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Examen neutrosófico PEST-SWOT de la influencia de la inteligencia artificial como método activo en la educación.

A PEST-SWOT neutrosophic examination of how artificial intelligence influences as an active method in education.

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Resumen. En el contexto contemporáneo de la educación, el análisis neutrosófico PEST-SWOT emerge como una poderosa herramienta para desentrañar los complejos entramados de la inteligencia artificial como metodología activa. Este enfoque no sólo pretende evaluar las amenazas y oportunidades potenciales (como lo haría un análisis DAFO convencional), sino que también incorpora la perspectiva neutrosófica para abordar las incertidumbres inherentes. En este sentido, la inteligencia artificial no se percibe simplemente como un avance tecnológico lineal, sino como un catalizador disruptivo que redefine tanto los paradigmas pedagógicos como las dinámicas de aprendizaje. Desde la perspectiva neutrosófica, se considera la coexistencia de elementos verdaderos, falsos e indeterminados en las evaluaciones de impacto, proporcionando así un marco más holístico y reflexivo para comprender cómo se transforma la educación bajo la influencia de la IA. Este análisis no se limita a sopesar los puntos fuertes y débiles de la integración de la IA en la educación, sino que también explora cómo interactúan estas tecnologías con factores externos como las cambiantes políticas educativas y la evolución de las expectativas sociales y económicas. En consecuencia, el enfoque neutrosófico de PEST-SWOT permite una evaluación más matizada y multidimensional, reconociendo la naturaleza dinámica y a menudo contradictoria de los impactos educativos de la IA. Esta metodología no sólo invita a considerar las oportunidades de mejora en la personalización del aprendizaje y la eficiencia educativa, sino que también destaca la necesidad crítica de gestionar los riesgos asociados, como la privacidad de los datos y la equidad en el acceso tecnológico. En resumen, este estudio refleja un esfuerzo por ir más allá de las dicotomías simplistas y abarcar la complejidad inherente a la transformación educativa impulsada por la inteligencia artificial.

Palabras clave: Inteligencia Artificial, Análisis DAFO, Análisis PEST, Números de Valor Único Neutrosófico, Análisis PEST-DAFO Neutrosófico.

Abstract. In the contemporary context of education, PEST-SWOT neutrosophic analysis emerges as a powerful tool to unravel the complex intertwinings of artificial intelligence as an active methodology. This approach not only seeks to assess potential threats and opportunities (as a conventional SWOT analysis would), but also incorporates the neutrosophic perspective to address inherent uncertainties. In this sense, artificial intelligence is not perceived simply as a linear technological advance, but as a disruptive catalyst that redefines both pedagogical paradigms and learning dynamics. From the neutrosophic perspective, the coexistence of true, false and indeterminate elements in impact evaluations is considered, thus providing a more holistic and reflective framework to understand how education is transformed under the influence of AI. This analysis is not limited to weighing the strengths and weaknesses of AI integration in education, but also explores how these technologies interact with external factors such as changing educational policies, evolving social and economic expectations. Consequently, PEST-SWOT's neutrosophic approach allows for a more nuanced and multidimensional assessment, recognizing the dynamic and often contradictory nature of AI's educational impacts. This methodology not only invites consideration of opportunities for improvement in learning personalization and educational efficiency, but also highlights the critical need to manage associated risks, such as data privacy and equity in technological access. In summary, this study reflects an effort to move beyond simplistic dichotomies and embrace the complexity inherent in educational transformation driven by artificial intelligence.

Keywords: Artificial Intelligence, SWOT Analysis, PEST Analysis, Neutrosophic Single Value Numbers, Neutrosophic PEST-SWOT Analysis.

1 Introduction

The influence of artificial intelligence (AI) in the educational field has triggered a revolution that reconfigures traditional teaching and learning methods. In a scenario where technology advances by leaps and bounds, AI stands not only as a set of sophisticated tools, but as a transformative force capable of redefining the entire educational experience [1]. This phenomenon manifests itself in various forms, from intelligent tutoring systems to adaptive learning platforms, each contributing significantly to the personalization of the educational process. Implementing AI in education poses an unprecedented challenge and opportunity. On the one hand, it offers the potential to personalize learning on a scale previously unimaginable, adapting to the individual needs of each student with a precision and efficiency that traditional methods cannot match. On the other hand, it introduces a series of ethical and practical considerations that require thorough evaluation to ensure that the benefits of these technologies are distributed equitably and responsibly [2]. In the academic context, the role of AI as an active teaching method not only changes the "what" is taught, but also the "how" it is taught. The ability of AI-based systems to analyze large volumes of data and generate precise elements allows for continuous adaptation of content and pedagogical methods, dynamically responding to the needs and learning rhythms of students. This approach, which we could call "smart education", promises to transform the classroom into a more interactive and adaptive environment.

Furthermore, the influence of AI on education covers a broad spectrum, from the development of innovative teaching resources to the improvement of assessment strategies. AI-based tools can facilitate a more objective and detailed assessment of student progress, providing real-time feedback and allowing for more timely intervention. This ability to adjust educational strategies based on individual performance and needs represents significant progress toward more inclusive and effective education. However, integrating AI into the educational environment also poses considerable challenges. Data privacy and security, equity in access to these technologies, and the risk of overreliance are critical aspects that must be addressed seriously. As educational institutions and educational policy makers face these challenges, it is critical to take a balanced approach that maximizes the benefits of AI while mitigating its potential risks [3]. The adoption of active methodologies driven by AI also implies a reconfiguration of traditional roles in the classroom. Teachers, instead of being mere transmitters of knowledge, become facilitators and guides in a more dynamic and personalized learning environment. This evolution in pedagogical roles underscores the need for continuous training and adaptation by educators to fully leverage the capabilities of AI.

