Neutrosophic Sets and Systems, {Special Issue: Neutrosophic and Plithogenic Approaches in Data Science and Multivariate Analysis: Contributions from the IX Ibero-American Biometry Meeting}, Vol. 89, 2025

University of New Mexico

Formative uncertainty and community perception in social engagement projects using Neutrosophic Z Numbers

Carlos Vélez[1*], Carla Espinoza[2], Manuel Espinoza[3], Fabrizzio Andrade Zamora[4], Óscar José Alejo Machado[5]

[1] Universidad César Vallejo, Peru. cvelezle31@ucvvirtual.edu.pe
[2] Instituto Superior Universitario Blue Hill College, Ecuador. carla.epsinoza@bluehill.edu.ec
[3] Universidad César Vallejo, Peru. mespinozaci87@ucvvirtual.edu.pe
[4] Instituto Superior de Investigaciones Científicas e Innovación (ISTICI), Ecuador. fabrizzio.andrade@istici.edu.ec
[5] Instituto Superior de Investigaciones Científicas e Innovación (ISTICI), Ecuador. oscar.alejo@istici.edu.ec

Abstract. This research addresses the gap of measuring social learning of social community projects, a controversial topic stemming from the subjectivity of all involved actors. It's a relevant topic because eventually, all community projects will need to be assessed for effective educational and social gains to ensure meaningful existence for sustainability purposes. However, the literature does not provide such assessments because actions are fuzzy or blended with communities and non-deterministic learning outcomes. This research attempts to assess the measurement of social learning of social community projects using Neutrosophic Z Numbers to bring uncertainty into the measurement equation. Beginning with a proposed community learn project as a hypothetic situation, the researcher then applies neutrosophic values to the quantitative and qualitative indicators of learning and viewpoints. Findings conclude that this solution works well for assessment since it represents uncertainty better than any particular value. The contribution of this research is twofold: the new solution for assessing social projects of a community nature with empirical findings applicable to project educational developments and policy efforts and a springboard for further investigation into the realm of uncertainty within dyadic, enhanced, social realms.

Keywords: Uncertainty, Social Learning, Community Perception, Neutrosophic Z Numbers, Social Engagement, Valuation, Modeling

1. Introduction

The assessment of social learning in community engagement projects is a fundamental pillar for ensuring the impact and sustainability of community initiatives. In a world where social and educational interactions confront dynamic and diverse contexts, understanding how communities perceive and evaluate these projects is essential. The relevance of this topic lies in its ability to inform educational policies and social intervention strategies that strengthen the community fabric. Recent studies highlight that social engagement projects not only foster skills and knowledge, but also promote collective cohesion and empowerment [1], [2]. However, the uncertainty inherent in the subjectivity of perceptions and educational outcomes poses significant challenges for effective evaluation.

Over the past few decades, social engagement projects have evolved from philanthropic initiatives to structured approaches that integrate community learning and engagement. In the 1970s, the concept of social learning began to gain traction, with an emphasis on collective capacity building [3]. Currently, globalization and technological advances have transformed these projects, incorporating multicultural dynamics and interdisciplinary approaches [4]. However, the literature points out that traditional evaluation methodologies, based on rigid metrics, often fail to capture the complexity of social contexts [5]. The central problem of this research lies in the difficulty of modeling uncertainty in the assessment of social learning and community perception. Factors such as the diversity of actors, subjective expectations, and dynamic environments generate ambiguity in the results. This leads to a key question: how can the educational and social impact of these projects be accurately assessed under conditions of uncertainty? The lack of tools that integrate this uncertainty limits the ability to design effective and sustainable interventions.

To address this issue, the study proposes the use of Neutrosophic Z Numbers, a mathematical tool that allows for modeling uncertainty by representing truth, falsity, and indeterminacy. This approach, applied to a hypothetical case of community education, seeks to capture the complexities of perceptions and learning outcomes. The research focuses on analyzing how communities value projects and how learning indicators can be assessed under uncertainty.

The magnitude of the problem is evident in contexts where social engagement projects operate in vulnerable communities, where perceptions can vary widely due to cultural, economic, and social factors [6]. The inability of conventional methodologies to address these variations reduces the effectiveness of interventions. This study aims to fill this gap by offering a framework that not only evaluates outcomes but also incorporates the ambiguity inherent in social processes. The relevance of this research transcends academia, as its findings can guide organizations and governments in designing more inclusive and effective projects. Modeling uncertainty opens the door to more robust evaluations that reflect the complex realities of communities. This is crucial in a global environment where sustainability and equity are priorities [7]. Integrating innovative approaches into social learning evaluation can transform the way these initiatives are implemented.

