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Limitations to learning and participation using the Neutrosophic Analytic Hierarchy Process (NAHP)

Marianela Silva Sánchez [1], María Mederos-Machado [2], Maya Jara-Sen San [3], and Adrián García-Perdigon [4]

[1] Santa Elena Peninsula State University, Ecuador. msilva@upse.edu.ec
[2] Santa Elena Peninsula State University, Ecuador. mmederos@upse.edu.ec
[3] Technical University of Babahoyo, Ecuador. mjaras@utb.edu.ec
[4] University of La Laguna, Canary Islands, Spain. agarcipe@ull.edu.es

Abstract. This study is related to obstacles to learning and participation and is a quintessential concern in creating inclusive systems and systems based on equity. The principal investigator question is: what are the obstacles to participation and learning, and how can they be assessed? The phenomenon occurs relative to the world today because too many marginalized communities across the globe do not have access to this form of education; socioeconomic access can be limited. Assessing its relevance supports future policy implications and assessments because it increases awareness of communities not easily accessible and struggles with diversity and uncertain patterned systems. Despite the changes made to education over the years, new assessments still take a common weighted average without employing tools to understand the uncertainty surrounding human viewpoints regarding obstacles to learning. This study offers a solution, the Neutrosophic Analytic Hierarchy Process (NAHP). From the assessment of the collection method relative to the NAHP which sought qualitative and quantitative assessment through interviews/questionnaires posed to teachers/students, the results were assessed through the NAHP. The findings concluded that the biggest challenges were lack of opportunity/resources, social alienation, and lack of funding for teacher training. This study contributes theoretically to an applicable framework for assessing obstacles to learning and practically contributes to findings that note the need for continued teacher training and teacher policy for inclusion that can be applicable in diverse classrooms with diverse efforts at participation and learning.

Keywords: Educational Barriers, Learning, Participation, Neutrosophic Analytic Hierarchy Process, NAHP, Inclusion, Uncertainty.

1. Introduction

Inclusive education is essential for vulnerable communities and the stable and equitable development of countries. Yet barriers to learning and participation are consistent. Thus, vulnerable and underrepresented groups do not have access and participation opportunities. The purpose of this study is to identify barriers to learning and participation and evaluate their importance because the need to assess such a topic is more relevant than ever due to unequal developments in education and access opportunities [1]. The rationale investigates the implications of barriers to equity access and why developments have not made equity a stable focus. For example, developments in global sustainable development goals indicate that issues of equity and access are compromised with the potential to undermine the sustainable development goals efforts. For example, developments within international policy indicate that vulnerable, marginalized populations have not had proper access to educational opportunities [2,3]. Therefore, assessing where developments are more appropriate and where solutions can be found relies upon a feasibility study of barriers to learning/review which possesses the most problematic developments that should be championed first for inclusivity and opportunities. In recent years, there have been many world movements that highlight the need for inclusivity and educated participation, from integration movements in the early 1900s to universal defining policies supporting the right for everyone to have free, basic access to education [4,5]. Today, education has been transformed via globalization and technological advancement; however, access and inclusivity have complicated realities for assessing barriers to learning and participation across nations and societies [4]. Yet this assessment has one caveat: it fails to assess—it's not assessed relative to importance because it spans socio-cultural, and economic factors that are not always assessed comprehensively. Therefore, the question this research seeks to answer is how to assess educational barriers relative to their importance when humanity is filled with uncertainty. This question has not been sufficiently answered yet; therefore, assessments of educational barriers assume factors without understanding of uncertainty surrounding such educational experiences.

