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Evaluation of the Effectiveness of Preventive Dental Education in Primary Schools

Marianela Buitrón Recalde[1], Sandra Rojas Rojas[2], Marco Zúñiga Llerena[3] and Anthony Rafael Sotolongo León[4]

[1]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.marielabr36@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.sandrarr80@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.marcozuniga@uniandes.edu.ec
[4]Ongres, Santiago de Chile, Chile. E-mail: asotolongo@ongres.com

Abstract. The study conducted focused on assessing the effectiveness of preventive dental education in a primary school in Puyo, using neutrosophic logic as the main approach. To achieve this purpose, the TOPSIS method was adapted to perform a quantitative evaluation of various alternative dental prevention education programs. In parallel, the traditional TOPSIS method was applied to compare the results obtained. Despite numerical discrepancies between both methods, there was a consensus in favor of the "Dental Health Clubs" program. However, the most notable aspect was that the Neutrosophic TOPSIS method stood out for its greater effectiveness in managing ambiguity and uncertainty present in the evaluation. This was reflected in higher proximity coefficient scores, suggesting that this approach provides a more solid foundation for selecting the most suitable educational program in the context of preventive dental education. This finding underscores the importance of incorporating neutrosophic logic in decision-making in situations where uncertainty and ambiguity are key factors.

Keywords: evaluation, education, dentistry, prevention, neutrosophic logic.

1. Introduction

A fundamental and inescapable aspect of every scientific research process lies in decision-making. This dimension is essential both in the scientific context and in the broader human sphere. The intrinsic necessity of addressing uncertain data in this decision-making process has led to the incorporation of fuzzy set theory (FS) as a tool for dealing with the uncertainty and imprecision of data [1]. Over the subsequent years, substantial efforts have been made in various research fields to integrate the vagueness present in initial information, thus seeking the capacity to solve complex real-life problems.[2], [3]

In this context, Florentín Smarandache introduced the neutrosophic set theory in 1995 as a generalization of "fuzzy" sets and "intuitionistic fuzzy" sets. Neutrosophy falls within the realm of philosophy and is dedicated to studying the origin, nature, and scope of neutralities [4]. Within this new branch, it is postulated that membership in truth, membership in indeterminacy, and membership in falsity are independent concepts and are situated in the non-standard unit interval [0-, 1+].[5-21]

Throughout the years, the applicability of neutrosophy has extended to various disciplines, including the sciences [6], engineering, society, and psychology [7], among others. This has prompted specialists in the field to develop neutrosophic models related to various conventional problem-solving techniques, allowing for a more personalized and effective approach to specific challenges in these fields.

To facilitate the practical application of neutrosophic sets, the concept of Single-Valued Neutrosophic Set (SVNS) has been defined, and theoretical set operations have been proposed, along with some properties of SVNS [8]. Likewise, the use of neutrosophy in combination with multi-criteria decision-making tools (MCDM) has been suggested. In such cases, to incorporate the vagueness of information into problem-solving, decision-makers tend to use methods of subjective evaluation. [9]–[11-22]

The application of neutrosophic logic has already been successfully applied in decision-making in the education sector. Due to its characteristics as a philosophical logic, neutrosophy provides a solid framework for evaluating and making decisions in virtually any educational context. Dental health is an essential component in the lives and health of all individuals, which takes on special significance in children during early childhood. Pediatric dentistry is a proposal currently applied in some countries to promote oral health during early childhood. Oral health is an integral part of a child's overall health.

Dental conditions can cause local problems such as pain, chewing difficulties, decreased appetite, weight loss, dental occlusion problems, speech and mastication difficulties, aesthetic deficiencies, difficulty sleeping, and behavioral disturbances. Similarly, these problems can lead to infections that trigger systemic diseases or the loss of dental organs.

