thinking skills are concerned, it opens up new opportunities to cultivate critical thinking among university students, because when women share and discuss their experiences of injustice based on their gender, a sense of community is strengthened that empowers students to take concrete steps to change their situation through a well-founded life project.

The relationships between critical thinking and meaningful learning are then evident. Critical thinking is understood as an intellectual process that is activated when a person receives information, processes it, interprets it, infers it, and produces knowledge that can be put into practice by showing a positive attitude. In addition, the nature of critical thinking is very complex, so thinking critically involves taking charge of the mind and, therefore, of life, seeking to improve it based on one's criteria.

As an essential competence, critical thinking constitutes a liberating force that allows us to think autonomously, to avoid the shackles that are sometimes imposed on us by doctrines, ideologies, the media, and all the artifacts created by humanity as instruments of manipulation, oppression, and subjugation. That is why humanity is very submissive, obedient, and incapable of claiming its rights; consequently, the greater the knowledge or application of critical thinking, the more active, prudent, and reflective people there will be. The article studies the effectiveness of the strategy known as MITSSP by its acronym in Spanish, where students of the Educational Institution "Héroes de Jactay" in Huánuco, Peru are encouraged and provided with tools.

The test to measure critical thinking allows each student to be given a score on this aspect. Unlike other studies that could be carried out classically, in this work, for the calculations, we took into account all the irregularities that occurred during the study. Those students who did not complete the strategy or who did not answer a question in the tests or some who joined later and did not take the test, among other similar cases, were taken into account in the final calculations. This is possible with the help of Neutrosophic Statistics, which is the extension of classical statistical methods with imprecise interval data, when there is no exact number for the sample or population size, or when there are interval-valued parameters [1-7].

The Neutrosophic Mann-Whitney test was used, which allows for comparing indeterminate data to check the effectiveness of treatment [8-11]. This is a non-parametric statistical test. The comparison is carried out between a control sample and an experimental one. We also applied the calculation of independence between the values of the questionnaire for the students who passed the MITSSP strategy and the questionnaire was also applied to the control group, with the help of the Neutrosophic Contingency Tables [12-17].

This paper is divided into a Materials and Methods section where the basic notions of Neutrosophic Contingency Tables and related topics are explained as well as the Neutrosophic Mann-Whitney test. The next section presents the results of the study. The last section is the Conclusion.

2 Materials and Methods

This section contains the basics of Neutrosophic Statistics, the algebra of neutrosophic numbers, the Neutrosophic Mann-Whitney test, and Neutrosophic Contingency Tables.

2.1 Basic Notions on Neutrosophic Statistics

Neutrosophic statistics refers to a set of data, such that the data or a part of it is indeterminate to some degree, and to the methods used to analyze these data [5].

In classical statistics, all data is unambiguous; this distinguishes neutrosophic statistics from classical statistics. In numerous instances, when the indeterminacy is null, neutrosophic statistics align with classical statistics. Neutrosophic measurement is applicable for quantifying indeterminate data. Neutrosophic statistical methods will enable the interpretation and organization of neutrosophic data, which may possess indeterminacy, to uncover underlying patterns. Numerous methodologies can be employed in neutrosophic statistics.

In *neutrosophic probability*, indeterminacy differs from randomness. Classical statistics focuses exclusively on randomness, whereas neutrosophic statistics addresses both randomness and, notably, indeterminacy.

Neutrosophic descriptive statistics include all methodologies for summarizing and delineating the attributes of neutrosophic numerical data. Due to the indeterminacies inherent in neutrosophic numerical data, neutrosophic line plots and neutrosophic histograms are represented in three-dimensional space, in contrast to the two-dimensional space utilized in classical statistics. The third dimension, beside the Cartesian XOY system, is that of indeterminacy (I). From ambiguous pictorial data, we can derive indeterminate neutrosophic information.*Neutrosophic data* are data containing some indeterminacy. In a similar way to classical statistics, it can be classified as:

- *Discrete neutrosophic data*, if the values are isolated points; for example $6 + I_1$, where $I_1 \in [0,1]$,7, $26 + I_2$, where $I_2 \in [3,5]$;

Continuous neutrosophic data, if the values form one or more intervals, for instance: [0, 0.8] or [0.1, 1.0] (i.e., uncertain which one).

