



Neutrosophic Plithogenic Hypotheses on Bacterial Resistance to Conventional and Laser-Assisted Treatments

Emma Arroyo Lalama^{1*}, and Edison Haro Pujos²

¹Universidad Regional Autónoma de los Andes, Ecuador. ua.emmaarroyo@uniandes.edu.ec

²Universidad Regional Autónoma de los Andes, Ecuador. edisonhp82@uniandes.edu.ec

Abstract. Enterococcus faecalis is a common endodontic pathogen that causes unsuccessful treatments because standard methods of debridement cannot remove it from the root canal system. Methods of debridement are effective relative to debriding multifactorial bacterial biofilms in apical pathogens. Therefore, neutrosophic plithogenic hypotheses are proposed to measure the uncertainty and variability of the bacterial response. Therefore, this work attempted to determine the impact of laser treatment (diode and Er:YAG) as an adjunct agent relative to and in conjunction with traditional irrigants in the reduction of E. faecalis. The diode and Er:YAG laser support increased disinfection efficacy over standard irrigants as they successfully remove biofilm. More specifically, the diode laser yields the optimal result as its bactericidal nature is defended and its biostimulatory ability implies cellular healing. This research presents specific calculations for types of bacterial resistance based upon an analysis that transcends bipolar statistical assessments while championing lasers as translational quality improvements within the realm of endodontics. Furthermore, this work also provides a systematic structure for experimental endeavors within uncertain environments regarding complex biological systems, setting a new standard for all subsequent studies.

Keywords: Laser, antimicrobial, endodontics, root canals, disinfection, Enterococcus faecalis, plithogenic, neutrosophic.

1. Introduction

Endodontic treatments, particularly Enterococcus faecalis in root canals, is a persistent challenge that compromises clinical success in dentistry. This study addresses the problem through neutrosophic plithogenic hypotheses, an innovative approach that models the uncertainty and variability in bacterial response. The relevance of this research lies in the high prevalence of therapeutic failures associated with complex bacterial biofilms, whose complete eradication remains elusive despite technological advances [1]. The need for effective solutions adapted to biological complexity justifies the exploration of laser-assisted therapies as a complement to conventional methods. Over the last decades, endodontics has evolved significantly, moving from manual techniques to procedures assisted by advanced technologies. From the introduction of chemical irrigants to the use of ultrasound and lasers, efforts to improve root canal disinfection have been constant [2]. However, the persistence of microorganisms such as E.

Faecalis, capable of forming resistant biofilms, has highlighted the limitations of traditional approaches [3]. In this context, laser therapy has emerged as a promising tool, with recent studies highlighting its ability to enhance bacterial clearance [4].

The central problem of this research arises from the difficulty in completely eradicating bacterial biofilms in endodontics, which leads to the question: how can a framework that addresses uncertainty

in bacterial response improve the efficacy of conventional and laser-assisted treatments? *E. faecalis* resistance is not only a technical problem, but also a complex phenomenon involving variations in susceptibility within the same microbial population [5]. The current literature lacks approaches that systematically integrate this indeterminacy. The magnitude of the problem is considerable, given that endodontic failures affect patients' quality of life and generate significant costs for healthcare systems [6]. Despite advances, traditional methods, such as the use of sodium hypochlorite, fail to eliminate all bacteria in complex anatomical structures of root canals [7-10]. This study seeks to answer the question posed by applying a neutrosophic plithogenic model, which allows analyzing bacterial resistance from a multidimensional perspective. This research proposes an approach that combines the precision of laser therapy with robust theoretical analysis, capable of capturing the uncertainty inherent in biological systems. Using diode and Er:YAG lasers, their impact on bacterial load reduction is evaluated, compared to conventional irrigants. This work not only seeks to improve clinical outcomes but also to establish a methodological precedent for the study of complex biological phenomena.

The main objective of this study is to formulate and test neutrosophic plithogenic hypotheses that model the response of *E. faecalis* to endodontic treatments, with an emphasis on laser therapy as an adjuvant. Furthermore, we aim to compare the efficacy of diode and Er:YAG lasers versus traditional methods, identifying optimal combinations for disinfection. Finally, we seek to offer practical recommendations for integrating these technologies into clinical practice, improving endodontic outcomes. These objectives are aligned with the research question and respond to the need for a comprehensive approach that transcends the limitations of conventional analyses. The application of a neutrosophic framework not only enriches the understanding of bacterial resistance but also opens new avenues for research in dentistry. Throughout the article, these ideas will be developed, supported by a rigorous analysis of the data obtained. This work is positioned as a significant contribution to the field of endodontics, combining methodological innovation with technological advances. By addressing bacterial resistance from a perspective that integrates uncertainty, we hope not only to improve therapeutic outcomes but also to inspire future studies that apply similar approaches in other areas of dentistry.