The literature is lacking on this phenomenon because, without an extensive study to include uncertainty, no one has truly figured out the proper assignment of educational constraints through systematic study (yet) [6]. Studies have shown under-resourcing, bias and discrimination, and improper training of teachers as significant constraints. However, few studies factor in indeterminacy into the equation which merely makes their findings limited to a part of a whole. This study's contribution will be generalizable and abstracted from theoretical foundations with an emphasis on inclusion. The discussed problem here is not one of a niche nature; millions of students worldwide are affected by inequitable developments that limit their potential to learn and move forward. Studies show that over 260 million children and adolescents are out of school worldwide; many constrained by structural issues [7,8]. Thus, such issues must be analyzed and recognized for education systems to come to truly be inclusive. This research intends to help promote this acknowledgment by being all-encompassing. The solution to the problem will be the use of the Neutrosophic Analytic Hierarchy Process (NAHP)[9] to provide for determination based on uncertainty. Since the phenomenon often is uncertain and comes from various points of view, this is the best way to create a hierarchy. The NAHP provides certain results based on uncertain inputs.

The importance of this research is both theoretical and practical—an application to learn of the potential variables and the ability to control them to create better educational policy. Thus, this research seeks to provide a foundation transferable to other realms of study by championing aspects of consideration and future rankings of obstacles. It's evident that the door has been opened for experimental participation in an ever-family-feeling world of education. Therefore, this study's purpose is twofold: 1) to identify and evaluate obstacles to learning and engagement; 2) to use the NAHP results to ease the constraints. These purposes align with the research question, help drive the article, and link results to relevance for academics and educators.

2. Materials and methods

2.1. Neutrosophic Set

Neutrosophic sets offer a brave new world in the area of set theory, as it contest the absolute true and false parameters by introducing a third element: indeterminate. Proposed by Florentin Smarandache, the neutrosophic theory asserts that a set can be made up of true elements and false elements—or—and this is the key addition—indeterminate elements; there are some elements for which it is not possible to say whether the elements are true or false [10]. This theory reflects the complexities of the real world, as so much of life is not black and white, but rather, in the gray. As such, agreeing with the idea of neutrosophic sets from both a mathematical and philosophical position falls in line with an effective means of controlling for uncertainty and the inevitability of things that may fall outside of rigid classification. Where fuzzy sets provide certain degrees of membership or interval sets provide ranges of sets, neutrosophic sets compile the uncollaborative components and uncertainties that so many human decisions can. On a mathematical scale, the ability to adopt such a set style furthers complex thinking, and on a real-world application scale, it gives areas like artificial intelligence the ability to computer more effectively when faced with conflicting or non-complete information [11]. When systems can welcome uncertainty as not an impediment, but rather, an effective compilation of potentially missing pieces, they become far more functional for human usage.

Yet others might argue that neutrosophic sets do more harm than good. By proposing that an indeterminate condition can exist, this can be taken as a flaw within linear set theory where specificity reigns supreme, and it complicates matters. However, this argument fails to recognize that in reality, appreciating an indeterminate element works where black and white does not; it is helpful to acknowledge that we do not know everything. With various applications that benefit from signaling such an awareness of the potential for indeterminacy and ambiguity, especially within artificial intelligence, this collection has greater possibilities for computing than to avoid a problem. In a world where duality reigns supreme, neutrosophic sets are a brave new world [12]. This theory takes philosophy and mathematics to the next level while championing deviations within the discipline for a more comprehensive understanding of human knowledge and human potential for decision-making. Ultimately, applying this theory across disciplines—from technology to social sciences—will create better systems and a more honest perspective of where we stand as humans in this complicated world—often without the right answers.

Definition 1 ([13-15]): The *neutrosophic set N* It is characterized by three membership functions, which are the truth membership function T_A, the indeterminacy membership functionI_A and falsehood membership function F_A , where U is the Universe of Discourse and $\forall x \in U$, $T_A(x), I_A(x), F_A(x) \subseteq]^-_A 0, 1^+[$, and $^-_A 0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$.

See that, by definition, $T_A(x), I_A(x)$ and $F_A(x)$ are standard or nonstandard real subsets of $]^-_A 0, 1^+[$and , hence $T_A(x), I_A(x)$and $F_A(x)$can be subintervals of $[0, 1]$. $^-0$and1^+ They belong to the set of hyperreal numbers.

