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# A Neutrosophic TwoFold Algebraic Framework for Modeling Uncertainty in University English Teachers' Development Competence in the Era of Big Data

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**Abstract-**In today's world, big data has changed the way we understand and measure teaching. For university English teachers, it is no longer easy to evaluate their true teaching performance. The information we collect about them can be uncertain, incomplete, or even confusing. Traditional methods do not fully capture this complexity. This study presents a new mathematical model based on Neutrosophic TwoFold Algebra. It allows us to represent each teaching skill with three parts. These are the degree of truth, the degree of uncertainty, and the degree of falsity. Together, they describe how much a teacher really has that skill, how unclear it is, and how much the skill is missing. We also introduce a new TwoFold operation. It combines two skills into one using a special formula. This formula includes mathematical operations that reflect how skills interact in real teaching environments where data is often mixed or unreliable. The model is designed to work with real educational data, even when that data is not perfect. This approach helps us better understand a teacher's full competence. It brings more accuracy to the evaluation process in a time when digital tools, online learning, and large data systems are everywhere.

**Keywords:** Neutrosophic TwoFold Algebra, teacher evaluation, big data, university education, competence model, uncertainty analysis, simple logic, neutrosophic sets.

## 1. Introduction

The role of English teachers in universities has become increasingly intricate in the digital era. The transition to online learning environments and the integration of advanced technologies have reshaped how educators engage with students. Beyond traditional competencies, such as lesson delivery or assignment evaluation, teachers are now expected to proficiently use digital platforms, interpret complex datasets, and respond to diverse learner needs in a technology-driven academic landscape [1]. This evolution necessitates a reevaluation of how teaching performance is assessed, moving toward methods that capture the multifaceted nature of modern education.

The advent of big data has revolutionized educational evaluation by providing vast amounts of information from sources like learning management systems, student feedback, and classroom analytics [2]. Yet, this data is frequently incomplete, ambiguous, or contradictory, posing challenges for traditional evaluation frameworks. Conventional systems, which often rely on rigid metrics or binary scoring, fail to adequately address the uncertainty and complexity inherent in educational data [3]. To address these shortcomings, a more robust and adaptable evaluation model is essential—one that accounts for both measurable performance and the uncertainties within the data.

This study introduces a pioneering evaluation framework based on Neutrosophic TwoFold Algebra, a hybrid mathematical structure designed to assess English teachers' skills in the big data age. Neutrosophic TwoFold Algebra represents each teaching skill with three components: truth, indeterminacy, and falsity. These components reflect the degree to which a skill is demonstrated, the uncertainty in the data, and any deficiencies in the skill, respectively. For example, a teacher may demonstrate strong proficiency in digital tool usage (high truth), but inconsistent student feedback could introduce indeterminacy, while limited classroom engagement might indicate some falsity [4]. This approach builds on the principles of neutrosophic sets, which generalize traditional fuzzy logic by incorporating indeterminacy as a distinct component [5].

The TwoFold Algebra was introduced by Smarandache in 2024 [6]. This is called a TwoFold Algebra because it has two types of algebras: (i) The first algebra is with respect to the elements x belonging to a set A (classical type algebra); (ii) and the second algebra is with respect to the neutrosophic components (t, i, f) or in general with respect to any fuzzy and fuzz-extension components of the elements. This is a hybrid structure, because a classical algebraic operation is inter-related with a fuzzy (or fuzzy extensions) operation.

To process these components, we propose the Neutrosophic TwoFold Law, a novel algebraic operation that combines teaching skills mathematically to produce a comprehensive assessment of a teacher's competence, even when data is incomplete or inconsistent [6]. Unlike classical algebraic models, this law operates on both the elements (skills) and their neutrosophic components (truth, indeterminacy, falsity), creating a hybrid structure suitable for heterogeneous and uncertain datasets [7]. By applying this model to real or simulated teaching scenarios, we aim to develop a fair, transparent, and flexible evaluation system that mirrors the complexities of modern university teaching.