The study is structured around a hypothetical case simulating a community education project in a vulnerable region. Through the application of Neutrosophic Z Numbers, key indicators such as knowledge acquired, skills developed, and community satisfaction are analyzed. This approach allows not only to quantify results but also to interpret the uncertainty associated with perceptions, offering a more complete view of the impact.

The objectives of this study are: first, to develop a model based on Neutrosophic Z Numbers to assess social learning under uncertainty; second, to analyze community perceptions in social engagement projects; and third, to propose practical recommendations to improve the evaluation of these initiatives. These objectives are aligned with the research question and seek to contribute to both theory and practice in the field of social learning.

2. Preliminaries

2.1 . Social Commitment Projects

Social engagement projects represent an essential pillar for fostering community development, promoting active participation and collective learning in diverse contexts. These initiatives, which range from educational programs to health and environmental interventions, seek to generate positive and sustainable impacts in communities. Their relevance lies in their ability to connect individuals and organizations with local needs, strengthening the social fabric. However, evaluating their effectiveness poses challenges due to the complexity of social contexts and the inherent subjectivity of the perceptions of those involved. This analysis examines the importance, challenges, and value of social engagement projects, highlighting their role in community transformation. Historically, social engagement projects emerged as responses to inequalities and specific needs in vulnerable communities. From the community action movements of the 1960s to modern initiatives driven by non-governmental organizations, these interventions have evolved to integrate participatory and interdisciplinary approaches. Today, globalization and technological advances have allowed these projects to adopt innovative methodologies, such as the use of digital platforms to coordinate efforts

[8]. However, its success depends on the ability to adapt to the cultural and social dynamics of each community.

One of the key values of social engagement projects is their capacity to generate social learning. Through the interaction between actors—organizations, volunteers, and communities—skills, knowledge, and attitudes are developed that transcend the individual. This learning strengthens community cohesion and empowers participants to autonomously address local challenges. However, the diversity of perspectives and expectations among actors can generate uncertainty in the assessment of results, which requires more sophisticated evaluative approaches. Furthermore, these projects face significant challenges related to sustainability and participation. Dependence on external funding or a lack of continuity in interventions can limit their long-term impact. Furthermore, community perceptions vary according to cultural, economic, and political factors, making it difficult to measure results. For example, one community may value a project for its immediate impact, while another prioritizes its sustainability [9]. This variability highlights the need for tools that integrate subjectivity and uncertainty into evaluation. The implementation of social engagement projects requires careful design that considers the specific needs of each community. The active participation of beneficiaries at all stages—from planning to evaluation—is crucial to ensuring the relevance and legitimacy of interventions. Furthermore, interdisciplinary collaboration between educators, sociologists, and other professionals allows problems to be addressed from multiple perspectives, enriching the results. However, a lack of coordination between actors can lead to conflicts or duplication of efforts.

A key aspect for assessing these projects is their ability to foster equity and inclusion. Successful initiatives prioritize marginalized groups, such as women, children, and indigenous communities, ensuring that their voices are heard [10]. This approach not only addresses structural inequalities but also promotes a sense of belonging and empowerment. However, achieving genuine inclusion requires overcoming barriers such as limited access to resources or cultural resistance to change, which demands strategies tailored to each context. The evaluation of social engagement projects must go beyond traditional quantitative metrics, such as the number of beneficiaries or resources invested. Qualitative methods, such as interviews and focus groups, allow for capturing community perceptions and intangible changes, such as increased trust or social cohesion. In this sense, innovative approaches, such as those based on neutrosophic logic, can model the uncertainty inherent in these perceptions, offering a more complete view of the impact [11]. These tools are essential for overcoming the limitations of conventional methods.

From a critical perspective, social engagement projects are not without controversy. In some cases, interventions can be perceived as paternalistic or decontextualized, which generates rejection in communities. To avoid this, it is essential that projects be co-developed with beneficiaries, respecting their knowledge and priorities. The authenticity of community participation largely determines the legitimacy and success of these initiatives, which underscores the importance of participatory approaches.

The transformative impact of social engagement projects is evident in their ability to generate structural changes in communities. By promoting learning, equity, and sustainability, these initiatives contribute to human development and the construction of more just societies. However, their success depends on the ability to overcome challenges such as uncertainty, lack of resources, and the complexity of social dynamics. The integration of advanced evaluation tools and interdisciplinary collaboration are key steps to maximizing their effectiveness.

In conclusion, social engagement projects are a powerful vehicle for change, but their implementation and evaluation require a careful and contextualized approach. By addressing uncertainty and prioritizing community participation, these initiatives can generate lasting impacts. Their value lies not only in the immediate results but also in their ability to empower communities and foster inclusive and sustainable development, adapted to the realities of a constantly changing world.

