TOPSIS NEUTROSÓFICO Y DISTANCIA DE HAUSDORFF COMBINADOS PARA MEDIR LA CALIDAD DE LA SIMULACIÓN CLÍNICA EN LA EDUCACIÓN DE ENFERMERÍA.

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ABSTRACT.
Clinical simulation is vital in nursing education, providing realistic, hands-on experiences that prepare students for current challenges in healthcare settings. However, measuring the quality of its use requires the use of tools to deal with vague or inconsistent information associated with the subjective elements involved. The objective of this research was to evaluate the quality of the use of clinical simulation in nursing education by applying a set of qualitative indicators of a linguistic nature, expressed as single-valued neutrosophic sets. The combined use of the TOPSIS neutrosophic method with the calculation of the Hausdorff distance, allowed to evaluate a survey applied to professors of the UNIANDES university Nursing career. It was found that the best results were obtained with the realization of 3 or more clinical simulation sessions, mainly in the implementation and feedback offered by the students.

KEYWORDS: Single-valued neutrosophic sets, Neutrosophic TOPSIS, Hausdorff Distance, Clinical simulation

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RESUMEN.
La simulación clínica es vital en la educación de enfermería, proporcionando experiencias prácticas y realistas que preparan a los estudiantes para los desafíos actuales en entornos de atención médica. Sin embargo, medir la calidad de su uso requiere herramientas para lidiar con información vaga o inconsistente asociada con los elementos subjetivos involucrados. El objetivo de esta investigación fue evaluar la calidad del uso de la simulación clínica en la educación de enfermería aplicando un conjunto de indicadores cualitativos de naturaleza lingüística, expresados como conjuntos neutrosóficos de valor único. El uso combinado del método neutrosófico TOPSIS con el cálculo de la distancia de Hausdorff permitió evaluar una encuesta aplicada a los profesores de la carrera de Enfermería de la universidad UNIANDES. Se encontró que los mejores resultados se obtuvieron con la realización de 3 o más sesiones de simulación clínica, principalmente en la implementación y retroalimentación ofrecida por los estudiantes.

PALABRAS CLAVE: Conjuntos neutrosóficos de valor único, TOPSIS neutrosófico, Distancia de Hausdorff, Simulación clínica

1. INTRODUCTION

Clinical simulation is a fundamental pillar in health instruction, as it offers a controlled and safe environment for students to acquire practical skills and consolidate theoretical knowledge. This methodology allows the recreation of realistic medical scenarios, from routine situations to complex emergencies, providing students with the opportunity to face diverse clinical cases without risk to real patients [17]. With technological advances, clinical simulation has evolved, incorporating high-fidelity simulators, virtual reality and digital tools that faithfully replicate medical practice, fostering the development of decision-making skills, teamwork and effective communication between health professionals.

In contemporary times, clinical simulation has become an unavoidable relevance in medical and health education in general. The demand for trained and competent professionals in varied and challenging clinical situations has increased significantly, making simulation an indispensable method for learning [19]. The versatility of these simulated environments makes it possible to adapt to training needs, from the practice of basic skills to training in complex procedures, improving the safety and quality of medical care provided by future health professionals. Moreover, in a context where constant updating is crucial, clinical simulation offers a space for continuous training and continuous improvement of competencies, promoting excellence in clinical practice and patient safety.

Nursing education at the undergraduate level faces constant challenges, and the effective integration of innovative pedagogical methodologies has become essential to prepare future health professionals. In this context, simulation emerges as a key pedagogical tool in undergraduate nursing education, offering a practical, realistic and safe experience that complements academic theory [18].

In addition to technical practice, simulation fosters the development of critical non-technical skills, such as decision-making, effective communication and teamwork. These skills are critical in today's dynamic and challenging healthcare environment. Simulation provides a space where students can learn to manage complex situations, interact with colleagues, and make informed decisions, all while receiving constructive feedback that contributes to their professional growth [4].

Simulation has been also used extensively in the successful implementation of the Objective Structured Clinical Examination (OSCE). The OSCE, recognized as a valuable assessment strategy for nursing competencies, benefits significantly from simulation-based learning. The OSCE stands as a recognized approach for evaluating the clinical competencies of nursing students and not only enhances students' confidence, but also contributes to a heightened sense of readiness for clinical duties [1-3]. Through simulated scenarios, students engage in realistic clinical situations that closely mirror the complexities they may encounter in actual practice. This not only allows for the refinement of clinical skills but also ensures that students are well-prepared for the structured and standardized format of the OSCE.

