NSS

Neutrosophic Sets and Systems, Vol. 83, 2025

University of New Mexico

Building Future Innovators: Single Valued Neutrosophic t-Conorm for Evaluating the Role of College English Education in Entrepreneurial Skill Development

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Abstract: The growing significance of entrepreneurial education within higher learning institutions necessitates innovative methodologies for assessing its effectiveness—especially when integrated with core subjects such as English education. This paper proposes a Single Valued Neutrosophic (SVN) t-Conorm-based multi-criteria decision-making (MCDM) approach to evaluate how English courses contribute to entrepreneurial skill development. The model accommodates uncertainty, indeterminacy, and vagueness in human judgments, essential when assessing educational outcomes like creativity, communication, and innovation. By incorporating subjective and linguistic input from students and educators, the framework offers a holistic and granular analysis. Two MCDM methods are used in this study such as CRITIC method to compute the criteria weights using the correlation values and the MULTIMOORA method to rank the alternatives using three parts: ratio system, reference point, and full multiplicative form. This proposed approach is validated using an application. This approach helps policymakers and educators enhance pedagogical strategies aligned with innovation and entrepreneurship goals.

Keywords: Single Valued Neutrosophic t-Conorm; Future Innovators; Entrepreneurial Skill Development.

1. Introduction

In an era driven by innovation and fast-paced technological development, cultivating entrepreneurial skills in students is more essential than ever. English education, often seen merely as a linguistic tool, has gained renewed interest as a medium for developing soft skills that foster creativity, global communication, and cross-cultural awareness. The interweaving of English language instruction with entrepreneurship learning creates a fertile ground for building future-ready innovators[1], [2]. Entrepreneurial capabilities such as problem-solving, strategic thinking, and leadership require context-sensitive and dynamic assessments. Therefore, novel computational tools are essential to measure the effectiveness of English education in this context. Multi-criteria decision-making methods (MCDM) offer the structural robustness needed for such evaluations[3], [4]. Among uncertainty framework, Single Valued Neutrosophic Sets (SVNS) provide a unique advantage by capturing the degrees of truth, falsity, and indeterminacy simultaneously. The proposed model utilizes SVN t-Conorm to integrate judgments, offering a more nuanced understanding of teaching effectiveness in entrepreneurial contexts. This level of granularity ensures that both subjective perceptions and objective outcomes are equitably considered. The inclusion of a t-Conorm operator allows for the aggregation of diverse stakeholder opinions—students, faculty, and experts—under uncertainty. It reflects real-world classroom dynamics where assessments are rarely black-and-white. In doing so, it embraces the vagueness and subjectivity inherent in educational evaluations, which are especially relevant when considering attributes like creativity and innovation[5], [6].

Furthermore, using this approach helps in identifying the specific pedagogical features of English education that contribute to entrepreneurial development. For example, courses that emphasize debate, case analysis, or project-based learning may better cultivate problem-solving skills. The model enables educators to prioritize curriculum components that yield the highest impact in entrepreneurial growth[7], [8]. The practical application of this model was tested on seven English course alternatives across multiple universities. Evaluation criteria included communication skills, creativity stimulation, collaboration, and digital literacy. The SVN t-Conorm approach not only revealed the most effective strategies but also exposed areas needing pedagogical enhancement. This study contributes both a theoretical framework and practical tool for educational stakeholders. By introducing the SVNS-based evaluation model, it bridges the gap between linguistic pedagogy and entrepreneurial competency assessment. It provides actionable insights that support future curriculum development and decision-making processes aligned with innovation-oriented education[9], [10].

1.1 Single Valued Neutrosophic Set

In 1965, Zadeh [11] created the fuzzy set (FS) and substituted a membership function between 0 and 1 for the conventional, sharp values of 0 and 1. A significant and fascinating area of study in the science and philosophy of decision-making is fuzzy theory. However, FS does not have a non-membership function; rather, it is defined only by its membership function, which ranges from 0 to 1. Atanassov [12] developed the idea of an intuitionistic fuzzy set (IFS), which is defined by its membership function and non-membership function between 0 and 1, to address the shortcomings of FS.

The idea of an interval-valued intuitionistic fuzzy set (IVIFS), which is defined by its interval membership function and interval non-membership function in the unit interval [0, 1], was further proposed by Atanassov and Gargov [13] as an extension of an IFS. From a philosophical perspective, Smarandache [14] created a neutrosophic set (NS) to convey ambiguous and inconsistent information because IFSs and IVIFSs are unable to express such information.

To make the concepts of a single-valued neutrosophic set (SVNS) and an interval neutrosophic set (INS) [15], [16] easily applicable to real-world applications, they were based on the real standard interval [0, 1]. Ye [17] introduced a simplified neutrosophic set (SNS), which includes the concepts of SVNS and INS, which are extensions of IFS and IVIFS. While SVNS and INS are subcategories of SNS, SNS is clearly a subclass of NS.

2. Background Overview

In today's competitive and innovation-driven world, universities are expected not only to deliver subject knowledge but also to help students develop entrepreneurial abilities. English education has traditionally focused on communication and literacy; however, it has now begun to play a larger role in fostering creativity, leadership, and critical thinking—skills essential for entrepreneurship. Teaching English with an innovation mindset allows students to engage in collaborative tasks, problem-solving, and interdisciplinary learning, which are directly tied to entrepreneurial outcomes.

To properly assess this evolving role of English education, advanced decision-making tools are needed. This research employs a model that integrates subjective feedback with formal computational methods using Single Valued Neutrosophic Sets (SVNS) and t-Conorm operations. The goal is to understand which aspects of English courses are most effective in enhancing entrepreneurial skill development, using real data from students and instructors.

