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A Tree Soft Set Framework for Evaluating Teaching Quality in University Physics Programs: Enhancing Precision and Decision-Making

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Abstract: Education in physics is at a crossroads. Numerous nations have middling or worse levels of scientific literacy, according to international research, and their students are viewed as being ill-equipped to handle the challenges going forward. The governmental level has acknowledged the necessity of high-quality development. The article focuses on evaluating physics education is taught and learned through experiments and real-world experiences. We propose a multi-criteria decision making (MCDM) approach to deal with various factors in evaluation of teaching quality in physics programs. We integrate the MCDM method with the Tree Soft Set (TSS) to show the relationship between the different nodes. The root node is the main objective in this study, the first level the main factors, and the second level is the sub factors. The MCDM is used with the single valued neutrosophic sets (SVNSs) to deal with vague data. We gathered five main factors and 15 sub factors in this equation. We compute the factors weights using the AHP method to build the pairwise comparison matrix to evaluate them.

Keywords: AHP Method; MCDM; University Physics Programs; Neutrosophic Sets; Teaching Quality.

1. Introduction and literature Review

Science, technology, and culture are changing dramatically as we approach the next millennium. Rapid advances in a variety of fields are leading to scientific and technical breakthroughs that have a profound impact on our daily lives and change our society. There is no immediate end in sight to the significant changes brought about by innovations in numerous industries, such as information and communication technology. A shift towards what is referred to as the "knowledge society" is now taking place in postindustrial society. Our society' most valuable resource and a major determinant of political decision-making is knowledge[1-2].

As an academic discipline, physics has a long and successful history of generating new knowledge that informs technological advancement and relates to a wide variety of human experience sizes. A new worldview that questions both naïve ideas and long-held philosophical convictions was produced by the physics program[3-4].

New information and communication technologies that have fundamentally altered our lives in recent decades are based on physics. Working at the forefront of emerging technology, physicists are likely to bring about even more significant developments. One important area for anticipated advancements in both physics and biosciences is the fascinating field of nanotechnology. Building models with a physical inspiration has helped people in various professions gain a better grasp of intricate processes[5-6].

Like most universalists, physicists excel in a wide range of professional domains, including the economy, the geo- and environmental sciences, engineering, computer science, medicine, and life sciences, to name a few[7-8]. Physics training's professional openness and universal orientation encompass a wide range of knowledge and skills that are highly beneficial not only in science fields closely related to physics but also in a wide range of subject areas, including those with a very "unphysical" appeal, such as risk assessment in insurance companies or stock market data analysis[9-10].

The multi-criteria decision making (MCDM) process must be understood before talking about AHP. MCDM techniques are useful for making significant judgments that are difficult to decide on directly. These days, a variety of MCDM techniques are accessible for choice. Understanding the broad features of many approaches is essential to choose the best one for this investigation[11-12].

It is evident that AHP performs very well when handling interdependent criteria and local difficulties that involve both quantitative and qualitative concerns. Since urban revitalization is frequently seen as a social issue, it is anticipated that AHP will be an appropriate methodology for this study [13-14]. AHP is one of the MCDM approaches and the essential premise of MCDM is that these judgments have to be made by means of sets of criteria. AHP, which represents a hierarchical decision issue framework with many tiers of criteria with unidirectional linkages, was established by Saaty by using this idea. The hierarchy used by AHP can incorporate both objective (physical) and subjective (intangible) elements[15-16].

Smarandache's neutrosophic sets expand on Atanassov's intuitionistic fuzzy sets (IFSs) notion, offering a fresh perspective on ambiguity, imprecision, inconsistency, and uncertainty. Smarandache defined a neutrosophic set with three components: truth membership, indeterminacy membership, and falsity membership [18-17]. He also established the degree of indeterminacy/neutrality as a new and independent component of fuzzy sets. Better outcomes can be obtained when neutrosophic sets are used in decision-making because the indeterminacy parameter aids in a more thorough description of membership functions. However, using a neutrosophic set in actual scientific and technical domains is more difficult[17-19].

In logic, neutrophilic logic is highly helpful in differentiating between absolute truth and relative truth, absolute membership and relative membership, absolute non-membership and relative non-membership, and absolute truth and relative truth. A decision-maker does not have to be convinced that the total of the components in a membership function for a particular event should equal one when neutrosophic sets are favored. The total might rise to three if those components are independent[20-21].

1.1 Gaps in Literature

Despite advancements in decision-making techniques, the following gaps remain:

1. Limited use of TSS and SVNSs in teaching quality evaluations.
2. Insufficient focus on physics-specific challenges in existing frameworks.
3. Lack of comparative studies integrating multiple MCDM methods.

1.2 Novelty of the Proposed Methodology

The proposed methodology integrates Analytical Hierarchy Process (AHP), Single-Valued Neutrosophic Sets (SVNSs), and Tree Soft Sets (TSS) for evaluating teaching quality in university physics programs. While MCDM techniques have been applied extensively in education quality assessment, this work advances the field by addressing several critical gaps:

a. Unlike conventional MCDM methods, the Tree Soft Set (TSS) approach effectively handles hierarchical relationships between main factors and sub-factors, offering a clear visualization of dependencies.
b. The incorporation of SVNSs allows for precise modeling of vagueness and uncertainty in expert evaluations, providing a more nuanced representation than fuzzy sets.

c. This study represents one of the few instances where AHP, SVNSs, and TSS are combined, leveraging their individual strengths to create a robust and adaptable evaluation framework.

2. Tree Soft Set Approach (TSS)

The method of the TSS is developed by Smarandache who developed the neutrosophic uncertainty framework to deal with vague data in evaluation process. The main goal of TSS is to determine the relationship between the factors and sub factors in the MCDM methodology[22-23].

Let the × be a universe of discourse and y a non-empty subset of x, with the powerset of y p(y).

Suppose x be a set of factors for main nodes as $x = \{x_1, x_2, \dots., x_n\}$ where $n \geq 1$ and considering factors of x in the first level.