Among the key tools for reducing the prevalence of oral diseases in children is education. To promote infant oral health, early involvement in guidance programs on healthy eating and hygiene habits is necessary. Furthermore, it is essential to provide education in oral health, which means acquiring information and developing skills that promote a change in behavior and attitudes, creating new values that benefit the oral health of both parents and infants.

In the context of preventive education, where decision-making focuses on the implementation of strategies to promote oral health and prevent oral diseases, the use of neutrosophic logic can allow for the consideration of uncertainty related to the effectiveness of different interventions. By integrating the vagueness of information into decision-making, educators and healthcare professionals can adapt their approaches more precisely, taking into account the variability in student responses and changing conditions.

In this regard, the present research aims to verify the applicability and effectiveness of neutrosophic logic for the evaluation of preventive dental education in a primary school in Puyo. To address this purpose, the TOPSIS method (Technique for Order of Preference by Similarity to Ideal Solution), a decision-making technique developed by Hwang and Yoon in 1981 [12], will be applied. This method can combine heterogeneous attributes into a unique dimensionless index, which is particularly useful when the attributes being evaluated are expressed in different units or scales. The basis of TOPSIS lies in the principle that the chosen alternative should have the smallest Euclidean distance to an ideal solution and the greatest Euclidean distance to an anti-ideal solution. [13-18] presented an adaptation of the TOPSIS method for selecting suitable suppliers in an intuitionistic fuzzy environment. Subsequently, the TOPSIS method has been expanded to address multicriteria decision-making problems in the context of fuzzy intuitionistic sets valued in intervals, as demonstrated by [14-19].

In this research, the contributions from neutrosophy and neutrosophic sets are integrated. Consequently, Neutrosophic TOPSIS will be used to discern the alternatives that, under quantitative evaluation, exhibit both the greatest strengths and the greatest weaknesses concerning certain specified criteria.

2 Preliminaries

Definition 1. Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by the truth-membership function T_A (x), indeterminacy-membership function I_A (x), and falsity membership function F_A (x). Then, an SVNS A can be denoted by A = {x, $T_A(x)$, $I_A(x)$, $F_A(x)$ x ∈ X}, where T_A (x), I_A (x), F_A (x) ∈ [0,1] for each point x in X. Therefore, the sum of T_A (x), I_A (x) and F_A (x) satisfies the condition $0 \leq T_A (x) + I_A(x) + F_A(x) \leq 3$.[15]

For convenience, an SVN number is denoted by A = $(a\ b\ c)$, where a, b, c ∈ [0,1] and a + b + c ≤ 3

Definition 2. Let A_1= A_1= (a_1,b_1,c_1) and $A_2 = (a_2,b_2,c_2)$ be two SVN numbers, then summation between A_1 y A_2 is defined as follows:

$$A_1 + A_2 = \left(a_1 + a_2 - a_{1a_2}, b_{1b_2}, c_{1c_2}\right) \tag{1}$$

Definition 3. Let A_1= (a_1,b_1,c_1) and $A_2 = (a_2,b_2,c_2)$ be two SVN numbers, then multiplication between A_1 y A_2 is defined as follows:

$$A_1 * A_2 = \left(a_{1a_2}, b_1 + b_2 - b_{1b_2}, c_1 + c_2 - c_{1c_2}\right) \tag{2}$$

Definition 4. Let A = (a, b, c) be an SVN number and $\lambda \in \mathbb{R}$ an arbitrary positive real number, then:

$$\lambda A = \left(1 - (1 - a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \tag{3}$$

Definition 5. Let $A = \{A_1, A_2, \ldots, A_n\}$ be a set of n SVN numbers, where $A_j = (a_j, b_j, c_j)$ (j= 1, 2, …, n). The single value neutrosophic weighted average operator on them is defined by:

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1 - \prod_{j=1}^{n}\left(1 - a_j\right)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}\right) \tag{4}$$

Where λ_j is the weight of A_j (j= 1, 2, …,n), $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$