This framework has practical implications for educational institutions seeking to evaluate teaching performance in data-rich environments. By embracing uncertainty and heterogeneity, the Neutrosophic TwoFold Algebra model offers a more nuanced understanding of teaching effectiveness, aligning with the demands of the big data era [8]. The subsequent sections of this paper outline the theoretical foundations of Neutrosophic TwoFold Algebra, define the Neutrosophic TwoFold Law, and demonstrate its application through case studies with detailed mathematical computations. Our objective is to provide a practical and innovative tool for assessing English teachers' skills in a rapidly evolving educational context.

## 2. Preliminaries and Basic Concepts

To build our evaluation model, we first need to understand the basic mathematical structures it is built on. These include Neutrosophic Sets and a special form called Neutrosophic TwoFold Algebra. In this section, we define these terms and explain how they apply to the evaluation of university English teachers.

### *2.1 Neutrosophic Sets*

A neutrosophic set is a mathematical way to describe information that is true, uncertain, and false at the same time. It was introduced by Florentin Smarandache to handle problems that contain unclear or conflicting data.

For any element x in a universe of study U, we define a neutrosophic value for that element as x(T,I,F) Where:

T is the degree of truth that the element has a certain property

I is the degree of indeterminacy or uncertainty

F is the degree of falsity

Each of these values is between 0 and 1, T,I,F∈[0,1] and usually, they satisfy:

0≤T+I+F≤3

This allows a very flexible way to model real-world knowledge, especially when things are not clear-cut.

### *2.2 TwoFold Structure*

In the traditional neutrosophic set, we describe one element by its T, I, F values. In Neutrosophic TwoFold Algebra, we go further. Each element is now seen from two sides:

1. The actual object or action (in our case, a teaching skill)
2. The degrees of truth, uncertainty, and falsity related to that object

So, a teaching skill like "digital content creation" will be written as $x_j(T_j, I_j, F_j)$

Here, $x_j$ is the skill (for example: online lesson planning), and ( $T_j, I_j, F_j$ ) shows how well this skill is performed, how unclear the evidence is, and how much the skill is missing.

In our model, each teacher has multiple skills. The full profile of a teacher is a set of TwoFold elements:

$$A = \{x_1(T_1, I_1, F_1), x_2(T_2, I_2, F_2), \dots, x_n(T_n, I_n, F_n)\}$$

Each element represents a separate skill. Together, they represent the teacher's total competence.

### 2.3 Neutrosophic TwoFold Law

To evaluate total competence, we must combine different skills mathematically. For this, we define a new operation called the TwoFold Law, written as:

$$x_1(T_1, I_1, F_1)\Delta x_2(T_2, I_2, F_2) = x_3(T_3, I_3, F_3)$$

We define the result using the following formulas:

$$T_3 = \sqrt{T_1 \cdot T_2}$$

$$I_3 = \frac{I_1 + I_2}{2}$$

$$F_3 = \frac{F_1 + F_2}{1 + |I_1 - I_2|}$$

These equations reflect how two skills interact in real-world situations. If both skills are strong (high $T$ ), their combined strength is also high. If uncertainty is present, it softens the final result. If falsity is high in either skill, and uncertainty is also high, the final result will show weakness.

### 2.4 Example of the Law

Let us take two skills for a teacher:

$x_1$ = "Using online teaching platforms"

$$(T_1 = 0.8, I_1 = 0.2, F_1 = 0.1)$$

$x_2$ = "Creating interactive materials"

$$(T_2 = 0.6, I_2 = 0.3, F_2 = 0.2)$$

Now we apply the TwoFold Law:

$$T_3 = \sqrt{0.8 \cdot 0.6} = \sqrt{0.48} \approx 0.6928$$

$$I_3 = \frac{0.2 + 0.3}{2} = 0.25$$

$$F_3 = \frac{0.1 + 0.2}{1 + |0.2 - 0.3|} = \frac{0.3}{1 + 0.1} = \frac{0.3}{1.1} \approx 0.2727$$

So the combined skill value is:

$$x_3(0.6928, 0.25, 0.2727)$$

This shows a strong but slightly uncertain skill with a moderate amount of weakness.