Definition 2 ([13-15] : The *single- valued neutrosophic set (* SVN S) $A$is U, $T_A: U \rightarrow [0, 1]$where $A = \{< x, T_A(x), I_A(x), F_A(x) > : x \in U\}$and $I_A: U \rightarrow [0, 1]$. $F_A: U \rightarrow [0, 1]. 0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$

The single-valued neutrosophic number (SVN N) is symbolized by

$N = (t, i, f)$, such that$0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3 ([13-15]): The *single-valued triangular neutrosophic number,* $\tilde{a} = \langle (a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set in $\mathbb{R}$, whose truth, indeterminacy, and falsity membership functions are defined as follows:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, x = a_2 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), a_2 < x \leq a_3 \\ 0, \text{otherwise} \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\beta_{\tilde{a}}(x-a_1))}{a_2-a_1}, a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, x = a_2 \\ \frac{(x-a_2+\beta_{\tilde{a}}(a_3-x))}{a_3-a_2}, a_2 < x \leq a_3 \\ 1, \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2 - x + \gamma_{\tilde{a}}(x - a_1))}{a_2 - a_1}, a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a},} x = a_2 \\ \frac{(x - a_2 + \gamma_{\tilde{a}}(a_3 - x))}{a_3 - a_2},\ a_2 < x \leq a_3 \\ 1, \text{otherwise} \end{cases} \quad (3)$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0, 1]$,$a_1,\ a_2, a_3 \in \mathbb{R}$ and $a_1 \leq a_2 \leq a_3$.

Definition 4 ([13-15]): Given$\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and$\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued triangular neutrosophic numbers andλ any non-zero number on the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$,
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$,
3. Investment: $\tilde{a}^{-1} = \langle (a_3{}^{-1}, a_2{}^{-1}, a_1{}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3 \neq 0$.
4. Multiplication by a scalar number:

$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, \lambda > 0 \\ \langle (\lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, \lambda < 0 \end{cases}$$

5. Division of two triangular neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 > 0 \text{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 < 0 \end{cases}$$

6. Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1 b_1, a_2 b_2, a_3 b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle,\ a_3 > 0 \text{ and } b_3 > 0 \\ \langle (a_1 b_3, a_2 b_2, a_3 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 > 0 \\ \langle (a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 < 0 \end{cases}$$

Where,$\wedge$ it is a ty norm$\vee$ it is a conorm t.

The AHP technique begins with the designation of a hierarchical structure, where the elements at the top of the tree are more generic than those at the lower levels. The main leaf is unique and denotes the objective to be achieved in decision-making[16, 17].

The level immediately below this contains the sheets representing the criteria. The sheets corresponding to the sub-criteria appear immediately below this level, and so on. The level below this level represents the alternatives. See Figure 1.

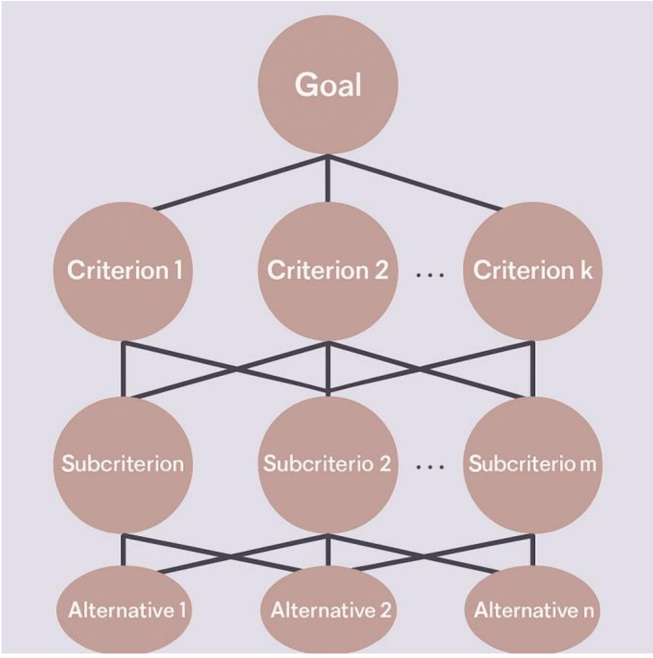

Figure 1: Schematic of a generic tree representing a Hierarchical Analytical Process

A square matrix is then formed that represents the opinion of the expert or experts and contains the pairwise comparison of the assessments of the criteria, sub-criteria, and alternatives.