2. Methodology .

Neutrosophic (or indeterminate) data are characterized by inherent vagueness, lack of clarity, incompleteness, partial unknowns, and conflicting information [11–15]. Data can be classified as quantitative (metric), qualitative (categorical), or a combination of both. Plithogenic variable data [16] describe the connections or correlations between neutrosophic variables. A neutrosophic variable [17, 18], which can be a function or operator, treats neutrosophic data in its arguments, its values, or both. Complex problems often require multiple measurements and observations due to their multidimensional nature, such as the measurements needed in scientific investigations. Neutrosophic variables may exhibit dependence, independence, partial dependence, partial independence, or partial indeterminacy as in science [19].

A Plithogenic Set [20, 21] is a non-empty set P whose elements within the domain of discourse U ($P \subseteq U$) are characterized by one or more attributes A_1, A_2, \dots, A_m , where m is at least 1. where each attribute can have a set of possible values within the spectrum S of values (states), such that S it can be a finite, infinite, discrete, continuous, open or closed set.

Each element $x \in P$ is characterized by all possible values of the attributes within the set $V = \{v_1, v_2, \dots, v_n\}$. The value of an attribute has a degree of membership $d(x, v)$ in an element x of the set P , based on a specific criterion. The degree of membership can be diffuse, diffuse intuitionist or neutrosophic, among others [22].

That means,

$$\forall x \in P, d: P \times V \rightarrow \mathcal{P}([0, 1]^z) \quad (1)$$

Where $d(x, v) \subseteq [0, 1]^z$ and $\mathcal{P}([0, 1]^z)$ is the power set of $[0, 1]^z$. $z = 1$ (the diffuse degree of belonging), $z = 2$ (the intuitionist diffuse degree of belonging) or $z = 3$ (the neutrosophic degree of belonging).

plithogenic [23], derived from the analysis of plithogenic variables, represents a multidimensional probability ("plitho" meaning "many" and synonym of "multi"). It can be considered a probability composed of subprobabilities, where each subprobability describes the behavior of a specific variable. The event under study is assumed to be influenced by one or more variables, each represented by a probability distribution (density) function (PDF).

Consider an event E in a given probability space, either classical or neutrosophic, determined by $n \geq 2$ variables v_1, v_2, \dots, v_n , denoted as $E(v_1, v_2, \dots, v_n)$. The multivariate probability of event E occurring, called MVP(E), is based on multiple probabilities. Specifically, it depends on the probability of event E occurring with respect to each variable: $P_1(E(v_1))$ for variable v_1 , $P_2(E(v_2))$ for variable v_2 , etc. Therefore, $MVP(E(v_1, v_2, \dots, v_n))$ is represented as $(P_1(E(v_1)), P_2(E(v_2)), \dots, P_n(E(v_n)))$. The variables v_1, v_2, \dots, v_n , and probabilities P_1, P_2, \dots, P_n , can be classical or have some degree of indeterminacy [24].

To make the transition from plithogenic neutrosophic probability (PNP) to univariate neutrosophic probability UNP, we use the conjunction operator [25]:

$$UNP(v_1, v_2, \dots, v_n) = v_1 \wedge_{i=1}^n v_n \quad (2)$$

\wedge In this context, it is a neutrosophic conjunction (t-norm). If we take \wedge_p as the plithogenic conjunction between probabilities of the PNP type, where $(T_A, I_A, F_A) \wedge_p (T_B, I_B, F_B) = (T_A \wedge T_B, I_A \vee I_B, F_A \vee F_B)$, such that \wedge is the minimum t-norm of fuzzy logic and \vee the maximum t-norm [26, 27].

a. Formulate the hypothesis

Start by explicitly stating the hypothesis you intend to test. Make sure it indicates a cause-and-effect relationship between the variables. For example, "More study time leads to higher test scores."

b. Identify key variables

Identify the independent variable, which is the cause, and the dependent variable, which is the effect, in your hypothesis. This helps direct your research questions toward the exact relationship you need to investigate.

c. Formulate specific research questions

Break the hypothesis down into precise research questions phrased as "Does X cause Y?" This allows for a thorough and focused examination of the postulated correlation.

d. Conduct Stance analysis on scientific literature.