2.2. Neutrosophic Z Numbers

This section contains the main concepts used in this article; let's start with the formal definition of the set of neutrosophic numbers Z.

Definition 1 ([12, 16]). Let *X be* a set of universes. A *neutrosophic number Z The set* in *X* is defined as follows:

$S_Z = \{\langle x, T(V,R)(x), I(V,R)(x), F(V,R)(x)\rangle : x \in X\}$ (1)

Where $T(V,R)(x) = (T_V(x), T_R(x))$, $I(V,R)(x) = (I_V(x), I_R(x))$, $F(V,R)(x) = (F_V(x), F_R(x))$are functions from X to $[0,1]^2$, which are the ordered pairs of truth, indeterminacy, and falsity, respectively. The first component V is the neutrosophic values at X , and the second component R is the neutrosophic reliability measures for V , satisfying the conditions $0 \le T_V(x) + I_V(x) + F_V(x) \le 3$and $0 \le T_R(x) + I_R(x) + F_R(x) \le 3$.

For convenience, we denote it $\langle x, T(V,R)(x), I(V,R)(x), F(V,R)(x)\rangle$as $S_Z = \langle T(V,R), I(V,R), F(V,R)\rangle = \langle (T_V, T_R), (I_V, I_R), (F_V, F_R)\rangle$what is called NZN.

Definition 2 ([12, 16]). Let$S_{Z_1} = \langle T_1(V,R), I_1(V,R), F_1(V,R)\rangle = \langle (T_{V_1}, T_{R_1}), (I_{V_1}, I_{R_1}), (F_{V_1}, F_{R_1})\rangle$ and$S_{Z_2} = \langle T_2(V,R), I_2(V,R), F_2(V,R)\rangle = \langle (T_{V_2}, T_{R_2}), (I_{V_2}, I_{R_2}), (F_{V_2}, F_{R_2})\rangle$ Let NZN and be two $\lambda > 0$. Then , we get the following relationships :

1. $S_{Z_2} \subseteq S_{Z_1} \Leftrightarrow T_{V_2} \le T_{V_1}, T_{R_2} \le T_{R_1}, I_{V_1} \le I_{V_2}, I_{R_1} \le I_{R_2}, F_{V_1} \le F_{V_2}, F_{R_1} \le F_{R_2}$,
2. $S_{Z_1} = S_{Z_2} \Leftrightarrow S_{Z_2} \subseteq S_{Z_1}$and $S_{Z_1} \subseteq S_{Z_2}$,
3. $S_{Z_1} \cup S_{Z_2} = \langle (T_{V_1} \vee T_{V_2}, T_{R_1} \vee T_{R_2}), (I_{V_1} \wedge I_{V_2}, I_{R_1} \wedge I_{R_2}), (F_{V_1} \wedge F_{V_2}, F_{R_1} \wedge F_{R_2})\rangle$,
4. $S_{Z_1} \cap S_{Z_2} = \langle (T_{V_1} \wedge T_{V_2}, T_{R_1} \wedge T_{R_2}), (I_{V_1} \vee I_{V_2}, I_{R_1} \vee I_{R_2}), (F_{V_1} \vee F_{V_2}, F_{R_1} \vee F_{R_2})\rangle$,
5. $(S_{Z_1})^c = \langle (F_{V_1}, F_{R_1}), (1 - I_{V_1}, 1 - I_{R_1}), (T_{V_1}, T_{R_1})\rangle$,
6. $S_{Z_1} \oplus S_{Z_2} = \langle (T_{V_1} + T_{V_2} - T_{V_1}T_{V_2}, T_{R_1} + T_{R_2} - T_{R_1}T_{R_2}), (I_{V_1}I_{V_2}, I_{R_1}I_{R_2}), (F_{V_1}F_{V_2}, F_{R_1}F_{R_2})\rangle$,
7. $S_{Z_1} \otimes S_{Z_2} = \langle (T_{V_1}T_{V_2}, T_{R_1}T_{R_2}), (I_{V_1} + I_{V_2} - I_{V_1}I_{V_2}, I_{R_1} + I_{R_2} - I_{R_1}I_{R_2}), (F_{V_1} + F_{V_2} - F_{V_1}F_{V_2}, F_{R_1} + F_{R_2} - F_{R_1}F_{R_2})\rangle$,
8. $\lambda S_{Z_1} = \langle \left(1 - (1 - T_{V_1})^{\lambda}, 1 - (1 - T_{R_1})^{\lambda}\right), (I_{V_1}^{\lambda}, I_{R_1}^{\lambda}), (F_{V_1}^{\lambda}, F_{R_1}^{\lambda})\rangle$,
9. $S_{Z_1}^{\lambda} = \langle (T_{V_1}^{\lambda}, T_{R_1}^{\lambda}), \left(1 - (1 - I_{V_1})^{\lambda}, 1 - (1 - I_{R_1})^{\lambda}\right), \left(1 - (1 - F_{V_1})^{\lambda}, 1 - (1 - F_{R_1})^{\lambda}\right)\rangle$.