TL Saaty, the founder of the original method, proposed a linguistic scale that appears in Table 1.

Table 1. Intensity of importance according to the classic AHP. Source [16-19].

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance of one over the other	Experience and judgment strongly favor one activity over another.
5	Essential or strong importance	Experience and judgment strongly favor one activity over another.
7	very strong importance	The activity is strongly favored and its mastery is demonstrated in practice.
9	Extremely important	The evidence that favors one activity over another is of the highest order of affirmation possible.
2, 4, 6, 8	Intermediate values between the two adjacent judgments.	When understanding is needed
Reciprocals	If activity i has one of the above numbers assigned compared to activity j , then j has the reciprocal value compared to i .	

On the other hand, Saaty established that the *Consistency Index* (CI) should depend on λ_{max}, the maximum eigenvalue of the matrix. He defined the equation $CI = \frac{\lambda_{max} - n}{n-1}$, where n is the order of the matrix. He further defined the *Consistency Ratio* (CR) with the equation CR = CI/RI, where RI is given in Table 2.

Table 2. RI associated with each order.

Order (n)	1	2	3	4	5	6	7	8	9	10
Rhode Island	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

If $CR \leq 10\%$we can consider that the experts' assessment is sufficiently consistent and therefore we can proceed to use AHP.

The objective of the AHP is to rank the criteria, sub-criteria, and alternatives according to a score. It can also be used in group decision-making problems. If this is the purpose, Equations 4 and 5 should be taken into account, where the expert's weight is evaluated based on their authority, knowledge, experience, etc [18].

$$\bar{x} = \left(\prod_{i=1}^{n} x_i^{w_i}\right)^{1/\sum_{i=1}^{n} w_i} (4)$$

If $\sum_{i=1}^{n} w_i = 1$, that is, when the expert's weights add up to one, Equation 4 becomes Equation 5,

$$\bar{x} = \prod_{i=1}^{n} x_i^{w_i} (5)$$

The hybridization of AHP with neutrosophic set theory was used in [19]. This is a more flexible approach to modeling uncertainty in decision-making. Indeterminacy is an essential component that must be assumed in real-world organizational decisions.

Table 3 contains the adaptation of the neutrosophic Saaty scale.

Table 3: The Saaty scale was translated into a neutrosophic triangular scale.

Saaty scale	Definition	Neutrosophic Triangular Scale
1	Equally influential	$\tilde{1} = \langle(1,1,1); 0.50, 0.50, 0.50\rangle$
3	Slightly influential	$\tilde{3} = \langle(2,3,4); 0.30, 0.75, 0.70\rangle$
5	Strongly influential	$\tilde{5} = \langle(4,5,6); 0.80, 0.15, 0.20\rangle$
7	Very influential	$\tilde{7} = \langle(6,7,8); 0.90, 0.10, 0.10\rangle$
9	Absolutely influential	$\tilde{9} = \langle(9,9,9); 1.00, 1.00, 1.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$ $\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$ $\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$ $\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

The pairwise neutrosophic comparison matrix is defined in Equation 6 .

$$\widetilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (6)$$

$\widetilde{A}$ satisfies the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, according to the inversion operator defined in Definition 4 .

