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A SuperHyperSoft Set-Based Analysis Framework for Innovation and Entrepreneurship Development in Higher Vocational Colleges: An Industry-Sector Integration Perspective

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Abstract-This study proposes a novel framework for evaluating innovation and entrepreneurship education (IEE) in higher vocational colleges using the SuperHyperSoft Set (SHSS) theory, integrated with fuzzy-neutrosophic logic. The SHSS model extends classical soft set approaches by addressing multidimensional, overlapping, and uncertain attributes inherent in industry-education integration. A formal mapping structure employs power sets of attribute spaces (e.g., curriculum orientation, pedagogy, industry involvement, innovation outcomes) to model educational configurations. Neutrosophic parameters capture partial truth, indeterminacy, and falsity in assessing effectiveness. Applied to a digital entrepreneurship program, the model evaluated three configurations, revealing that hybrid or industry-driven curricula, project- or mentorship-based pedagogy, and industry co-development achieved optimal outcome alignment, while traditional academic formats exhibited higher uncertainty and misalignment. These findings validate the SHSS framework's utility in complex educational environments, offering a theoretical advancement and a practical tool for curriculum and policy optimization.

Keywords: SuperHyperSoft Set, Innovation and Entrepreneurship Education, Industry-Education Integration, Fuzzy Evaluation, Neutrosophic Analysis, Higher Vocational Colleges.

1. Introduction

The increasing global emphasis on innovation-driven economies has placed considerable demands on higher vocational education systems to produce graduates equipped not only with technical proficiency but also with entrepreneurial competence and adaptive thinking. As industries undergo continuous transformation under the pressures of digitalization and globalization, vocational institutions are expected to align their educational offerings with dynamic market needs through robust models of industry-education integration (IEI) [1].

IEE in this context is no longer limited to the delivery of business theory or isolated startup projects. Instead, it involves holistic program designs that foster interdisciplinary thinking, real-world problem-solving, and strategic collaboration with industry partners. However, one persistent challenge remains: how to effectively evaluate the quality, adaptability, and outcomes of such programs when the criteria are inherently multidimensional, overlapping, and often uncertain.

Traditional evaluation frameworks such as rubrics or single-criteria assessments fail to capture the complexity of these educational ecosystems. Models based on deterministic or linear logic often ignore contextual dependencies, qualitative factors, and indeterminate feedback from stakeholders. Furthermore, many conventional decision-making methods assume fixed attributes and crisp classifications, which are misaligned with the fuzzy, evolving, and negotiated nature of innovation-focused education.

To overcome these limitations, researchers have explored alternative mathematical tools. The Soft Set Theory, introduced by Molodtsov [2], offered a parameter-free method for dealing with uncertainty in decision-making contexts. This approach was later extended into HyperSoft Sets, which enabled multi-attribute mappings through Cartesian product structures [3]. While valuable, both models remain limited in their capacity to represent combined, flexible attribute sets and manage degrees of truth, uncertainty, and contradiction.

To address this gap, the SHSS theory was developed by Smarandache [4]. It generalizes HyperSoft Sets by mapping combinations of attribute value sets (i.e., power sets) into the power set of outcomes, allowing evaluators to operate with overlapping, collective, and variable criteria. Furthermore, its fuzzy extension accommodates neutrosophic logic, incorporating not only degrees of membership (truth) but also indeterminacy and non-membership (falsity) [4-5]. This makes SHSS particularly suitable for modeling the complexities inherent in evaluating entrepreneurship education within integrated industry-academic frameworks.

This paper applies the SHSS model to construct a novel framework for evaluating IEE in higher vocational colleges. By integrating flexible attribute groupings with neutrosophic evaluation, the framework reflects the real-world variability of educational strategies, teaching methods, and industry collaborations. A case study is conducted using this model to assess configurations in a digital entrepreneurship program, demonstrating its utility in identifying impactful pedagogical and structural elements.

2. Literature Review

Over the past decade, the evaluation of entrepreneurship and innovation education has evolved from standardized output metrics to more dynamic, multidimensional assessment frameworks. Scholars have increasingly recognized that measuring the impact of entrepreneurship education requires models that account for subjective, uncertain, and interrelated factors, particularly within industry-linked educational environments.