The integration of simulation in OSCE preparation offers a controlled environment where students can familiarize themselves with the examination's structure and expectations. Simulated scenarios can be tailored to encompass a wide range of nursing procedures and patient interactions, providing students with exposure to diverse clinical scenarios that contribute to their competence and confidence. Moreover, the feedback received during simulated OSCE scenarios becomes a crucial component in the learning process, allowing students to identify areas for improvement and refine their performance in a supportive and constructive setting [11-13].

Assessing the quality of nursing education through simulation entails a meticulous examination of various facets, employing scientific rigor to ascertain the effectiveness and impact of simulation-based teaching methodologies. Quantitative metrics, such as objective performance indicators and standardized assessment scores, offer quantitative insights into the acquisition of clinical competencies by nursing students [9]. Furthermore, qualitative analyses encompassing the perception of learners and educators, as well as the integration of feedback mechanisms, contribute to a comprehensive evaluation of the pedagogical value of simulation.

It is recurrent in this type of study the use of INACSL Standards of Best Practice: Simulation Design [10-14]. This multifaceted approach, grounded in scientific principles, allows for a nuanced understanding of how simulation enhances the overall quality of nursing education, providing a foundation for evidence-based advancements in teaching methodologies within the healthcare education landscape. Although the use of quantitative indicators is proposed, authors such as Yang et al. [23], refer that the quality of simulation-based teaching is inherently ambiguous, susceptible to the influence of various uncertain factors, which justifies the use of fuzzy numbers for its measurement.

While in [7-15], they propose the use of linguistic variables to express qualitative data, whose values are based on subjective elements such as opinions, feelings or points of view, and contains incomplete and uncertain information. Therefore, they propose the use of neutrosophic sets (NS), as the generalization of fuzzy sets of intervals, as an effective tool to handle inconsistent and vague data. Specifically, they use single-valued neutrosophic sets (SVNSS), to describe the uncertainty of qualitative data and improve the credibility and validity of the assessment.

Based on the above, this paper proposes to evaluate the quality of the use of clinical simulation in nursing education based in OSCE, through the application of a group of qualitative indicators of a linguistic nature, expressed as single-valued neutrosophic sets. Aggregation and multi-criteria methods for decision making, will also be applied in their neutrosophic versions, the foundations of which are discussed below.

2. MAIN CONCEPTS AND THEORY

Neutrosophy, a new branch of philosophy, emerged as a generalization of Dialectics and YinYang Chinese philosophy. It delves into not just the dynamics of opposites but also the dynamics of opposites in conjunction with their neutrals (<A>, <neutA>, <antiA>), where <A> represents an item, <antiA> its opposite, and <neutA> their neutral state (indeterminacy between them). Neutrosophy emphasizes the significance of neutrality/indeterminacy (<neutA>), giving rise to concepts like neutrosophic set, logic, probability, statistics, and measure, with diverse practical applications across fields. Particularly, the Single-Valued Neutrosophic Set/Logic components could sum up to 3, highlighting the independence among these components [20-22].

Definition 1, [6], [2]. Let X be a space of basics element denoted by $x \in X$. A NS A in X, is described by a truth-membership function $T_A(x)$, indeterminacy-membership function $I_A(x)$ and falsity-membership function $F_A(x)$. These membership functions are real standard or non-standard subsets of $]0^-,1^+[$, i.e., $T_A(x){:}X \to]0^-,1^+[$, $I_A(x){:}X \to]0^-,1^+[$ and $F_A(x){:}X \to]0^-,1^+[$, where $0^- = 0 - \varepsilon$ and $1^+ = 1 + \varepsilon$, while ε is a number greater than 0. As NSs have a mentioned restriction on the sum of the three membership functions, so $0^- \le \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \le 3^+$.

In addressing the challenges associated with the practical application of Neutrosophic Sets (NSs) in a technical and scientific manner, Wang et al. introduced the concept of Single-Valued Neutrosophic Sets (SVNSs) [21].