Definition 6. Let $A^* = \{A_1^*, A_2^*, \ldots, A_n^*\}$ be a vector of n SVN numbers, such that $A_j^* = (a_j^*, b_j^*, c_j^*)$ (j= 1,2,…,n), and $B_i = \{B_{i1}, B_{i2}, \ldots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…,n). Then the separation measure between B_i and A^* based on Euclidian distance is defined as follows:

$$s_i = \left(\frac{1}{3}\sum_{j=1}^{n}\left(\left|a_{ij} - a_j^*\right|\right)^2 + \left(\left|b_{ij} - b_j^*\right|\right)^2 + \left(\left|c_{ij} - c_j^*\right|\right)^2\right)^{\frac{1}{2}} \tag{5}$$

(i= 1, 2, …, m)

Next, a scoring function for ranking SVN numbers is proposed:

Definition 7. Let A = (a, b, c) be a single-valued neutrosophic number, a scoring function S of a single-valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsity membership degree is defined by:

$$S(A) = \frac{1+a-2b-c}{2} \quad (6)$$

where $S(A) \in [-1,1]$

The scoring function S is reduced to the score function proposed by [16-20] if b = 0 and a + b ≤ 1.

The utilization of a linguistic variable proves to be highly advantageous in addressing decision-making scenarios of an intricate nature. The quantification of a linguistic variable is delineated as an element contained within its set of terms. These linguistic values can be effectively represented through the utilization of single-valued neutrosophic numbers.

Table 1. Linguistic variable and SVNSs. Source: [17].

Linguistic term	SVNSs
Very no influential/ (VNI)	(0.9;0.1;0.1)
No influential/(NI)	(0.75;0.25;0.20)
Medium influential/(M)	(0.50;0.5;0.50)
Influential/(I)	(0.35;0.75;0.80)
Very high influential/(VHI)	(0.10;0.90;0.90)

In this particular methodology, the scenario involves k decision-makers, *m* alternatives, and *n* criteria. Each of the k decision-makers assesses the significance of the *m* alternatives within the context of the *n* criteria and subsequently ranks the performance of the *n* criteria based on linguistic expressions that have been transformed into single-valued neutrosophic numbers. The assignment of importance weights is accomplished by considering single-valued neutrosophic values associated with the linguistic terms, as illustrated in Table 1.

2.1 The TOPSIS method for SVNS

The TOPSIS procedure applied to single-valued neutrosophic sets (SVNS) involves a series of specific steps. Suppose there is a set of alternatives $A = \{\rho_1, \rho_2, \dots, \rho_m\}$ and a set of criteria $G = \{\beta_1, \beta_2, \dots, \beta_n\}$. The steps to follow are these:

- Step 1: The determination of the relative importance of the experts is carried out. To perform this evaluation, experts use the linguistic scale detailed in Table 1. The calculations are performed considering the Single Value Neutrosophic Set (SVNS) denoted as $A_t = (a_t, b_t, c_t)$, associated with the t-th decision-maker (where t = 1, 2, ..., k). The weight is calculated using Equation (7).

$$\delta_t = \frac{a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)} \quad (7)$$

$$\delta_t \geq 0 \; and \; \sum_{t=1}^{k} \delta_t = 1$$

- Step 2: The neutrosophic decision matrix is generated, which aggregates the individual single values. This matrix, represented as D, is defined through the expression $D = \sum_{t=1}^{k} \lambda_t D^t$, where each element d_{ij} takes the form of (u_{ij}, r_{ij}, v_{ij}). The purpose is to merge all the individual evaluations made by each expert $(u_{ij}^t, r_{ij}^t, v_{ij}^t)$ using their respective weights λ_t, as established in Equation 4. This results in a matrix $D = (d_{ij})_{ij}$, where each d_{ij} represents a Single Value Neutrosophic Number (SVNN), considering i as the index of alternatives (i = 1, 2, ..., m) and j as the index of criteria (j = 1, 2, ..., n).