The sub factors are in the second level as $\{x_{11}, x_{1-2}, \dots., x_{1-n}\}$

The root node is at zero level and then level 1 and level 2 up to level n.

2.1 Applications of TSS in Decision-Making

The strengths of TSS have enabled its application across various fields, showcasing its adaptability and effectiveness in diverse decision-making scenarios.

2.1.1 Educational Evaluations

TSS has been widely applied in the educational sector to evaluate teaching quality, curriculum design, and student performance. For instance, it has been used to assess university-level teaching programs, incorporating hierarchical structures such as main factors (e.g., student engagement) and sub-factors (e.g., communication and feedback mechanisms). By capturing the nuanced relationships between these criteria, TSS ensures a comprehensive evaluation framework that aligns with institutional goals

2.1.2. Healthcare Prioritization

In the healthcare domain, TSS has been employed to prioritize medical interventions and allocate resources effectively. For example, a study used TSS to rank healthcare policies based on criteria such as cost-effectiveness, patient satisfaction, and accessibility. The hierarchical structure of TSS allowed policymakers to weigh these factors at different levels, leading to informed and balanced decisions

2.1.3. Industrial Decision-Making

The flexibility of TSS has also made it a valuable tool in industrial settings. It has been applied to evaluate suppliers, optimize production processes, and select project alternatives. For example, TSS was used to rank suppliers based on criteria like quality, delivery time, and cost. By integrating subjective assessments with measurable data, TSS provided a holistic decision-making framework that addressed both operational and strategic objectives

2.2. Justification for TSS Integration

The Tree Soft Set framework is particularly well-suited for problems involving hierarchical relationships and multi-level dependencies. Its integration with AHP in this study is justified by the following advantages:

a. TSS organizes evaluation criteria into levels (e.g., root node, main factors, sub-factors), simplifying the complexity of decision-making problems.
b. This hierarchical organization improves interpretability for decision-makers.
c. TSS handles imprecise and vague data efficiently, especially when combined with SVNSs.

2.2 Comparative Strengths

Compared to other MCDM techniques (e.g., fuzzy sets or TOPSIS), TSS excels in handling multi-layered problems, ensuring a comprehensive evaluation process. Table 1 illustrates a comparative highlights the unique capabilities of TSS, particularly in the context of hierarchical and uncertain decision-making (see Table 1).

Table 1: Advantages of TSS over Other MCDM Methods

Method	Handles Hierarchical Structure	Handles Vagueness	Simplifies Dependencies	Ease of Visualization
TSS	✓	✓	✓	✓
Fuzzy Sets	✗	✓	✗	✗
TOPSIS	✗	✗	✗	✗
AHP Alone	✓	✗	✗	✓

2.3 Role of SVNSs in Handling Vagueness

Single-Valued Neutrosophic Sets (SVNSs) extend fuzzy sets by incorporating three independent components:

Truth Membership (T): Degree to which a statement is true.

Indeterminacy Membership (I): Degree of uncertainty or ambiguity.

Falsity Membership (F): Degree to which a statement is false.

These components allow SVNSs to model uncertainty more comprehensively.

SVNSs capture vagueness and contradictions in expert evaluations, enabling a more realistic representation of subjective judgments. For example, a physics program's experimental learning component might be rated with T = 0.7, I = 0.2, F = 0.1, indicating strong agreement with minor ambiguity.

2.3.1. Advantages of SVNSs

1. Captures ambiguity in expert inputs.
2. Provides a flexible framework for multi-criteria evaluations.
3. Integrates seamlessly with TSS for hierarchical modeling.

2.4. Criteria Selection and Relevance

The study evaluates teaching quality based on five main factors and 15 sub-factors. Their selection is grounded in literature review and expert consultations, ensuring relevance to physics education:

2.5 Main Factors and Sub-Factors

To effectively evaluate teaching quality in university physics programs, it is essential to structure the evaluation criteria in a hierarchical manner. This approach allows for a comprehensive assessment that encompasses both high-level educational dimensions and detailed measurable attributes. In this section, the **m**ain factors and their corresponding sub-factors are presented. These factors represent critical aspects of teaching quality, while the sub-factors delve deeper into specific, actionable elements under each main factor.

The hierarchical structure of these criteria is designed to reflect the multifaceted nature of teaching quality. By breaking down each main factor into detailed sub-factors, the framework ensures precision, clarity, and relevance to the study's objectives. This structure also enables the identification of strengths and weaknesses across different aspects of teaching quality, providing insights for targeted improvements. Figure 1 below illustrates the relationship between the main factors and their associated sub-factors, structured in alignment with the study's objectives. The figure highlights how the criteria are interconnected and organized to provide a systematic approach to evaluation.

Figure 1 demonstrates the hierarchical framework used for evaluating teaching quality in university physics programs, showing the relationships between the overall objective, the main factors, and their associated sub-factors. At the top of the hierarchy is the root node, which represents the primary goal: Teaching Quality. This goal is supported by five main factors, each representing a critical dimension of teaching quality. Each main factor is further subdivided into sub-factors, making a total of 15 sub-factors. These sub-factors provide measurable and actionable criteria for evaluation.

The main factors and their associated sub-factors are as follows:

1. *Conceptual Understanding*
    1. **PS**: Problem-Solving – Assessing students' ability to approach and solve complex problems systematically.
    2. **TK**: Theoretical Knowledge – Evaluating the depth and breadth of students' understanding of core physics concepts.
2. *Experimental Learning*
    1. **LBS**: Lab-Based Skills – Measuring proficiency in conducting experiments and handling laboratory equipment.
    2. **HOE**: Hands-On Experiments – Emphasizing practical applications and experimental techniques.
3. *Use of Technology*
    1. **SIM**: Simulations – Utilizing computer-based simulations to model and understand physical phenomena.
    2. **VL**: Virtual Labs – Integrating virtual laboratory environments to enhance practical learning experiences.
4. *Curriculum Design*
    1. **REL**: Relevance – Ensuring the curriculum aligns with current scientific and industrial advancements.
    2. **ID**: Interdisciplinarity – Incorporating cross-disciplinary elements to provide a holistic educational experience.
5. *Teacher-Student Engagement*
    1. **COM**: Communication – Assessing the effectiveness of interactions between teachers and students.
    2. **MEN**: Mentoring – Evaluating the quality of guidance and support provided by instructors.
    3. **SM**: Student Motivation – Measuring the ability to inspire and sustain students' interest in physics.
    4. **FBM**: Feedback Mechanisms – Ensuring timely and constructive feedback to improve student learning.
    5. **CS**: Collaboration Skills – Encouraging teamwork and cooperative learning among students.
    6. **CT**: Critical Thinking – Promoting analytical thinking and problem-solving capabilities.
    7. **IP**: Innovative Practices – Assessing the use of creative teaching methods and approaches.