Recent frameworks have incorporated qualitative data, stakeholder feedback, and real-world project outcomes as evaluation components. For example, Nabi et al. highlighted the need for longitudinal and multi-perspective approaches that go beyond immediate knowledge gains and focus on entrepreneurial mindset development and ecosystem integration [6]. Similarly, Lans et al. emphasized the importance of competence-based assessment models that consider not just content delivery, but behavioral and attitudinal changes among learners [7].

In parallel, decision science has introduced various multi-criteria decision-making (MCDM) techniques into the educational domain. Methods such as Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Fuzzy Delphi have been applied to rank alternatives and synthesize expert judgment in uncertain settings [8-9]. While effective in controlled decision spaces, these models often assume fixed attribute sets and cannot natively represent overlapping criteria or combinations of values an inherent limitation when evaluating integrated educational systems.

More recent advances in soft computing have attempted to address this issue. The intuitionistic fuzzy set and q-rung orthopair fuzzy models, for instance, extend binary logic into multi-valued representations that accommodate degrees of acceptance, rejection, and hesitation [10]. Although these models support vagueness in evaluations, they often lack the structural capacity to combine multiple attribute spaces into a unified representation of decision scenarios.

Within this context, a growing body of research has explored hybridized models that merge soft set theory with fuzzy logic. These include Picture Fuzzy Sets, Spherical Neutrosophic Sets, and Plithogenic Sets, which allow more sophisticated representation of uncertainty, contradiction, and contextual adaptation [11-12]. However, few of these models have been explicitly operationalized within educational assessment, and most remain theoretical in scope.

The SuperHyperSoft Set framework builds on this trajectory by combining power set structures with fuzzy-neutrosophic logic. It uniquely enables evaluators to consider combinations of attribute values from different domains such as curriculum, pedagogy, and industry role—while expressing the degree to which each configuration aligns with intended educational outcomes. Unlike classical soft computing methods, it can decompose complex evaluations into discrete, interpretable decision paths, facilitating implementation in real educational environments. Yet, despite its theoretical promise, its application in vocational education remains largely unexplored.

This study leverages SHSS to evaluate IEE, contributing a practical framework and extending soft set theory to vocational education contexts.

3. Objectives and Motivations

The primary motivation is to construct a mathematically rigorous framework for evaluating IEE in higher vocational colleges, addressing the complexity of curriculum, pedagogy, industry collaboration, and innovation outcomes.

3.1 Research Structure

The study pursues three objectives, as shown in Table 1.

1. O1: Develop a flexible, multidimensional evaluation model capturing interdependencies among curriculum type, teaching method, industry role, and innovation performance.
2. O2: Integrate fuzzy-neutrosophic logic to quantify partial truth, uncertainty, and contradiction.
3. O3: Validate the model using real-world case study data to ensure operational feasibility.

Table 1. Research Objectives and Structure

ID	Objective Description	Primary Attributes	Expected Output
O1	Develop evaluation model for IEE	{Curriculum Type, Teaching Method, Industry Role, Innovation Output}	SHSS-based structure
O2	Integrate fuzzyneutrosophic logic	{Truth (T), Indeterminacy (I), Falsity (F)}	Uncertainty modeling
O3	Validate model with case study	{Attribute Combinations, Outcomes}	Empirical evidence

3.2 Mathematical Formulation of the Model

3.2 Mathematical Formulation

For O1, the SHSS model is defined as:

$$F: P(A_1) \times P(A_2) \times \cdots \times P(A_n) \rightarrow P(U) \tag{1}$$

where: - U : Universe of educational outcomes. - $P(A_i)$: Power set of attribute domain A_i. - A_i : Educational dimension (e.g., curriculum type).

3.3 Fuzzy-Neutrosophic Integration

For O2, the mapping incorporates neutrosophic logic:

$$F: P(A_1) \times \cdots \times P(A_n) \rightarrow P\big(U(x_c)\big) \tag{2}$$

Each outcome $x_c \in U$ has a triplet:

$$x_c = (T, I, F), T, I, F \in [0,1] \tag{3}$$

where T, I, and F represent truth, indeterminacy, and falsity, respectively.