To compare two NZNs that have $S_{Z_i} = \langle T_i(V,R), I_i(V,R), F_i(V,R)\rangle = \langle (T_{V_i}, T_{R_i}), (I_{V_i}, I_{R_i}), (F_{V_i}, F_{R_i})\rangle$(i = 1, 2), we have the scoring function:

$\Upsilon(S_{Z_i}) = \frac{2 + T_{V_i}T_{R_i} - I_{V_i}I_{R_i} - F_{V_i}F_{R_i}}{3}$ (2)

Note that $\Upsilon(S_{Z_i}) \in [0,1]$. Therefore, $\Upsilon(S_{Z_2}) \le \Upsilon(S_{Z_1})$implies $S_{Z_2} \preccurlyeq S_{Z_1}$.

Let's illustrate equation 2 with an example.

Example 1. Let $S_{Z_1} = \langle (0.9, 0.8), (0.1, 0.9), (0.2, 0.9)\rangle$, then we have $\Upsilon(S_{Z_1}) = \frac{2 + (0.9)(0.8) - (0.1)(0.9) - (0.2)(0.9)}{3} = 0.81666$.

Definition 3 ([12, 16]) **. Let** $S_{Z_i} = \langle T_i(V,R), I_i(V,R), F_i(V,R)\rangle = \langle (T_{V_i}, T_{R_i}), (I_{V_i}, I_{R_i}), (F_{V_i}, F_{R_i})\rangle$(i = 1, 2 , … , n) be a set of NZN and *NZNWAA* is a map from $[0,1]^n$into $[0,1]$, such that the operator NZNWAA is defined as follows:

$NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \sum_{i=1}^{n} \lambda_i S_{Z_i}$ (3)

Where is λ_i $(i = 1,2,\cdots,n)$the weight of S_{Z_i}satisfying $0 \le \lambda_i \le 1$and $\sum_{i=1}^{n} \lambda_i = 1$.

Thus, the NZNWAA formula is calculated as:

$$NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \langle \left(1 - \prod_{i=1}^{n}(1 - T_{V_i})^{\lambda_i}, 1 - \prod_{i=1}^{n}(1 - T_{R_i})^{\lambda_i}\right), \left(\prod_{i=1}^{n} I_{V_i}^{\lambda_i}, \prod_{i=1}^{n} I_{R_i}^{\lambda_i}\right), \left(\prod_{i=1}^{n} F_{V_i}^{\lambda_i}, \prod_{i=1}^{n} F_{R_i}^{\lambda_i}\right) \rangle \quad (4)$$

NZNWAA satisfies the following properties:

1. Is an NZN,
2. It is idempotent $NZNWAA(S_Z, S_Z, \cdots, S_Z) = S_Z$,
3. Note, $min\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\} \leq NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \leq max\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\}$,
4. Monotony, if $\forall i\ S_{Z_i} \preccurlyeq S_{Z_i}^{*}$then $NZNWAA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \preccurlyeq NZNWAA(S_{Z_1}^{*}, S_{Z_2}^{*}, \cdots, S_{Z_n}^{*})$.

Definition 4 ([12, 16]) **.** Let $S_{Z_i} = \langle T_i(V,R), I_i(V,R), F_i(V,R) \rangle = \langle (T_{V_i}, T_{R_i}), (I_{V_i}, I_{R_i}), (F_{V_i}, F_{R_i}) \rangle$(i = 1, 2 , … , n) be a set of NZN and *NZNWGA* be a map from $[0,1]^n$into $[0,1]$, such that the operator NZNWGA is defined as follows:

$$NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \sum_{i=1}^{n} S_{Z_i}^{\lambda_i} \quad (5)$$

Where is λ_i $(i = 1,2, \cdots, n)$the weight of S_{Z_i}satisfying $0 \leq \lambda_i \leq 1$and $\sum_{i=1}^{n} \lambda_i = 1$.