2.1. Statement of the Challenge

Evaluating the contribution of English education to entrepreneurial development is complex because it involves multiple subjective and uncertain factors. Traditional evaluation systems often fail to capture elements like creativity, critical thinking, and adaptability. Additionally, diverse opinions from students and educators can vary widely, especially in qualitative aspects like innovation or leadership.

This research addresses that gap by applying a structured, neutrosophic-based MCDM framework that can model uncertainty and conflicting judgments. The problem lies not in a lack of awareness, but in the absence of reliable tools that can evaluate linguistic teaching outcomes in entrepreneurial contexts.

2.2. Aim and Scope of the Study

The main aim of this study is to propose and apply an intelligent evaluation framework for assessing how English education contributes to entrepreneurial skill development. This framework should:

Account for both objective and subjective assessments.

Reflect the uncertainties in educational outcomes.

Prioritize different course components based on their real impact on innovation and entrepreneurship.

The model is tested on seven English course alternatives across multiple universities, evaluated against eight criteria related to communication, creativity, digital skills, and collaboration.

2.3. Theoretical Foundation

The methodology is grounded in Single Valued Neutrosophic Set (SVNS) theory, which allows for a flexible representation of uncertainty. This is essential when modeling human perception and evaluation in education. The model also integrates t-Conorm operations, which help in aggregating individual judgments from different sources.

This theoretical foundation enhances the objectivity of decision-making models and ensures that vague, ambiguous, or partially defined opinions can still contribute to structured outcomes.

3. Preliminaries

This section shows some definitions of the single valued Neutrosophic numbers with t-conorm operations [1], [18].

We can define the t-conorm as:

$t^*: [0,1] \times [0,1] \rightarrow [0,1]$ is called t-conorm if it satisfies the following terms

$$t^*(0, y) = y \; and \; t^*(1, y) = 1 \tag{1}$$

$$t^*(y, z) = t^*(z, y) \; for \; x \; and \; y \tag{2}$$

$$t^*\big(y, t^*(z, a)\big) = t^*(t^*(y, z), a) \text{ for all y, z, a} \tag{3}$$

The default t-conorm: $t^*_{max}\,(y, z) = \max(y, z)$ (4)

The bounded t-conorm: $t^*_{bounded}(y, z) = \min(1, y + z)$ (5)

The algebraic t-conorm: $t^*_{algebric}(y, z) = y + z - yz$ (6)

We can define the union and intersection with t-norm and t-conorm such as:

$$y \cap t, t^* z = \big(t, (T_1, T_2), t^*(I_1, I_2), t^*(F_1, F_2)\big) \tag{7}$$

$$y \cup t, t^* z = \big(t^*, (T_1, T_2), t(I_1, I_2), t(F_1, F_2)\big) \tag{8}$$

We can define operations of two SVNNs such as:

$$y \oplus z = \begin{pmatrix} t^*(T_1, T_2), t(I_1, I_2), t(F_1, F_2) = \\ \begin{pmatrix} h\big(h^{-1}(T_1)\big), h^{-1}(T_2), \\ g\big(g^{-1}(I_1)\big), g^{-1}(I_2), \\ g\big(g^{-1}(F_1)\big), g^{-1}(F_2) \end{pmatrix} \end{pmatrix} \tag{9}$$

$$y \otimes z = \begin{pmatrix} t(T_1, T_2), t^*(I_1, I_2), t^*(F_1, F_2) = \\ \begin{pmatrix} g\left(g^{-1}(T_1)\right), g^{-1}(T_2), \\ h\left(h^{-1}(I_1)\right), h^{-1}(I_2), \\ h\left(h^{-1}(F_1)\right), h^{-1}(F_2) \end{pmatrix} \end{pmatrix} \tag{10}$$

$$\varphi y = \begin{pmatrix} h\left(\varphi h^{-1}(T_1)\right), \\ g\left(\varphi g^{-1}(I_1)\right), \\ g\left(\varphi g^{-1}(F_1)\right) \end{pmatrix} \tag{11}$$

$$y^{\varphi} = \begin{pmatrix} g\left(\varphi g^{-1}(T_1)\right), \\ h\left(\varphi h^{-1}(I_1)\right), \\ h\left(\varphi h^{-1}(F_1)\right) \end{pmatrix} \tag{12}$$

The single valued Neutrosophic number operator can be defined as:

$$opt(y_1, y_2, \dots, y_n) = \begin{pmatrix} \prod_{j=1}^{n} T_j^{w_j}, \\ \prod_{j=1}^{n} \left(1 - I_j\right)^{w_j}, \\ \prod_{j=1}^{n} \left(1 - F_j\right)^{w_j} \end{pmatrix} \tag{13}$$

4. CRITIC-MULTIMOORA Approach

This section shows the steps of the CRITIC methodology to obtain the criteria weights and the MULTIMOORA methodology to rank the alternatives.

Build the decision matrix.

$$A = \left[\begin{pmatrix} A_{11} & \cdots & A_{n1} \\ \vdots & \ddots & \vdots \\ A_{m1} & \cdots & A_{mn} \end{pmatrix}\right]_{m \times n}; i = 1, \dots, m; j = 1, \dots, n \tag{14}$$

Compute the normalized decision matrix for the negative and cost criteria such as:

$$r_{ij} = \frac{A_{ij} - A_i^-}{A_i^+ - A_i^-}; i = 1, \dots, m; j = 1, \dots, n \tag{15}$$

$$r_{ij} = \frac{A_{ij} - A_i^+}{A_i^- - A_i^+}; i = 1, \dots, m; j = 1, \dots, n \tag{16}$$

$$A_i^- = \min\left(A_{ij}\right) \tag{17}$$

$$A_i^+ = \max\left(A_{ij}\right) \tag{18}$$

The correlation values between the criteria are computed ϖ_{jk} and the standard deviation is computed for the criteria ρ_j.