Definition 2. [2],[21]. Let X be a space of basics elements wich is denoted by x $\in X$. B is a SVNS in X with membership functions: truth T_B (x), indeterminacy I_B(x) and falsity F_B(x), which belong to the interval [0,1]. So for any x element, T_B (x) ∈ [0,1], I_B(x) ∈ [0,1] and F_B(x) ∈ [0,1], therefore it is satisfied that $0 \le T_B(x) + I_B(x) + F_B(x) \le 3$. For a SVNS B in X, a triplet b will be represented as $\langle T_B(x), I_B(x), F_B(x) \rangle$ for x ∈ X, or as (T_b, I_b, F_b), in a simplified form, and it´s defined as a singled-valued neutrosophic number (SVNN), an element of the SVNS B in X.

Definition 3. [21]. Let A and B be two SVNSs in the space X. It can be stated that B contains A ($A \subseteq B$), if and only if $T_A(x) \le T_B(x), I_A(x) \ge I_B(x)$ *and* $F_A(x) \ge F_B(x)$ for all x ∈ X.

Definition 4. [8]. Let $\{B_1, B_2, \dots, B_n\}$ SVNNs ∈ SVNS(x), the Single Valued Neutrosophic Weighted Average Operator (SVNWAO), then is defined as:

$$\mathrm{SVNWAO}_w(B_1, B_2, \dots, B_n) = \langle 1 - \prod_{j=1}^{n} \left(1 - T_{B_j}(x)\right)^{w_j}, \prod_{j=1}^{n} \left(I_{B_j}(x)\right)^{w_j}, \prod_{j=1}^{n} \left(F_{B_j}(x)\right)^{w_j} \rangle \tag{1}$$

where $B_j = (T_j, I_j, F_j)$ (j = 1, 2, …, n) and $w = (w_1, w_2, \dots, w_n)$ is a vector, such $\sum w_j = 1,$ and $w_n \in$ [0,1]

Definition 5. [24]. The normalized hamming distance between a=(T_a, I_a, F_a) and b=(T_b, I_b, F_b), SVNNs of the SVNS C in X, is defined as:

$$d_{Xu}(a,b) = \frac{1}{3}\{|T_a - T_b| + |I_a - I_b| + |F_a - F_b|\} \tag{2}$$

Definition 6 [12]. The Hausdorff distance between a=(T_a, I_a, F_a) and b=(T_b, I_b, F_b), SVNNs of the SVNS C in X, is defined as:

$$d_{Xu}(a,b) = max\{|T_a - T_b|, |I_a - I_b|, |F_a - F_b|\} \tag{3}$$

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), it´s an efficient methodology, to handling complex multi criterial decision problems, such as prioritizing quality elements. Operating on the principle of identifying ideal and anti-ideal solutions, TOPSIS facilitates a nuanced understanding of the decision space, distinguishing optimal from suboptimal choices [5-16]. Through a similarity metric, it quantitatively measures the desirability of each option, enhancing objectivity. The integration of neutrosophical elements enhances TOPSIS, adding sophistication in handling indeterminate information, aligning with the evolving landscape of decision science, and providing a more robust framework for addressing uncertainties and improving decision-making efficacy.

The SVNNS ideal criteria are calculated as fallow. Be *B* the positive type criteria and *C* the cost type criteria, so, the ideal SVNNS for each case its calculated by :

$$B *= \left(T_{\rho^+w}(\beta_j), I_{\rho^+w}(\beta_j), F_{\rho^+w}(\beta_j)\right) \tag{4}$$

Denotes the positive ideal solution, corresponding to *B*.

$$\mathrm{C} *= \left(T_{\rho^-w}(\beta_j), I_{\rho^-w}(\beta_j), F_{\rho^-w}(\beta_j)\right) \tag{5}$$

Denotes the negative ideal solution, corresponding to C.

Where

$$T_{\rho^+w}(\beta_j) = \begin{cases} max_i\left[T_{\rho_i w}(\beta_j)\right], & if \quad j \in B \\ min_i\left[T_{\rho_i w}(\beta_j)\right], & if \quad j \in C \end{cases} \tag{6}$$

$$I_{\rho^+w}(\beta_j) = \begin{cases} min_i\left[I_{\rho_i w}(\beta_j)\right], & if \quad j \in B \\ max_i\left[I_{\rho_i w}(\beta_j)\right], & if \quad j \in C \end{cases} \tag{7}$$

$$F_{\rho^+w}(\beta_j) = \begin{cases} min_i\left[F_{\rho_i w}(\beta_j)\right], & if \quad j \in B \\ max_i\left[F_{\rho_i w}(\beta_j)\right], & if \quad j \in C \end{cases} \tag{8}$$

