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A Neutrosophic Logic Framework for Evaluating Virtual Reality-Enhanced Open Educational Resources

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Abstract

A revolutionary strategy for raising the caliber of teaching and learning in higher education is the incorporation of virtual reality (VR) into open educational teaching materials. Teachers may overcome the constraints of conventional teaching materials and establish dynamic learning environments by utilizing virtual reality (VR), which offers immersive, interactive, context-rich experiences. With an emphasis on important factors including content quality, interaction, immersive experience, accessibility, pedagogical efficacy, technical performance, cost effectiveness, and collaboration potential, this research assesses open educational teaching materials via the prism of virtual reality technology. We integrated the neutrosophic logic with the Virtual Reality Technology for Open Educational Teaching Resources Evaluation. We use the neutrosophic logic to overcome uncertainty information. While there are drawbacks in terms of cost and technology requirements, the research also shows how VR-based instructional tools may greatly increase student engagement, information retention, and the development of practical skills. According to research, VR-enabled open resources offer a creative and scalable solution to serve a variety of learners and close the gap between educational theory and practice.

Keywords: Neutrosophic Logic; Virtual Reality Technology; Open Educational Teaching Resources Evaluation.

1 | Introduction

Decision-making approaches offer organized and methodical approaches for assessing several frequently incompatible criteria to facilitate this intricate selection process. Decision-making approaches have become dependable instruments for combining various aspects and facilitating well-informed decision-making, which will assist experts in efficiently assessing and ranking Open Educational Teaching Resources Evaluation. These techniques methodically tackle difficult decision-making issues with several goals and characteristics. Numerous industries employ popular decision-making techniques. To increase decision accuracy, decision-making approaches have occasionally been combined [1].

To rank options, the decision-making technique can either use traditional, clear data or include data that isn't quite clear. However, when faced with ambiguity and contradicting data, traditional decision-making techniques frequently fall short. We provide a decision-making framework based on neutrosophic sets to



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overcome this constraint, which successfully captures and models inconsistency and indeterminacy in decision-making [2].

The suggested approach provides a more reliable and practical means of dealing with such ambiguous data by using Smarandache [3] neutrosophic set theory. To choose the best technique for Open Educational Teaching Resources Evaluation, this study uses a decision-making methodology in a neutrosophic setting.

1.1 | Motivation

We talked about Open Educational Teaching Resources Evaluation using decision-making methodologies based on a few recent research articles.

- Complex approaches are required for the Open Educational Teaching Resources Evaluation due to the growing complexity of evaluation. Later, sophisticated strategies were developed using neutrosophic techniques.
- Strategic selection methodologies have been used in recent advancements. Fuzzy techniques combined with neutrosophic set theory applications have enhanced contemporary study.
- This development in study highlights the urgent need for all-encompassing, flexible frameworks for decision-making that can successfully handle the complex issues.

2 | Literature Review

Teaching strategies that use virtual reality (VR) have the potential to help medical students learn more. An open educational resource software for immersive virtual reality settings, EVENT is designed to be used without the need for programming knowledge. In work of Würstle, et al. [4] EVENT was utilized in a virtual reality lesson on pancreatic cancer for medical students. Participants in the training were invited to be medical students. Participants filled out a VR experience questionnaire and a multiple-choice knowledge test with a maximum score of 10 before and after the VR simulation. The main objective was to compare test results before and after the VR simulation. Usability and variables that could influence test scores and learning progress were secondary goals.

Teaching, learning, and research materials that have been made publicly available for use, sharing, and modification are known as open educational resources, or OERs. An interdisciplinary team at the University of Nottingham Ningbo China (UNNC), a Sino-foreign Higher Education Institution in China, has been working on a new virtual reality (VR) OER, initially targeted at students and teachers in the department of civil engineering. They are motivated by recent successes in OER development. The VR OER focuses on creating a virtual field trip (VFT) to capture experiences and information that students don't normally have access to. Dave Towey et al. [5] looked at the project's history and goals, describes the tactics and collaboration used thus far, and discusses the difficulties and advancements made.

The use of virtual reality (VR) and augmented reality (AR) has become a game-changer in education in recent years, transforming conventional teaching techniques. The purpose of project of Rossetto et al. [6] is to investigate how well AR and VR work as teaching tools to improve solar system instruction. An application with two modules—AR and VR—was developed as part of the study process, and its effects on the educational process were assessed. Additionally, a comparison analysis was done to assess how immersive, interactive, and user-friendly these technologies are. The results show that both AR and VR have potential to enhance the educational process, with the VR module receiving very favorable reviews.