The C index value of the CRITIC method is computed such as:

$$C_j = \rho_j \sum_{k=1}^{n} (1 - \varpi_{jk}) \tag{19}$$

The criteria weights are computed.

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{20}$$

The steps of the MULTIMOORA method are introduced such as:

We start to normalize the decision matrix

$$U_{ij}^{*} = \frac{A_{ij}}{\left(\sum_{i=1}^{m} A_{ij}^{2}\right)^{0.5}} \tag{21}$$

The ratio system is computed as:

$$T_i = \sum_{j=1}^{g} w_j U_{ij}^{*} - \sum_{j=g+1}^{n} w_j U_{ij}^{*} \tag{22}$$

Compute the reference point

$$F_i = \max_{j} \left| w_j \max U^{*}{}_j - w_j U_{ij}^{*} \right| \tag{23}$$

Compute the full multiplicative form

$$V_i = \frac{\prod_{j=1}^{g} \left(U_{ij}^{*}\right)^{w_j}}{\prod_{j=g+1}^{n} \left(U_{ij}^{*}\right)^{w_j}} \tag{24}$$

5. Methodological Strategy

5.1 Data Gathering and Expert Input

The study uses evaluations collected from four experts in language education and educational innovation. Each expert provided assessments for seven English course alternatives based on eight criteria. Neutrosophic values were used to represent their judgments, allowing each input to reflect levels of truth, falsity, and indeterminacy.

5.2 Decision Matrix Construction

A decision matrix was built using these SVNNs. These neutrosophic numbers were then aggregated using a t-Conorm operator, which provided a unified view of the collective expert evaluation.

5.3 Weight Assignment Using CRITIC

To assign importance to each criterion, the CRITIC method was applied. It considers both the contrast intensity (standard deviation) and the inter-criterion correlation. The higher the contrast and the lower the redundancy, the greater the weight assigned.

5.4 Ranking Alternatives with MULTIMOORA

Once the criteria weights were established, the MULTIMOORA method was used to rank the alternatives. This method uses three approaches simultaneously: ratio system, reference point, and full multiplicative form, providing a more robust ranking mechanism.

6. Implementation of the Model and Analysis of Results

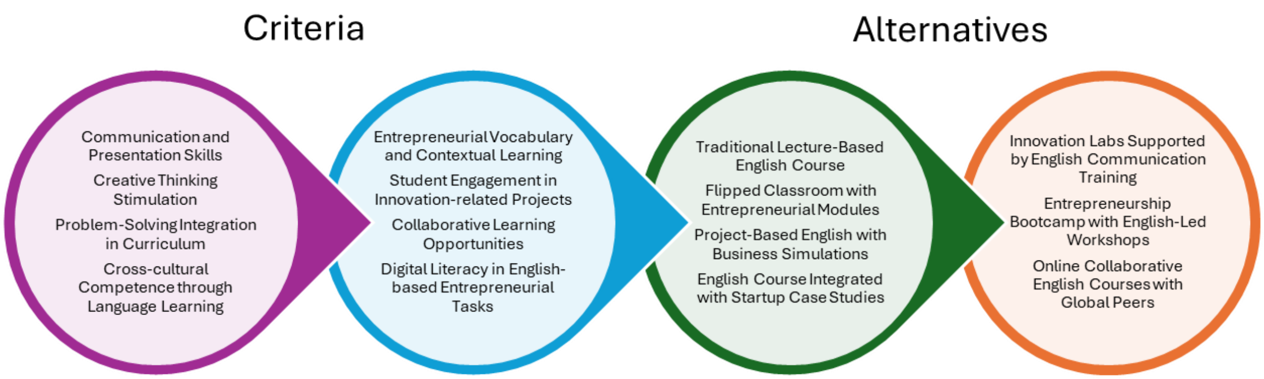

Fig 1. The different criteria and options.

The proposed method was applied in a real evaluation scenario to determine the relative importance of each criterion and to rank the alternatives accordingly. A total of eight evaluation criteria and seven course options were selected for this purpose, as illustrated in Fig. 1.

To assess the performance of these alternatives, four domain experts provided their judgments using Single-Valued Neutrosophic Numbers (SVNNs), which are presented in Table 1. These evaluations were processed through a t-conorm aggregation mechanism designed specifically for SVNNs and subsequently transformed into crisp numerical values for further analysis, as displayed in Fig. 2.

The decision matrix was then standardized using the normalization procedure defined in Eq. (15), with the results also shown in Fig. 2 for reference.

Following this, the correlation between criteria was calculated to understand the relationships and interdependencies among them. This was accompanied by the computation of standard deviation values to measure the variability within the data, as shown in Fig. 3.

Next, the contrast intensity for each criterion, referred to as the C value, was calculated using Eq. (19). The outcomes of this step are illustrated in Fig. 4.

Finally, the weights of the criteria were determined based on the CRITIC method, which utilizes both correlation and standard deviation to derive meaningful significance levels. These weights were calculated using Eq. (20) and are summarized in Fig. 5.