In Abdel-Basset et al. [20] Two indices are defined to convert a neutrosophic triangular number into a sharp number. See Equation 7 for the *score* and Equation 8 for *accuracy.*

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (7)$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (8)$$

The algorithm to be applied to the NAHP is as follows:

Given the Criteria, sub criteria and alternatives, the NAHP consists of the following steps:

1. Design an AHP tree. It contains the selected criteria, sub criteria , and alternatives.
2. Create the level matrices from the AHP tree, according to expert criteria expressed in neutrosophic triangular scales and respecting the matrix scheme of Equation 6.
3. To evaluate the consistency of these matrices, convert the elements of $\widetilde{A}$ in a crisp matrix by applying Equation 7 or 8 and then testing the consistency of this new crisp matrix.
4. Follow the other steps of a classic AHP.
5. Equation 7 or 8 is applied to convert, w_1, w_2,…, w_n to crisp weights.
6. If more than one expert performs the assessment, then w_1, w_2,… , w_n are replaced by $\overline{w}_1, \overline{w}_2, \cdots, \overline{w}_n$, which are their corresponding weighted geometric mean values, see Equations 4 and 5 .

3. Results and Discussion.

This study addresses the assessment of barriers to learning and participation in inclusive educational settings, a persistent and multifaceted challenge affecting millions of students worldwide. The central question guiding this research is: How can educational barriers be effectively identified and prioritized, considering the uncertainty inherent in human perceptions?

The persistence of educational inequalities requires innovative approaches to understand and address the constraints that prevent full inclusion in education systems. Global statistics reveal that more than 260 million children and young people remain outside the education system due to structural barriers, underscoring the urgency of this analysis.

To address this challenge, the study employs the Neutrosophic Analytic Hierarchy Process (NAHP), a methodology that integrates uncertainty and ambiguity into decision-making. This approach captures and assesses the complexities of perceptions about educational barriers, providing a robust framework for identifying and prioritizing constraints in diverse educational contexts.

Four experts in inclusive education (university professors with experience in addressing diversity, educational consultants, directors of schools with inclusion programs, and specialists in special educational needs) were selected to assess and prioritize the main barriers to learning and participation. Each expert was given equal weight (w_i=1/4) for the analysis.

Identification of educational barriers

Based on the literature and expert judgment, seven main barriers to learning and participation were identified:

- **BE1** : Limitations in educational resources - Shortage of materials, technologies and support necessary to facilitate learning for all students.
- **BE2** : Traditional pedagogical practices - Rigid methodologies that do not adapt to the diversity of learning and participation methods.
- **BE3** : Inaccessible physical environments - Educational spaces that present architectural obstacles and non-inclusive designs.
- **BE4** : Insufficient teacher training - Lack of adequate preparation of teachers to address diversity in the classroom.
- **BE5** : Exclusionary educational policies - Regulatory frameworks that do not favor or hinder the inclusion of all students.
- **BE6** : Negative attitudes and stereotypes - Prejudices and misconceptions about diversity that generate discrimination.
- **BE7** : Limited family communication and participation - Low involvement and collaboration between families and educational institutions.

NAHP Assessment Procedure

Following the NAHP algorithm, the procedure was as follows:

1. Design of the hierarchical tree with the objective, criteria and alternatives.
2. Creating pairwise comparison matrices using neutrosophic triangular scales.
3. Conversion of neutrosophic matrices to sharp matrices.
4. Consistency check (CR ≤ 10%).
5. Calculation of weights for each barrier according to each expert.
6. Aggregation of evaluations using the weighted geometric mean.

This section presents the results of the assessment of barriers to learning and participation in educational settings, obtained through the application of the Neutrosophic Analytic Hierarchy Process (NAHP).