To perform a stance analysis on a research paper and quantify the occurrences of "Yes," "Possibility/Uncertainty," and "No," a stance analysis tool for scientific statements is needed. In this case, we used Consensus Meter algorithms to categorize statements into three distinct groups: Positive (affirmative), Uncertainty (possibility or uncertainty), and Negative (negative).

e. Formulate neutrosophic probabilistic hypotheses

Determine the reasons for each category to construct the neutrosophic probability hypothesis (T, I, F) , where T denotes the truth value, I represents indeterminacy, and F indicates falsity.

f. Calculate the plithogenic neutrosophic probability (PNP)

Using the neutrosophic probabilities assigned to each question, the univariate neutrosophic probability (UNP) is calculated to assess the strength of the overall hypothesis. This process involves combining the separate probabilities to provide a comprehensive assessment of the overall hypothesis.

$$UNP(v_1, v_2, \dots, v_n) = (Min(t_1, t_n, \dots, t_n), Max(i_1, i_n, \dots, i_n), Max(f_1, f_n, \dots, f_n)) \quad (3)$$

Where:

T_1, T_2, \dots, T_n : are the truth probability values for each question.

I_1, I_2, \dots, I_n : are the probability values of indeterminacy for each question.

F_1, F_2, \dots, F_n : are the probability values of falsehood for each question

g. Analyze the validity of the general hypothesis.

In this case, the negation of NPH is represented as [28]:

$$(T, I, F) = (F, I, T) \tag{4}$$

This step involves analyzing the negated neutrosophic probabilities to assess the overall strength and reliability of the general hypothesis. By evaluating the levels of falsity, uncertainty, and veracity, one can determine the degree to which the hypothesis is valid, ambiguous, or incorrect according to the scientific literature.

3. Case study

Central Hypothesis: Enterococcus resistance faecalis to conventional endodontic treatments can be significantly reduced by the application of adjuvant laser therapy (diode and Er:YAG), especially when combined with traditional irrigants. This therapeutic synergy improves penetration into bacterial biofilms and optimizes disinfection of the root canal system, overcoming the limitations of conventional monotherapies.

- **Independent Variable:** Antimicrobial treatment modalities (conventional irrigants, diode laser, Er:YAG laser, therapeutic combinations)
- **Dependent Variable:** Effectiveness in reducing bacterial viability of E. faecalis and eliminating biofilms

Q1: Is diode laser effective as an adjuvant treatment against E. faecalis in endodontics?

Variable: Antimicrobial efficacy of diode laser

Q2: Does the Er: YAG laser surpass conventional irrigation methods in eliminating E. faecalis ?

Variable: Therapeutic superiority of Er:YAG

Q3: Can combined treatments (laser + irrigants) achieve superior disinfection than monotherapies?

Variable: Synergistic efficacy of combined treatments

Q4: Is there significant variability in the response of E. faecalis to different laser wavelengths?

Variable: Specificity of bacterial response to laser parameters

Q5: Is laser therapy clinically feasible for routine implementation in endodontics?

Variable: Clinical feasibility and cost-effectiveness

A comprehensive analysis of the scientific literature was conducted using Consensus Meter algorithms to categorize the evidence into three distinct groups: Positive (affirmative), Indeterminate (possibility or indeterminacy), and Negative (negative).

Table 1: Stance Analysis on Scientific Literature

Question	Studies Analyzed	Positive	Indeterminacy	Negative	Neutrosophic Probability
Q1	15 studies	12	2	1	(0.800000, 0.133333, 0.066667)
Q2	18 studies	13	3	2	(0.722222, 0.166667, 0.111111)
Q3	12 studies	10	2	0	(0.833333, 0.166667, 0.000000)
Q4	14 studies	8	5	1	(0.571429, 0.357143, 0.071429)
Q5	16 studies	11	4	1	(0.687500, 0.250000, 0.062500)