The impact of AI on education is not uniform; varies significantly depending on the context in which it is applied. Differences in technological infrastructure, teacher preparation, and access to resources can influence the effectiveness and reach of AI applications in different educational settings. Therefore, it is crucial to consider these variables when evaluating the impact of AI in education, adapting technological solutions to the specific realities of each institution [4]. Furthermore, the analysis of how AI acts as an active method in education must consider not only the technological dimensions, but also the social and cultural ones. The way AI is perceived and accepted by students, teachers and parents can influence the effectiveness of its implementation. Therefore, a holistic approach that considers these dimensions is essential for the successful integration of AI in educational systems. In summary, the influence of artificial intelligence as an active method in education represents a fascinating and multifaceted field of study. The combination of technological advances with changes in pedagogical methodologies opens a new horizon of possibilities, but also requires critical reflection on the challenges and opportunities that this transformation entails. As we enter this era of educational innovation, it is imperative to continually evaluate the impact of AI and adapt our strategies to ensure that the future of education is inclusive, equitable and enriching for all involved [5].

2 Related Works.

2.1. Artificial Intelligence (AI).

Artificial intelligence (AI) has emerged as one of the most significant technological developments of the modern era, bringing with it a series of profound transformations in numerous sectors. From its beginnings as a simple academic curiosity to its current position as an engine of innovation in industries as diverse as health, education and the economy, AI has proven to be a tool of unprecedented disruptive capacity. The essence of AI lies in its ability to simulate human cognitive processes, such as learning and decision-making, using complex algorithms and mathematical models. This capability not only redefines our expectations about what machines can do, but also raises fundamental questions about the very nature of intelligence and creativity [6].

The impact of AI on contemporary society is undeniable and multifaceted. On the one hand, it has driven notable advances in areas such as personalized medicine, where AI systems can analyze large amounts of data to predict diseases and suggest more effective treatments. This type of applications not only promises to improve the quality of life by offering more precise diagnoses and more specific treatments, but also raises a reflection on the limits of technological intervention in such intimate aspects of the human experience. The promise of AI to provide solutions to complex problems often clashes with the ethical challenge of ensuring that these solutions are accessible and

equitable [7]. In the workplace, AI presents an intriguing paradox: while it promises to increase efficiency and productivity, it also poses the risk of job displacement. AI-powered automation has the potential to perform repetitive and dangerous tasks with unmatched accuracy and speed, potentially freeing humans to focus on jobs that require creative and problem-solving skills. However, this change may also result in significant labor market dislocation, requiring a re-evaluation of employment and training policies to prepare the workforce for emerging demands.

Another crucial aspect in the discussion about AI is its influence on privacy and security. As AI systems become integrated into our daily lives, from online product recommendations to surveillance in public spaces, the amount of personal data collected and processed has increased exponentially. This accumulation of data raises serious concerns about the security and misuse of information, underscoring the need to strengthen data protection regulations and ensure that technological advances do not compromise the fundamental rights of individuals [8]. In terms of ethics, AI challenges our traditional conceptions of responsibility and decision-making. The increasing autonomy of machines raises questions about the attribution of responsibility in the event of errors or malfunctions. If an AI system makes a mistake that results in harm or harm, who should be held responsible? This dilemma not only challenges our current legal structures, but also demands deeper reflection on how we assign and share responsibility in an environment increasingly mediated by technology.

Additionally, AI has the potential to transform education by delivering personalized and adaptive learning experiences. AI-based tutoring systems can analyze students' progress in real time, adjusting content and pedagogical strategies to suit their individual needs. However, this technology also raises questions about the quality of human interaction in the educational process and whether over-reliance on automated systems could reduce the role of the educator to mere technical facilitators. The influence of AI on strategic decision-making also deserves detailed analysis. In the business arena, AI algorithms can process large volumes of data to identify patterns and forecast trends, thus offering a significant competitive advantage. However, blind trust in these systems can lead to erroneous decisions if the algorithms are biased or poorly designed [9]. This risk underscores the importance of combining AI analysis with human intuition and judgment to make more balanced and fair decisions. As we move toward deeper integration of AI into all aspects of life, the question of equity becomes central. Accessibility to advanced technologies can exacerbate existing inequalities if only a portion of the population has access to the benefits of AI. It is therefore essential that public policies and research efforts focus on ensuring that AI serves all sectors of society, promoting a fair distribution of resources and opportunities.

On the other hand, the continued development of AI requires interdisciplinary collaboration and constant review of its impacts. Advances in AI must be accompanied by constant dialogue between technicians, ethicists, legislators and society in general to address emerging challenges and ensure that technological evolution aligns with human values and needs. This comprehensive approach is crucial to maximizing the benefits of AI while mitigating its potential risks. Finally, although AI offers a promising horizon of possibilities, it is also vital to maintain a critical and reflective attitude. The fascination with technological advances should not blind us to the challenges and dilemmas that AI poses. The integration of artificial intelligence into our lives must be guided by a balance between innovation and ethical consideration, ensuring that it ultimately serves to enrich and elevate the human experience rather than dilute it. In this era of change, the ability to navigate these challenges will define how artificial intelligence can become a positive and transformative force in our society [10].