Example:

$F(\{\text{ Hybrid }\}, \{\text{ Project-based }\}, \{\text{ Co-development }\}, \{\text{ Commercialization }\}) = \{x_1(0.9, 0.05, 0.05)\}$

This indicates high alignment ($T = 0.9$), low uncertainty ($I = 0.05$), and minimal contradiction ($F = 0.05$), derived from expert evaluations.

3.4 Empirical Validation

For O3, the model evaluates configurations in a Cartesian product space:

$$P(A_1) \times P(A_2) \times \cdots \times P(A_n) \tag{5}$$

The number of combinations is:

$$\prod_{i=1}^{n} |P(A_i)| \tag{6}$$

For four attributes, each with 3 values (e.g., A_1 = { Academic, Hybrid, Industry-driven }):

- $|A_i| = 3$, so $|P(A_i)| = 2^3 = 8$.
- Total combinations: $8 \cdot 8 \cdot 8 \cdot 8 = 4096$.

This supports detailed analysis and policy optimization.

3.5 Design Logic

The objectives ensure, O1: Theoretical completeness, O2: Analytical expressiveness and O3: Empirical relevance.

4. Methods: Proposed Evaluation Framework

The SHSS-based evaluation framework is constructed through four methodological steps, summarized in Table 2.

Table 2. Structured Methodology Overview

Step ID	Process Description	Mathematical Representation	Purpose and Outcome
M1	Define universe of discourse and educational attribute domains	$U=\{x_1,x_2,\ldots,x_n\}$; $A_i \subset$ Attributes	Establish semantic structure of the evaluation model
M2	Construct SuperHyperSoft Set mapping using power sets of attributes	$F:P(A_1)\times\cdots\times P(A_k)\rightarrow P(U)$	Enable combinatorial mapping of complex attribute profiles
M3	Integrate fuzzy-neutrosophic components into evaluation model	$x(d_0)$ = (T, I, F) ∈ [0,1]	Allow partial, uncertain, and contradictory evaluations
M4	Apply model to real configurations for empirical evaluation	$F(\{a_1,a_2\},\ldots,\{a_k\})=\{x_1(d_0),x_2(d_0),\ldots\}$	Demonstrate practicality and analytical granularity

4.1 Step M1: Defining Universe and Attributes

The universe $U = \{x_1, x_2, \ldots, x_n\}$ represents educational outcomes (e.g., student success). Attribute domains include:

- A_1: Curriculum Type = { Academic, Hybrid, Industry-driven }.
- A_2 : Teaching Method = { Lecture, Project-based, Mentorship }.
- A_3 : Industry Role = { None, Advisory, Co-development }.
- A_4 : Innovation Outcome = { Ideation, Prototyping, Commercialization }.

4.2 Step M2: SHSS Mapping

The mapping is:

$$F: P(A_1) \times \cdots \times P(A_k) \rightarrow P(U) \tag{7}$$

This maps subsets of attribute values to outcome subsets, enabling flexible analysis.

4.3 Step M3: Neutrosophic Integration

Each outcome x_c is assigned:

$$x_c = (T, I, F) \tag{8}$$

Example:

$F(\{\text{ Hybrid }\},\{\text{ Project-based }\},\{\text{ Co-development }\},\{\text{ Commercialization }\}) = \{x_1(0.9,0.05,0.05)\}$

4.4 Step M4: Empirical Application

The model evaluates real-world configurations, as shown in Section 5. Sample Evaluation:

Curriculum	Teaching Method	Industry Role	Innovation Output	F Output
Hybrid	Project-based	Co-development	Commercialization	{x1(0.9,0.05,0.05)}
Industry-driven	Mentorship	Co-development	Commercialization	{x2(0.88,0.07,0.05)}
Academic	Lecture	None	Ideation	{x3(0.40,0.40,0.20)}

4.5 Step M5: Derivation of Neutrosophic Values

Neutrosophic values were derived as follows:

1. Expert Scoring: A panel of five experts (three academics, two industry professionals) scored configurations based on criteria (e.g., outcome alignment, pedagogical clarity). Scores were normalized to [0,1].
2. Student Data: Project success rates and student feedback validated expert scores.
3. Aggregation: Scores were averaged, with T reflecting alignment, I uncertainty (e.g., conflicting feedback), and F misalignment.