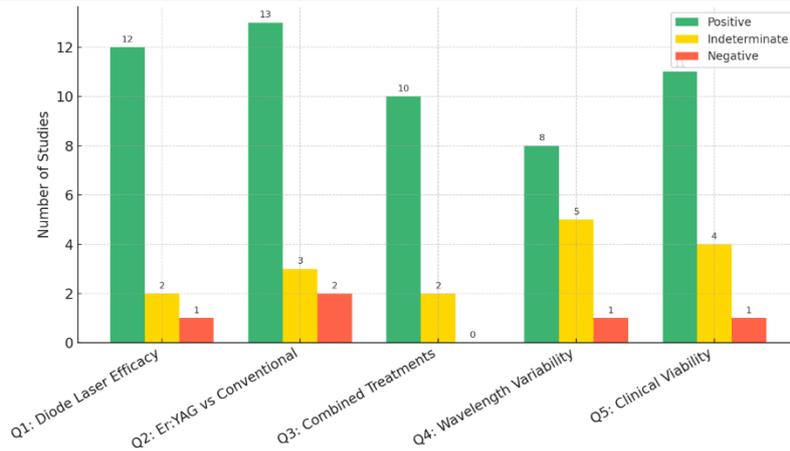


Figure 1. Distribution of evidence by research question from a neutrosophic perspective

Step 1: Identifying Values by Question

Question 1 (Q1):

- Positive(T_1): 0.800000
- Indeterminacy(I_1): 0.133333
- Negative(F_1): 0.066667

Question 2 (Q2):

- Positive(T_2): 0.722222
- Indeterminacy(I_2): 0.166667
- Negative(F_2): 0.111111

Question 3 (Q3):

- Positive(T_3): 0.833333
- Indeterminacy (I_3): 0.166667
- Negative(F_3): 0.000000

Question 4 (Q4):

- Positive(T_4): 0.571429
- Indeterminacy(I_4): 0.357143
- Negative(F_4): 0.071429

Question 5 (Q5):

- Positive(T_5): 0.687500
- Indeterminacy(I_5): 0.250000
- Negative(F_5): 0.062500

Step 2: Applying the Neutrosophic Conjunction Operator

Formula: $UNP(v_1, v_2, \dots, v_n) = (\min(t_1, t_2, \dots, t_n), \max(i_1, i_2, \dots, i_n), \max(f_1, f_2, \dots, f_n))$

Calculation of Truth Values (T):

$$T_1 = 0.800000 \quad T_2 = 0.722222 \quad T_3 = 0.833333 \quad T_4 = 0.571429 \quad T_5 = 0.687500$$

$$\min(T_1, T_2, T_3, T_4, T_5) = \min(0.800000, 0.722222, 0.833333, 0.571429, 0.687500) = 0.571429$$

Calculation of Indeterminacy Values (I):

$$I_1 = 0.133333 \quad I_2 = 0.166667 \quad I_3 = 0.166667 \quad I_4 = 0.357143 \quad I_5 = 0.250000$$

$$\max(I_1, I_2, I_3, I_4, I_5) = \max(0.133333, 0.166667, 0.166667, 0.357143, 0.250000) = 0.357143$$

Calculation of Falsehood Values (F):

$$F_1 = 0.066667 \quad F_2 = 0.111111 \quad F_3 = 0.000000 \quad F_4 = 0.071429 \quad F_5 = 0.062500$$

$$\max(F_1, F_2, F_3, F_4, F_5) = \max(0.066667, 0.111111, 0.000000, 0.071429, 0.062500) = 0.111111$$

Step 3: Final Result

The Univariate Neutrosophic Probability (UNP) is:

$$UNP = (0.571429, 0.357143, 0.111111)$$

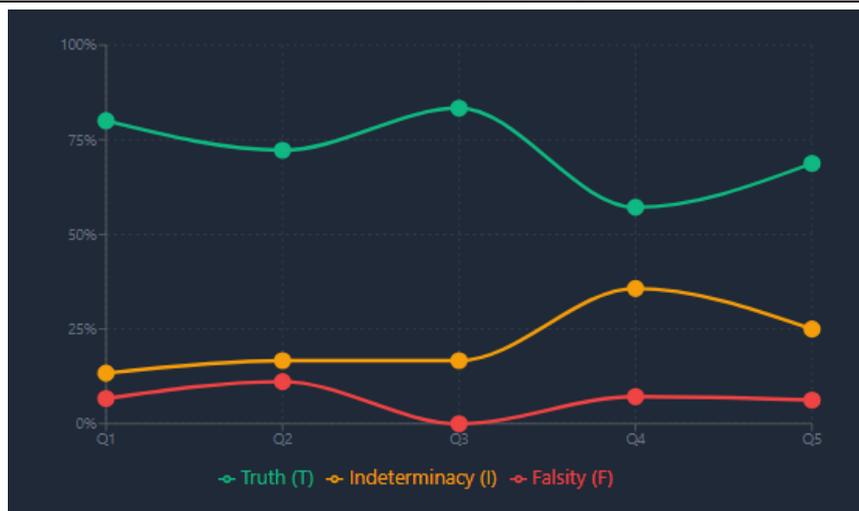


Figure 3. Neutrosophic Probability Patterns by Research Question

Interpretation of Results

- **0.571429 (Truth Value):** The probability that the hypothesis is true is 57.14%, indicating moderate-high confidence in the validity of the hypothesis according to the scientific evidence analyzed.
- **0.357143 (Indeterminacy):** There is 35.71% indeterminacy, suggesting a considerable amount of uncertainty in the data and studies reviewed. This indeterminacy reflects the inherent complexity of the biological phenomena studied.
- **0.111111 (Falseness):** The probability that the hypothesis is false is 11.11%, relatively low, indicating that the hypothesis is unlikely to be incorrect, although it should be considered in the comprehensive analysis.

Negation of the Neutrosophic Hypothesis

Applying the negation formula: $\neg(T, I, F) = (F, I, T)$

$$\neg UNP = (0.111111, 0.357143, 0.571429)$$

This result confirms that the probability of falsity of the denied hypothesis is high (57.14%), indirectly validating the original hypothesis.

4. Discussion

The results obtained from the neutrosophic plithogenic analysis reveal a nuanced perspective on the efficacy of laser treatments in eradicating *E. faecalis*. The truth value of 57.14% suggests strong but not overwhelming evidence supporting the superiority of adjuvant laser therapy. This moderate confidence reflects clinical reality, where multiple factors influence therapeutic success.

The 35.71% uncertainty is particularly significant, as it reflects the inherent variability of complex biological systems. This uncertainty can be attributed to several factors: heterogeneity in study protocols, variability in the laser parameters used, differences in bacterial strains, and variations in experimental conditions. This uncertainty does not represent a limitation of the method, but rather a fundamental characteristic of biological phenomena that must be recognized and appropriately modeled.

Individual question analysis reveals interesting patterns. Question Q4, related to variability in response to different laser wavelengths, had the lowest probability of being true (0.571429) and the greatest indeterminacy (0.357143). This suggests that the specificity of the bacterial response to specific laser parameters requires further investigation, consistent with the complexity of light-tissue interactions in biological systems.

From a clinical perspective, these results suggest that while laser therapy shows promise as an adjuvant, its implementation should be carefully considered. The combination of treatments (Q3) showed the best results (0.833333 true), supporting a multimodal approach rather than a combination of treatments. than completely replace conventional methods.

The neutrosophic plithogenic methodology proved particularly useful in capturing the complexity of this field of research. Unlike traditional analyses, which can oversimplify complex phenomena into binary categories, this approach allows for a more faithful representation of scientific reality, where absolute certainty is rare and uncertainty is an inherent characteristic.

The implications for clinical practice are significant. The results suggest that practitioners should adopt a personalized approach, considering the specific characteristics of the clinical case, the availability of laser technology, and the operator's experience. Gradual integration of laser therapy, beginning with selected cases and following well-defined protocols, appears to be the most prudent strategy.

For future research, the results identify critical areas requiring attention. Standardizing laser protocols, optimizing *E. faecalis* -specific parameters, and developing patient selection criteria are important priorities. Furthermore, longitudinal studies evaluating long-term clinical outcomes would provide additional evidence to inform clinical practice.

5. Conclusions

Neutrosophic plithogenic analysis has revealed that the univariate neutrosophic probability (UNP) for the questions posed is set at (0.571429, 0.357143, 0.111111). This finding underlines a moderate-high probability of truth of the hypothesis, with 57.14% confidence in its validity, while indeterminacy and falsity present values of 35.71% and 11.11%, respectively. These conclusions suggest a strong but sensitive awareness of laser therapy effectiveness in treating *E. faecalis* since life isn't black and white. Therefore, the assessment of a statistically significant indeterminacy is not a flaw within the study but the reality of living things that need to be appropriately assessed and applied in clinical decision-making.