2.2. SWOT Analysis.

SWOT analysis, also known as SWOT (Strengths, Weaknesses, Opportunities, Threats), is a strategic tool widely used to evaluate the current situation of an organization, project or specific phenomenon. This analysis provides a framework to identify and understand the strengths, weaknesses, opportunities and threats that can impact the success of an entity or initiative. Below is a detailed description of each component of the SWOT analysis [11]:

Strengths.

Strengths refer to the internal, positive characteristics that give the organization or project a competitive advantage. These may include aspects such as:

Unique resources: Availability of advanced technology, highly qualified human capital, or a strong network of contacts.

Distinctive competencies: Specialized skills or efficient processes that outperform competitors.

Reputation and brand: A solid image in the market that generates trust among clients and partners.

Innovation: Ability to develop new products or services that respond to market demands.

Identifying strengths allows an organization to leverage its competitive advantages and build on its core capabilities to maximize performance.

Weaknesses.

Weaknesses are internal aspects that present disadvantages and limitations, preventing optimal performance or the achievement of objectives. These may include:

Insufficient resources: Lack of funding, obsolete technology or insufficient staff.

Inefficient processes: Operating procedures that generate bottlenecks or frequent errors.

Negative brand image: Reputation problems or an unfavorable perception among customers and partners.

Lack of innovation: Inability to adapt to new trends or technologies.

Recognizing weaknesses allows an organization to proactively address these issues, developing strategies to mitigate or overcome them.

Opportunities.

Opportunities are external factors that can benefit the organization or project if properly exploited. These may include:

Market trends: Changes in consumer preferences or market conditions that can be exploited.

Technological development: Technological advances that can be used to improve products or processes.

Regulatory changes: New policies or regulations that create a favorable environment for growth.

Geographic expansion: New markets or regions that represent growth opportunities.

Identifying opportunities allows an organization to focus its efforts on areas that can generate growth and success, adapting to a dynamic environment.

Threats.

Threats are external factors that can put the performance or success of the organization or project at risk. These may include:

Competition: New competitors or aggressive moves by existing companies that can reduce market share.

Changes in legislation: New regulations or laws that may increase costs or restrict operations.

Adverse economic conditions: Recessions, fluctuations in input prices, or economic crises that affect financial stability.

Natural Disasters: Unexpected events such as natural disasters that can disrupt operations or supply chains.

Analyzing threats allows an organization to prepare to face potential challenges and develop contingency plans.

Application of SWOT Analysis

SWOT analysis is applied through the collection of relevant information, team discussion and evaluation of each of the four components. It is often used in strategic planning to develop strategies that maximize strengths, minimize weaknesses, exploit opportunities, and mitigate threats [12].

Application Example:

Let's imagine a technology company that wants to launch a new product. Using SWOT analysis, you could identify that your strength is innovative technology, your weakness is the lack of marketing staff, your opportunity is the growing demand for technological solutions, and your threat is strong competition in the market [13]. With this information, the company could develop a strategy that uses its strength in technology to compete in the market, while working to improve its marketing team and develop strategies to face competitors. In summary, SWOT analysis is a valuable tool for strategic evaluation, offering a comprehensive view that helps organizations plan more effectively and adapt to a constantly changing environment.

2.3. PEST Analysis.

PEST (Political, Economic, Social and Technological) analysis is a strategic tool used to identify and evaluate external factors that can influence the functioning of an organization or project. Unlike SWOT analysis, which focuses on internal and external factors specific to the entity being analyzed, PEST provides a macro perspective that examines the overall environment in which it operates. Below is a detailed description of each component of the PEST analysis [14]:

Politician (P)

The political environment encompasses the influences and decisions of governments and public policies that may affect the organization or project. Political factors include:

Regulations and Legislation: Laws and regulations that affect the operation, such as labor, environmental and safety regulations.

Political Stability: The stability of the government and the possibility of political changes that may affect the business environment.

Fiscal Policies: Policies related to taxes, subsidies and other economic measures that impact costs and profitability.

International Relations: International trade agreements and treaties that affect the ability to operate in global markets.

Understanding the political environment allows organizations to anticipate and adapt to regulatory and policy changes that may impact their strategy and operations.

Economical (E)

The economic environment refers to the factors that influence the economy in general and, therefore, business activity. Economic factors include:

Economic Growth: The rate of GDP growth and the overall state of the economy, which affects the purchasing power of consumers.

Inflation and Exchange Rates: Inflation levels and fluctuations in exchange rates that impact operating costs and international competitiveness.

Interest Rate: Interest rates that affect the cost of financing and business investment.

Employment Trends: Employment and unemployment levels that affect labor availability and labor costs.

Analyzing the economic environment allows organizations to adjust their strategies based on economic conditions and anticipate how economic changes may affect their performance.

Social

The social environment encompasses the trends and changes in society that can influence the organization or project. Social factors include:

Demographics: Changes in demographic structure, such as age, population growth, and geographic distribution, that affect demand for products and services.

Lifestyles: Changes in consumer preferences and behaviors, such as trends towards sustainability or responsible consumption.

Education and Training: Levels of education and training that affect the availability of skilled labor and employee expectations.

Culture and Values: Cultural changes and social values that can influence customer expectations and preferences.

Understanding the social environment helps organizations align their offerings with societal demands and expectations, as well as anticipate changes in consumer preferences.

Technological (T)

The technological environment refers to advances and changes in technology that can affect the functioning and competitiveness of the organization. Technological factors include:

Innovation and Development: Technological advances and new innovations that can offer opportunities to improve products, processes and services.

Automation: The adoption of automation technologies that impact operational efficiency and cost reduction.