Table 1. The Neutrosophic Numbers.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_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)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.7,0.3,0.4)
A_2	(0.9,0.1,0.2)	(0.2,0.7,0.8)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.6,0.4,0.5)
A_3	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.5,0.5,0.5)
A_4	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.2,0.7,0.8)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.4,0.5,0.6)
A_5	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.2,0.7,0.8)	(0.6,0.4,0.5)	(0.2,0.7,0.8)
A_6	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.2,0.7,0.8)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.4,0.5,0.6)
A_7	(0.4,0.5,0.6)	(0.4,0.5,0.6)	(0.7,0.3,0.4)	(0.4,0.5,0.6)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.5,0.5,0.5)
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.7,0.3,0.4)
A_2	(0.7,0.3,0.4)	(0.2,0.7,0.8)	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.6,0.4,0.5)
A_3	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.5,0.5,0.5)
A_4	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.4,0.5,0.6)
A_5	(0.2,0.7,0.8)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.2,0.7,0.8)	(0.9,0.1,0.2)	(0.5,0.5,0.5)
A_6	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.2,0.7,0.8)	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.2,0.7,0.8)	(0.4,0.5,0.6)
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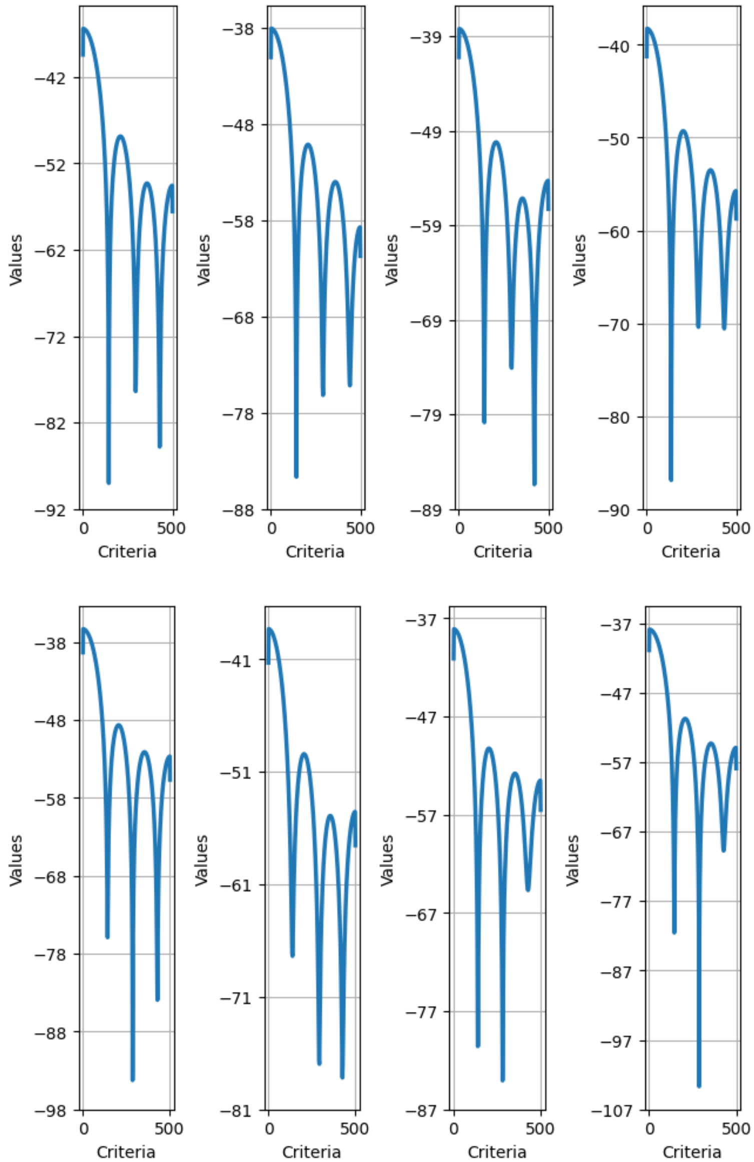

Fig 1. The crisp values.

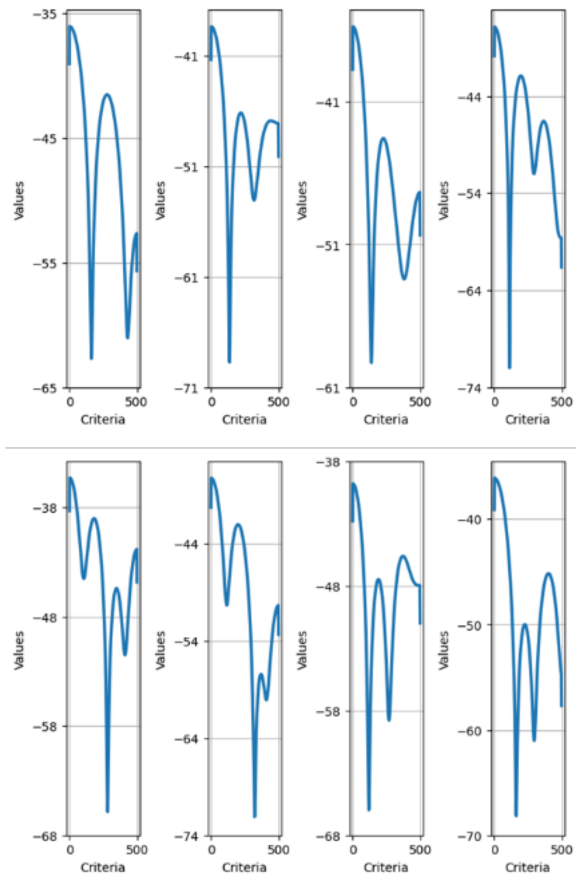

Fig 2. The normalized decision matrix.

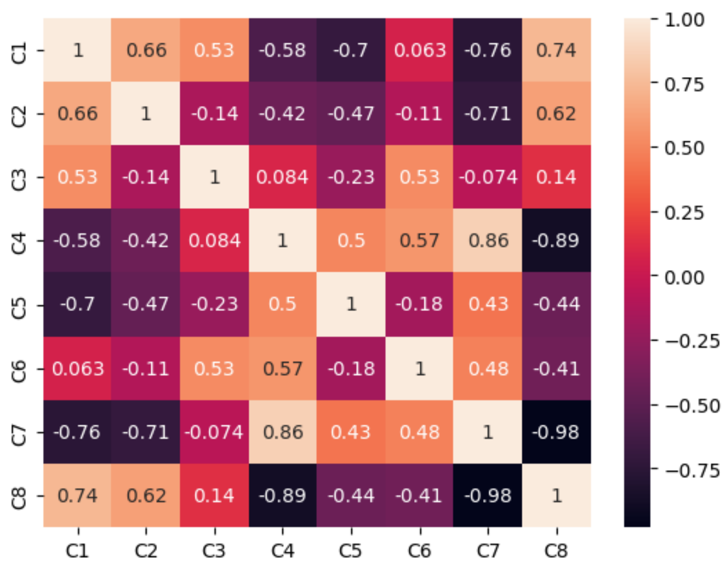

Fig 3. Correlation values.