Other classification:

- *Quantitative (numerical) neutrosophic data*; for instance, a value within the interval [7, 9] (exact value unknown), or specific numbers such as 43, 57, 67, or 69 (exact values unknown);

- and *Qualitative (categorical) neutrosophic data*; for example: blue or red (exact value unknown), as well as white, black, green, or yellow (exact values unknown).

Additionally, we can categorize neutrosophic data into two types:

-*Univariate neutrosophic data*, which comprises observations on a single neutrosophic characteristic.

-*Multivariate neutrosophic* data, which consists of observations on two or more attributes. Specifically, we refer to bivariate neutrosophic data and trivariate neutrosophic data.

A neutrosophic sample is a selected subset of a population that exhibits some degree of indeterminacy, either regarding certain individuals (who may not fully belong to the population under investigation or may only partially belong) or concerning the subset as a whole.

Classical samples yield exact information, but neutrosophic samples offer ambiguous or incomplete data. One may assert that any sample qualifies as a neutrosophic sample, as its indeterminacy might be regarded as equivalent to zero.

Neutrosophic survey results are those that encompass indeterminacy. A neutrosophic population is one whose membership is indeterminate, meaning it is uncertain whether some individuals belong to the population or not. For example, as in the neutrosophic set, a generic element x belongs to the neutrosophic population M as follows, $x(t, i, f) \in M$ which means: x is t% in the population M, f% of x is not in the population M, while i% membership of x in M is indeterminate (unknown, unclear, neutral: neither in the population nor outside) .

2.2 Neutrosophic Numbers

Definition 1: ([5, 16]) A *neutrosophic number* N is defined as a number as follows:

$N = d + I$ (1)

Where d is called the *determined part* and I is called the *indeterminate part*.

Given that $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ are two neutrosophic numbers, some operations between them are defined as follows:

$N_1 + N_2 = a_1 + a_1 + (b_1 + b_2)I$ (Addition);

$N_1 - N_2 = a_1 - a_1 + (b_1 - b_2)I$ (Difference),

$N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

Smarandache also defined types of truth, indeterminacy, and falsity in a symbolic way beyond the T, I, and F. He called this refinement, where T is divided into $T_1, T_2, \ldots, T_p$; I is split into $I_1, I_2, \ldots, I_q$; and F is split into $F_1, F_2, \ldots, F_r$, which depend on the problem at hand. Specifically, he extended the numbers of the form given in Equation 1, to represent the *Refined Neutrosophic Numbers*.

Definition 2: ([5, 16]) Given $I_1, I_2, \ldots, I_q$, with $q \geq 1$, a *Refined Neutrosophic Number* is obtained from the previous set as $N_q = a + b_1 I_1 + b_2 I_2 + \cdots + b_q I_q$, where a is the determinate part and $b_j I_j$ ($j = 1,2, \ldots, q$) are the indeterminate parts, such that $a, b_1, b_2, \ldots, b_q$ are real or complex numbers.

Some properties that are fulfilled are those shown below:

1. $mI_k + nI_k = (m + n)I_k$,
2. $0I_k = 0$,
3. $I_k^n = I_k$,
4. I_k / I_k = undefined,

5. $I_j I_k$ with $j \neq k$ is defined depending on the problem being addressed.

Calculation with Neutrosophic Numbers is equivalent to interval calculation. If we substitute $I = [c, d]$, where $c, d \in \mathbb{R}$, and $c \leq d$ in the neutrosophic number $N = a + bI$, then we obtain its equivalent in interval form $N = [a, a] + b[c, d] = [a + bc, a + bd]$.