### 2.5 Why This Matters

This method gives us a way to:

i. Combine different aspects of teaching performance
ii. Reflect both strong and weak areas

iii. Handle uncertainty in student feedback or digital data
iv. Give a fair and flexible evaluation of the teacher

**3. The Evaluation Model and Proposed Law in Detail**

In this section, we explain the complete evaluation model. The model uses Neutrosophic TwoFold Algebra to measure the total competence of a university English teacher. It takes into account both the individual teaching skills and the uncertainty in how those skills are observed or reported. The model uses a step-by-step mathematical process to combine these skills into one final evaluation.

***3.1 The Structure of Evaluation***

Each teacher is evaluated based on a list of important skills. These are core abilities needed to teach English effectively at the university level. Examples include digital content creation, online communication, data-based decision making, and interactive lesson planning.

Each skill is represented as a TwoFold element $x_j(T_j, I_j, F_j)$

Where:

$x_j$ is the skill

$T_j$ is the truth level (how clearly the teacher shows this skill)

$I_j$ is the indeterminacy level (how uncertain the data is)

$F_j$ is the falsity level (how much the skill is missing)

Let us consider five common teaching skills and give them sample values. These values could come from expert review, student feedback, or automated learning analytics.

Tablde 1. Sample Evaluation Table

| Skill No. | Skill Name | Truth (T) | Indeterminacy (I) | Falsity (F) |
|---|---|---|---|---|
| $x_1$ | Use of digital platforms | 0.8 | 0.2 | 0.1 |
| $x_2$ | Digital material development | 0.7 | 0.3 | 0.2 |
| $x_3$ | Data-driven feedback | 0.6 | 0.4 | 0.3 |
| $x_4$ | Student engagement in class | 0.9 | 0.1 | 0.0 |
| $x_5$ | Curriculum planning with AI | 0.5 | 0.3 | 0.4 |

Table 1 shows the values for each skill. The truth value tells how well the teacher shows the skill. The indeterminacy reflects unclear or mixed data. The falsity value reflects weakness or gaps in that skill. These skills will be combined using our proposed law to compute an overall competence level.

**3.2 Algebraic Justification of the TwoFold Law**

This section provides mathematical justification for the TwoFold Law used to combine two neutrosophic elements that represent teaching skills. Each skill is defined by three values: truth $(T)$, indeterminacy $(I)$, and falsity $(F)$.

Let us consider two sample skills:

$x_a = (T_a = 0.8, I_a = 0.3, F_a = 0.2)$

$x_b = (T_b = 0.5, I_b = 0.5, F_b = 0.4)$

We define their combined result $x_c = (T_c, I_c, F_c)$ using the TwoFold Law:

$$T_c = \sqrt{T_a \cdot T_b} = \sqrt{0.8 \cdot 0.5} = \sqrt{0.4} \approx 0.6325$$

The use of the geometric mean ensures that if either skill is weak, the combined truth is moderated. This reflects the educational principle that consistent performance across all dimensions is required for strong competence.

Next, we compute the average indeterminacy:

$$I_c = \frac{I_a + I_b}{2} = \frac{0.3 + 0.5}{2} = \frac{0.8}{2} = 0.4$$

This reflects the idea that uncertainty accumulates from both sources and should be treated equally unless domain-specific weights are introduced.

Then, the falsity is computed as:

$$F_c = \frac{F_a + F_b}{1 + |I_a - I_b|} = \frac{0.2 + 0.4}{1 + |0.3 - 0.5|} = \frac{0.6}{1 + 0.2} = \frac{0.6}{1.2} = 0.5$$

Here, the denominator adjusts the contribution of falsity depending on the inconsistency of indeterminacy between the two inputs. A large difference in uncertainty makes the falsity less reliable, and the model reflects that by dampening its weight.

So, the resulting skill is: $x_c = (T_c \approx 0.6325, I_c = 0.4, F_c = 0.5)$

This result reflects a moderate skill strength, moderate uncertainty, and a relatively high lack of ability, all derived systematically.

**3.3 Logical Constraints of the Model**

To ensure that the outputs of the model are consistent with logical reasoning, we define a constraint on the combined sum of the neutrosophic components:

$$T_j + I_j + F_j \leq 2.5 \text{ for each skill } x_j$$

This constraint limits the total intensity of truth, uncertainty, and falsity to a realistic maximum. While neutrosophic logic allows up to 3.0, this upper bound prevents contradictory or overloaded states that would not make sense in practical evaluation.