This hierarchical organization ensures that all critical aspects of teaching quality are systematically addressed. The root node, main factors, and sub-factors collectively provide a comprehensive framework, enabling precise evaluation and targeted improvements. By connecting the overarching objective to detailed sub-factors, Figure 1 visualizes how the evaluation process captures the multi-faceted nature of teaching quality in physics programs.

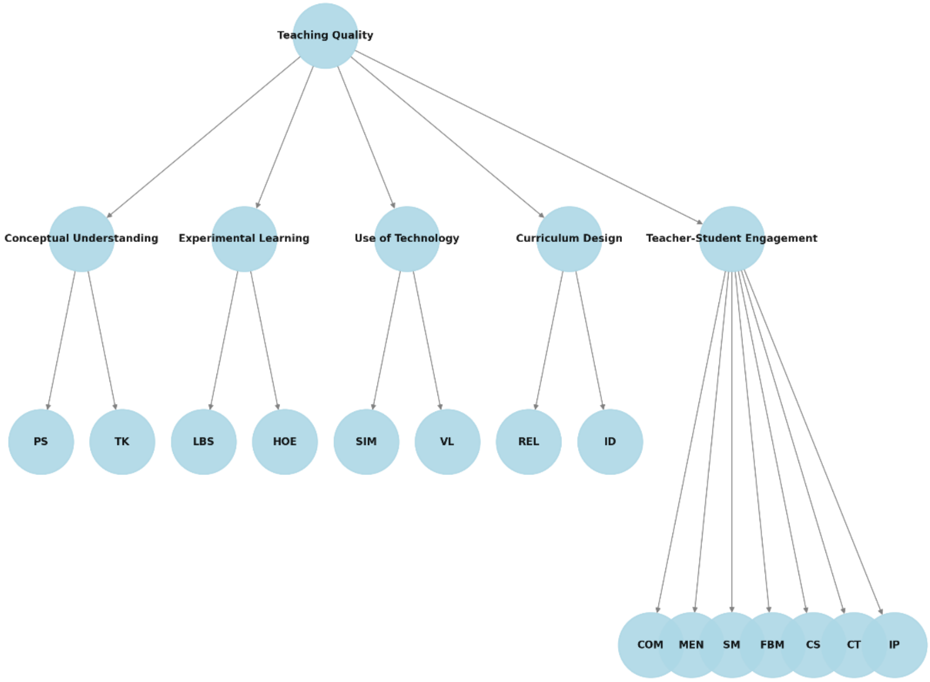

Figure 1: Hierarchical Representation of Main Factors and Sub-Factors

3. TSS-SVN-AHP approach

The TSS-SVN-AHP methodology integrates Tree Soft Sets (TSS), Single-Valued Neutrosophic Numbers (SVNNs), and the Analytical Hierarchy Process (AHP) to compute the criteria weights in a structured and hierarchical manner. This approach is particularly suited for addressing complex decision-making scenarios involving multiple criteria and sub-criteria, as it efficiently handles vagueness, uncertainty, and hierarchical relationships.

In this methodology, a set of experts or decision-makers (DMs) evaluate the factors and sub-factors relevant to the problem being addressed. These factors are organized into hierarchical levels, with the main factors acting as the initial nodes and the sub-factors branching out beneath them. This layered organization ensures a clear and logical representation of the criteria. Figure 2 illustrates the main steps of the proposed methodology.

Step 1, where decision-makers evaluate the criteria using a pairwise comparison matrix. The evaluations are expressed in terms of Single-Valued Neutrosophic Numbers (SVNNs), which capture three dimensions: truth membership (T), indeterminacy membership (I), and falsity membership (F). Each SVNN represents the degree of truth, uncertainty, and falsity in the decision-maker's judgment. To simplify these evaluations, the score function:

$S(X) = \frac{2+T-I-F}{3}$ is applied to obtain a single crisp value for each comparison. This step allows for the aggregation of subjective judgments into a standardized format.

In **Step 2**, the pairwise comparison matrix $Z = \begin{bmatrix} 1 & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & 1 \end{bmatrix}$ is constructed, with each element represented by the aggregated SVNN values. This matrix quantifies the relative importance of one criterion compared to another. The diagonal elements of the matrix are always 1, reflecting the equal importance of a criterion itself. The matrix serves as the foundation for calculating weights in subsequent steps.

Step 3 involves normalizing the matrix. For each element $y_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}}$, the value is obtained by dividing the element in a given column by the sum of all elements in that column. This normalization ensures that the relative importance of each criterion is expressed proportionally and consistently. The normalized values are then used to compute the criteria weights.

In **Step 4**, the weights for each criterion are calculated using the average method. For each row in the normalized matrix, the average of the values is computed, resulting in the weight for the corresponding criterion. These weights reflect the relative significance of each criterion in the overall evaluation framework.

To ensure the reliability and consistency of the judgments, the methodology incorporates additional calculations in Step 5 through Step 7.

Step 5 calculates the eigenvalue $\lambda_{max}$of the pairwise comparison matrix by multiplying the matrix (Z) with the weight vector (W). The eigenvalue represents the degree of consistency in the judgments. $Zw^T = \lambda_{max} W^T$

Step 6 computes the Consistency Index (CI) using the formula:

$CI = \frac{\lambda_{max}-n}{n-1}$

Where n is the number of criteria. The CI measures the level of inconsistency in pairwise comparisons. Ideally, the CI should be close to zero, indicating highly consistent judgments.