3 | Preliminaries

This section shows the definitions of neutrosophic logic (NL) [7].

Definition 3.1: The linguistic set is characterized by membership functions such as:

$$U = (Q_U(K))$$

Definition 3.2: Single valued linear neutrosophic set is characterized by three membership functions such as:

$$U = (T_U(K), I_U(K), F_U(K))$$

Definition 3.3: Single valued neutrosophic set (SVNS) has different operations

$$\begin{aligned} U_1 + U_2 &= (T_{U_1}(K) + T_{U_2}(K) - T_{U_1}(K)T_{U_2}(K), I_{U_1}(K)I_{U_2}(K), F_{U_1}(K)F_{U_2}(K)) \\ U_1 U_2 &= (T_{U_1}(K)T_{U_2}(K), I_{U_1}(K) + I_{U_2}(K) - I_{U_1}(K)I_{U_2}(K), F_{U_1}(K) + F_{U_2}(K) - F_{U_1}(K)F_{U_2}(K)) \\ \delta U_1 &= (1 - (1 - T_{U_1}(K))^\delta, (I_{U_1}(K))^\delta, (F_{U_1}(K))^\delta) \\ U_1^\delta &= ((T_{U_1}(K))^\delta, 1 - (1 - I_{U_1}(K))^\delta, 1 - (1 - F_{U_1}(K))^\delta) \end{aligned}$$

Definition 3.4: The reliability of SVNS is characterized by:

$$e_j = \begin{cases} \frac{|T_{U_1}(K_j) - F_{U_1}(K_j)|}{T_{U_1}(K_j) + I_{U_1}(K_j) + F_{U_1}(K_j)} & \text{if } T_{U_1}(K_j) + I_{U_1}(K_j) + F_{U_1}(K_j) \neq 0 \\ 0 & \text{if } T_{U_1}(K_j) + I_{U_1}(K_j) + F_{U_1}(K_j) = 0 \end{cases}$$

4 | Methodology

This section shows the steps of the proposed approach. Figure 1 shows steps flowchart of the methodology.

To find viable alternatives and pertinent evaluation standards, form an expert group.

- Specify linguistic variables and use single-valued neutrosophic numbers (SVNNs) as input to represent them.
- Compile professional opinions on each option in relation to every criterion.
- Create the linguistic choice matrix by converting these expert evaluations into single-valued neutrosophic numbers.
- Combine the decision matrix.
- Rank the alternatives.