And

$$T_{\rho^-w}(\beta_j) = \begin{cases} min_i\left[T_{\rho_i w}(\beta_j)\right], & if \quad j \in B \\ max_i\left[T_{\rho_i w}(\beta_j)\right], & if \quad j \in C \end{cases} \tag{9}$$

$$I_{\rho^- w}(\beta_j) = \begin{cases} max_i[I_{\rho_i w}(\beta_j)], \; if \quad j \in B \\ min_i[I_{\rho_i w}(\beta_j)], \; if \quad j \in C \end{cases} \tag{10}$$

$$F_{\rho^- w}(\beta_j) = \begin{cases} max_i[F_{\rho_i w}(\beta_j)], \; if \quad j \in B \\ min_i[F_{\rho_i w}(\beta_j)], \; if \quad j \in C \end{cases} \tag{11}$$

The distance between each SVNNs and both ideal values will be calculated by (3), while the proximity coefficient (PC), will be calculated by:

$$PC_j = \frac{D^-}{D^+ + D^-}$$

Where

$$0 \leq PC_j \leq 1$$

$$D^- = d_{Xu}(\beta_j, C *) \tag{12}$$

$$D^+ = d_{Xu}(\beta_j, B *) \tag{13}$$

3. RESULTS

The present study was carried out at the Ambatos branch of UNIANDES university. A group of 8 professors of the Nursing career, where selected by intentional sampling, based on their professional profiles, experience in the clinical simulation use and contributions to scientific production on that field. Professors identified different levels of implementation of clinical simulation, but the most frequent ones correspond to those reported in the literature: 1, 2 and 3 or more simulation sessions per semester [11]. Assessing the clinical simulation quality in nursing education (CSQNE) at this institution, by comparing the 3 levels detected, involved measuring 16 quality indicators [10], [7], , organized into dimensions as presented in Table 1.

Dimension	Variable
Planning	Conducting Needs Assessment
	Construction of Measurable Objectives
	Structuring of the Simulation Format
	Scenario or Case Design
	Use of Varied Fidelity
Implementation	Facilitative Participant-Centered Approach
	Start with Pre-Briefing
	Follow-up with Briefing/Feedback
	Inclusion of Evaluations
	Provision of Materials and Resources
	Testing Prior to Full Implementation
Feedback	Knowledge Retention
	Team Interaction
	Clinical Performance
	Student Competencies
	Student Satisfaction

Table 1. Dimensions and variables of CSQNE

Based on the personals experiences, each professor assigned a linguistic term to each level (alternative), according with the measured variables. The questionaries where processes by the scale used on [7], wich its shown at table 2.

Linguistic term	Categorie	SVNN ($\mathbf{T}_B(\mathbf{x}), \mathbf{I}_B(\mathbf{x}), \mathbf{F}_B(\mathbf{x})$)
Extremely good/ high	Egh	(0,99;0,01;0,01)
Very good/ high	Vgh	(0,9;0,1;0,1)
Good/ high	Gh	(0,8;0,2;0,15)
Medium good/ high	Mgh	(0,7;0,3;0,3)
Medium/ fair	Mf	(0,5;0,5;0,5)
Medium bad/ low	Mbl	(0,3;0,65;0,6)
Bad/ low	Bl	(0,2;0,75;0,8)
Very bad/ low	Vbl	(0,1;0,9;0,9)

Extremely bad/ low	Ebl	(0,01;0,99;0,99)

Table 2. Scale of linguistic terms and SVNNs

To implement the chosen methodology, the assumption was made that all specialists and criteria carry equal weight, thereby utilizing identical weighting coefficients for the calculations. By aggregating the results of all the teachers for each of the variables, in each dimension, the results shown in Table 3 were obtained.