Therefore, the NZNWGA formula is calculated as:

$$NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) = \langle \left(\prod_{i=1}^{n} T_{V_i}^{\lambda_i}, \prod_{i=1}^{n} T_{R_i}^{\lambda_i}\right), \left(1 - \prod_{i=1}^{n}(1 - I_{V_i})^{\lambda_i}, 1 - \prod_{i=1}^{n}(1 - I_{R_i})^{\lambda_i}\right), \left(1 - \prod_{i=1}^{n}(1 - F_{V_i})^{\lambda_i}, 1 - \prod_{i=1}^{n}(1 - F_{R_i})^{\lambda_i}\right) \rangle \quad (6)$$

NZNWGA satisfies the following properties:

1. Is an NZN,
2. It is idempotent $NZNWGA(S_Z, S_Z, \cdots, S_Z) = S_Z$,
3. Note, $min\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\} \leq NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \leq max\{S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}\}$,
4. Monotony, if $\forall i\ S_{Z_i} \preccurlyeq S_{Z_i}^{*}$then $NZNWGA(S_{Z_1}, S_{Z_2}, \cdots, S_{Z_n}) \preccurlyeq NZNWGA(S_{Z_1}^{*}, S_{Z_2}^{*}, \cdots, S_{Z_n}^{*})$.

3. Material ans Methods

The study included a sample of 60 participants divided into two groups:

- Group A: 30 final-year students
- Group B: 30 recently graduated students (with less than one year of professional practice)

Inclusion criteria

- Regularly enrolled senior students
- Recent graduates with a degree issued by UNMSM
- Participants who signed the informed consent
- Ages between 22 and 35 years old

Exclusion criteria

- Participants with training in other institutions
- Students with more than 2 years of extracurricular professional experience
- Recent graduates with a specialization or postgraduate studies in progress
- Participants who did not fully complete the assessment instruments

Phases of the investigation

Phase I: Preparation and Consent An initial interview was conducted with participants to explain the study objectives, the methodology used, and data confidentiality. Written informed consent was obtained from all participants.

Phase II: Design and validation of the instrument A self-assessment questionnaire was designed that covered 14 professional competencies grouped into three domains:

1. Knowledge theoretical (4 competencies)
2. Skills clinics (6 competencies)
3. Interpersonal and professional skills (4 competencies)

The instrument was validated by a panel of 5 education experts using the Delphi method.

Phase III: Data Collection Participants completed the self-assessment questionnaire using a linguistic scale to assess their level of preparation in each competency, as well as their level of confidence in this assessment. The scale shown in Table 1 was used for this purpose.

Table 1: Linguistic truth and reliability values and their corresponding numerical value.

Numerical value equivalent	Reliability value linguistics	Truth value linguistic
0.1	Very insecure	Very low
0.3	Not very sure	Low
0.5	Not even sure neither insecure	Half
0.7	Sure	High
0.9	Very sure	Very high

Participants provided three ratings for each competency:

1. A couple of values about your level of preparation (truth value and reliability)
2. A pair of values about its level of indeterminacy (indeterminacy value and reliability)
3. A couple of values about your level of unpreparedness (falsehood and reliability value)

Phase IV: Neutrosophic data analysis The data obtained were analyzed using the following procedure:

1. Transformation of linguistic evaluations into neutrosophic Z numbers
2. Aggregation of competency ratings using the NZNWAA operator
3. Converting aggregate values to scores using the score function
4. Application of the Mann- Whitney U test to compare both groups

4. Results

This study explores the assessment of self-perceived competencies in a highly uncertain field such as social work. The aim is to apply an advanced mathematical model, based on **Neutrosophic Z Numbers (NZN)** , to more accurately capture the complex nature of professional assessment. This approach allows for modeling not only the degree of perceived knowledge (truth), but also doubt (indeterminacy) and the recognition of deficiencies (falsehood), along with confidence in said self-assessment. This approach seeks to offer a more robust and nuanced diagnosis than traditional methods.

The study was conducted with a sample of 60 participants, segmented into two homogeneous groups for effective comparison:

- **Group A:** 30 final-year students of the Social Work degree.

- **Group B:** 30 newly qualified social workers (with less than one year of professional experience).

Inclusion and Exclusion Criteria

- **Inclusion:** Current senior students, professionals with degrees from the reference university, signed informed consent, and ages between 21 and 34.
- **Exclusion:** Participants with prior training in other institutions, students with more than two years of formal professional experience, and professionals pursuing postgraduate studies.

Phases of the Investigation

1. **Phase I: Preparation and Consent:** Information sessions were held to explain the objectives and methodology, ensuring confidentiality and obtaining informed consent from all those involved.
2. **Phase II: Instrument Design:** A self-assessment questionnaire was designed with 14 key competencies, grouped into three fundamental domains for Social Work:
   - Knowledge and Planning (4 competencies)
   - Intervention Skills (6 competencies)
   - Interpersonal and Ethical Skills (4 competencies)
3. **Phase III: Data Collection:** Participants assessed their level of preparation and confidence in the assessment for each competency. A linguistic scale was used, the numerical values of which are presented in Table 1.

For each competency, participants provided three pairs of values, forming a Neutrosophic Z Number.