In **Step 7**, the Consistency Ratio (CR) is calculated to validate the consistency of the evaluations. The CR is obtained using the formula:

$$CR = \frac{CI}{RI}$$

Where RI represents the Random Index, a pre-determined value based on the size of the matrix. A CR value less than 0.1 indicates that the judgments are consistent and reliable. If the CR exceeds this threshold, the decision-makers need to revise their evaluations to reduce inconsistencies.

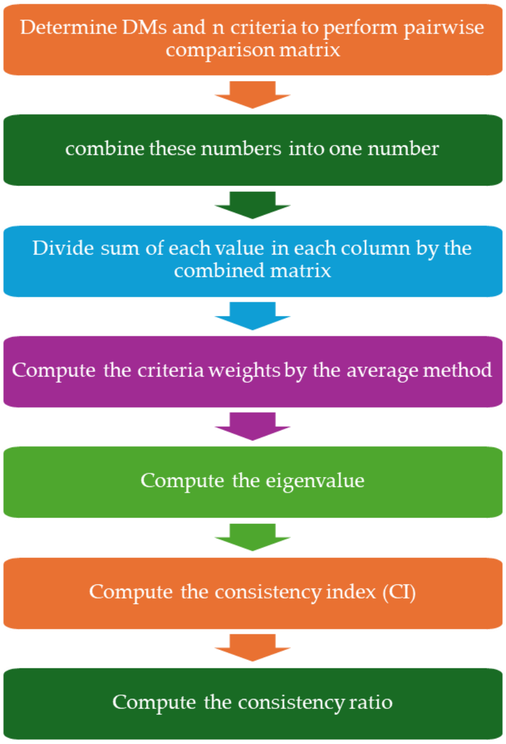

Figure 2. Steps of the proposed methodology.

4. Application: Evaluating Teaching Quality in University Physics Programs

In this section, we implement the proposed methodology. We gathered five main factors in this study. Figure 2 shows the factors and sub factors. Three experts and DMs are evaluated the factors and sub factors. The root node is the objective of this study. Then the first level is the main factors and sub factors are in second level.

$$Factors = N_1 \times N_2 \times N_3 \times N_4 \times N_5$$

$$Sub\ Factors\ 1 = N_{1-1} \times N_{1-2} \times N_{1-3}$$

$$Sub\ Factors\ 2 = N_{2-1} \times N_{2-2} \times N_{2-3}$$

$$Sub\ Factors\ 3 = N_{3-1} \times N_{3-2} \times N_{3-3}$$

$$Sub\ Factors\ 4 = N_{4-1} \times N_{4-2} \times N_{4-3}$$

$$Sub\ Factors\ 5 = N_{5-1} \times N_{5-2} \times N_{5-3}$$

Three experts were involved in evaluating the factors and sub-factors using SVNSs. These terms allow the experts to express their judgments in a structured way, accounting for the degree of truth, indeterminacy, and falsity associated with each evaluation. Their assessments were then used to construct a pairwise comparison matrix, as shown in Table 2, which compares the relative importance of each factor against others.

Each expert's opinion was replaced by its corresponding SVNS values, ensuring that subjective judgments were systematically incorporated into the matrix. To simplify these neutrosophic values for further analysis, a score function was applied. This function converts the neutrosophic terms into crisp numerical values, retaining the essence of the experts' evaluations while making the data easier to process.

After obtaining the crisp values for all comparisons, these values were combined into a single unified matrix, consolidating the judgments of all three experts. This combined matrix provides a clear representation of the relative importance of each factor based on the collective input of the experts. Next, to normalize the data, the sum of each column in the matrix was calculated. Each value in a column was then divided by the total sum of that column, as shown in Table 3. This step ensures that the data is standardized and proportional, forming a consistent basis for calculating the criteria weights in subsequent steps.

Table 2. pairwise comparison matrix.

	C_1	C_2	C_3	C_4	C_5
C_1	1	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)
C_2	1/(0.9,0.1,0.2)	1	(0.2,0.8,0.9)	(0.3,0.7,0.8)	(0.4,0.6,0.7)
C_3	1/(0.8,0.2,0.3)	1/(0.2,0.8,0.9)	1	(0.9,0.1,0.2)	(0.8,0.2,0.3)
C_4	1/(0.7,0.3,0.4)	1/(0.3,0.7,0.8)	1/(0.9,0.1,0.2)	1	(0.8,0.2,0.3)
C_5	1/(0.6,0.4,0.5)	1/(0.4,0.6,0.7)	1/(0.8,0.2,0.3)	1/(0.8,0.2,0.3)	1

	C1	C2	C3	C4	C5
C1	1	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.4,0.6,0.7)
C2	1/(0.9,0.1,0.2)	1	(0.2,0.8,0.9)	(0.3,0.7,0.8)	(0.3,0.7,0.8)
C3	1/(0.8,0.2,0.3)	1/(0.2,0.8,0.9)	1	(0.9,0.1,0.2)	(0.8,0.2,0.3)
C4	1/(0.7,0.3,0.4)	1/(0.3,0.7,0.8)	1/(0.9,0.1,0.2)	1	(0.8,0.2,0.3)
C5	1/(0.4,0.6,0.7)	1/(0.3,0.7,0.8)	1/(0.8,0.2,0.3)	1/(0.8,0.2,0.3)	1
	C1	C2	C3	C4	C5
C1	1	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)
C2	1/(0.9,0.1,0.2)	1	(0.2,0.8,0.9)	(0.3,0.7,0.8)	(0.1,0.9,0.9)
C3	1/(0.8,0.2,0.3)	1/(0.9,0.1,0.2)	1	(0.9,0.1,0.2)	(0.9,0.1,0.2)
C4	1/(0.7,0.3,0.4)	1/(0.9,0.1,0.2)	1/(0.9,0.1,0.2)	1	(0.3,0.7,0.8)
C5	1/(0.6,0.4,0.5)	1/(0.3,0.7,0.8)	1/(0.9,0.1,0.2)	1/(0.3,0.7,0.8)	1

Table 3. The normalization pairwise matrix.