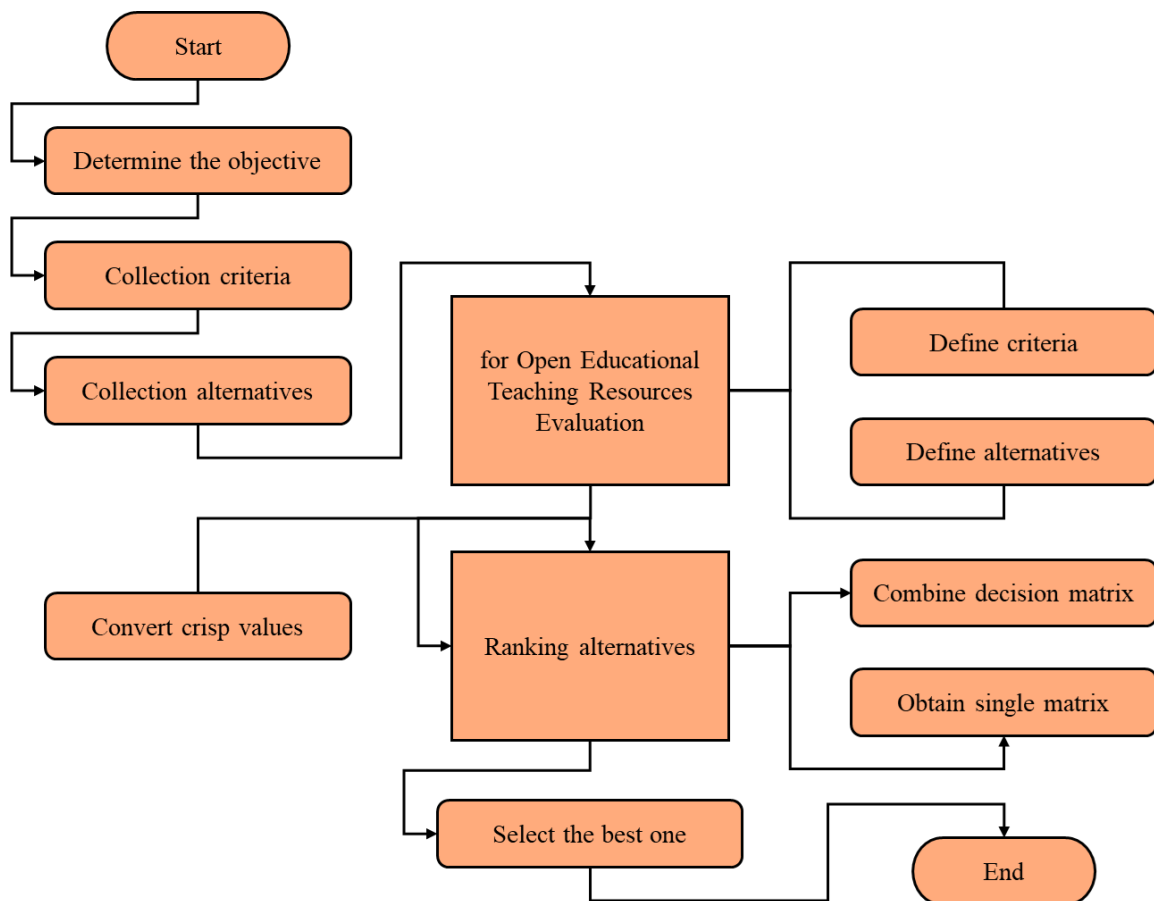


Figure 1. Overview of the proposed methodology.

5 | Open Educational Teaching Resources Evaluation

With advancements in telecommunications, increased technical development, and sustainability, the creation, adoption, and use of contemporary technological advances have changed society on both a social and economic level. Some technical studies have proposed that we start a fourth industrial revolution, known as "Industry 4.0," because of these changes' rapid spread, which has reached a major scale and scope. Applications of artificial intelligence techniques for categorization are growing in popularity.

Education has the challenge of being able to concentrate students' attention on many interactive materials in the face of the present digitalization process brought about by Industry 4.0 and the continual interference of the abundance of available information. The area of teaching has been undergoing change to better match with the current global reality and embrace new pedagogical practices that respect how individuals integrate into contemporary society, given the challenges facing education in the twenty-first century.

5.1 | Criteria

This part shows the criteria of this study. We use eight criteria such as:

- Content Quality (Benefit)
- Interactivity Level (Benefit)
- Immersive Experience (Benefit)
- Accessibility and Usability (Benefit/Cost)
- Pedagogical Effectiveness (Benefit)
- Technical Performance (Cost/Benefit)
- Cost Efficiency (Cost)

- Collaboration and Sharing Potential (Benefit)

5.2 | Alternatives

This part shows the alternatives of this study. We use eight alternatives such as:

- Virtual Science Laboratories
- Historical & Cultural Heritage Simulations
- Virtual Language Learning Environments
- Medical and Nursing Training Simulations
- Engineering & Architecture VR Models
- Virtual Field Trips
- Soft Skills & Professional Training Simulations
- Gamified Learning Platforms

5.3 | Experts

Table 1 shows the choice matrix that was created based on the evaluations of three specialists. Their assessments, which provide the foundation for more research, cover 8 essential criteria and eight options.

Table 1. Experts' panel.

	Industry	Experience	Role
Expert 1	Artificial intelligence	20	Manager
Expert 2	Virtual Reality	25	Manager
Expert 3	Education	18	Manager

6 | Results and Discussion

This section shows the results of the proposed approach. Three experts create the decision matrix as shown in Tables 2-4. Combined decision matrix is obtained as shown in Table 5. Score values of each alternative are obtained as shown in Table 6. Ranks of alternatives are shown in Table 7.

Table 2. First decision matrix.

	VRC ₁	VRC ₂	VRC ₃	VRC ₄	VRC ₅	VRC ₆	VRC ₇	VRC ₈
VRA₁	(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, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.7, 0.3, 0.4)
VRA₂	(0.9, 0.1, 0.2)	(0.2, 0.7, 0.8)	(0.4, 0.6, 0.4)	(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)
VRA₃	(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, 0.6, 0.4)	(0.8, 0.2, 0.3)	(0.8, 0.2, 0.3)	(0.5, 0.5, 0.5)
VRA₄	(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, 0.6, 0.4)
VRA₅	(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)
VRA₆	(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, 0.6, 0.4)	(0.5, 0.5, 0.5)	(0.4, 0.6, 0.4)
VRA₇	(0.2, 0.7, 0.8)	(0.7, 0.3, 0.4)	(0.6, 0.4, 0.5)	(0.2, 0.7, 0.8)	(0.9, 0.1, 0.2)	(0.8, 0.2, 0.3)	(0.4, 0.6, 0.4)	(0.5, 0.5, 0.5)
VRA₈	(0.9, 0.1, 0.2)	(0.6, 0.4, 0.5)	(0.5, 0.5, 0.5)	(0.4, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.7, 0.3, 0.4)	(0.2, 0.7, 0.8)	(0.4, 0.6, 0.4)

Table 3. Second decision matrix.