Expert evaluations

The four experts evaluated the seven educational barriers using pairwise comparison matrices based on the neutrosophic scale. The resulting matrices are presented below:

Table 4. Neutrosophic pairwise comparison matrix of Expert 1

Variable	BE1	BE2	BE3	BE4	BE5	BE6	BE7
BE1	1	1/2	1/3	1/3	1/3	1/3	1/2
BE2	2	1	2	1/2	1/2	1	1/3
BE3	3	1/2	1	1	1/3	1	2
BE4	3	2	1	1	1	1	1/3
BE5	3	2	3	1	1	2	1
BE6	3	1	1	1	1/2	1	2
BE7	2	3	1/2	3	1	1/2	1

Table 5. Neutrosophic pairwise comparison matrix of Expert 2

Variable	BE1	BE2	BE3	BE4	BE5	BE6	BE7
BE1	1	1/3	1/3	1/2	1/2	1/3	1/3
BE2	3	1	1	1/3	1/2	2	1/2
BE3	3	1	1	2	1	1/3	1
BE4	2	3	1/2	1	1	1/2	2
BE5	2	2	1	1	1	1	1
BE6	3	1/2	3	2	1	1	1
BE7	3	2	1	1/2	1	1	1

Table 6. Neutrosophic pairwise comparison matrix of Expert 3

Variable	BE1	BE2	BE3	BE4	BE5	BE6	BE7
BE1	1	1/3	1/2	1/2	1/3	1/3	1
BE2	3	1	1/3	1/2	2	1/2	1/2
BE3	2	3	1	1	1/3	1	1
BE4	2	2	1	1	1/2	2	2
BE5	3	1/2	3	2	1	1	1
BE6	3	2	1	1/2	1	1	2
BE7	1	2	1	1/2	1	1/2	1

Table 7. Neutrosophic pairwise comparison matrix of Expert 4

Variable	BE1	BE2	BE3	BE4	BE5	BE6	BE7
BE1	1	1/2	1/3	1/3	1/3	1/3	1/2
BE2	2	1	2	1/2	1/2	1	1/2
BE3	3	1/2	1	1	1/3	1	1
BE4	3	2	1	1	1	1	1
BE5	3	2	3	1	1	2	1/3
BE6	3	1	1	1	1/2	1	1/2
BE7	2	2	1	1	3	2	1

Consistency check

The calculation of the Consistency Ratios (CR) yielded the following results:

- Expert 1: CR = 8.4221%
- Expert 2: CR = 3.8753%
- Expert 3: CR = 4.9632%
- Expert 4: CR = 6.3278%

All evaluations showed CR ≤ 10%, confirming that the comparison matrices are consistent and valid for the analysis.

Weights of educational barriers

The following table shows the weights assigned by each expert to the seven educational barriers:

Table 8. Weights obtained for each barrier according to each expert

Expert/Variable	BE1	BE2	BE3	BE4	BE5	BE6	BE7
1	0.05826	0.11587	0.12358	0.14572	0.21439	0.14962	0.19256
2	0.05231	0.12047	0.13285	0.16428	0.14389	0.19653	0.18967
3	0.06124	0.11278	0.13156	0.18962	0.17542	0.16324	0.16614
4	0.05129	0.12158	0.11247	0.16825	0.19742	0.12586	0.22313

To obtain the total weight vector, the average of the weights assigned by each expert was calculated:

Table 9. Total vector of weights of educational barriers

Barrier	Average weight
BE1	0.05578
BE2	0.11768
BE3	0.12512
BE4	0.16697
BE5	0.18278
BE6	0.15881
BE7	0.19288