Research and Development: Investments in R&D that boost an organization's ability to develop new solutions and remain competitive.

Technological Infrastructure: Availability and quality of technological infrastructure, such as networks and communication systems, that affect the ability to operate effectively.

Analyzing the technological environment allows organizations to identify opportunities to innovate and adapt to technological advances, maintaining their competitiveness in a constantly evolving market.

Application of PEST Analysis

PEST analysis is applied through the collection and evaluation of relevant information on each of the four factors. It is often used in strategic planning to understand the external environment in which the organization operates, facilitating the identification of opportunities and threats that can influence its success [15].

Application Example:

Let's imagine a technology company that is considering expanding into a new market. Using PEST analysis, the company could identify that the political environment of the new market is stable, but with strict regulations on data privacy. Economically, the country has a high growth rate and low inflation, which is favorable for investment. Socially, the population is rapidly adopting new technologies and is highly educated, which represents an opportunity for the company. Technologically, the market has an advanced infrastructure, which will facilitate the implementation of its products. With this information, the company can develop a strategy that takes advantage of new market opportunities while preparing to comply with local regulations. In summary, PEST analysis is a valuable tool for evaluating the macroeconomic and strategic environment in which an organization operates. It provides a comprehensive vision that helps companies anticipate changes and adapt their strategies to maximize their success in a dynamic and constantly evolving context [16].

2.4. Basic concepts about Neutrosophia.

Unlike traditional PEST-SWOT methods, in this work the evaluations are carried out based on Triangular Neutrosophic Numbers of Single Value. Below are the fundamental explanations on this topic.

Definition 1 ([17]) : The neutrosophic set Nis characterized by three membership functions, which are the truth membership function T_A, the indeterminacy membership functionI_A and membership function to falsehood F_A, where Uis the Universe of Discourse and $\forall x \in U$, $T_A(x), I_A(x), F_A(x) \subseteq]^{-}0, 1^{+}[$, and $^{-}0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^{+}$.

See that by definition, $T_A(x), I_A(x)$and $F_A(x)$are standard or non-standard real subsets of $]^{-}0, 1^{+}[$and, therefore, $T_A(x), I_A(x)$and $F_A(x)$can be subintervals of $[0, 1]$. $^{-}0$and1^{+} They belong to the set of hyperreal numbers.

Definition 2 ([17]) : The single-valued neutrosophic set $F_A: U \rightarrow [0, 1]$(SVN N) Ais U, $T_A: U \rightarrow [0, 1]$where $A = \{< x, T_A(x), I_A(x), F_A(x) > : x \in U\}$and $I_A: U \rightarrow [0, 1]$. $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The single-valued neutrosophic number (SVN N) is symbolized by

$N = (t, i, f)$, such that $0 \leq t, i, f \leq 1$and $0 \leq t + i + f \leq 3$.

Definition 3 ([17]) : The single- $\tilde{a} = \langle (a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$valued triangular neutrosophic number , , is a neutrosophic set in $\mathbb{R}$, whose membership functions of truth, indeterminacy and falsity are defined as follows:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}, x=a_2} \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), a_2 < x \leq a_3 \\ 0, \text{otherwise} \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\beta_{\tilde{a}}(x-a_1))}{a_2-a_1}, a_1 \leq x \leq a_2 \\ \beta_{\tilde{a},}\, x = a_2 \\ \frac{(x-a_2+\beta_{\tilde{a}}(a_3-x))}{a_3-a_2},\ a_2 < x \leq a_3 \\ 1, \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\gamma_{\tilde{a}}(x-a_1))}{a_2-a_1}, a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a},} x = a_2 \\ \frac{(x-a_2+\gamma_{\tilde{a}}(a_3-x))}{a_3-a_2},\ a_2 < x \leq a_3 \\ 1, \text{otherwise} \end{cases} \quad (3)$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0, 1]$,$a_1,\ a_2, a_3 \in \mathbb{R}$ and $a_1 \leq a_2 \leq a_3$.

Definition 4 ([17]) : Given$\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and$\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two triangular neutrosophic numbers of a single value andλ any non-zero number on the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$,
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$,
3. Investment: $\tilde{a}^{-1} = \langle ({a_3}^{-1}, {a_2}^{-1}, {a_1}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3 \neq 0$.

4. Multiplication by a scalar number:

$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, \lambda > 0 \\ \langle (\lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, \lambda < 0 \end{cases}$$

5. Division of two triangular neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 > 0 \text{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 < 0 \end{cases}$$

6. Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1b_1, a_2b_2, a_3b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, \ a_3 > 0 \text{ and } b_3 > 0 \\ \langle (a_1b_3, a_2b_2, a_3b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 > 0 \\ \langle (a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \text{ and } b_3 < 0 \end{cases}$$

Where,∧ It's a norm∨ It is a conorm t.

3. Results and Discussion.

The study is carried out on the factors of artificial intelligence that influence as an active method in education. For this purpose, experts on the subject and specialized literature were consulted. In this way the following factors were identified:

Personalization of Learning:

AI can adapt content and teaching methods based on each student's individual needs and progress. By analyzing data on learner performance and preferences, AI systems deliver personalized learning materials that optimize understanding and retention of information.

Smart Tutoring:

AI-based tutoring systems provide personalized support to students, answering questions, explaining concepts, and offering real-time feedback. This allows students to receive constant help without relying exclusively on the teacher's instructional time.

Predictive Performance Analysis:

AI can analyze historical and current data to forecast future student performance, identifying areas where they might need additional help. This predictive ability allows educators to proactively intervene to address problems before they significantly impact academic performance.