- Step 3: It involves determining the weights assigned to the criteria. Let's assume that the criterion weights are described as $W = (w_1, w_2, \ldots, w_n)$, where w_j denotes the relative relevance of criterion j and is represented by the value $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. Each w_j^t represents the evaluation of criterion λ_t by the t-th expert. Equation 4 is applied to combine the w_j^t with the corresponding weights λ_t.
- Step 4: The neutrosophic decision matrix is developed from the weighted average of unique values in relation to the criteria.

$$D^* = D * W, \tag{8}$$

Where $d_{ij} = (a_{ij}, b_{ij}, c_{ij})$

- Step 5: The calculation of the ideal solutions in Single Value Neutrosophic Numbers (SVNNs), both positive and negative, is carried out. It is important to note that criteria can be categorized into two types: those of a beneficial or cost type. For this purpose, the set G_1 encompasses the beneficial criteria, and the set G_2 includes the cost-type criteria. The ideal solutions are established as follows:

The positive ideal solution, which corresponds to the criteria contained in G_1

$$\rho^+ = a_{\rho+w}(\beta_j), b_{\rho+w}(\beta_j), ac_{\rho+w}(\beta_j) \tag{9}$$

The negative ideal solution corresponding to G_2

$$\rho^- = (a_{\rho-w}(\beta_j), b_{\rho-w}(\beta_j), ac_{\rho-w}(\beta_j)) \tag{10}$$

Where:

$$a_{\rho+w}(\beta_j) = \begin{cases} max_i a_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ min_i a_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases} \qquad a_{\rho-w}(\beta_j) = \begin{cases} min_i a_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ max_i a_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases}$$

$$b_{\rho+w}(\beta_j) = \begin{cases} max_i b_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ min_i b_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases} \qquad b_{\rho-w}(\beta_j) = \begin{cases} min_i b_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ max_i b_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases}$$

$$c_{\rho+w}(\beta_j) = \begin{cases} max_i c_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ min_i c_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases} \qquad c_{\rho-w}(\beta_j) = \begin{cases} min_i c_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ max_i c_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases}$$

- Step 6: Calculate the distances with respect to the ideal solutions in Single Value Neutrosophic Numbers (SVNNs), both positive and negative. These distances are obtained by applying Equation 5, which is used to calculate the following expressions:

$$d_i^+ = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^+\right)^2 + \left(b_{ij} - b_j^+\right)^2 + \left(c_{ij} - c_j^+\right)^2\right\}\right)^{\frac{1}{2}} \tag{11}$$

$$d_i^- = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^-\right)^2 + \left(b_{ij} - b_j^-\right)^2 + \left(c_{ij} - c_j^-\right)^2\right\}\right)^{\frac{1}{2}} \tag{12}$$

- Step 7: Calculate the Coefficient of Proximity (CP) of each alternative in relation to the ideal solutions, both positive and negative.

$$\widetilde{\rho_J} = \frac{s^-}{s^+ + s^-} \tag{13}$$

Where $0 \leq \widetilde{\rho_J} \leq 1$.

- Step 8: The order of the alternatives is determined. These are classified based on the values of $\widetilde{\rho_J}$, where the order is established from highest to lowest. The condition that corresponds to the optimal solution $(\widetilde{\rho_J}) \rightarrow 1$ is met.

3 Results

In the context of this research, the aim is to evaluate the effectiveness of different interactive programs recently implemented to promote preventive dental education in the school environment. This study focuses on the identification and application of programs that offer the greatest potential for prevention and educational impact on students. To achieve this goal, discrimination is made through the execution of three specific programs:

1. The first program involves the establishment of "Dental Health Clubs," which are extracurricular groups dedicated to promoting dental health. In these clubs, students have the opportunity to acquire knowledge about oral hygiene, share advice, and encourage preventive practices in an interactive environment.
2. The second program focuses on "Educational Theater," characterized by the creation and performance of theatrical works with educational content related to dental health. This strategy actively involves students in the interpretation of scenes that address oral care and the importance of dental visits.
3. The third approach, known as the "Mentorship Program," is based on pairing older students with their younger peers, assigning the former the role of mentors in matters related to dental health. These mentors play a crucial role in providing personalized support and sharing relevant information with younger students.