Ordering the barriers by importance: BE7 > BE5 > BE4 > BE6 > BE3 > BE2 > BE1

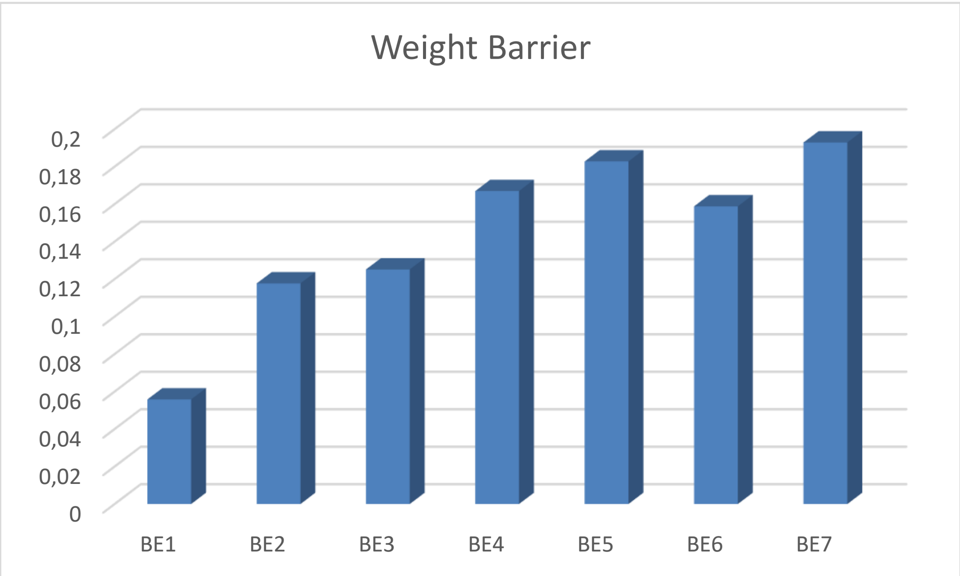

Figure 2. Total vector of weights of educational barriers.

Analysis of results

The NAHP results reveal that the most significant barriers to learning and participation are:

1. **Limited family communication and participation (BE7, 19.29%):** It emerges as the most important barrier, highlighting the fundamental role of family-school collaboration for inclusive educational success.

2. **Exclusionary educational policies (BE5, 18.28%):** Inadequate regulatory frameworks represent a significant structural obstacle to inclusion.
3. **Insufficient teacher training (BE4, 16.70%):** Teacher training to address diversity is positioned as a critical factor.
4. **Negative attitudes and stereotypes (BE6, 15.88%):** Prejudices and misconceptions constitute a major barrier to effective inclusion.

The barriers with less relative weight, although equally relevant, are:

5. **Inaccessible physical environments (BE3, 12.51%)**
6. **Traditional pedagogical practices (BE2, 11.77%)**
7. **Limitations in educational resources (BE1, 5.58%)**

Relationship between the variables studied

The NAHP analysis reveals significant interconnections between the identified barriers. These relationships can be viewed as a complex system where barriers reinforce each other:

1. **Relationship between policies and resources:** Exclusionary educational policies (BE5) directly influence the availability of resources (BE1). Inadequate regulatory frameworks often result in insufficient budget allocations for inclusive materials and support.
2. **Link between teacher training and pedagogical practices:** Inadequate teacher training (BE4) has a direct impact on the persistence of traditional pedagogical practices (BE2). Teachers without adequate training tend to reproduce rigid methodologies that fail to address diversity.
3. **Influence of attitudes on family participation:** Stereotypes and negative attitudes (BE6) significantly affect family communication and participation (BE7). Prejudices toward certain groups can alienate families, limiting their involvement in the educational process.
4. **Connection between policies and physical accessibility:** Educational policies (BE5) largely determine the accessibility of physical environments (BE3). The absence of regulations on universal design perpetuates architectural barriers.
5. **Exclusion-participation feedback loop:** Limited family participation (BE7) reinforces exclusionary policies (BE5) by reducing social pressure for change, creating a negative feedback loop.

This interconnectedness suggests that the most effective interventions will be those that address multiple barriers simultaneously, recognizing their systemic nature.

Recommendations

Based on the results of the NAHP analysis, the following recommendations are proposed to overcome barriers to learning and participation:

To improve family communication and participation (BE7)

- Implement structured family engagement programs that include a variety of schedules, formats, and communication channels.
- Establish liaisons between schools and families, especially for marginalized communities or those with language barriers.
- Develop educational activities that actively involve families in the learning process.
- Create shared decision-making spaces where families have a voice in relevant aspects of education.