	VRC ₁	VRC ₂	VRC ₃	VRC ₄	VRC ₅	VRC ₆	VRC ₇	VRC ₈
VRA 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, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.7, 0.3, 0.4)
VRA ₂	(0.7, 0.3, 0.4)	(0.2, 0.7, 0.8)	(0.4, 0.6, 0.4)	(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)
VRA 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)
VRA 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, 0.6, 0.4)
VRA 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)
VRA 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)	(0.4, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.4, 0.6, 0.4)
VRA ₇	(0.2, 0.7, 0.8)	(0.7, 0.3, 0.4)	(0.9, 0.1, 0.2)	(0.5, 0.5, 0.5)	(0.2, 0.7, 0.8)	(0.5, 0.5, 0.5)	(0.2, 0.7, 0.8)	(0.2, 0.7, 0.8)
VRA ₈	(0.6, 0.4, 0.5)	(0.6, 0.4, 0.5)	(0.2, 0.7, 0.8)	(0.4, 0.6, 0.4)	(0.9, 0.1, 0.2)	(0.6, 0.4, 0.5)	(0.8, 0.2, 0.3)	(0.9, 0.1, 0.2)

Table 4. Third decision matrix.

	VRC ₁	VRC ₂	VRC ₃	VRC ₄	VRC ₅	VRC ₆	VRC ₇	VRC ₈
VRA 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, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.7, 0.3, 0.4)
VRA ₂	(0.2, 0.7, 0.8)	(0.2, 0.7, 0.8)	(0.4, 0.6, 0.4)	(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)
VRA ₃	(0.4, 0.6, 0.4)	(0.9, 0.1, 0.2)	(0.6, 0.4, 0.5)	(0.5, 0.5, 0.5)	(0.4, 0.6, 0.4)	(0.8, 0.2, 0.3)	(0.2, 0.7, 0.8)	(0.5, 0.5, 0.5)
VRA ₄	(0.5, 0.5, 0.5)	(0.2, 0.7, 0.8)	(0.9, 0.1, 0.2)	(0.9, 0.1, 0.2)	(0.9, 0.1, 0.2)	(0.9, 0.1, 0.2)	(0.4, 0.6, 0.4)	(0.4, 0.6, 0.4)
VRA ₅	(0.6, 0.4, 0.5)	(0.4, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.9, 0.1, 0.2)	(0.2, 0.7, 0.8)	(0.9, 0.1, 0.2)	(0.5, 0.5, 0.5)	(0.2, 0.7, 0.8)
VRA ₆	(0.7, 0.3, 0.4)	(0.5, 0.5, 0.5)	(0.4, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.4, 0.6, 0.4)	(0.2, 0.7, 0.8)	(0.6, 0.4, 0.5)	(0.4, 0.6, 0.4)
VRA ₇	(0.2, 0.7, 0.8)	(0.7, 0.3, 0.4)	(0.5, 0.5, 0.5)	(0.2, 0.7, 0.8)	(0.9, 0.1, 0.2)	(0.4, 0.6, 0.4)	(0.6, 0.4, 0.5)	(0.5, 0.5, 0.5)
VRA ₈	(0.9, 0.1, 0.2)	(0.6, 0.4, 0.5)	(0.6, 0.4, 0.5)	(0.4, 0.6, 0.4)	(0.8, 0.2, 0.3)	(0.5, 0.5, 0.5)	(0.7, 0.3, 0.4)	(0.4, 0.6, 0.4)

Table 5. Combined matrix.

	VRC ₁	VRC ₂	VRC ₃	VRC ₄	VRC ₅	VRC ₆	VRC ₇	VRC ₈
VRA ₁	0.766667	0.766667	0.66667	0.56667	0.5	0.46667	0.23333	0.667
VRA ₂	0.588889	0.233333	0.46667	0.52222	0.5667	0.66667	0.76667	0.567
VRA ₃	0.666667	0.733333	0.56667	0.55556	0.5	0.76667	0.55556	0.5
VRA ₄	0.644444	0.522222	0.8	0.83333	0.5889	0.86667	0.63333	0.467
VRA ₅	0.433333	0.533333	0.52222	0.83333	0.6222	0.44444	0.64444	0.322
VRA ₆	0.577778	0.522222	0.53333	0.32222	0.5222	0.38889	0.43333	0.467
VRA ₇	0.233333	0.666667	0.64444	0.32222	0.6556	0.57778	0.42222	0.411
VRA ₈	0.766667	0.566667	0.43333	0.46667	0.6222	0.57778	0.55556	0.6

Table 6. Final score.