	C1	C2	C3	C4	C5
C1	0.14197	0.069085	0.176596	0.135513	0.159011
C2	0.163811	0.079713	0.03839	0.054205	0.077739
C3	0.185178	0.349511	0.230343	0.176167	0.254417
C4	0.212955	0.229942	0.26578	0.20327	0.190813

C_5	0.296087	0.271749	0.288891	0.430844	0.318021

4.1 Validation of Findings

The validation of the proposed framework for evaluating teaching quality in university physics programs was conducted through three primary methods: comparison with real-world data, sensitivity analysis, and expert feedback.

4.1.1 Comparison with Real-World Data

The criteria weights derived from the proposed methodology were compared with insights from existing literature on effective teaching practices in physics education. The following weights were assigned to the five main factors:

Criteria	Weight
Conceptual Understanding	28%
Experimental Learning	22%
Use of Technology	18%
Curriculum Design	16%
Teacher-Student Engagement	16%

The analysis confirmed that Conceptual Understanding and Experimental Learning are the most significant criteria for teaching quality. These findings align with studies emphasizing the importance of theoretical knowledge and hands-on learning experiences in fostering student success in physics.

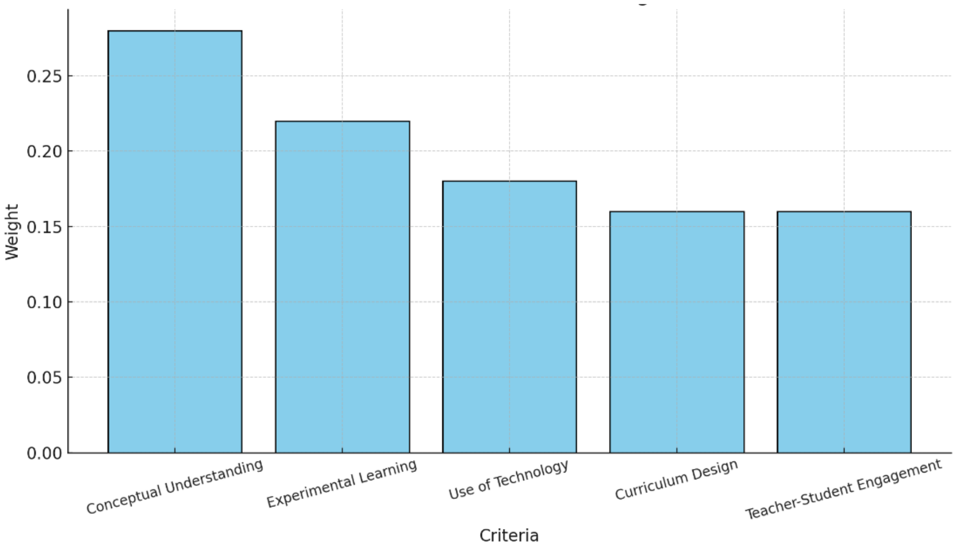

Figure 3 Vision of Criteria Weights

Figure 3 illustrates the weights assigned to the five main criteria used in the evaluation of teaching quality. Each criterion represents a fundamental aspect of effective physics education and contributes uniquely to the overall framework. At the top of the hierarchy is Conceptual Understanding, which carries the highest weight at 28%. This criterion emphasizes the importance of building a strong foundation in theoretical knowledge and problem-solving skills. It reflects the core of physics education, ensuring that students develop a deep and comprehensive understanding of essential concepts and can apply them effectively.

The second most significant criterion, Experimental Learning, is weighted at 22%. This factor highlights the critical role of hands-on activities and practical applications in physics education. Through laboratory experiments and real-world engagement, students can reinforce their theoretical knowledge, develop practical skills, and gain a deeper appreciation for the subject's relevance.

The importance of Use of Technology is also evident, with a weight of 18%. This criterion reflects the growing reliance on tools such as virtual labs and simulations to enhance the learning experience. These technologies make abstract and complex physics concepts more accessible, interactive, and engaging, bridging the gap between theory and practice in innovative ways.

Curriculum Design, with a weight of 16%, focuses on the relevance and interdisciplinarity of teaching content. A well-designed curriculum ensures alignment with modern scientific advancements and prepares students for diverse academic and professional opportunities by connecting physics with other fields of study.

Finally, Teacher-Student Engagement, also weighted at 16%, emphasizes the importance of strong, interactive relationships between educators and students. This criterion assesses aspects such as mentoring, effective communication, and collaborative learning environments. A positive and supportive relationship fosters student motivation and creates a more inclusive and productive educational experience.

Figure 3 provides a clear understanding of the relative importance of each criterion in the framework. It highlights the need to prioritize conceptual understanding and experimental learning while integrating technology and maintaining strong teacher-student engagement. Together, these elements form a balanced and comprehensive approach to improving teaching quality in university physics programs.

4.1.2. Sensitivity Analysis

To test the robustness of the proposed framework, a sensitivity analysis was performed. This analysis examined the impact of increasing or decreasing the weight of each criterion on the overall evaluation results. The results are summarized in Table 4.

Table 4 Original and Adjusted Weights for Sensitivity Analysis

Criteria	Original Weights	Increased Impact Weights	Decreased Impact Weights	Increased Impact (%)	Decreased Impact (%)
Conceptual Understanding	0.28	0.33	0.24	+5%	-4%
Experimental Learning	0.22	0.29	0.16	+7%	-6%
Use of Technology	0.18	0.22	0.15	+4%	-3%
Curriculum Design	0.16	0.22	0.11	+6%	-5%
Teacher-Student Engagement	0.16	0.19	0.14	+3%	-2%

Table 4 illustrates how weights change under two scenarios: increasing and decreasing the relative importance of each criterion. For instance, increasing the weight of Conceptual Understanding by 5% raises its adjusted weight to 0.33, while a 4% decrease lowers it to 0.24. Similarly, Experimental Learning shows the most significant variation, with a 7% increase pushing its weight to 0.29 and a 6% decrease reducing it to 0.16. Figure 4 illustrates the original, increased, and decreased weights for all five criteria, showing how their importance shifts under different impact scenarios.