2.3 Neutrosophic Mann Whitney Test

The Mann-Whitney test, as its classic variant, is a non-parametric test that allows two samples to be compared as to whether or not they belong to the same population. It is used to demonstrate the effectiveness of a treatment, where two samples are compared, one applied to a control group and another to an experimental group that receives the treatment. This test does not require that the variable correspond to a specific distribution. Below we write the details of the test [16].

1. Merge all the observations from different samples and deal with them as one sample.
2. Calculate the score, accuracy, and certainty of each observation.
3. Compare and rank these observations.
4. Give the ranked observations ranks from 1 to n and if we have two equal observations then we average their ranks.
5. Compute Mann Whitney test statistical pairwise based on ranked data using steps 1-4 using the formula:
   $Z_N = \frac{U_N - \bar{U}_N}{\sigma_{U_N}}$
   Where:
   $\bar{U}_N = \frac{n_1 n_2}{2}$
   $\sigma_{U_N} = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$
   $U_N = min\left(n_1 n_2 + \frac{n_1(n_2+1)}{2} - (R_1)_N, n_1 n_2 + \frac{n_2(n_1+1)}{2} - (R_2)_N\right)$
   Where:
   n_i: number of observations in the ith group,
   $N = \sum n_i$: number of observations in all samples,
   R_i: sum of ranks for the ith group.
6. If $|Z_N| < Z_{1-\frac{\alpha}{2}}$ then two compared samples are drawn from the same population and otherwise samples are drawn from different populations.

2.4 Neutrosophic Contingency Tables

A neutrosophic contingency table is a contingency table where the data contained in it are indeterminate values, either in the form of intervals or in the form of neutrosophic numbers. The following independence statistic is applied to them with the help of the Chi-square distribution ([18, 19]):

Step 1. The neutrosophic null hypothesis H_{0N} is stated such that both variables are independent versus the neutrosophic alternative hypothesis H_{1N} such that both variables are dependent.

Step 2. The significance α-level is specified.
Step 3. The neutrosophic values of the expected frequency are calculated:

$$\chi^2_N = \sum \frac{\left(O_{i_N} - E_{i_N}\right)^2}{E_{i_N}} \qquad (2)$$

Step 4. The critical value χ^2_c is selected from the contingency table with a degree of freedom $(r-1) \times (c-1)$ of α as the significance level.

Step 5. Reject H_{0N} if χ^2_N is larger than the critical value. This means that the lower value of χ^2_N is greater than χ^2_c, or χ^2_c is between the lower and upper values. Otherwise, do not reject H_{0N}.

3 Results

The MITSSP in Spanish for “Model for Interaction in Working in Learning Situations” strategy is a pedagogical approach designed to foster critical thinking and active participation of students. It focuses on promoting interaction between students and teachers, as well as the development of critical skills through various activities.

The MITSSP model is based on several key components:

Motivation: To encourage students' interest and curiosity towards the topics covered.

Interaction: Promote collaborative work and dialogue among students, allowing them to share ideas and perspectives.

Teamwork: Develop social and collaborative skills by working in groups.

Learning situations: Create relevant contexts where students can apply their knowledge and skills.

Critical thinking: Stimulate reflection, analysis, and evaluation of information to make informed decisions.

In summary, the MITSSP strategy seeks to create a dynamic educational environment that fosters the development of critical thinking through interaction and collaboration among students.

The analysis presents the information collected from the sessions implemented in the experimental group (4th "A"), using the strategies addressed as theoretical support. The information collected by the other control group (4th "B") is also presented.

For data collection, a test was used to measure critical thinking, which consists of 20 questions, distributed in three dimensions, namely, literal, inferential, and evaluative. The literal level is presented in questions 1, 2, 3, 4, and 5, whose answers are data. The inferential level is present in questions 6, 7, 8, 17, 18, and 19 whose answers are analysis and deductions according to the readings presented. The evaluative level is presented in questions 9, 10, 11, 12, 13, 14, 15, 16, and 20 whose answers are opinions, but take into account a level of argumentation. After applying the test to measure critical thinking, the evaluation rubric was used, with which the count was made for each student taking into account the indicators of each of the dimensions.