Evaluation Automation:

The marking and evaluation of tests, essays and exams can be automated using AI, reducing the workload for teachers and offering faster and more consistent feedback to students. AI systems can evaluate open-ended responses and provide detailed performance analysis.

Creation of Educational Content:

AI can assist in the creation of educational materials, from the generation of interactive exercises to the development of multimedia resources. This not only speeds up content development, but also allows for greater variety and creativity in learning materials.

Adaptive Learning:

Adaptive learning systems, powered by AI, adjust the pace and difficulty level of exercises based on the student's responses. This ensures that each student receives challenges appropriate to their skill level, facilitating more effective and personalized learning.

Virtual Assistants for Students:

AI-based chatbots and virtual assistants provide ongoing support to students, answering frequently asked questions, guiding them through learning platforms, and offering academic guidance. These assistants are available 24 hours a day, making it easy to access information at any time.

Facilitation of Collaboration:

AI can foster collaboration among students by identifying peers with complementary skills and creating work groups that maximize collaborative learning. Additionally, you can mediate group interactions, providing suggestions and resources to improve team dynamics.

Inclusion and Accessibility:

AI systems can offer additional support to students with special needs, such as text-to-speech, automatic closed captioning, and accommodations for students with disabilities. This improves accessibility and ensures that all students can fully participate in the educational process.

Evaluation and Continuous Improvement of Educational Programs:

AI facilitates continuous evaluation of the effectiveness of educational programs by analyzing data on student performance and the quality of learning materials. This analysis helps educators and administrators adjust and improve programs to better align with educational objectives.

These factors highlight how AI not only acts as a support tool, but also actively transforms the educational process, making teaching and learning more efficient, personalized and inclusive.

Developing a strategy to ensure a positive impact of artificial intelligence as an active method in education may face several obstacles that require attention and consideration – The main obstacles to include are:

Inequalities in Access to Technology:

Lack of access to appropriate technologies in some regions or schools may limit the effective implementation of AI-based tools. This creates a digital divide that can exacerbate existing educational inequalities, where only certain groups of students benefit from technological innovations.

Privacy and Data Security:

The collection and storage of personal student data raises serious privacy and security concerns. Security breaches and misuse of information can compromise trust in AI tools and violate fundamental rights.

Technological Dependency:

An excessive focus on technology can lead to a dependency that displaces the critical role of educators. If AI becomes the primary means of instruction, it can reduce human interaction and pedagogical judgment, key aspects in the educational process.

Bias in Algorithms:

AI systems can perpetuate and amplify existing biases if algorithms are trained on biased data. This can result in unfair recommendations and evaluations that negatively impact certain groups of students, exacerbating inequalities rather than resolving them.

Lack of Training for Educators:

Teachers may not be sufficiently trained to use AI tools effectively. Lack of training and support can limit educators' ability to integrate AI into their teaching methods and fully reap its benefits.

Costs and Financial Resources:

Implementing AI solutions can be expensive and require significant investment in infrastructure, software, and training. For many educational institutions, especially those with fewer resources, these costs can be prohibitive and limit the adoption of AI-based technologies.

Curriculum Adaptation Problems:

Integrating AI into the curriculum can be complex and require significant adjustments to existing curricula. Difficulties in adapting content and teaching methods can hinder the effective implementation of AI tools.

Resistance to change:

Resistance on the part of educators, administrators, and students toward new technologies can be a significant obstacle. Conservative attitudes and lack of trust in AI can hinder its adoption and effective use in the educational environment.

Impact on Social Interaction:

Overreliance on AI can reduce opportunities for social interaction and the development of soft skills, such as communication and collaboration. These skills are crucial for the overall development of students and can be compromised if AI replaces too much human interaction.

Ethical and Regulatory Challenges:

The lack of clear ethical and regulatory frameworks for the use of AI in education can lead to issues related to equity, transparency and informed consent. The absence of adequate guidelines can lead to uncertainty and misunderstanding about the use and implications of AI in the educational environment.

These obstacles highlight the complexity and challenges associated with effectively implementing AI in education. To ensure a positive impact, it is crucial to address these issues comprehensively and develop strategies that promote equitable, safe and effective integration of technology.

Based on the PEST analysis, we can categorize the mentioned factors as threats and opportunities in relation to the four components of this analysis.

Strengths

S 1: Personalization of Learning

AI allows content and teaching methods to be adapted to the individual needs of each student, optimizing their understanding and retention of information. This not only improves the quality of learning, but can also cater to students with different learning styles and paces.

S 2: Intelligent Tutoring

AI-based tutoring systems provide personalized support and real-time feedback, allowing students to receive continuous and accurate help. This can complement the teacher's instruction and offer additional assistance that is tailored to the student's specific needs.

S 3: Evaluation Automation

The ability of AI to mark and evaluate tests in an automated manner lightens the workload of teachers and provides fast and consistent feedback. This improves efficiency in assessment and allows teachers to focus more on teaching and interacting with students.

Opportunities

O 1: Advances in Learning Personalization and Adaptation Technologies

AI offers opportunities to innovate in the personalization of learning, adapting educational content to the individual needs and levels of students. This adaptability can significantly improve the effectiveness of the educational process.

O 2: Creation of Innovative Educational Content

AI facilitates the creation of interactive and multimedia educational materials, promoting greater variety and creativity in available resources. This can enrich the learning process and keep students more engaged.