To conduct the evaluation and selection among these alternatives, the experience and expertise of three highly qualified professionals in the fields of dentistry and education are enlisted. These experts will play a fundamental role in analyzing the results and making informed decisions about the implementation of the most effective programs in terms of promoting dental health and preventive education among school students.

To effectively evaluate the assessed programs, the experts are asked to analyze the methodology, educational content, and scope of each of the programs under review. Subsequently, they are requested to provide an evaluation of each program, taking into account four criteria for necessary analysis.

- Criterion 1: Theoretical and Practical Foundation for Achieving Oral Hygiene Change: Evaluate the strength of the theoretical foundation on which the programs are based. This involves assessing whether the programs are supported by current scientific evidence and whether they are based on recognized theories in the fields of dentistry and education.
- Criterion 2: Application of Teaching Methodologies and Strategies Focused on Healthy Dietary Education: Evaluate the teaching strategies proposed in the programs that encourage the reduction of the consumption of sugary foods and sugary beverages, which exacerbate the occurrence of dental caries.
- Criterion 3: Evaluation and Measurement of the Impact Associated with the Reduction of Oral Diseases: Evaluate whether the programs include evaluation methods that allow measuring their impact and effectiveness in the context of the progressive and demonstrable reduction of oral diseases, healthy behaviors, etc.
- Criterion 4: Adaptability and Flexibility: Determine if the programs can be adapted to different educational contexts and student groups.

Expert decision-makers use a set of weighted linguistic assessments to establish performance on each criterion. In this sense, the evaluations offered to determine the weight of each criterion allow us to obtain the weight vector shown below:

Table 2. Vector of weights associated with each of the selected evaluation criteria.

Criteria	Criterion category	Weights vector
Criterion 1	Benefit	(0.85573;0.14427;0.13195)
Criterion 2	Benefit	(0.85573;0.14427;0.13195)
Criterion 3	Benefit	(0.76091;0.23909;0.20913)
Criterion 4	Benefit	(0.71283;0.28717;0.24022)

With this analysis, the experts can assess each of the proposed programs in light of the evaluation criteria. The gathered data is transformed into neutrosophic sets for further use. This allows for the normalization and weighting of matrices. The evaluations conducted by the experts form the basis on which the mentioned method's operations are applied to obtain the decision matrix.

After applying Equation (8), the neutrosophic decision matrix is generated, representing the single-valued weighted average with respect to the criteria (refer to Table 3), where the results obtained after following the procedure are presented.

Table 3. Vector of weights associated with each of the selected evaluation criteria.

Programs	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Dental Health Clubs	(0.704;0.295;0.264)	(0.521;0.478;0.447)	(0.716;0.283;0.275)	(0.441;0.558;0.387)
Educational Theater	(0.665;0.334;0.29)	(0.413;0.586;0.539)	(0.302;0.783;0.825)	(0.432;0.567;0.396)
Mentor Program	(0.611;0.388;0.326)	(0.500;0.499;0.47)	(0.716;0.283;0.275)	(0.441;0.558;0.387)

The use of this approach is crucial in the field of decision-making and program evaluation, as it allows for a more precise and structured representation of data and expert preferences. By converting data into neutrosophic sets, it takes into account both uncertainty and ambiguity in criterion evaluations, which can be common in complex decision-making situations. The resulting matrix, showing the weighted average of single values, provides a clear view of how programs are ranked based on criteria assessed by experts.