Dimension	**Variable**	**Agregated SVNN** **Level 1**	**Level 2**	**Level 3**
Planning	Conducting Needs Assessment	(0,36;0,61;0,57)	(0,73;0,26;0,23)	(0,8;0,2;0,17)
	Construction of Measurable Objectives	(0,06;0,94;0,94)	(0,9;0,1;0,09)	(0,73;0,27;0,25)
	Structuring of the Simulation Format	(0,61;0,39;0,39)	(0,83;0,16;0,15)	(0,82;0,18;0,18)
	Scenario or Case Design	(0,79;0,21;0,19)	(0,88;0,12;0,11)	(0,8;0,2;0,17)
	Use of Varied Fidelity	(0,21;0,77;0,78)	(0,92;0,08;0,07)	(0,71;0,29;0,26)
Implementation	Facilitative Participant-Centered Approach	(0,21;0,74;0,76)	(0,13;0,85;0,85)	(0,71;0,29;0,26)
	Start with Pre-Briefing	(0,36;0,61;0,57)	(0,46;0,52;0,49)	(0,61;0,39;0,38)
	Follow-up with Briefing/Feedback	(0,27;0,71;0,72)	(0,68;0,32;0,31)	(0,93;0,07;0,07)
	Inclusion of Evaluations	(0,71;0,29;0,27)	(0,64;0,35;0,34)	(0,93;0,07;0,06)
	Provision of Materials and Resources	(0,21;0,76;0,73)	(0,25;0,72;0,72)	(0,87;0,13;0,12)
	Testing Prior to Full Implementation	(0,42;0,57;0,56)	(0,14;0,83;0,86)	(0,78;0,22;0,18)
Feedback	Knowledge Retention	(0,02;0,98;0,98)	(0,73;0,27;0,25)	(0,82;0,18;0,15)
	Team Interaction	(0,34;0,64;0,64)	(0,61;0,39;0,38)	(0,85;0,15;0,13)
	Clinical Performance	(0,42;0,55;0,51)	(0,79;0,21;0,18)	(0,81;0,19;0,16)
	Student Competencies	(0,22;0,76;0,77)	(0,39;0,59;0,59)	(0,73;0,27;0,25)
	Student Satisfaction	(0,09;0,89;0,91)	(0,74;0,26;0,23)	(0,87;0,13;0,11)

Table 3. Aggregate values of specialists per variable for each level

In global terms, and in order to have an individual idea of each of the dimensions, beyond the level of implementation applied, a frequency graph was constructed for each evaluative category or linguistic term, as shown in Figure 1.

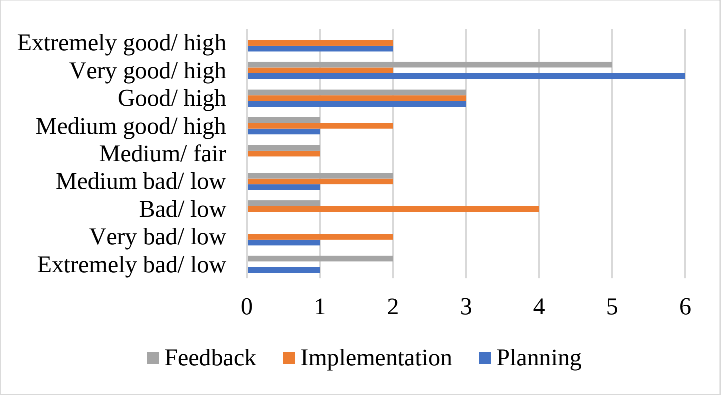

Figure 1. Frequency graph for each dimension

The frequency histogram provides a detailed overview of the evaluations in the dimensions of Planning, Implementation and Feedback. In general terms, planning is predominantly perceived positively, with a total of 11 evaluations in the Good/High, Very good/High and Extremely good/High levels. On the other hand, implementation shows a variety of evaluations, highlighting the presence of 2 evaluations in the Very bad/low level and 4 in the Bad/low level, pointing to possible areas for improvement in this aspect. Regarding feedback, the trend is mostly positive, with Very good/High being the most frequent category, with a total of 5 evaluations. It is important to highlight some extreme values, such as the Extremely good/High level in the Planning dimension with a frequency of 2.

This extreme value could indicate areas of excellence that could be identified and shared as best practices. On the other hand, the presence of 2 assessments at the Very bad/low level in the Implementation dimension highlights critical areas that may require immediate attention to improve the overall perception in this aspect. Those values offer key insights for decision making and implementation of improvement strategies in the specific areas identified. Table 4 shows the results of the aggregation of the variables in each dimension at each level. Thus, the evaluation values of each alternative according to each criterion are considered.