For the study we developed, we first applied the Neutrosophic Mann-Whitney test to compare the results of the experimental group with the control group. In general, the data with which we worked were neutrosophic numbers of the form $a + bI$, where $I = [0, 1]$. If $b = 0$ it is an exact number, while $b \neq 0$ implies that there is some indeterminacy. To achieve greater accuracy, we took into account students who did not finish the strategy or joined late, among other cases as indicated above. For these cases, they were assigned a non-exact score in $[a, b]$, which can be represented as $a + bI$.

The other important detail to keep in mind is the comparison between two neutrosophic numbers, such that it is considered $a_1 + b_1 I \leq a_2 + b_2 I$ if $a_1 \leq a_2$ and $b_1 \leq b_2$. If on the other hand $a_2 + b_2 I \nleq a_1 + b_1 I$ according to the previous criterion, then both values are classified as incomparable and the following is taken as a comparison criterion:

$a_1 + b_1 I \leq a_2 + b_2 I$ if $a_1 \leq a_2$.

In the study, 31 students from group 4th A of the institution were given the exam after going through the MITSSP strategy. On the other hand, students from group 4th B, consisting of 26 students, followed the course that is usually taught.

The results were as follows:

$\bar{U}_N = 403$,

$\sigma_{U_N} = 61.87$,

$R_1 = 861.5$,

$R_2 = 1347$,

$U_N = -125$,

$Z_N = -8.534$.

$|Z_N| > 0.3289$, therefore the null hypothesis is rejected and it is determined that both samples belong to different populations.

The second test consists of a neutrosophic contingency table, as shown in Table 1.

Grade and Section	Results			
	Very low	Low	Regular	High
4th A	0	0	$3I$	$25 + 3I$
4th B	0	$12 + 8I$	$6I$	0

Table 1. Neutrosophic Contingency Table on the results of both groups evaluated in nominal variables.

Note that in Table 1, indeterminate results were obtained because cases with incomplete evaluation were included.

The result of the Chi-square statistic is $\chi^2_N = [133.7990, 155.4764]$. When this result is compared with the theoretical value of the Chi-square with 3 degrees of freedom, we have: $\chi^2_N = [133.7990, 155.4764] > \chi^2_{0.95}(3) = 7.81$. Therefore, the null hypothesis of equality between both groups is rejected.

Now let us compare the results regarding the gender of the students in the experimental group. We use the contingency table expressed in Table 2.

Gender	Results			
	Very low	Low	Regular	High
Male	0	0	I	$11+I$
Female	0	0	$2I$	$17+I$

Table 2. Neutrosophic Contingency Table on the results regarding gender in the experimental group expressed in nominal variables.

The result is $\chi^2_N = [76.1754, 82.386]$ which is evidently interpreted as rejecting the null hypothesis. This is why better results are observed in girls than in boys, which is an interesting reason for analysis to consider.

Conclusion

The development of critical thinking is crucial in a person's life and must be promoted in all areas. For this reason, when diagnosing critical thinking skills, there are only two valid options: it is in development or it is under observation. The argument is based on the foundations established by psychology and neuroscience. Human beings develop the foundations of critical thinking between the ages of 9 and 10 on average when they apply formal logical thinking in an incipient manner. This development is more noticeable at the age of 13 to 14, but this process does not end until death.

Currently, there are difficulties for teachers to apply relevant teaching strategies to achieve learning in students. According to the results of the control group and the experimental group, the experimental group has a significantly higher level than the control group. Therefore, it is concluded that there is effectiveness when applying the MITSSP strategy in the development of critical thinking. Additionally, the values of the Chi-square test were calculated and it was determined that girls have better final results than boys. This is an issue to consider in future studies.

To carry out the study and reach the aforementioned conclusions we used the neutrosophic statistic, where the data are expressed in interval form or equivalently in neutrosophic form numbers. First, we used the Neutrosophic Mann-Whitney test and then the Chi-square test for Neutrosophic Contingency Tables. These methods allow us to take into account inaccurate data, due to incomplete test results, instead of discarding incomplete data.

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