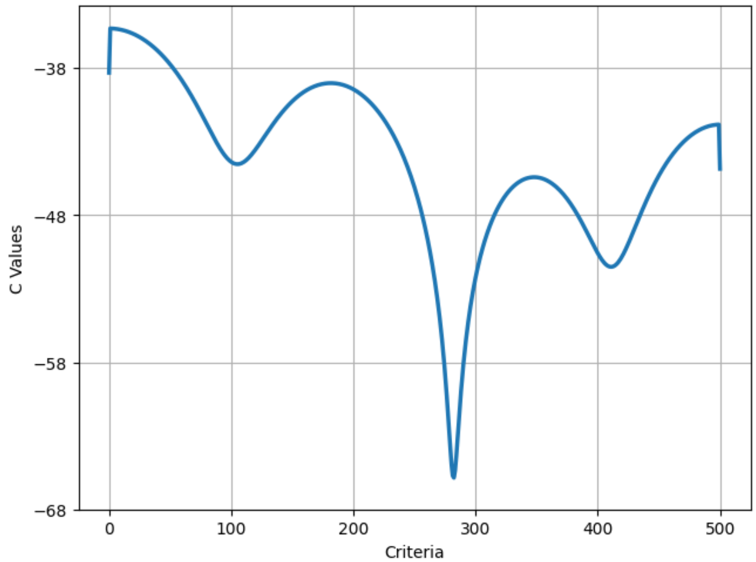

Fig 4. The value of C index.

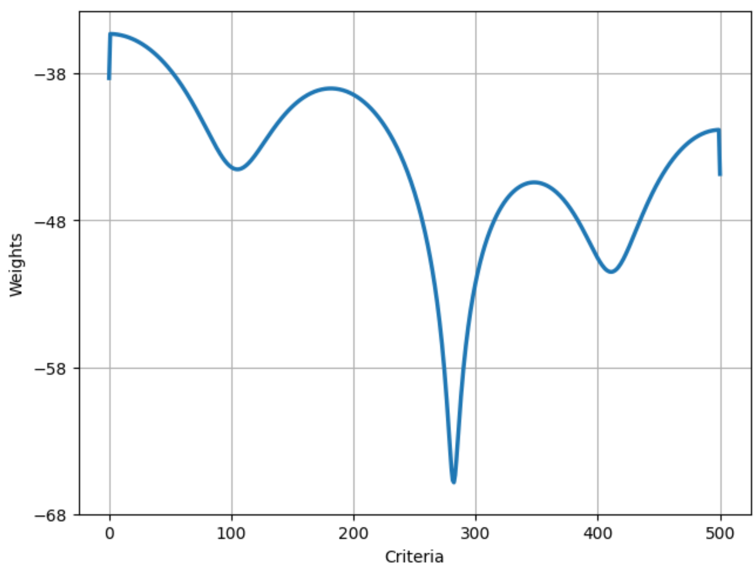

Fig 5. The criteria weights.

The MULTIMOORA method was applied to normalize the decision matrix using Eq. (21), with the resulting values shown in Fig. 6. Based on the calculated criteria weights, the weighted decision matrix was then constructed, as illustrated in Fig. 7.

The next step involved applying the ratio system, which was computed using Eq. (22). The outcomes of this method are displayed in Fig. 8, reflecting the relative performance of each alternative.

A reference point was then determined using Eq. (23), serving as a baseline for comparison across all options, as shown in Fig. 9. Following that, the full multiplicative form was calculated through

Eq. (24) to capture the overall influence of each criterion in combination, with the results presented in Fig. 10.

Based on the outputs of all three components within the MULTIMOORA method, the final rankings of the alternatives were established. These rankings are summarized in Fig. 11.