4.6 Methodological Strengths

The framework offers multidimensional representation, uncertainty modeling, scalability, and interpretability.

5. Case Study

To empirically validate the SuperHyperSoft Set-based evaluation framework, a case study was conducted at a higher vocational institution offering a specialized program in digital entrepreneurship. The case study focused on analyzing three representative configurations of the program, each reflecting a distinct alignment between curriculum design, teaching methodology, level of industry collaboration, and expected innovation outcome.

5.1. Attribute Structure and Case Selection

Each configuration was constructed using the predefined attribute sets from Section 4:

- A_1: Curriculum Type
- A_2: Teaching Method
- A_3: Industry Role
- A_4: Innovation Output

Three real-world combinations were chosen based on institutional records, instructional strategies, and collaboration models.

Table 3 presents the exact configurations along with their corresponding neutrosophic evaluations for two student cases x_1 and x_2.

Table 3. Case Study Evaluation using SHSS

Case ID	Curriculum Type	Teaching Method	Industry Role	Innovation Output	$x(d_0)$ for x_1	$x(d_0)$ for x_2
C1	Hybrid	Project-based	Co-development	Commercialization	(0.90, 0.05, 0.05)	(0.85, 0.10, 0.05)
C2	Industry-driven	Mentorship	Co-development	Commercialization	(0.88, 0.07, 0.05)	(0.86, 0.10, 0.04)
C3	Academic	Lecture	None	Ideation	(0.40, 0.40, 0.20)	(0.42, 0.35, 0.23)

5.2. Evaluation Results and Interpretation

Case C1: Hybrid Curriculum + Project-Based Learning + Co-Development + Commercialization

F({Hybrid}, {Project-based}, {Co-development}, {Commercialization})= {x_1(0.90, 0.05, 0.05), x_2(0.85, 0.10, 0.05)}

1. T: Both students scored ≥ 0.85, indicating strong alignment with desired entrepreneurial outcomes.
2. I: Minimal (≤ 0.10), reflecting clarity in evaluation and low ambiguity in the model.
3. F: Nearly absent (0.05), reinforcing the efficacy of this configuration.

This arrangement represents an optimal model for entrepreneurial capacity development. The combination of hands-on pedagogy and deep industry involvement ensures relevance, engagement, and practical outcome realization.

Case C2: Industry-Driven Curriculum + Mentorship + Co-Development + Commercialization
F({Industry-driven},{Mentorship},{Co-development},{Commercialization})={x1(0.88,0.07,0.05), x2(0.86,0.10,0.04)}
1. T: High levels of effectiveness consistent with case C1.
2. I: Slightly higher uncertainty due to the mentorship model, which varies depending on individual mentor effectiveness.
3. F: Lowest among all three cases for x_2 (0.04), confirming the robustness of this design.

The mentorship-based approach is effective when supported by consistent industry co-development. This combination fosters personalized learning while maintaining high relevance to market demands.

Case C3: Academic Curriculum + Lecture-Based Learning + No Industry + Ideation
F({Academic},{Lecture},{None},{Ideation})={x1(0.40,0.40,0.20), x2(0.42,0.35,0.23)}
1. T: Below 0.45, indicating insufficient alignment with entrepreneurial outcomes.
2. I: Very high (≥ 0.35), suggesting evaluator uncertainty due to the absence of experiential or industry elements.
3. F: Between 0.20–0.23, demonstrating notable misalignment between educational inputs and intended innovation outputs.

This configuration lacks both practical engagement and external validation. The high uncertainty and contradiction make it unsuitable for cultivating entrepreneurial competencies in vocational settings.

5.3. Comparative Insight

By mapping these cases through the SHSS model, several key insights emerged:

- Configurations involving co-development and commercialization consistently outperformed others across all neutrosophic dimensions.
- The project-based and mentorship-based pedagogies, when paired with hybrid or industry-driven curricula, yielded high truth scores and minimal falsity.
- Traditional academic-lecture approaches, in isolation, failed to produce competitive results, highlighting their limitations in dynamic vocational ecosystems.