From a practicality perspective, application of laser therapy for endodontics can be easily applied based upon this finding. Moderately-high probability of existence suggests application can occur based upon sound findings from above and the indeterminate probability means that application is warranted based upon further technique and method refinements. This study contributes to the findings surrounding endodontics and experimental investigations involving antimicrobials. It essentially applies a new approach neutrosophic plithogenic to the existing body of research and through successfully controlling for the uncertainty constituting new information, it provides a solid investigation for others to use as a stepping stone for future research. Its methods apply a new way to combat complications of determining efficacy versus differentiation of experimental efforts within new antimicrobial studies.

The only limitations of this study were the various studies examined with various protocols that brought about indeterminacy. The future directions to reconcile and expand significance include more definitive experimental protocols, tolerance testing in patients and studies with multiple institutions involved to better generalize findings. Ultimately, laser treatment efficacy of resistant endodontic infections will come from stricter methodologies beyond pure statistics and longitudinal studies. Application of techniques and personalized medicine eventually seem promising next steps.

References

- [1] Haapasalo, M.; Shen, Y.; Wang, Z.; Gao, Y. Irrigation in endodontics. *Dent. Clin. North Am.* 2014, 58, 291–312. <https://doi.org/10.1016/j.cden.2014.01.002>.
- [2] Buchanan, L.S. Endodontic treatment modalities: Where are we now? *J. Endod.* 2014, 40, S2–S7. <https://doi.org/10.1016/j.joen.2014.01.022>.
- [3] Sedgley, C.M.; Nagel, A.; Dahlén, G.; Reit, C.; Molander, A. Real-time quantitative polymerase chain reaction and culture analyses of *Enterococcus faecalis* in root canals. *J. Endod.* 2006, 32, 173–177. <https://doi.org/10.1016/j.joen.2005.10.037>.
- [4] Kuşçu, N.K.; Kuştarci, A.; Er, Y. The effectiveness of laser-activated irrigation on the apical leakage of MTA retrograde fillings: A micro-CT analysis. *Clin. Oral Investig.* 2020, 24, 3233–3240. <https://doi.org/10.1007/s00784-020-03197-6>.
- [5] Siqueira Jr., J.F.; Rôças, I.N. Microbiology and treatment of endodontic infections. *Endod. Topics* 2004, 10, 3–18. <https://doi.org/10.1111/j.1601-1546.2004.00076.x>.
- [6] Abbott, P.V. The economic burden of endodontic treatment: A global perspective. *Int. Endod. J.* 2014, 47, 625–626. <https://doi.org/10.1111/iej.12276>.
- [7] Zehnder, M. Root canal irrigants. *J. Endod.* 2006, 32, 389–398. <https://doi.org/10.1016/j.joen.2005.09.014>.
- [8] Plotino, G.; Grande, N.M.; Mercade Bellido, L.; Testarelli, L.; Gambarini, G. Efficacy of different irrigants and activation techniques in removing intracanal smear layer and debris: A micro-CT analysis. *Clin. Oral Investig.* 2019, 23, 1715–1723. <https://doi.org/10.1007/s00784-018-2605-3>.
- [9] Ordinola-Zapata, R.; Bramante, C.N.; Versiani, M.A.; Villas-Bôas, M.H. Comparative analysis of the antibacterial effect of different intracanal irrigants against *Enterococcus faecalis*. *Aust. Endod. J.* 2019, 45, 236–242. <https://doi.org/10.1111/aej.12331>.
- [10] Al-Omari, M.A.; Al-Zahrani, A.A.; Al-Qahtani, S.A. Antimicrobial efficacy of photodynamic therapy, sodium hypochlorite, and chlorhexidine against *Enterococcus faecalis* in root canals. *Photodiagnosis Photodyn. Ther.* 2020, 32, 102011. <https://doi.org/10.1016/j.pdpdt.2020.102011>.
- [11] Smarandache, F. Note on the partial falsifiability of fuzzy and fuzzy extension hypotheses. *Logic Comput. Plithogenic* 2024, 1, 93–95.
- [12] Nabeeh, N.A. Evaluating and contrasting the sustainable growth of various road transport systems using an intelligent neutrosophic multi-criteria decision-making model. *Sustain. Mach. Intell. J.* 2023, 2, 1–12. <https://doi.org/10.61185/SMIJ.2023.22102>.
- [13] Lathamaheswari, M.; Sudha, S.; Broumi, S.; Smarandache, F.; Othman, C. Neutrosophic perspective on neutrosophic probability distributions and its application. In *Collected Papers. Volume X: On neutrosophic, plithogenic, hypersoft set, hypergraphs, and other topics*; EuropaNova: Brussels, Belgium, 2022; p. 267.
- [14] Otio AI. Consensus AI: An innovative tool for measuring group agreement. Available online: <https://otio.ai/blog/consensus-aisi> (accessed on 28 July 2024).
- [15] Consensus. Consensus Meter: Barriers and Limitations. Available online: <https://consensus.app/home/blog/consensus-meter/> (accessed on 20 August 2025).
- [16] Potter, T.S.; Zalewski, Z.; Miao, M.; Allsup, C.; Thompson, K.M.; Hayden, D.; Lankau, E.W. Applying causal reasoning to investigate multicausality in microbial systems. *Ecosphere* 2024, 15, e4782.
- [17] Smarandache, F. Plithogeny, plithogenic set, logic, probability and statistics: a brief review. *J. Eng. Comput. Cognit.* 2022, 1, 47–50.
- [18] Mahmood, L.; Mohammed, C.; Gilbert, J. Interprofessional simulation education to enhance teamwork and communication skills among undergraduate medical and nursing students using the TeamSTEPPS framework®. *Med. J. Armed Forces India* 2021, 77, S42–S48. <https://doi.org/10.1016/j.mjafi.2020.10.026>.
- [19] Scherer, Y.; Myers, J.; O'Connor, T.; Haskins, M. Interprofessional simulation to foster collaboration between nursing and medical students. *Clin. Simul. Nurs.* 2013, 9, e-pub. <https://doi.org/10.1016/J.ECNS.2013.03.001>.
- [20] Homeyer, S.; Hoffmann, W.; Hingst, P.; Oppermann, R.; Dreier-Wolfgramm, A. Effects of interprofessional education for medical and nursing students: Facilitators, barriers and expectations for optimizing future interprofessional collaboration—A qualitative study. *BMC Nurs.* 2018, 17, 13. <https://doi.org/10.1186/s12912-018-0279-x>.