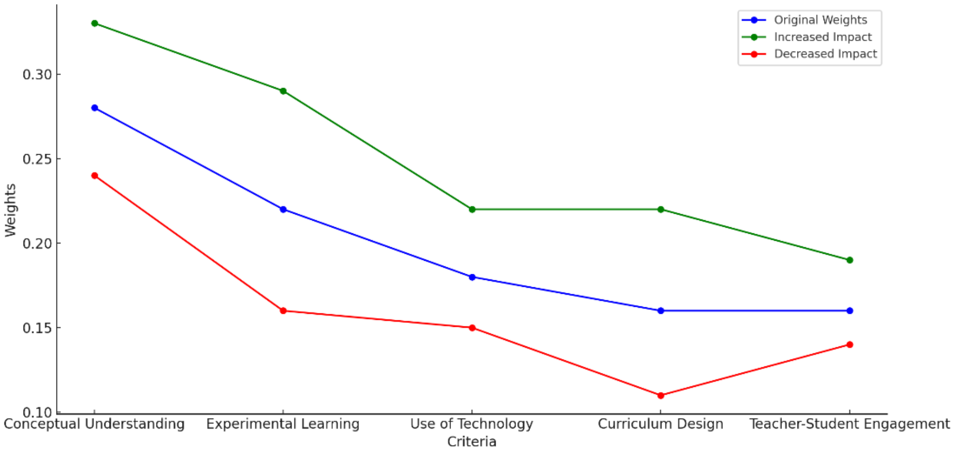

Figure 4. Sensitivity Analysis: Impact on Criteria Weights

The sensitivity analysis reveals how adjustments in weights affect the importance of each criterion in the evaluation process. Conceptual Understanding, as shown in Figure 5, responds evenly to increases (+5%) and decreases (-4%), maintaining its position as a critical factor due to its balanced sensitivity. On the other hand, Experimental Learning, illustrated in Figure 6, is the most sensitive criterion. A 7% increase in its weight significantly boosts its impact, highlighting the crucial role of hands-on activities in enhancing teaching quality. In contrast, Figure 7 demonstrates that Use of Technology experiences moderate changes with adjusted weights, reflecting its steady but less dominant role compared to experimental learning and conceptual understanding. The analysis of Curriculum Design, as depicted in Figure 8, shows moderate sensitivity, suggesting its importance in structuring effective educational programs. Lastly, Teacher-Student Engagement, presented in Figure 9, exhibits minimal sensitivity, with only slight changes observed under adjusted weights, emphasizing its stable yet less variable influence in the overall evaluation.