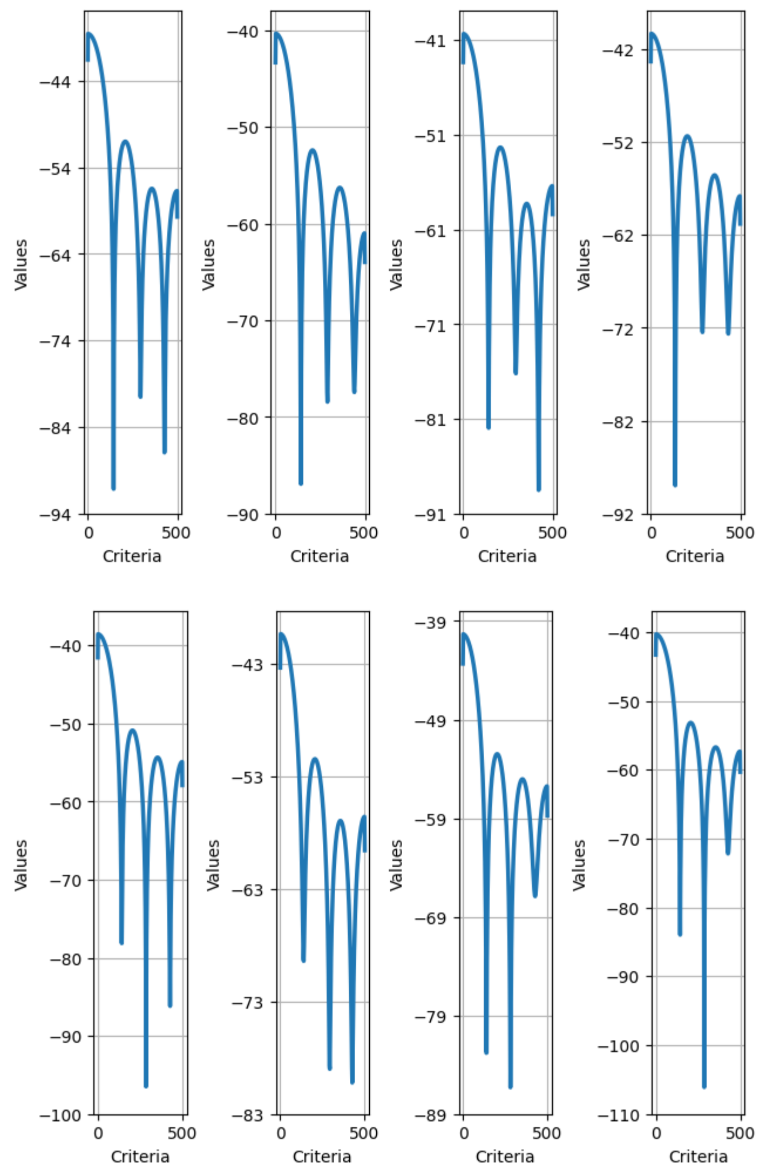

Fig 6. The normalized value by ranking method.

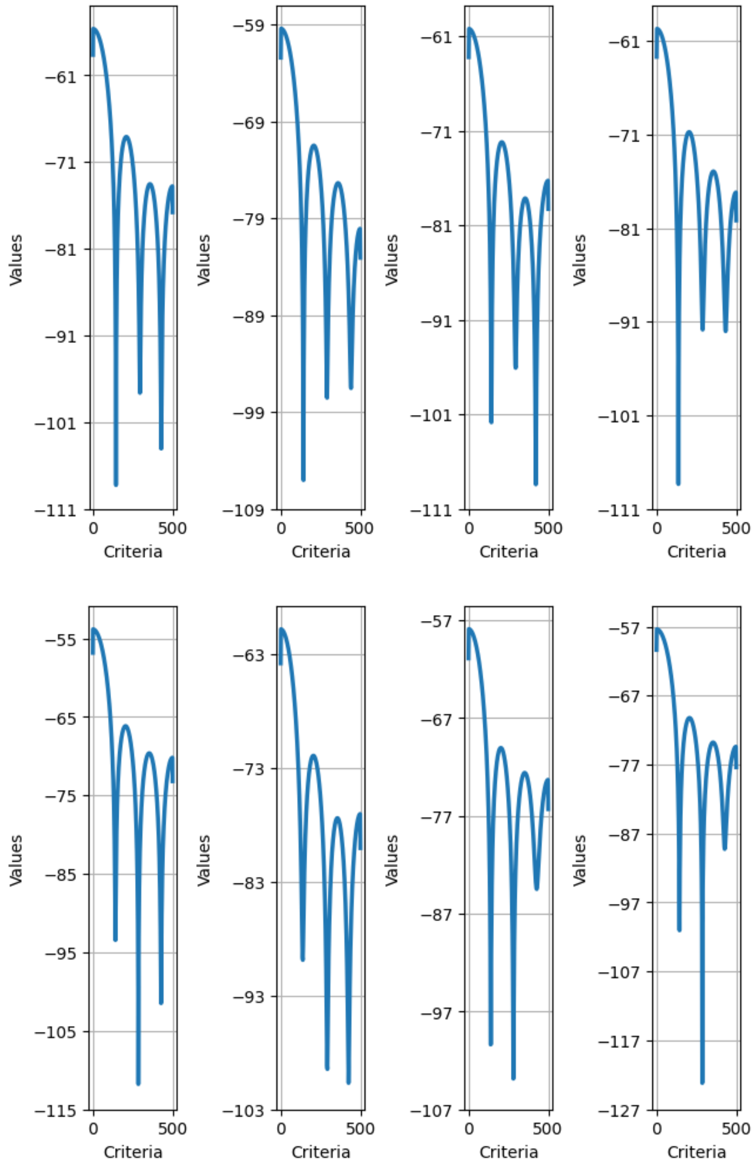

Fig 7. The weighted decision matrix.

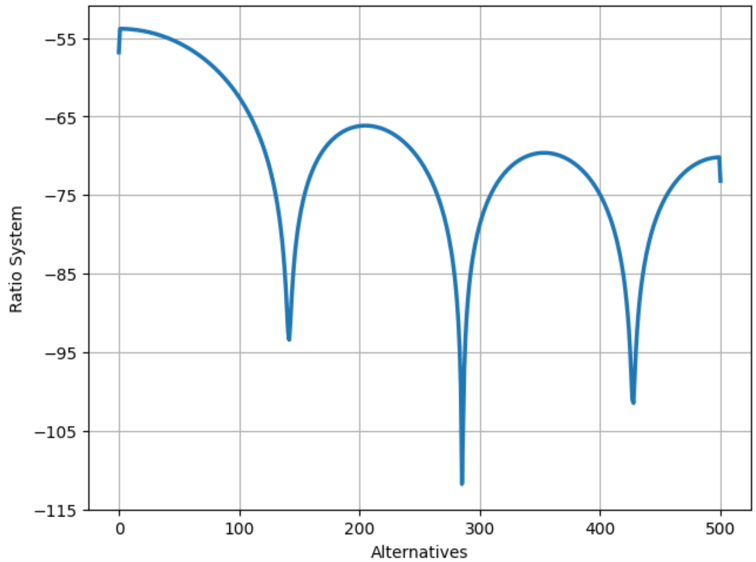

Fig 8. The ratio system values.