Let us test two examples.
Example 1: Valid Input
Skill: $x_1 = (T = 0.7, I = 0.4, F = 0.5)$

Sum: $T + I + F = 0.7 + 0.4 + 0.5 = 1.6 \leq 2.5 \Rightarrow$ Valid

The total is below the limit. This is a typical real-world case where a teacher has decent performance, some confusion, and minor gaps.

Example 2: Invalid Input
Skill: $x_2 = (T = 1.0, I = 0.9, F = 0.8)$

Sum: $T + I + F = 1.0 + 0.9 + 0.8 = 2.7 > 2.5 \Rightarrow$ Invalid

This input violates the logical constraint. It suggests the teacher is fully skilled, completely uncertain, and highly lacking at the same time, which is illogical.

This constraint ensures that each skill's representation remains within bounds of logical consistency. It also serves as an internal validator: any evaluation exceeding this limit should be reviewed, flagged, or recalculated with corrected data.

**3.4 The Proposed Neutrosophic TwoFold Law**

To combine skills mathematically, we use the Neutrosophic TwoFold Law, defined as follows:
Given two skill elements:

$$x_a(T_a, I_a, F_a) \text{ and } x_b(T_b, I_b, F_b)$$

We define:

$$x_a \Delta x_b = x_c(T_c, I_c, F_c)$$

Where:

$$T_c = \sqrt{T_a \cdot T_b}$$
$$I_c = \frac{I_a + I_b}{2}$$
$$F_c = \frac{F_a + F_b}{1 + |I_a - I_b|}$$

This law reflects real-life teaching complexity. The truth values combine through a geometric mean to keep the result sensitive to low performance. The indeterminacy is averaged, and falsity is adjusted based on how different the uncertainty levels are. This captures the idea that falsity becomes more harmful when uncertainty is high.

### *3.5 Combining All Skills Using Weighted Average*

Now we compute the total evaluation. Each skill has a weight $w_j$, depending on its importance. For example, digital communication may be more important than curriculum planning.

Let the weights for the five skills be:

$$w_1 = 0.2, w_2 = 0.2, w_3 = 0.2, w_4 = 0.25, w_5 = 0.15$$

We compute the weighted average for the final competence values:

$$T_{\text{final}} = \sum_{j=1}^{5} w_j \cdot T_j = (0.2)(0.8) + (0.2)(0.7) + (0.2)(0.6) + (0.25)(0.9) + (0.15)(0.5) = 0.16 + 0.14 + 0.12 + 0.225 + 0.075 = 0.72$$

$$I_{\text{final}} = \sum_{j=1}^{5} w_j \cdot I_j = (0.2)(0.2) + (0.2)(0.3) + (0.2)(0.4) + (0.25)(0.1) + (0.15)(0.3) = 0.04 + 0.06 + 0.08 + 0.025 + 0.045 = 0.25$$

$$F_{\text{final}} = \sum_{j=1}^{5} w_j \cdot F_j = (0.2)(0.1) + (0.2)(0.2) + (0.2)(0.3) + (0.25)(0.0) + (0.15)(0.4) = 0.02 + 0.04 + 0.06 + 0.0 + 0.06 = 0.18$$

So the final result is:

$$\text{Final Competence Score } = (T = 0.72, I = 0.25, F = 0.18)$$

This means the teacher shows a high level of competence, but there is some uncertainty in the data, and a small amount of weakness in some areas.

### **3.6 Clarification of the Results**

The score shows that the teacher is mostly strong and confident in their skills, especially in engaging students and using digital tools. However, some skills like curriculum planning with AI are weaker and may need development. The moderate indeterminacy suggests that not all data is clear or consistent. This is typical in big data environments, where student feedback and digital activity logs may not always agree.

This mathematical approach allows education managers to look at teachers' strengths and weaknesses in a balanced, realistic, and data-sensitive way.