4. **Phase IV: Data Analysis:** The analysis followed a rigorous process:
   - Transformation of valuations to Neutrosophic Z Numbers (NZN).
   - Aggregation of ratings per participant using the **NZNWAA operator** .
   - Converting aggregated NZNs to numeric values using the **score function** .
   - Application of the nonparametric **Mann- Whitney U test** for group comparison.

3.1 Sociodemographic Data

Tables 2 and 3 summarize the demographic characteristics of the participants in both groups.

Table 2. Sociodemographic Data of Group A (Students)

Variable	Category	Frequency	Percentage
GENDER	Female	21	70%
	Male	9	30%
AGE RANGE	21-23	18	60%
	24-26	10	33.3%
	27-29	2	6.7%
TOTAL		**30**	**100%**

Table 3. Sociodemographic Data of Group B (Recent Graduates)

Variable	Category	Frequency	Percentage
GENDER	Female	19	63.3%
	Male	11	36.7%
AGE RANGE	23-25	11	36.7%
	26-28	16	53.3%
	29-32	3	10%
TOTAL		**30**	**100%**

3.2 Competence Assessment

To convert the neutrosophic ratings into a comparable numerical value, the scoring function was applied:

$$S(Z) = \frac{[(T \cdot R_T) + (1 - I) \cdot (1 - R_I) + (1 - F) \cdot (1 - R_F)]}{3}$$

Illustrative examples are presented below.

Table 4. Examples of Ratings for "Conflict Mediation"

NZN Rating	Detailed Calculation of the Scoring Function	Result
⟨ (0.7, 0.7), (0.5, 0.5), (0.3, 0.7) ⟩	[3(0.7·0.7) + (1-0.5)(1-0.5) + (1-0.3)(1-0.7)] / 3 = [0.49 + 0.25 + 0.21] / 3 = 0.95 / 3	0.316667
⟨ (0.5, 0.7), (0.5, 0.7), (0.5, 0.5) ⟩	[3(0.5·0.7) + (1-0.5)(1-0.7) + (1-0.5)(1-0.5)] / 3 = [0.35 + 0.15 + 0.25] / 3 = 0.75 / 3	0.250000
⟨ (0.9, 0.7), (0.1, 0.9), (0.1, 0.9) ⟩	[3(0.9·0.7) + (1-0.1)(1-0.9) + (1-0.1)(1-0.9)] / 3 = [0.63 + 0.09 + 0.09] / 3 = 0.81 / 3	0.270000
⟨ (0.7, 0.9), (0.3, 0.7), (0.1, 0.7) ⟩	[3(0.7·0.9) + (1-0.3)(1-0.7) + (1-0.1)(1-0.7)] / 3 = [0.63 + 0.21 + 0.27] / 3 = 1.11 / 3	0.370000

3.3 Aggregation of Ratings

Each participant's ratings for the 14 competencies were aggregated and converted into a final numerical score, as shown in Table 5, which forms the basis for statistical analysis.

Table 5. Aggregate Results and Score per Participant

Students (A)	Score	Newly Graduates (B)	Score
$\bar{x}(A_1)$	0.641	$\bar{x}(B_1)$	0.742
$\bar{x}(A_2)$	0.663	$\bar{x}(B_2)$	0.765
$\bar{x}(A_3)$	0.689	$\bar{x}(B_3)$	0.723
$\bar{x}(A_4)$	0.615	$\bar{x}(B_4)$	0.788
$\bar{x}(A_5)$	0.652	$\bar{x}(B_5)$	0.756
$\bar{x}(A_6)$	0.667	$\bar{x}(B_6)$	0.731
$\bar{x}(A_7)$	0.629	$\bar{x}(B_7)$	0.762
$\bar{x}(A_8)$	0.675	$\bar{x}(B_8)$	0.746
$\bar{x}(A_9)$	0.703	$\bar{x}(B_9)$	0.777
... (21 more)	...	... (21 more)	...
$\bar{x}(A_{30})$	0.664	$\bar{x}(B_{30})$	0.756

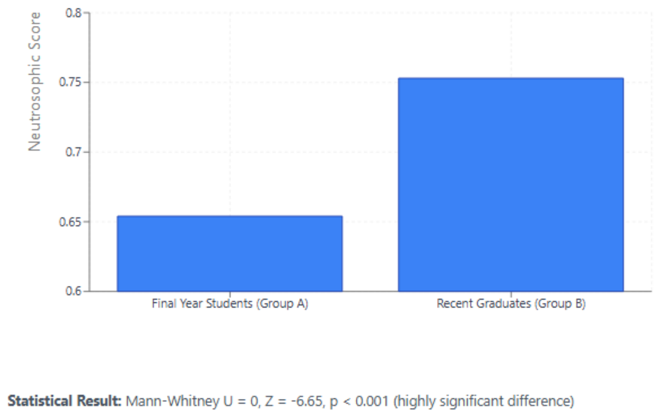

Figure 1: Average Competency Self-Assessment Scores by Group

3. 4 Detailed Statistical Analysis (Mann- Whitney U Test)

This non-parametric test was applied to compare the distributions of the scores of both groups and determine whether there were statistically significant differences.