5.4. Implications

The case study affirms the model's ability to:

- Detect differences across program structures with mathematical rigor,
- Represent real-world ambiguity and overlap via neutrosophic extensions,
- Serve as a practical tool for institutional policy reform and strategic planning in IEE.

The SHSS framework, thus, proves both theoretically sound and practically actionable.

6. Results and Analysis

This section analyzes the outcomes derived from applying the SHSS model to the case study presented in Section 5. The focus lies on the three case configurations C_1, C_2, and C_3 and their respective evaluations for student x1 , using neutrosophic values (T, I, F) to quantify the truth degree, indeterminacy, and falsity of outcome alignment.

6.1. Truth Membership (T) Analysis

Figure 1 illustrates the:

1. Case C_1 (Hybrid + Project-based): T=0.90
2. Case C_2 (Industry-driven + Mentorship): T=0.88
3. Case C_3 (Academic + Lecture-based): T=0.40

Analysis:

1. C_1 and C_2 show high levels of truth alignment, confirming that both configurations support IEE outcomes effectively.
2. C_3 falls significantly behind, demonstrating the poor alignment of traditional, non-integrated academic models with entrepreneurial competencies.

Inference: Programs involving real industry engagement and experiential learning correlate strongly with student success in entrepreneurship.

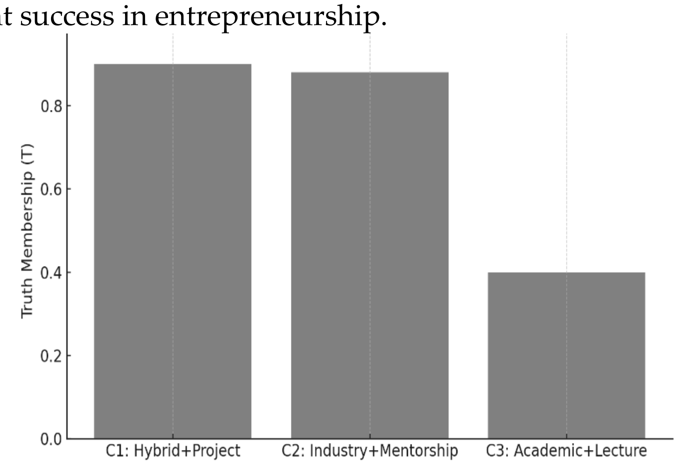

Figure 1. T values for student x_1 across the three configurations

6.2. Indeterminacy and Falsity Evaluation

Figure 2 presents the indeterminacy (I) and falsity (F) values for x_1 under each configuration. Table 4 compares the I and F degrees of student x_1 across the three configurations.

Table 4. Indeterminacy and Falsity Comparison for x_1

Case ID	Indeterminacy (I)	Falsity (F)
C1	0.05	0.05
C2	0.07	0.05
C3	0.40	0.20

Interpretation:
1. C1 and C2 maintain low I and F values, indicating high evaluation clarity and minimal contradiction between program components and outcomes.
2. C3 records the highest levels of indeterminacy (0.40) and falsity (0.20). These values reflect the lack of practical alignment and the evaluator's uncertainty in judging success due to the absence of industry involvement or active learning methods.