## **4. Case Study**

To show how the Neutrosophic TwoFold Algebra model works in practice, we will use a full case study. This case is based on a simulated English university teacher. The teacher is evaluated in five key skills. For each skill, the evaluator provides three values: truth (T), indeterminacy (I), and falsity (F). Each skill also has a weight that reflects how important the skill is in the teaching context.

Table 2. The five skills and their values

| Skill No. | Skill Description | TjT_jTj | IjI_jIj | FjF_jFj | wjw_jwj |
|---|---|---|---|---|---|
| x1x_1x1 | Use of online platforms | 0.9 | 0.1 | 0.1 | 0.25 |
| x2x_2x2 | Creating digital materials | 0.7 | 0.3 | 0.2 | 0.20 |
| x3x_3x3 | Providing data-driven feedback | 0.6 | 0.4 | 0.3 | 0.20 |
| x4x_4x4 | Engaging students in discussion | 0.8 | 0.2 | 0.1 | 0.20 |
| x5x_5x5 | Planning curriculum with big data | 0.5 | 0.4 | 0.5 | 0.15 |

Table 2 shows the simulated teacher profile with full neutrosophic values for each skill.

*Step 1: Weighted Aggregation of Truth Values*

We compute the total truth score $T_{\text{final}}$ using the formula:

$$T_{\text{final}} = \sum_{j=1}^{5} w_j \cdot T_j$$

$$T_{\text{final}} = (0.25)(0.9) + (0.20)(0.7) + (0.20)(0.6) + (0.20)(0.8) + (0.15)(0.5)$$

$$T_{\text{final}} = 0.225 + 0.14 + 0.12 + 0.16 + 0.075 = 0.72$$

Step 2: Weighted Aggregation of Indeterminacy Values

$$I_{\text{final}} = \sum_{j=1}^{5} w_j \cdot I_j$$

$$I_{\text{final}} = (0.25)(0.1) + (0.20)(0.3) + (0.20)(0.4) + (0.20)(0.2) + (0.15)(0.4)$$

$$I_{\text{final}} = 0.025 + 0.06 + 0.08 + 0.04 + 0.06 = 0.265$$

Step 3: Weighted Aggregation of Falsity Values

$$F_{\text{final}} = \sum_{j=1}^{5} w_j \cdot F_j$$

$$F_{\text{final}} = (0.25)(0.1) + (0.20)(0.2) + (0.20)(0.3) + (0.20)(0.1) + (0.15)(0.5)$$

$$F_{\text{final}} = 0.025 + 0.04 + 0.06 + 0.02 + 0.075 = 0.22$$

Step 4: Applying the Neutrosophic TwoFold Law Between Pairs

We will now show how to combine two skills step by step using the TwoFold Law:

Let's take:

$x_1(0.9,0.1,0.1)$

$x_2(0.7,0.3,0.2)$

Using the proposed formula:

$$T_3 = \sqrt{T_1 \cdot T_2} = \sqrt{0.9 \cdot 0.7} = \sqrt{0.63} \approx 0.7937$$
$$I_3 = \frac{I_1 + I_2}{2} = \frac{0.1 + 0.3}{2} = 0.2$$
$$F_3 = \frac{F_1 + F_2}{1 + |I_1 - I_2|} = \frac{0.1 + 0.2}{1 + |0.1 - 0.3|} = \frac{0.3}{1 + 0.2} = \frac{0.3}{1.2} = 0.25$$

Result:

$$x_1 \Delta x_2 = x_3(0.7937, 0.2, 0.25)$$

We can apply the same method between $x_3$ and $x_4$, and so on, to simulate layer-by-layer fusion of all skills. This is useful for building multi-layer competence models, but for simplicity in this paper, we focus on the weighted aggregation approach for the total score.

From the weighted calculations above, the teacher's final competence score is:

$$(T, I, F) = (0.72, 0.265, 0.22)$$

This result tells us that the teacher shows strong overall performance with 72% clarity or certainty. There is 26.5% uncertainty in the available data, and 22% of the behavior suggests weakness or missing skills. These results are realistic for modern teaching environments, where digital tools, student feedback, and data systems are not always consistent or fully reliable.

The model helps to clearly see where a teacher is strong and where support or training might be needed. It also allows for flexible decision-making when data is incomplete or partly unreliable.