- **Null Hypothesis (H_0):** There are no significant differences in self-perception of preparation between students and recent graduates.
- **Alternative Hypothesis (H_1):** There are significant differences.
- **Significance level (α): 0.05** .

Step 1: Sort and Rank the Data

The 60 scores were combined and ranked from lowest to highest. The analysis revealed **perfect separation** between the groups: all Group A scores were lower than those of Group B.

- The 30 participants in **Group A** (Students) occupied **ranks 1 to 30** .
- The 30 participants in **Group B** (Recent Graduates) ranked **31 to 60** .

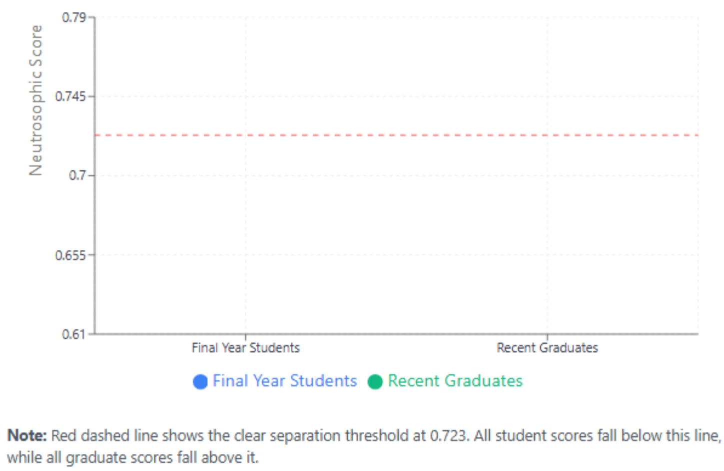

Figure 2: Distribution of Individual Competency Scores

Step 2: Add the Ranks of Each Group
Given the perfect separation, the sum of ranks is direct.

- **Sum of Ranks for Group A (R_1):** $R_1 = n_1(n_1+1)/2 = 30(31)/2 = 465$
- **Sum of Ranks for Group B (R_2):** $R_2 = n(n+1)/2 - R_1 = 60(61)/2 - 465 = 1830 - 465 = 1365$

Step 3: Calculate the U Statistics
The formulas with $n_1 = 30$ and $n_2 = 30$ are used.

- $U^1 = n^1n^2 + \frac{n^1(n^1+1)}{2} - R^1 = (30)(30) + 465 - 465 = 900$
- $U^2 = n^1n^2 + \frac{n^2(n^2+1)}{2} - R^2 = (30)(30) + 465 - 1365 = 0$

The test statistic U is the smaller of U_1 and U_2. **U = 0**

Step 4: Calculate the Z-statistic and the p-value
For large samples (n_1, $n_2 > 20$), the distribution of U approaches a normal one.

- **Mean of the distribution of U (μ_u):** $\mu_u = \frac{n^1n^2}{2} = \frac{30\cdot 30}{2} = 450$
- **Standard deviation of U (σ_u):** $\sigma_u = \sqrt{\left[\frac{n^1n^2(n^1+n^2+1)}{12}\right]} = \sqrt{\left[900\cdot\frac{61}{12}\right]} = \sqrt{4575} \approx 67.638749$
- **Calculation of the Z statistic:** $Z = \frac{U - \mu_u}{\sigma_u} = \frac{0 - 450}{67.638749} \approx -6.652797$

The Z value of **-6.65** is extremely low, corresponding to a **value$p < 0.001$.**

Statistical Analysis Conclusion: Since the p-value is practically zero, and therefore much lower than the significance level of $\alpha = 0.05$, **the null hypothesis (H_0) is rejected with maximum statistical certainty** . This clearly demonstrates that there are significant differences in the self-perception of professional preparation between final-year students and newly graduated social workers.

The findings of this study, enhanced by the granularity of the neutrosophic analysis, robustly confirm that newly graduated professionals have a significantly higher self-perception of their competencies than students. The categorical rejection of the null hypothesis ($U = 0, p < 0.001$)not only validates this gap, but also underscores its **magnitude and defining nature** .