At the end of the process, the results enable the determination of both positive and negative ideal values for each criterion. This information is subsequently used to calculate ideal distances, which are employed in the calculation of the proximity coefficient. Table 4 presents a summary showing the distances with respect to the positive and negative ideal values for each alternative, considering the criteria used, and also includes the calculated proximity coefficients.

Obtaining ideal values, both positive and negative, is essential in multi-criteria decision-making, as it provides a reference point to assess how close or far each alternative is from the ideals based on different criteria. The determination of ideal distances is crucial for calculating the proximity coefficient, which provides a quantitative measure of how suitable each alternative is in relation to the defined ideals.

Table 4. Positive and negative ideal distances and proximity coefficients calculated in comparative analysis in TOPSIS neutrosophic and TOPSIS.

Neutrosophic TOPSIS Method				TOPSIS method		
Alternatives	d+	d-	CP	d+	d-	Pi
Dental Health Clubs	0.00885	0.6	0.985	0.0221	0.044	0.667
Educational Theater	0.50318	0.33	0.396	0.0879	0.066	0.427
Mentor Program	0.08776	0.59	0.871	0.0244	0.033	0.577

The comparative analysis conducted using the TOPSIS method and the Neutrosophic TOPSIS method for the evaluation of alternatives in the context of a specific problem reveals notable divergences in the classification of alternatives. In the Neutrosophic TOPSIS method, it is observed that the alternative "Dental Health Clubs" has the highest coefficient of proximity (CP), with a value of 0.427, followed by "Educational Theater" with 0.345 and "Mentorship Program" with 0.210. These results indicate that, according to the Neutrosophic TOPSIS method, "Dental Health Clubs" is considered the preference.

In parallel, in the conventional TOPSIS method, while the calculation values may not be identical, the overall results show significant similarity. In both methods, the preference order of the alternatives remains consistent. The method preferred by the experts is still "Dental Health Clubs," while "Educational Theater" is ranked as the least favored alternative in both methods.

It is intriguing to note that, despite the consistency in the priority order in both methods, the proximity coefficient between "Educational Theater" and "Mentorship Program" is lower in the conventional TOPSIS method. This suggests that perhaps the ambiguity and uncertainty in the evaluation of "Educational Theater" and "Mentorship Program" are handled more efficiently in the Neutrosophic TOPSIS method, resulting in a higher CP score compared to the traditional TOPSIS method.

In this regard, despite the differences in numerical values, the consistency in the overall ranking of alternatives in both methods indicates that "Dental Health Clubs" is the preferred choice, while "Educational Theater" is the least favored. However, the Neutrosophic TOPSIS method seems to handle ambiguity and uncertainty in the evaluation more effectively, resulting in a higher CP score compared to the conventional TOPSIS method.

3 Discussion

The application of neutrosophy and the Neutrosophic TOPSIS method in the evaluation of the effectiveness of preventive dental education in the study plays a crucial role in informed decision-making. Neutrosophy, as an approach that considers ambiguity and uncertainty, is particularly valuable in the evaluation of educational programs, where results can depend on multiple factors and are not always absolute. The Neutrosophic TOPSIS method, derived from neutrosophy, expands the utility of this approach in multi-criteria decision-making. In the context of the study of preventive dental education, this method has enabled the effective and systematic evaluation of multiple educational programs through a variety of criteria of interest.

The importance of this methodology lies in its ability to handle the inherent ambiguity in the evaluation of educational programs, as expert perceptions and results can vary depending on interpretation and uncertainty. By using the Neutrosophic TOPSIS method, more robust and consistent results could be obtained by considering uncertainty and ambiguity in the evaluations, providing a stronger foundation for the selection of the best educational program in the context of preventive dental education.

Ultimately, the application of neutrosophy and the Neutrosophic TOPSIS method in this study has improved the quality of decision-making by providing a more comprehensive and accurate evaluation of educational programs. This has contributed to the selection of the program that offers the best opportunities for prevention and education in students, considering the multifaceted nature of preventive dental education and the inherent uncertainty in its evaluation.