	Ranks
VRA₁	4.6333333
VRA₂	4.3777778
VRA₃	4.8444444
VRA₄	5.3555556
VRA₅	4.3555556
VRA₆	3.7666667
VRA₇	3.9333333
VRA₈	4.5888889

Table 7. Ranks of alternatives.

	Ranks
VRA₁	6
VRA₂	4
VRA₃	7
VRA₄	8
VRA₅	3
VRA₆	1
VRA₇	2
VRA₈	5

A de-neutrosophication procedure was used to transform neutrosophic information into distinct values following the construction of the SVNN-based decision matrices. Compatibility with the decision making methods for alternative ranking is guaranteed in this stage. A formula that combines the truth, indeterminacy, and falsity components into a single representative score is used to do the de-neutrosophication. This enables systematic calculation in the decision-making process while preserving the uncertainty represented in expert judgments.

VRA4 stands out as the top-performing alternative. It demonstrates the strongest qualities across the evaluation criteria, reflecting excellence in effectiveness, reliability, or contribution to the overall objective. This makes VRA4 the most favorable option in the set.

VRA3 secures the second-highest position, showing consistently strong outcomes. While not as dominant as VRA4, it is highly competitive and can be considered a robust choice in most evaluation scenarios.

VRA1 performs better than most alternatives, ranking in the upper tier. It indicates solid effectiveness and reliability, though it still leaves room for improvement compared to the leaders A3 and A4.

VRA8 shows satisfactory performance, ranking in the middle-to-upper range. It demonstrates balanced qualities but lacks the distinctive strengths of higher-ranked options.

VRA2 occupies the mid-range position, indicating acceptable but not outstanding outcomes. It may perform well in some areas but requires enhancement to be a top contender.

VRA5 falls on the lower side of the ranking, signaling weaker performance. It may face shortcomings in consistency, effectiveness, or contribution to overall objectives.

VRA7 is ranked second to last, suggesting considerable limitations. Its performance is noticeably weaker compared to other alternatives, making it a less viable option unless significant improvements are made.

VRA6 is at the bottom of the ranking, indicating the least favorable outcomes. It underperforms in most evaluation aspects and requires substantial restructuring or support before being reconsidered as a viable choice.

7 | Managerial Implications

Making strategic investment decisions requires university administrators to weigh the long-term advantages of virtual reality infrastructure for student outcomes and institutional competitiveness against the high upfront expenditures.

- **Curriculum Development:** To improve experiential learning and guarantee conformity with learning objectives, academic leaders must include VR-based resources into course design.
- **Faculty Support and Training:** Supervisors ought to fund professional development initiatives that provide educators with the know-how to create, modify, and distribute VR-enhanced free materials
- **Infrastructure and Accessibility:** To lessen student disparity, educational institutions should set up procedures for fair access, such as shared VR laboratories, loan programs for devices, or cloud-based VR platforms.
- **Collaboration and Partnerships:** Collaborations with industry stakeholders, technology suppliers, and other academic institutions may save costs and promote creativity in the creation of excellent open VR content.
- **Frameworks for Continuous Evaluation:** To keep an eye on the efficacy, scalability, and sustainability of VR-based teaching resources, managers need to implement data-driven assessment methods.

8 | Conclusions

Immersion and interaction have a significant role in educational innovation, according to an assessment of free educational teaching resources based on virtual reality technology. Virtual reality (VR) facilitates the investigation of complicated or otherwise unattainable settings, encourages active involvement, and improves learner-centered instruction. Notwithstanding these benefits, problems like cost, infrastructure, and accessibility still pose significant obstacles that need to be overcome to guarantee widespread use. This study used the neutrosophic set to overcome uncertainty information. We proposed a decision-making model to rank the alternatives. All things considered, VR-based free resources offer a potent instrument for enhancing courses and matching learning objectives with the competencies needed in a digital world. A thorough assessment of the cost-benefit ratio will be necessary when organizations adopt digital transformation to ensure long-term adoption.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Author Contributions

All authors contributed equally to this work.

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