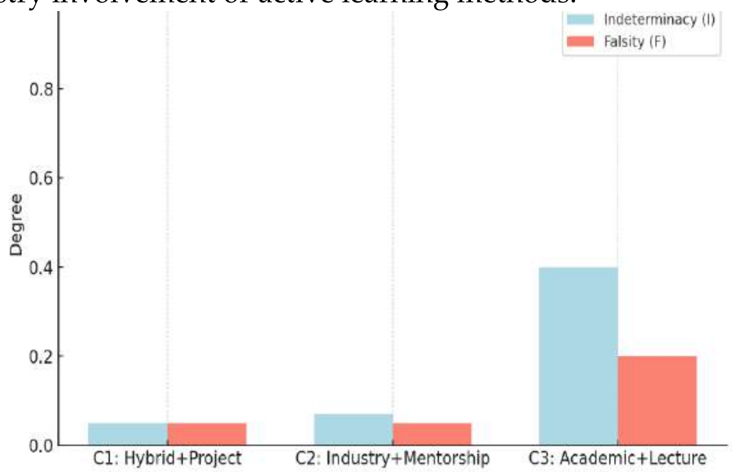

Figure 2. Uncertainty and Falsity Levels of x1 in Each Configuration

6.3. Semantic Interpretation of Neutrosophic Results
Let us consider each value as a semantic indicator:
1. T> 0.85: High validation of pedagogical strategy.
2. I< 0.10: Confidence in evaluation (clear criteria, consistent inputs).
3. F≈ 0.05: Minimal contradiction well-aligned educational design.

In contrast:
1. T< 0.50: Poor structural support for innovative objectives.
2. I> 0.30: Ambiguity in evaluation (vague goals or delivery).
3. F> 0.15: Structural mismatch objectives not met by strategy.

C3 violates all optimal bounds, highlighting structural deficiencies in its approach to entrepreneurship education.

6.4. Comparative Summary of Configurations
Table 5 summarizes and rank the performance of each configuration based on the neutrosophic outputs.

Table 5. Summary Comparison of SHSS Evaluation Outcomes

Metric	C1 (Best)	C2 (Strong)	C3 (Weak)
Truth (T)	0.90	0.88	0.40

Indeterminacy	0.05	0.07	0.40
Falsity (F)	0.05	0.05	0.20
Overall Result	Optimal Alignment	High Alignment	Misaligned / Unclear

6.5. Implications of the Analysis

1. SHSS successfully differentiates between effective and ineffective configurations.
2. Real-world combinations (hybrid + co-development) show superior alignment, validating the industry-education integration principle.
3. The model quantifies vagueness, giving planners precise information about where uncertainties exist and how severe they are.

6.6. Observational Commentary

1. Figure 1 confirms that truth values alone are not sufficient—indeterminacy and falsity must also be analyzed for a complete picture.
2. Figure 2 highlights the stability of innovative configurations (low I and F) and exposes the instability of traditional formats.
3. The SHSS framework, with its decomposable outputs and interpretability, proves more insightful than binary or even traditional fuzzy systems.

7. Limitations of the Study

Although the SuperHyperSoft Set-based evaluation framework demonstrated strong applicability in modeling the complex and uncertain landscape of IEE, several limitations should be acknowledged:

4. The model's interpretability and accuracy are influenced by the quality and completeness of the input data. Inconsistent or limited case data may reduce the reliability of neutrosophic outputs.
5. The definition of attribute domains (what constitutes "hybrid" curricula or "co-development" roles) relies on institutional context and expert judgment, which may vary across settings.
6. Although SHSS enables high-dimensional analysis through power sets, the exponential growth in combinations may require computational optimization in large-scale implementations.
7. The case study was limited to a single vocational institution with specific contextual factors. Broader testing across diverse educational systems is needed to validate model robustness.

7. Conclusion and Future Work

This study introduced a new way to evaluate innovation and entrepreneurship education in vocational colleges by combining SHSS theory with fuzzy-neutrosophic logic. The model helps us understand complex and unclear aspects of education by using values for truth, uncertainty, and falsity. A case study showed that programs with practical, industry-involved teaching methods performed better. Traditional lecture-based models showed more uncertainty and weaker results. Overall, the model helps:

1. Understand the complexity of education programs.
2. Offer clear, data-based suggestions for improvement.

3. Compare different teaching strategies effectively.

Appendix A. Notations Table

To clarify all mathematical symbols and variables used in the SHSS-based model, as referenced throughout the paper.

Table 6: Notations Used

Definition	Symbol
Universe of outcomes	U
Attribute domains	A_i
Power set of A_i	$P(A_i)$
SHSS mapping	F
SHSS expression	$F: P(A_1) \times \cdots \times P(A_n) \to P(U)$
Outcome triplet	x_c
Neutrosophic triplet	$(T, I, F) \in [0,1]^3$
Student instances	x_i
Case identifiers	C_i

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