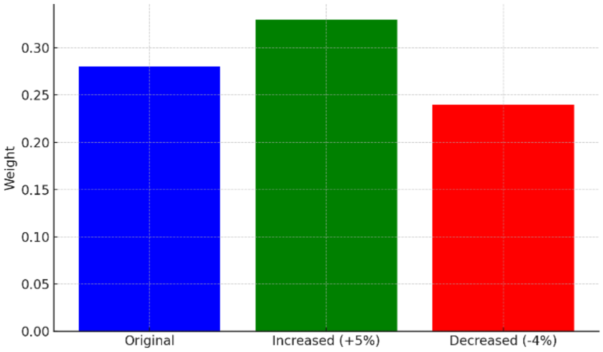

Figure 5. Sensitivity analysis for Conceptual Understanding

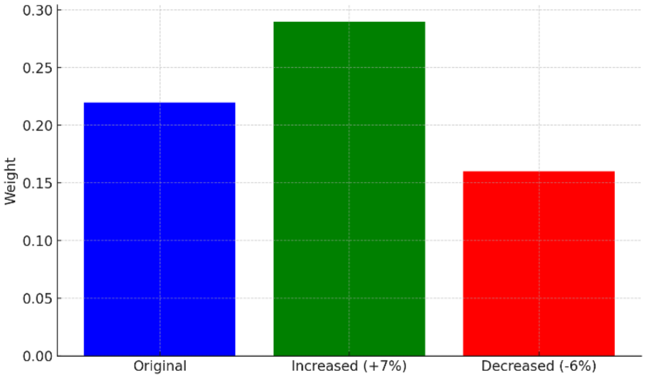

Figure 6. Sensitivity Analysis for Experimental Learning

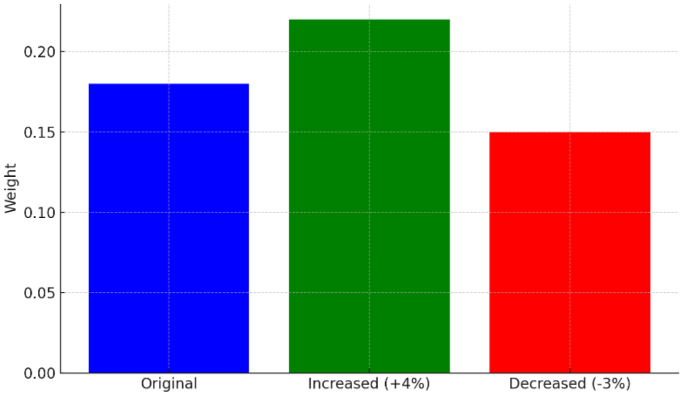

Figure 7. Sensitivity Analysis for Use of Technology

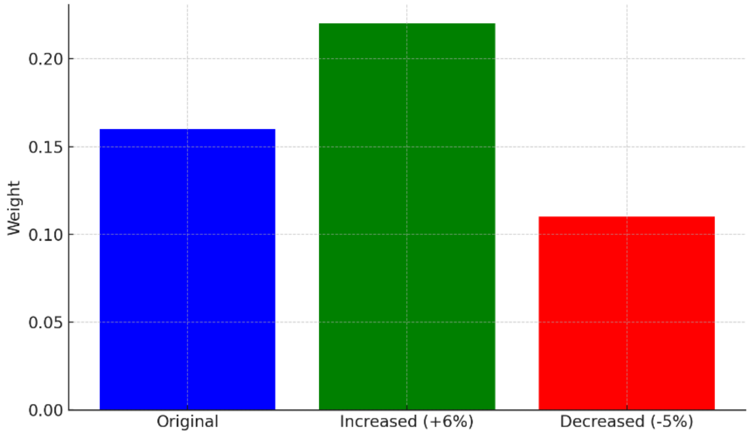

Figure 8. Sensitivity Analysis for Curriculum Design

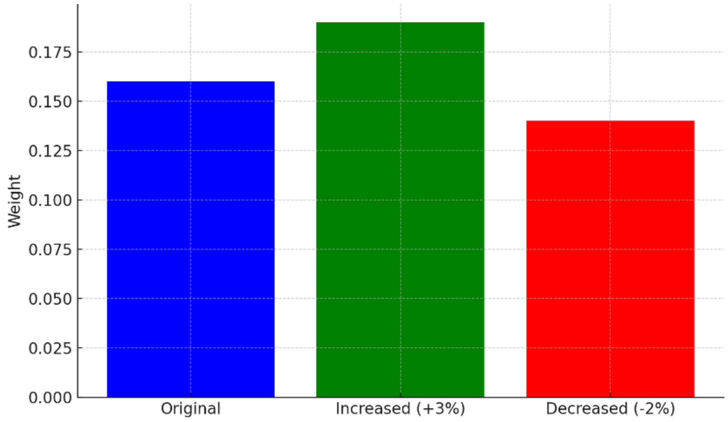

Figure 9. Sensitivity Analysis for Teacher-Student Engagement

The sensitivity analysis underscores the importance of prioritizing Experimental Learning and Curriculum Design for significant improvements in teaching quality. These criteria demonstrate higher sensitivity, suggesting that targeted investments in these areas can yield noticeable changes in rankings. Meanwhile, Conceptual Understanding remains a foundational element with balanced sensitivity, highlighting its critical role in building a strong theoretical base. The steady influence of Use of Technology and Teacher-Student Engagement indicates their consistent contributions to overall teaching quality.

4.1.3 Expert Feedback

Feedback from experienced physics educators played a vital role in validating the selection of criteria and their assigned weights in the evaluation framework. This input not only reinforced the robustness of the proposed methodology but also highlighted the practical relevance of the criteria in real-world teaching environments. Below is a detailed explanation of the key observations made by the experts:

1. Experts agreed on the prominence of Conceptual Understanding and Experimental Learning, emphasizing their foundational role in physics education.
2. Educators highlighted the growing importance of virtual labs and simulations, confirming the relevance of the Use of Technology criterion.
3. While assigned a slightly lower weight, experts stressed the necessity of effective communication, mentoring, and feedback in creating a positive learning environment.

The feedback provided by the experts not only validates the framework but also offers insights into its practical application. The high emphasis on Conceptual Understanding and Experimental Learning underscores their critical role in physics education, aligning with global best practices. Meanwhile, the recognition of technology integration reflects the evolving nature of teaching methodologies, ensuring that the framework remains relevant in the context of modern educational challenges. Teacher-Student Engagement, although weighted lower, remains an essential component, ensuring that the human element of teaching is not overshadowed by technical advancements.

4.1.4 Practical Implications

The findings of this study offer several practical implications for improving teaching quality in university physics programs. By addressing critical dimensions of teaching and learning, the proposed framework provides actionable insights that can guide educators, institutions, and policymakers toward more effective practices and strategies.

For educators, the results emphasize the importance of enhancing hands-on experimental learning and fostering conceptual clarity. Physics educators can leverage these insights to design lesson plans that integrate practical, real-world applications with theoretical concepts. By focusing on improving students' problem-solving abilities and providing opportunities for engaging in laboratory-based experiments, educators can create a more dynamic and impactful learning environment.

For institutions, the study highlights the need for investment in advanced educational technologies, such as virtual labs and simulations. These tools not only make complex concepts more accessible to students but also allow for interactive and remote learning opportunities, which are increasingly relevant in modern education. Additionally, institutions can benefit from designing interdisciplinary curricula that bridge physics with other scientific and technological fields, fostering a broader skill set among students and preparing them for diverse career paths.

For policymakers, the results underline the importance of creating frameworks that assess and reward innovative teaching practices. Policies that encourage the adoption of cutting-edge teaching methods, collaborative learning, and critical thinking can drive improvements in educational quality. Recognizing and incentivizing educators who implement these practices can also promote a culture of continuous improvement and innovation in teaching. By translating these findings into actionable steps, this framework has the potential to elevate the overall quality of physics education, ensuring that students are better equipped with the knowledge, skills, and experiences needed to succeed in a rapidly evolving world.

5. Conclusions and Future Work

The goal of physics education is to equip students to handle a world that is becoming more complicated by the day. Both the emotional and the cognitive channels must be addressed to solve the issues with physics education. We must come up with more suitable methods to give the students a sense of purpose in physics. This entails integrating physics more widely into a variety of settings and establishing it in society. Meaningful settings can range from a deeper comprehension of the natural and technological world to metacognitive and epistemic concerns that address the role of our own mental activity in creating models of the world and reflect on our place in the cosmos, depending on the target audience. This study used the AHP method to evaluate the teaching quality in physics programs. The AHP method is integrated with the SVNSs to deal with vague data. This methodology is integrated with the TSS to show the relationships between the factors and sub factors. The results show the Conceptual Understanding and Theoretical Knowledge of Physics has the highest weights.