**5. Comparative Analysis with a Classical Model**

This section compares the new Neutrosophic TwoFold model with a traditional method of evaluation. In classical systems, each skill is judged using only one value - usually a simple score like 0.8 or 0.9 . These models do not include uncertainty or missing information.

For example, if we use only the truth values (T) from our case study and apply weighted averaging, we get:

$$\text{Score} = (0.25)(0.9) + (0.20)(0.7) + (0.20)(0.6) + (0.20)(0.8) + (0.15)(0.5) = 0.72$$

This gives the same value as our neutrosophic $T_{\text{final}}$ , but it hides many important aspects.

It does not show that some skills may be unclear (indeterminate), or that some might be missing (falsity). The classical result looks clean, but it lacks meaning.

In contrast, our model provides:

$$(T, I, F) = (0.72, 0.265, 0.22)$$

This result is much richer. It gives decision-makers more detail. They can see not only how well a teacher performs, but also how certain the data is and where there are weaknesses. This makes the Neutrosophic model more useful and fair.

**6. Sensitivity Analysis**

Let us test how the model reacts when one input changes. This helps us understand how sensitive the model is to new or changing information.

We increase the indeterminacy (I) value for one skill. In the original data, the indeterminacy for "Providing data-driven feedback" was 0.4. Now, we change it to 0.6.

New indeterminacy list:

$$I = [0.1, 0.3, 0.6, 0.2, 0.4]$$

We recalculate the final indeterminacy:

$$I_{\text{final}} = (0.25)(0.1) + (0.20)(0.3) + (0.20)(0.6) + (0.20)(0.2) + (0.15)(0.4)$$

$$I_{\text{final}} = 0.025 + 0.06 + 0.12 + 0.04 + 0.06 = 0.305$$

Before the change, $I_{\text{final}}$ was 0.265 . Now it is 0.305 . This shows that the model responds clearly to changes. If there is more uncertainty in just one skill, the final result changes too. This helps give a more realistic view of performance.

**7. Interpretation of Boundary Cases**

To understand how the model behaves in extreme conditions, we look at two boundary cases.

*Case 1: A perfect teacher*

Let us assume all skills have perfect truth, with no uncertainty or falsity:

$$T = [1,1,1,1,1], I = [0,0,0,0,0], F = [0,0,0,0,0]$$

Final result:

$$(T_{\text{final}}, I_{\text{final}}, F_{\text{final}}) = (1,0,0)$$

This means the teacher has full skills, no unclear data, and no missing abilities.

*Case 2: A weak and uncertain teacher*

Now, assume low skill, high uncertainty, and missing ability:

$$T = [0.4,0.4,0.4,0.4,0.4], I = [0.6,0.6,0.6,0.6,0.6], F = [0.5,0.5,0.5,0.5,0.5]$$

Weighted average gives:

$$(T_{\text{final}}, I_{\text{final}}, F_{\text{final}}) = (0.4, 0.6, 0.5)$$

This means the teacher shows weak performance, a lot of uncertainty in the data, and strong signs of missing skills.

These examples show that the model works well for both strong and weak cases. It gives consistent and clear results, even when the situation is extreme.

## 5. Conclusion and Future Work

This paper introduced a new evaluation model for university English teachers by using Neutrosophic TwoFold Algebra. The model gives a structured way to assess teaching skills while handling incomplete or unclear data. It allows for three levels of meaning: how much a skill is present, how uncertain the data is, and how much the skill is lacking. By applying a specially designed TwoFold Law, the model shows how teaching skills can be combined into a total performance score. The case study provided full calculations that demonstrate how the method works. The results show realistic insights into both strengths and areas needing improvement.

Future work can expand the model to include more complex skill sets or to assess groups of teachers instead of individuals. It is also possible to connect the model with live data systems from learning platforms or student apps. This would allow real-time evaluation that reflects the dynamic nature of modern education. Another possible direction is to develop new algebraic rules that reflect different teaching environments, such as blended learning or AI-assisted classrooms. The flexibility of the neutrosophic approach makes it well suited for ongoing changes in higher education.

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