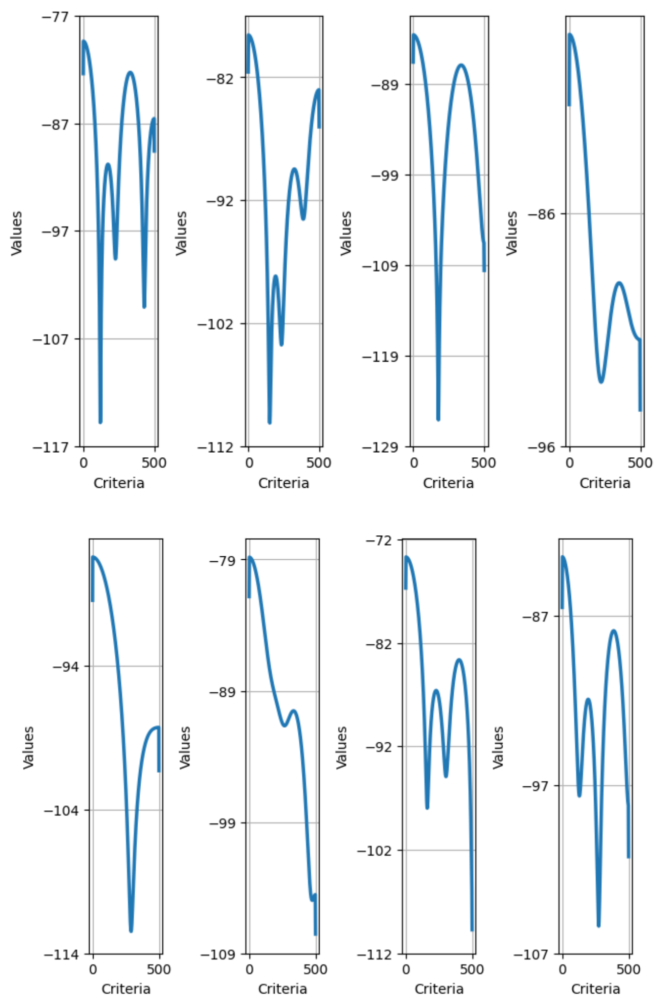

Fig 9. The reference point values.

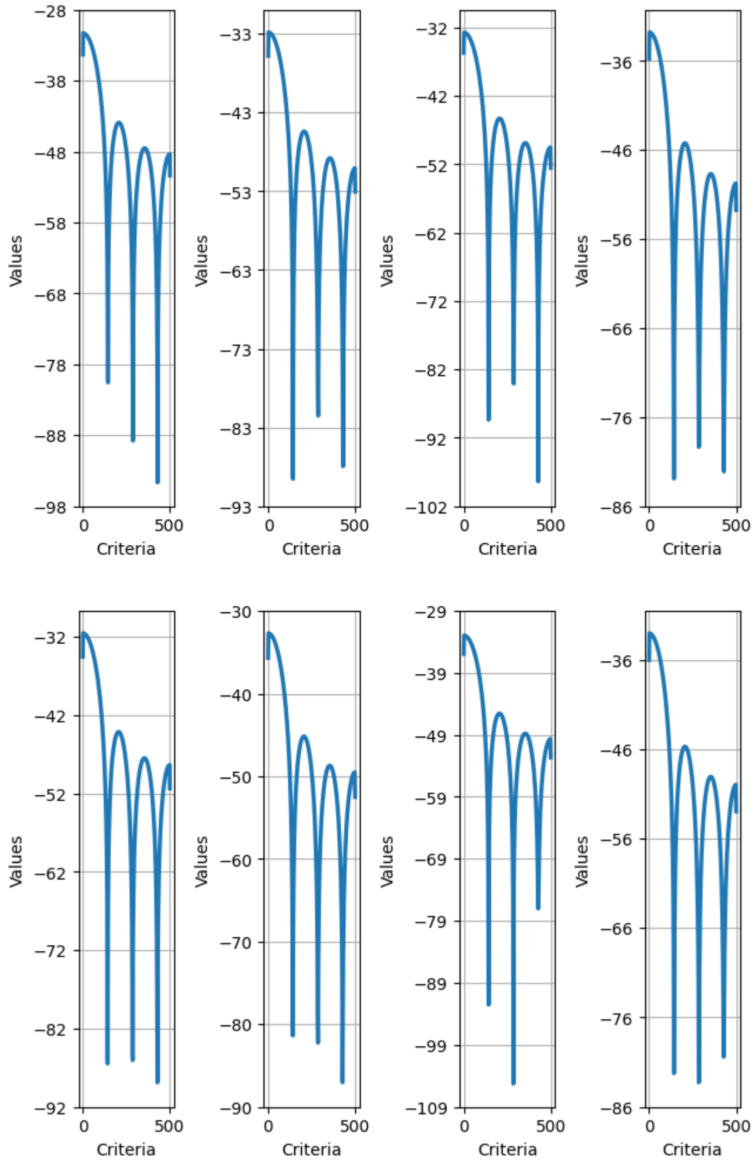

Fig 10. The full multiplicative values.