O 3: Inclusion and Accessibility

AI-based tools can improve accessibility for students with special needs, offering accommodations such as text-to-speech and automatic closed captioning. This ensures that education is more inclusive and accessible to all.

Weaknesses

W 1: Shortage of Training for Educators

Lack of adequate training for teachers in the use of AI-based tools may limit the effectiveness of these technologies in the classroom. Without proper training, educators may have difficulty integrating and effectively using these tools.

W 2: Technological Dependency

The risk of over-reliance on technology can displace the critical role of teachers in education. If AI becomes the primary method of instruction, it could reduce the human interaction and pedagogical judgment essential in the educational process.

Threats

T 1: Privacy and Data Security

The collection and storage of students' personal data raises serious privacy and security concerns. Security breaches or misuse of information can compromise trust in AI tools and violate fundamental rights.

T 2: Bias in Algorithms

AI can perpetuate biases present in the data used to train algorithms. This can result in unfair assessments and recommendations that negatively impact certain groups of students, exacerbating inequalities rather than resolving them.

T 3: Implementation and Maintenance Costs

Implementing AI solutions can be expensive and require significant investment in infrastructure, software, and training. For many educational institutions, especially those with limited resources, these costs can be prohibitive.

This SWOT analysis shows how artificial intelligence offers important advantages and opportunities in the field of education, such as personalization of learning and automation of assessments. However, it also presents significant challenges, including privacy issues and the need for adequate training for educators. Addressing these obstacles is crucial to ensuring that the implementation of AI in education is effective and beneficial for all students.

This structured analysis allows you to visualize in a clear and organized way the various factors that influence artificial intelligence as an active method in education. , as well as the opportunities and challenges that arise in this dynamic and technological context.

A team made up of eleven experts was in charge of analyzing various combinations between an external and an internal factor. Each of them were asked to carry out evaluations using the linguistic terms detailed in Table 4.

Table 1. Linguistic terms for evaluations and their associated SVTNNs. See [14-17].

Linguistic Terms	SVTNN
Very low (VL)	$\langle(0,0,1);0.00,1.00,1.00\rangle$
Low (L)	$\langle(0,1,3);0.17,0.85,0.83\rangle$
Medium Low (MDL)	$\langle(1,3,5);0.33,0.75,0.67\rangle$
Medium (M)	$\langle(3,5,7);0.50,0.50,0.50\rangle$

Linguistic Terms	SVTNN
Medium High (MDH)	$\langle(5,7,9);0.67,0.25,0.33\rangle$
Height (H)	$\langle(7,9,10);0.83,0.15,0.17\rangle$
Very high (VH)	$\langle(9,10,10);0.00,1.00,1.00\rangle$

Specifically, there are the following sets:
$W = \{W_1, W_2\}$ denotes the set of Weaknesses,
$S = \{S_1, S_2, S_3\}$denotes the set of Strengths,
$T = \{T_1, T_2, T_3, T_4, T_5, T_6, T_7\}$denotes the set of Threats,
$O = \{O_1, O_2, O_3, O_4, O_5\}$denotes the set of Opportunities.

The steps are the following:

1. Each expert was asked to evaluate the possible combinations between the elements of SO, ST, WO and WT.
2. Linguistic terms are replaced by the equivalent single-valued triangular neutrosophic numbers (SVTNN) in Table
3. A single SVTNN is obtained by calculating the median of the SVTNNs of all experts for each pair of items.
4. The arithmetic mean of the SVTNN is calculated for each quadrant SO, ST, WO and WT.
5. The final result of each quadrant is converted to a crisp value using precision Equation 4. This converts them into values on a numerical scale out of 10 that allows the results to be compared.

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (4)$$

Tables 5, 6, 7 and 8 summarize the results obtained after applying the previous steps.

Table 2. Calculation results for the SW quadrant. The medians of all experts are shown.

		Opportunities				
		O_1	O_2	O_3	O_4	O_5
Strengths	S_1	h	V.H.	V.H.	h	h
	S_2	V.H.	h	h	h	V.H.
	S_3	h	MDH	h	h	h

Table 3. Calculation results for the ST quadrant. The medians of all experts are shown.

		Threats						
		T_1	T_2	T_3	T_4	T_5	T_6	T_7
Strengths	S_1	MDVH	V.H.	MDVH	MDVH	V.H.	V.H.	VVH
	S_2	h	VVVH	V.H.	h	h	VVH	h
	S_3	V.H.	MDH	h	V.H.	V.H.	MDH	V.H.

Table 4. Calculation results for the WO quadrant. The medians of all experts are shown.

		Opportunities				
		O_1	O_2	O_3	O_4	O_5
Weaknesses	w_1	MDH	MDH	MDH	MDH	MDH
	w_2	MDH	MDH	MDH	MDH	MDH

Table 5. Calculation results for the WT quadrant. The medians of all experts are shown.

		Threats						
		T_1	T_2	T_3	T_4	T_5	T_6	T_7
Weaknesses	w_1	V.H.	V.H.	h	V.H.	h	V.H.	V.H.
	w_2	MDH	MDH	MDH	MDH	MDH	MDH	MDH

From Tables 5 to 8, we have the following results:

- Potentials (Opportunities+Strengths): $\langle((8.6468, 9.2638, 9.9813); 0.58, 0.55, 0.63\rangle$,
- Risks (Strengths+Threats): $\langle((5.5190, 6.5814, 9.8519); 0.58, 0.25, 0.33\rangle$,
- Challenges (Weaknesses+Opportunities) $\langle((6, 5,9); 0.58, 0.35, 0.13\rangle$:
- Limitations (Weaknesses+Threats): $\langle((6.2, 8.0, 5.5); 0.55, 0.43, 0.51\rangle$.