To transform exclusionary educational policies (BE5)

- Review educational regulatory frameworks with the participation of diverse groups and representative organizations.
- Develop policies based on Universal Design for Learning (UDL).
- Establish evaluation and incentive systems that reward inclusive practices.
- Ensure specific funding for educational inclusion programs.

To strengthen teacher training (BE4)

- Reformulate initial training programs by incorporating specific skills in inclusive education.
- Implement ongoing professional development programs to address diversity.
- Create communities of practice and learning among teachers to share inclusive experiences.
- Establish mentoring between experienced inclusion teachers and new teachers.

To transform attitudes and stereotypes (BE6)

- Develop awareness campaigns aimed at the entire educational community.
- Incorporate diversity and inclusion content into the school curriculum.
- Promote positive contact between diverse students through collaborative projects.
- Make visible positive models of inclusion and educational success in diversity.

Other identified barriers

- **Physical environments:** Implement accessibility audits and progressive improvement plans.
- **Pedagogical practices:** Promote active, cooperative and personalized methodologies.
- **Educational Resources:** Develop and share accessible materials in open repositories.

The study demonstrates the effectiveness of the Neutrosophic Analytic Hierarchy Process (NAHP) for assessing barriers to learning and participation, providing an approach that integrates the uncertainty inherent in perceptions about complex educational phenomena.

The results highlight that the main barriers to educational inclusion go beyond purely material or physical aspects and focus on social, political, and professional dimensions. Family-school communication, educational policies, teacher training, and attitudes toward diversity emerge as critical factors requiring priority attention.

The interconnectedness of these different barriers suggests the need for systemic and coordinated interventions, rather than isolated efforts in specific areas. Addressing these limitations from a comprehensive perspective is essential for moving toward truly inclusive education systems.

This analysis contributes both to the theoretical field, offering an innovative methodological framework for assessing educational barriers, and to the practical sphere, providing specific guidelines for the design of policies and programs that promote educational inclusion.

4. Conclusion

This study was able to identify barriers and rank them via the Neutrosophic Analytic Hierarchy Process (NAHP) related to learning and participation in inclusive education, with findings revealing the top barriers are minimal family communication about learning opportunities, failure to adhere to mandated inclusive educational laws, non-state regulated necessity for teacher training, and extreme bias due to misinformed parents and trained school personnel. In addition to these barriers, they were also correlated through a significance that one barrier contributed to, or could be viewed as the effect of, another barrier. This is important because it recognizes the relative connectedness of barriers confounding the situation of education. Ultimately, the findings are significant for real-world application for education policymakers and school leaders. Suggested decisions such as outreach programs for family inclusion, state regulatory changes for compliance for inclusive policies like Universal Design for Learning, and associated training for teachers who want to teach diversity can change the essential microcosm of education to a more equitable one if these recommended actions are adopted. Furthermore, inclusive non-compliance will be diminished by allowing the opportunity for increased inclusion when previously these policies and actions were noncompliant, which is significant for a greater understanding of what inclusive education means. Finally, this research elevates the state of the art within inclusive education because of how NAHP is employed through data processing as a legitimate means to understand complicated systems in uncertainty. The contributions made are theoretical assessments when assessing barriers but also practical assessments of how one might prioritize solutions. The consideration of uncertainty and humanness can be adjusted and transformed to fit populations worldwide.

Of course, there are limitations to this study. First, because the results are based on perception, there may be subjectivity involved that influences certain elements of the findings. Second, applying this form of approach within a singular arena may limit one's ability to generalize the study findings into alternative communities to see if they hold. Thus, while the study is successful in creating something new, caution should be taken when assessing the findings of this study. For future research, it would be beneficial to combine this study with social network analysis or artificial intelligence social networking techniques to gain a more holistic view of comprehensive educational atmospheres. Testing these barriers across culture and geography would aid in legitimizing this work. It would also be interesting to see if developed barriers could emerge from rising technologies like digital learning systems. Ultimately, this study is a great first step in a vast direction toward equity and inclusion in education.

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