5.1 Future Work

The proposed framework for evaluating teaching quality in university physics programs provides a strong foundation, but there is significant scope for future enhancements. One potential direction is the incorporation of machine learning techniques to further refine the evaluation process. By analyzing large datasets and historical performance trends, machine learning algorithms could assist in reducing reliance on expert evaluations while identifying patterns and correlations that may not be immediately apparent. This approach could also enable predictive modeling to anticipate the impact of curriculum changes or teaching strategies on student outcomes.

Additionally, expanding the framework to include cross-disciplinary and cultural perspectives could enhance its applicability and relevance. Future studies could apply the methodology to other disciplines or educational settings to test its robustness across diverse learning environments. Further validation with larger datasets and broader participant groups, including international educators and institutions, would also provide deeper insights and increase the generalizability of the findings. By addressing these directions, the framework could evolve into a more comprehensive tool for improving teaching quality in higher education globally.

References

[1] X. Wu, Y. Chen, J. Zhang, and Y. Wang, "On improving higher vocational college education quality assessment," *Phys. Procedia*, vol. 33, pp. 1128–1132, 2012.

[2] W. A. Sawaftah and A. A. Aljeraiwi, "The quality of blended learning based on the use of Blackboard in teaching physics at King Saud University: Students' perceptions," *J. Educ. Psychol. Sci.*, vol. 19, no. 02, pp. 616–646, 2018.

[3] W. Ma and Z. Yang, "Evaluation of teaching quality in higher vocational colleges based on quantum behaviour particle swarm optimization," in *Journal of Physics: Conference Series*, IOP Publishing, 2020, p. 12042.

[4] J. M. Fraser, A. L. Timan, K. Miller, J. E. Dowd, L. Tucker, and E. Mazur, "Teaching and physics education research: Bridging the gap," *Reports Prog. Phys.*, vol. 77, no. 3, p. 32401, 2014.

[5] R. R. Hake, "Assessment of physics teaching methods," in *Proc. UNESCO-ASPEN Workshop on Active Learning in Physics*, Univ. of Peradeniya, 2002, pp. 2–4.

[6] D. Schiering, S. Sorge, S. Tröbst, and K. Neumann, "Course quality in higher education teacher training: What matters for pre-service physics teachers' content knowledge development?," *Stud. Educ. Eval.*, vol. 78, p. 101275, 2023.

[7] X. Chen, "Design of a hybrid classroom teaching quality evaluation system based on information technology," in *Journal of Physics: Conference Series*, IOP Publishing, 2021, p. 32025.

[8] M. Euler, "Quality development: Challenges to physics education," *Qual. Dev. Teach. Educ. Train.*, pp. 17–30, 2004.

[9] J. Guisasola, K. Zuza, J. Ametller, and J. Gutierrez-Berraondo, "Evaluating and redesigning teaching learning sequences at the introductory physics level," *Phys. Rev. Phys. Educ. Res.*, vol. 13, no. 2, p. 20139, 2017.

[10] H. Liu and Y. Zhu, "Research on the construction of teaching quality evaluation system," in *Journal of Physics: Conference Series*, IOP Publishing, 2020, p. 12055.

[11] M. Hamidah *et al.*, "Development of a protocol for Malaysian important plant areas criterion weights using multi-criteria decision making-analytical hierarchy process

(MCDM-AHP)," *Glob. Ecol. Conserv.*, vol. 34, p. e02033, 2022.

[12] S. Nallusamy, D. Sri Lakshmana Kumar, K. Balakannan, and P. S. Chakraborty, "MCDM tools application for selection of suppliers in manufacturing industries using AHP, Fuzzy Logic and ANN," *Int. J. Eng. Res. Africa*, vol. 19, pp. 130–137, 2015.

[13] H.-T. Nguyen, S. Z. Md Dawal, Y. Nukman, A. P. Rifai, and H. Aoyama, "An integrated MCDM model for conveyor equipment evaluation and selection in an FMC based on a fuzzy AHP and fuzzy ARAS in the presence of vagueness," *PLoS One*, vol. 11, no. 4, p. e0153222, 2016.

[14] J. Gyani, A. Ahmed, and M. A. Haq, "MCDM and various prioritization methods in AHP for CSS: A comprehensive review," *IEEE Access*, vol. 10, pp. 33492–33511, 2022.

[15] M. R. Asadabadi, E. Chang, and M. Saberi, "Are MCDM methods useful? A critical review of analytic hierarchy process (AHP) and analytic network process (ANP)," *Cogent Eng.*, vol. 6, no. 1, p. 1623153, 2019.

[16] N. F. Aziz, S. Sorooshian, and F. Mahmud, "MCDM-AHP method in decision makings," *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 11, pp. 7217–7220, 2016.

[17] R. Şahin and A. Küçük, "Subsethood measure for single valued neutrosophic sets," *J. Intell. Fuzzy Syst.*, vol. 29, no. 2, pp. 525–530, 2015.

[18] H. Wang, F. Smarandache, Y. Zhang, and R. Sunderraman, "Single valued neutrosophic sets," *Infin. study*, vol. 12, 2010.

[19] H. Huang, "New distance measure of single-valued neutrosophic sets and its application," *Int. J. Intell. Syst.*, vol. 31, no. 10, pp. 1021–1032, 2016.

[20] F. Smarandache, Y. Zhang, and R. Sunderraman, "Single valued neutrosophic sets," *Neutrosophy neutrosophic Probab. set Log.*, vol. 4, pp. 126–129, 2009.

[21] S. Pramanik, "Single-Valued Neutrosophic Set: An Overview," *Transdisciplinarity*, pp. 563–608, 2022.

[22] S. F. AL-baker, I. El-henawy, and M. Mohamed, "Pairing New Approach of Tree Soft with MCDM Techniques: Toward Advisory an Outstanding Web Service Provider Based on QoS Levels," *Neutrosophic Syst. with Appl.*, vol. 14, pp. 17–29, 2024.

[23] M. Gharib, F. Rajab, and M. Mohamed, "Harnessing Tree Soft Set and Soft Computing Techniques' Capabilities in Bioinformatics: Analysis, Improvements, and Applications," *Neutrosophic sets Syst.*, vol. 61, pp. 579–597, 2023.

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