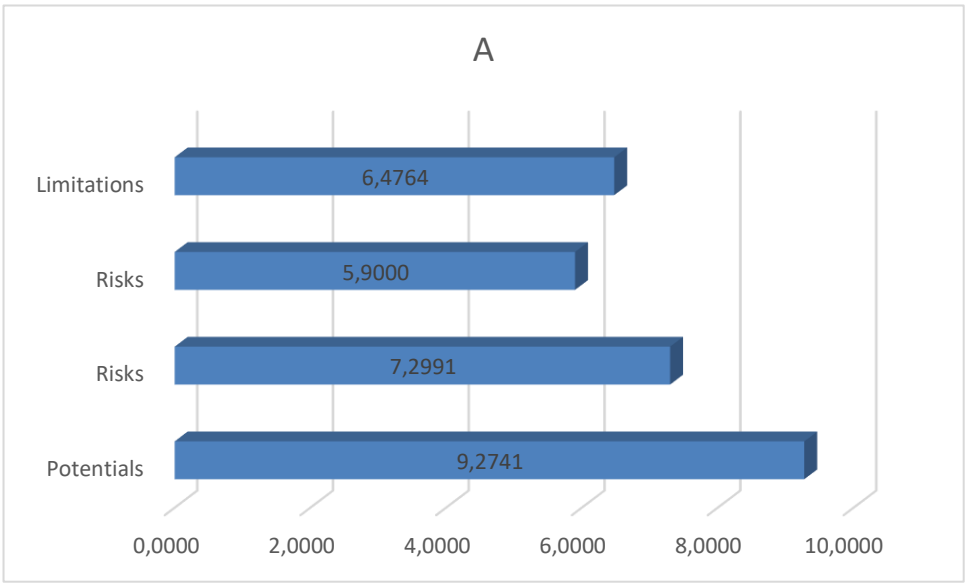
As a last step, these values are converted into a neat scale with a maximum of 10 using Equation 4. From here we have the following results :

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (4)$$

	TO	a1	a2	a3	α	β	γ
Potentials	**9.2741**	8.6468	9.2638	9.9813	0.5800	0.5500	0.6300
Risks	**7.2991**	5.5190	6.5814	9.8519	0.5800	0.2500	0.3300
Challenges	**5.9000**	6,0000	5,0000	9,0000	0.5800	0.3500	0.1300
Limitations	**6.4764**	6,2000	8,0000	5,5000	0.5500	0.4300	0.5100

1. Potentials (Opportunities+Strengths): 9.2741
2. Risks (Strengths + Threats): 7.2991.
3. Challenges (Weaknesses + Opportunities): 5.9000.
4. Limitations (Weaknesses + Threats): 6.4764.

Figure 1. Calculation results for the WO quadrant.



In the vast landscape of the integration of artificial intelligence (AI) in education, multiple dimensions are revealed that deserve close scrutiny. The evaluation of AI factors allows us to classify these aspects into potentials, risks, challenges and limitations, with the aim of developing a critical and nuanced perspective on its implementation and effectiveness. First of all, the analysis of the potentials shows an encouraging picture of the impact of AI on education. With an outstanding score of 9.2741, it is evident that the combined strengths and opportunities suggest a positive trend. Personalization of learning, a key strength, stands out as a powerful driver for adapting content to the individual needs of students. This approach not only optimizes information retention, but also allows each student to progress at their own pace, overcoming the limitations of the traditional approach and offering a truly personalized educational experience.

Added to this is AI's ability to offer intelligent tutoring, another crucial strength that provides continuous support and real-time feedback. This aspect effectively complements the teacher's instruction, offering students additional and precise assistance that facilitates learning in specific areas. At the same time, automating assessments represents a significant advance, easing the administrative burden on teachers and providing faster and more consistent feedback, which in turn allows for better time management and a more focused approach to teaching. The identified opportunities further reinforce the positive outlook. The possibility of innovating in the personalization of learning and creating interactive educational materials through AI highlights the ability of this technology to enrich the educational experience. Creating multimedia and adaptive content not only keeps students engaged, but also facilitates an inclusive and accessible education for everyone, regardless of their special needs.

However, risk analysis reveals that, despite the promising benefits, there are significant challenges that should not be ignored. The combination of strengths and threats gives a score of 7.2991, indicating that, although the benefits are evident, the risks are also considerable. Concern for data privacy and security is paramount. Managing large volumes of student personal data raises serious questions about information protection and the potential misuse of this data, which can compromise trust in technology. Likewise, bias in algorithms is a worrying threat. AI systems trained on biased data can perpetuate inequalities and lead to unfair evaluations. This situation not only affects educational equity, but can also deepen existing gaps in the educational system.

Regarding challenges, the score of 5.9000 indicates that the combined weaknesses and opportunities show areas for improvement. The shortage of training for educators emerges as a significant challenge. The effectiveness of AI in the classroom depends largely on teachers' ability to integrate and use these tools. Without adequate training, educators may face difficulties in effectively implementing technology, limiting its beneficial potential. Technological dependence also presents itself as a considerable challenge. The risk of AI replacing human pedagogical judgment is real and may reduce meaningful interaction between teachers and students. This situation puts at risk the balance necessary for a comprehensive education that is not only based on technology, but also on human experience and personal contact. Finally, the limitations reflect a score of 6.4764, showing that the combined weaknesses and threats represent important barriers. Implementation and maintenance costs are a notable limitation, especially for institutions with limited resources. The investment required to develop, implement and maintain AI systems can be

prohibitive, creating a significant economic barrier to widespread adoption. In summary, the SWOT analysis of artificial intelligence in education reveals a complex and nuanced picture. While the strengths and opportunities suggest significant potential to improve the personalization and accessibility of learning, the associated risks and challenges, such as privacy issues, algorithmic bias, and economic challenges, should not be underestimated. To maximize the positive impact of AI in education, it is crucial to proactively address these challenges and balance technological advances with careful consideration of their ethical and practical implications.