The fundamental contribution of the **Neutrosophic Z-Numbers methodology** lies in its ability to go beyond a simple self-rating scale. By allowing participants to express their **indeterminacy** and **confidence** in their judgment, a more honest and complete view of self-perception was obtained. The abysmal difference between the groups suggests that the transition to professional practice is not merely a process of accumulating experience, but a **transformative event that reconfigures professional identity** . We argue that the initial experience acts as a catalyst that forces the integration of theoretical knowledge into a coherent praxis, a process that fundamentally **reduces the uncertainty and ambiguity** that characterize the final stage of academic training.

This study, therefore, not only confirms that recent graduates feel more prepared (higher Truth), but, more importantly, that they are more confident in their assessments (higher Confidence) and have fewer doubts about their abilities (lower Indeterminacy). This level of analysis is crucial for curriculum design, as it allows us to distinguish a knowledge gap from a confidence gap, each requiring distinct pedagogical interventions.

5. Conclusions

In conclusion, this research establishes a statistically irrefutable gap in the self-perception of competencies between final-year Social Work students and recently graduated professionals, with the latter reporting considerably higher levels of preparation. The initial professional experience acts as a decisive catalyst for developing confidence and consolidating practical skills, validating the theories of situated learning and learning-by-doing. The application of Neutrosophic Z-Numbers has been a superior methodological contribution, allowing for a richer and more precise assessment of formative uncertainty by modeling truth, indeterminacy, and confidence. This approach also made it possible to identify critical areas of uncertainty among students, offering a clear guide for curricular enhancement.

Based on these findings, it is recommended for academic training to increase high-fidelity practice opportunities, better integrate theory with practice, and add content on professional management and applied ethics. For recent graduates, it is suggested to develop mentoring and continuing education programs that facilitate the professional transition and collaborative learning. Finally, for future research, it is proposed to expand the study to other cohorts, conduct longitudinal follow-ups, and further explore the application of neutrosophic methodologies in the educational assessment of other social and health sciences.

References

[1] J. P. Carpenter, D. G. Krutka, How and Why Educators Use Social Media: A Systematic Review, Computers & Education, 146, 103749, (2020).

[2] M. T. Cole, D. J. Shelley, L. B. Swartz, Engaging Students Through Social Media: Evidence-Based Practices for Use in Student Affairs, Journal of College Student Development, 56(7), 747-753, (2015).

[3] A. Bandura, Social Learning Theory, Prentice-Hall, Englewood Cliffs, NJ, (1977).

[4] E. Wenger, Communities of Practice: Learning as a Social System, The Systems Thinker, 9(5), 2-3, (1998).

[5] P. Rossi, M. Lipsey, H. Freeman, Evaluation: A Systematic Approach, 7th ed., Sage Publications, Thousand Oaks, CA, (2004).

[6] C. A. Torres, Education and Neoliberal Globalization, Comparative Education Review, 54(3), 321-335, (2010).

[7] United Nations, Transforming Our World: The 2030 Agenda for Sustainable Development, General Assembly Resolution 70/1, p. 14, (2015).

[8] S. Bennett, A. X. Liu, D. Maton, Digital Technologies and Community Development: Exploring the Digital Divide, Information, Communication & Society, 22(5), 678-695, (2019).

[9] K. Cornwall, R. Jewkes, What is Participatory Research?, Social Science & Medicine, 41(12), 1667-1676, (1995).

[10] M. M. Gavazzi, J. F. Rodriguez, Community Engagement and Social Justice: Making a Difference Through Participatory Approaches, American Journal of Community Psychology, 65(3-4), 305-317, (2020).

[11] C. E. Shannon, W. Weaver, The Mathematical Theory of Communication, University of Illinois Press, Urbana, IL, (1949).

[12] F. Smarandache, Neutrosophic Logic - A Generalization of the Intuitionistic Fuzzy Logic, Journal of Multiple-Valued Logic and Soft Computing, 24(3-4), 287-304, (2015).

[13] E. U. Oti, M. O. Olusola, P. A. Esemokumo, Statistical Analysis of the Median Test and the Mann-Whitney U test, International Journal of Advanced and Applied Research, 7(9), 44-51, (2021).

[14] J. Ye, Generalized Distance-Based Similarity Measures of Neutrosophic Z-Number Sets and Their Multi-Attribute Decision-Making Method, Soft Computing, 25(22), 13975-13985, (2021).

[15] S. Du, J. Ye, R. Yong, F. Zhang, Some Neutrosophic Z-Number Aggregation Operators and Their Multi-Criteria Decision-Making Method, Complex & Intelligent Systems, 7, 429-438, (2021).

[16] F. Smarandache, Neutrosophic Statistics is an Extension of Interval Statistics, While Plithogenic Statistics is the Most General Form of Statistics (Fourth Version), Neutrosophic Computing and Machine Learning, 23, (2022).

Received: June 02, 2025. Accepted: July 13, 2025.