Conclusion

The present study has allowed us to verify the applicability and effectiveness of neutrosophic logic in the evaluation of the effectiveness of preventive dental education in a primary school located in Puyo. An adaptation of the TOPSIS method that incorporates neutrosophic logic was introduced to distinguish between different alternatives for the selection of a dental prevention education program through quantitative evaluation. Simultaneously, the conventional TOPSIS method was applied to compare the results obtained using both approaches. Despite numerical discrepancies, both methodologies supported the preference for the "Dental Health Clubs" program. However, the Neutrosophic TOPSIS method proved to be more efficient in managing the ambiguity and uncertainty present in the evaluation, as reflected in higher proximity coefficient scores. This suggests that the Neutrosophic TOPSIS method provides a more robust basis for selecting the most suitable educational program in the context of preventive dental education, considering the complexity of results and expert perceptions.

References

[1] G. Morales-Luna, “Introducción a la lógica difusa,” Cent. Investig. y Estud. Av. México, 2002, [Online]. Available: https://www.academia.edu/download/32422813/1Introduccinalalgicadifusa.pdf.

[2] I. Kaya, M. Colak, and F. Terzi, “A comprehensive review of fuzzy multi criteria decision making methodologies for energy policy making,” Energy Strateg. Rev., vol. 24, pp. 207–228, 2019, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2211467X19300252.

[3] P. Quattrone, “Embracing ambiguity in management controls and decision-making processes: On how to design data visualisations to prompt wise judgement,” Account. Bus. Res., vol. 47, no. 5, pp. 588–612, 2017, [Online]. Available: https://www.tandfonline.com/doi/abs/10.1080/00014788.2017.1320842.

[4] M. Grida, R. Mohamed, and A. H. Zaid, “A novel plithogenic MCDM framework for evaluating the performance of IoT based supply chain,” Neutrosophic Sets Syst., vol. 33, no. 1, pp. 323–341, 2020, [Online]. Available: https://books.google.com/books?hl=es&lr=&id=w2L5DwAAQBAJ&oi=fnd&pg=PA323&dq=A+novel+plithogenic+MCDM+framework+for+evaluating+the+performance+of+IoT+based+supply+chain&ots=aQnFfYFDCH&sig=bbJyvNc8ACCxKlYtxDOLt3VGVUk.

[5] F. Smarandache and M. Ali, “Neutrosophic Triplet Group (revisited),” Neutrosophic sets Syst., vol. 26, no. 1, p. 2, 2019.

[6] D. Cadena-Piedrahita, S. Helfgott-Lerner, A. Drouet-Candel, F. Cobos-Mora, and N. Rojas-Jorgge, “Herbicides in the Irrigated Rice Production System in Babahoyo, Ecuador, Using Neutrosophic Statistics,” Neutrosophic Sets Syst., vol. 39, pp. 153–163, 2021.

[7] F. Smarandache, Neutropsychic Personality. A mathematical approach to psychology, 3rd ed. Brusels: Pons, 2018.

[8] A. Awang, A. T. A. Ghani, L. Abdullah, and M. F. Ahmad, “A DEMATEL method with single valued neutrosophic set (SVNS) in identifying the key contribution factors of Setiu Wetland’s coastal erosion,” AIP Conf. Proc., vol. 1974, 2018, doi: 10.1063/1.5041542.

[9] A. S. S. L. F. Autran, M. Gomes, and K. R. Vijayalakshmi, “Assessment of MCDM problems by TODIM using aggregated weights,” Neutrosophic sets Syst., vol. 35, no. 1, pp. 78–99, 2020, [Online]. Available: https://books.google.com/books?hl=es&lr=&id=y2L5DwAAQBAJ&oi=fnd&pg=PA78&dq=Assessment+of+MCDM+problems+by+TODIM+using+aggregated+weights,&ots=B5dkkx7J8e&sig=oCW4uR-soTuQvui1mNGRPJciFyTc.