Level	Dimension Planning	Implementation	Feedback
Level 1	(0,55;0,44;0,44)	(0,41;0,56;0,54)	(0,23;0,75;0,75)
Level 2	(0,95;0,05;0,04)	(0,48;0,51;0,49)	(0,76;0,24;0,21)

Level 3	(0,87;0,13;0,12)	(0,94;0,06;0,06)	(0,89;0,11;0,11)

Table 4. Aggregate values by dimension

In relation to Planning, it is observed that Level 2, classified as Extremely good/high, stands out significantly compared to the other levels, which are in the Medium/fair or Very good/high category. This suggests that, at Level 2, planning for the implementation of simulation in nursing education is perceived as exceptionally positive, possibly indicating a planned and effective strategy.

Regarding Implementation, Level 3 presents an evaluation of Extremely good/high, standing out as the level with the best performance in this dimension. Levels 1 and 2 are in the Medium/fair category, indicating a more moderate performance in simulation implementation. This contrast suggests that, although Level 2 has exceptional planning, its implementation is only moderate, while Level 3 achieves exceptional implementation.

In the Feedback dimension, Level 3 leads with an evaluation of Very good/high, followed by Level 2 in the Good/high category, and finally Level 1 with Bad/low. This variability suggests that, although all levels have potential for improvement in feedback, Level 3 has achieved a higher level of satisfaction in this area.

To quantify the ranking and establish the order of priority of the levels, the ideal positive and negative values, shown in table 5, were calculated for each evaluation criterion.

Criteria (Dimension)	Ideal positive value	Ideal negative value
Planning	(0,95;0,05;0,04)	(0,55;0,44;0,44)
Implementation	(0,94;0,06;0,06)	(0,41;0,56;0,54)
Feedback	(0,89;0,11;0,11)	(0,23;0,75;0,75)

Table 5. Ideals values

Table 6 presents the values of the calculated distances by the presented Hausdorff distance method, and the proximity coefficient for the three levels of application of the simulation in nursing education at UNIANDES university.

Alternatives	d+	d-	PC	Order
Level 1	1,4042	1,0689	0,5677	3
Level 2	1,1677	1,2599	0,4810	2
Level 3	1,1015	1,4068	0,4391	1

Table 6. Distances and proximity coefficient

As can be seen in the results of Table 6, the third level of application presents the lowest values of the proximity coefficient, with 0.439, followed by the second and first levels, respectively. This indicates that the best results were observed with the performance of three or more simulation sessions. Similar results were obtained in research such as those consulted by Kassabry [11] and Hanshaw & Dickerson [9]. The results of the studies cited by these authors highlight the importance of the dose or frequency of exposure to simulations in the context of nursing education.

In some of the research discussed by [9], it was observed that multiple exposures to simulations were necessary to achieve significant improvements in critical thinking, and the groups subjected to three simulations demonstrated notable increases. In contrast, groups with one or two exposures to simulations did not experience the same level of gains. Similarly, they highlighted the benefits of immediate repeated exposure to high-fidelity simulations, demonstrating that this approach led to significantly higher scores in knowledge, learner satisfaction, self-confidence and clinical performance compared to a single simulation exposure. The repeated dose of simulation had a pronounced impact on learning outcomes, contributing to significant gains in several learning variables.

4. CONCLUSION

Clinical simulation provides a controlled and safe environment for students to acquire practical skills and consolidate theoretical knowledge. The evolving simulation landscape, incorporating advanced technologies and high-fidelity simulators, provides a realistic and versatile training ground. Beyond technical competency, simulation fosters the development of critical non-technical skills, preparing students for the dynamic healthcare environment.

The application of TOPSIS to measure the quality of teaching, by incorporating neutrosophic theory, allows the uncertainty inherent in educational assessment to be addressed more comprehensively. The ability of neutrosophic TOPSIS to handle imprecise and subjective information, as well as to consider different perspectives and opinions, is presented in this paper as a significant contribution to improving accuracy and fairness in assessing educational quality in a more holistic manner.

The application of the neutrosophic TOPSIS combined with HD allowed identifying that to obtain better results in the use of clinical simulation for nursing education, it is required to perform at least three simulation sessions. This level showed the highest values in terms of quality in implementation and student feedback. With outstanding results in variables such follow-up with briefing/feedback, inclusion of evaluations, team interaction and students satisfaction.

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