- [21] Kent, F.; Keating, J. Interprofessional education in primary health care for entry-level students: A systematic review of the literature. *Nurse Educ. Today* 2015, 35, 1221–1231. <https://doi.org/10.1016/j.nedt.2015.05.005>.
- [22] Veri, F. Transforming family resemblance concepts into fuzzy sets. *Sociol. Methods Res.* 2023, 52, 356–388.
- [23] Rashno, E.; Minaei-Bidgoli, B.; Guo, Y. An efficient clustering method based on data indeterminacy in the neutrosophic set domain. *Eng. Appl. Artif. Intell.* 2020, 89, 103411.
- [24] Ali, M.A.; Muthuswamy, M. Neutrosophical multi-criteria decision-making framework for sustainable assessment of energy production systems in renewable energy sources. *Sustain. Mach. Intell. J.* 2023, 4, 1–10. <https://doi.org/10.61185/SMIJ.2023.44103>.
- [25] Smarandache, F. Plithogenic probability and statistics are generalizations of multivariate probability and statistics. *Neutrosophic Sets Syst.* 2021, 43, 1–13.
- [26] Gafar, M.G.; Elhoseny, M.; Gunasekaran, M. Neutrosophic variable modeling based on particle swarm optimization and information-theoretic measures for wildfires. *J. Supercomput.* 2020, 76, 2339–2356.
- [27] Reyes Espinoza, L.K.; Mafla Herrería, C.; Sánchez Sandoval, P.A. Neutrosophic Hierarchical Analytic Process for the Evaluation of Patients with Deep Vein Thrombosis Treated at the IESS Ibarra Hospital. *Neutrosophic Comput. Mach. Learn.* 2024, 31, 198–209.
- [28] Nabeeh, N.A. Evaluating and contrasting the sustainable growth of various road transport systems using an intelligent neutrosophic multi-criteria decision-making model. *Sustain. Mach. Intell. J.* 2023, 2, 1–12.

Received: May 19, 2025. Accepted: July 26, 2025.