[10] D. Ajay, S. Broumi, and J. Aldring, “An MCDM method under neutrosophic cubic fuzzy sets with geometric bonferroni

mean operator," Neutrosophic Sets Syst., vol. 32, no. 1, pp. 187–202, 2020, [Online]. Available: https://fs.unm.edu/NSS2/index.php/111/article/download/326/270.

[11] V. Uluçay, A. Kılıç, İ. Yıldız, and M. Şahin, "An outranking approach for MCDM-problems with neutrosophic multi-sets," Neutrosophic Sets Syst., vol. 30, no. 1, pp. 213–224, 2019, [Online]. Available: http://fs.unm.edu/NSS2/index.php/111/article/view/450.

[12] Y.-J. Lai, T.-Y. Liu, and C.-L. Hwang, "Topsis for MODM," Eur. J. Oper. Res., vol. 76, no. 3, pp. 486–500, 1994, [Online]. Available: https://www.sciencedirect.com/science/article/pii/0377221794902828.

[13] F. E. Boran, S. Genç, M. Kurt, and D. Akay, "A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method.," Expert Syst. Appl., vol. 36, no. 8, pp. 11363–11368, 2006, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0957417409002772.

[14] F. Ye, "An extended TOPSIS method with interval-valued intuitionistic fuzzy numbers for virtual enterprise partner selection.," Expert Syst. Appl., vol. 37, no. 10, pp. 7050–7055, 2010, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0957417410001946.

[15] D. Xu, X. Wei, H. Ding, and H. Bin, "A new method based on PROMETHEE and TODIM for multi-attribute decision-making with single-valued neutrosophic sets.," Mathematics, vol. 8, no. 10, p. 1816, 2020, [Online]. Available: https://www.mdpi.com/2227-7390/8/10/1816.

[16] D. F. Li, "Multiattribute decision-making models and methods using intuitionistic fuzzy sets.," J. Comput. Syst. Sci., vol. 70, no. 1, pp. 73–85, 2005, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0022000004000777.

[17] P. Biswas, S. Pramanik, and B. C. Giri, "TOPSIS method for multi-attribute group decision-making under single-valued neutrosophic environment.," Neural Comput. Appl., vol. 27, no. 3, pp. 727–737, 2016, [Online]. Available: https://link.springer.com/article/10.1007/s00521-015-1891-2.

[18] Ricardo, J. E., Fernández, A. J. R., Martínez, T. T. C., & Calle, W. A. C. ¨Analysis of Sustainable Development Indicators through Neutrosophic Correlation Coefficients¨, 2022

[19] Estupiñan Ricardo, J., Romero Fernández, A. J., & Leyva Vázquez, M. Y. ¨Presencia de la investigación científica en los problemas sociales post pandemia¨. Conrado, vol 18 núm 86, pp 258-267, 2022

[20] P.Anbarasi Rodrigo, & S.Maheswari. ¨Neutrosophic gsα* - Open and Closed Maps in Neutrosophic Topological Spaces¨. Neutrosophic Systems With Applications, vol 8, pp 42–49, 2023. https://doi.org/10.61356/j.nswa.2023.39

[21] Jeyaraman. M, Iswariya. S, & Pandiselvi. R. ¨Generalized Double Statistical Convergence Sequences on Ideals in Neutrosophic Normed Spaces¨. Neutrosophic Systems With Applications, vol 8, pp 50–60, 2023. https://doi.org/10.61356/j.nswa.2023.40

[22] Waleed Tawfiq Al-Nami. ¨Ranking and Analysis the Strategies of Crowd Management to Reduce the Risks of Crushes and Stampedes in Crowded Environments and Ensure the Safety of Passengers¨. Neutrosophic Systems With Applications, vol 8, pp 61–78, 2023. https://doi.org/10.61356/j.nswa.2023.50

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