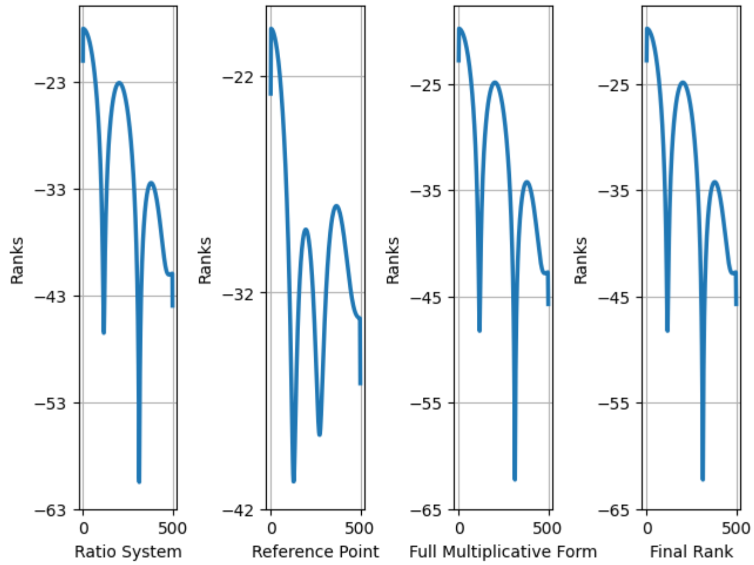

Fig 11. The ranks of alternatives.

The developed evaluation framework was applied to real academic data collected from English language courses designed to foster entrepreneurial thinking. Using inputs from field experts, evaluations were structured into a decision matrix built on single-valued neutrosophic numbers. These inputs captured not only the strength of agreement or disagreement but also the uncertainty often present in educational judgments.

To ensure fairness in comparison, the matrix was normalized to remove scale inconsistencies across criteria. Following this, the CRITIC method was applied to determine the weight of each criterion based on both its contrast intensity and its degree of independence from other criteria. This step helped prioritize the most informative elements within the evaluation process.

Using computed weights, the MULTIMOORA technique was employed to rank the seven course alternatives. Each alternative was assessed through three perspectives: how it performed relative to an ideal solution, how it aligned with a reference profile, and how it behaved under multiplicative comparisons. The combined results revealed notable variation in the effectiveness of course structures. Courses with components such as group projects, real-time interaction, and digital content creation consistently received higher rankings. These learning experiences appeared to support key entrepreneurial attributes, including leadership, adaptability, and collaborative problem-solving. The results provided strong evidence that not all English language courses contribute equally to entrepreneurial development, and that instructional design plays a critical role in shaping outcomes.

7. Implications for Educational Practice

The findings of this study highlight the need for a more strategic approach in designing language education that aims to support entrepreneurial competencies. It became evident that courses grounded in participatory learning methods offer more than just language skills; they also build confidence, initiative, and strategic thinking.

For academic institutions, the framework offers a practical tool for evaluating and refining existing programs. It encourages curriculum developers to assess not only the content but also the instructional format, delivery method, and alignment with real-world skill demands.

Administrators may also find value in using the model for internal quality audits or accreditation purposes, especially when entrepreneurial education is part of the institutional vision. The multi-method approach ensures that judgments are not solely based on intuition but grounded in structured reasoning and data.

Moreover, instructors can benefit by gaining insights into which teaching techniques resonate most with students in terms of entrepreneurial development. This allows for more targeted improvements and helps bridge the gap between theory and application in language education.

8. Study Scope and Constraints

Despite the usefulness of the proposed framework, there are limitations that should be acknowledged. The scope of the evaluation was limited to a specific sample of experts and institutions. While this helped maintain focus, it may have influenced the generalizability of the outcomes.

Another constraint lies in the technical complexity of the model. While the use of neutrosophic numbers and multiple evaluation layers improves accuracy, it also adds to the learning curve for practitioners not familiar with advanced decision-making tools.

Furthermore, the study only considered expert perspectives. Including additional viewpoints, such as those from students or industry stakeholders, could further enrich the understanding of how English education contributes to entrepreneurship. Finally, certain contextual variables, such as local education policies and institutional priorities, may influence how transferable the results are to other environments.

9. Suggestions for Further Research

To enhance the reliability and adaptability of this model, future research can explore a broader range of case studies involving diverse educational contexts. Including different universities, course formats, and cultural backgrounds would strengthen the model's robustness and confirm its scalability.

Researchers are also encouraged to incorporate student-generated data, such as feedback surveys, project evaluations, or self-assessment tools. Doing so would offer a more comprehensive view of how entrepreneurial learning is experienced and perceived by learners.

Another promising direction involves integrating real-time learning analytics, allowing the model to respond dynamically to course progress. This could transform the framework from a static assessment tool into an ongoing performance monitoring system.

Finally, developing digital platforms or simplified toolkits based on this model would significantly increase its practical application, especially for institutions with limited access to data analysts or advanced computational tools.

10. General Assumptions

This research illustrates the potential of using advanced evaluation models to better understand how English education can influence entrepreneurial capabilities. Through the integration of expert input, neutrosophic theory, and structured decision-making techniques, the study provides a reliable and adaptable approach to educational assessment.

The results confirm that teaching methods emphasizing active engagement, digital collaboration, and student empowerment are more effective in fostering innovation-related skills. These findings support a broader shift in language education toward a more competency-based, outcome-driven approach. By offering a structured way to evaluate and improve course effectiveness, the framework proposed in this study contributes meaningfully to both the theory and practice of educational innovation. It also encourages further exploration into how interdisciplinary teaching models can prepare students for complex professional environments.

5. Conclusions

The integration of English education with entrepreneurship training presents a powerful avenue for nurturing future innovators. The use of Single Valued Neutrosophic t-Conorm in evaluating this intersection offers a robust and flexible mechanism that accounts for uncertainty and subjectivity in educational assessments. This study confirms the viability and usefulness of such an approach in real-world academic environments. As higher education institutions seek to align with global innovation goals, adopting such intelligent evaluation tools will be critical. This study used two MCDM methods such as CRITIC method to compute the criteria weights and the MULTIMOORA method to rank the alternatives. These methods are used under the neutrosophic set to deal with uncertainty and vague information. The results from this study can inform more adaptive and interdisciplinary curriculum designs, ultimately fostering a generation of linguistically equipped, globally competent entrepreneurs.

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Received: Nov. 3, 2024. Accepted: April 5, 2025