Conclusion

The integration of artificial intelligence (AI) in the educational field opens a horizon of promising possibilities, transforming the way we conceive learning and teaching. The analysis carried out reveals that, despite the inherent challenges, the strengths and opportunities provided by AI offer significant potential to revolutionize education. Personalization of learning emerges as a key strength, allowing for meticulous adaptation of content to the individual needs of each student. This approach not only optimizes the retention and understanding of information, but also results in an educational experience adjusted to the pace and learning style of each student, thus overcoming the limitations of traditional methods. In addition, intelligent tutoring, enabled by AI systems, strengthens the capacity of educators by offering continuous support and real-time feedback. This personalized support complements the teacher's instruction and provides additional assistance, especially in areas where the student may need reinforcement. The automation of evaluations, for its part, will lighten the administrative burden on teachers, allowing faster and more consistent feedback. This efficiency not only optimizes educators' time, but also contributes to more effective management of the educational process. However, the analysis of the risks associated with the implementation of AI in education should not be minimized. The score obtained suggests that, despite the obvious advantages, the risks are equally significant. The privacy and security of student data emerge as primary concerns. Managing large volumes of personal information poses serious challenges in terms of protection and ethical use of this data, potentially compromising trust in AI tools. Additionally, bias in the algorithms used to train AI systems can perpetuate existing inequalities, resulting in unfair assessments and recommendations that can exacerbate educational gaps rather than mitigate them.

The identified challenges underscore the urgent need to address the shortage of training for educators in the use of AI-based tools. The effectiveness of technology in the classroom is closely linked to teachers' ability to adequately integrate it into their pedagogical practice. Without adequate training, the implementation of these tools can be compromised, limiting their positive impact. Furthermore, overreliance on technology poses a risk of crowding out human pedagogical judgment, which can reduce meaningful interaction between teachers and students. Comprehensive education requires a balance between technology and human experience, ensuring that the role of educators is not undermined. Finally, financial constraints are a prominent barrier to widespread adoption of AI in education. The costs associated with implementing and maintaining these technologies can be prohibitive, especially for institutions with limited resources. This economic reality poses a considerable challenge to the expansion and accessibility of AI-based solutions, limiting their potential impact. In conclusion, while AI presents an unprecedented opportunity to enrich and personalize education, it is imperative to proactively address the associated risks and challenges. To maximize the positive impact of AI in education, technological advancement must be balanced with careful consideration of its ethical, practical and economic implications. The successful integration of AI in education will not only depend on its effective implementation, but also on the ability of the educational community to adapt and manage these changes in an equitable and responsible manner.

References

[1] J. Schmidhuber , “Deep Learning in Neural Networks: An Overview,” *Neural Networks* , vol. 61, pp. 85-117, Jan. 2015, doi : 10.1016/j.neunet.2014.09.003.

[2] A. Mnih et al., “Human-level control through deep reinforcement learning,” *Nature* , vol. 518, no. 7540, pp. 529-533, Feb. 2015, doi : 10.1038/nature14236.

[3] Y. Bengio , “Learning Deep Architectures for AI,” *Foundations and Trends® in Machine Learning* , vol. 2, no. 1, pp. 1-127, 2009, doi : 10.1561/2200000006.

[4] K. He, X. Zhang, S. Ren, and J. Sun, “Delving Deep into Rectifiers: Surpassing Human-Level Performance on ImageNet Classification,” *IEEE Transactions on Pattern Analysis and Machine Intelligence* , vol. 38, no. 10, pp. 1947-1960, Oct. 2016, doi : 10.1109/TPAMI.2016.2538088.

[5] A. Radford, K. Narasimhan , T. Salimans , and I. Sutskever , "Learning Transferable Visual Models From Natural Language Supervision," *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)* , pp. 8748-8763, 2021, doi : 10.1109/CVPR46437.2021.00861.

[6] C. C. Aggarwal, *Machine Learning for Text* , Springer, 2018, ISBN: 978-3319630352.
[7] S. Amershi et al., "Software Engineering for Machine Learning: A Case Study," *IEEE Software* , vol. 37, no. 6, pp. 50-57, Nov. 2020, doi : 10.1109/MS.2020.2985675.
[8] EA Shihab and MA Khalil, "Artificial Intelligence Techniques for Autonomous Vehicles: A Review," *IEEE Access* , vol. 8, pp. 65717-65732, 2020, doi : 10.1109/ACCESS.2020.2989235.
[9] T. G. Dietterich , "Ensemble Methods in Machine Learning," *Proceedings of the First International Workshop on Multiple Classifier Systems* , vol. 1857, pp. 1-15, 2000, doi : 10.1007/3-540-45014-9_1.
[10] L. Breiman , "Random Forests," *Machine Learning* , vol. 45, no. 1, pp. 5-32, Oct. 2001, doi : 10.1023/A:1010933404324.
[11] Benzaghta , M.A., Elwalda , A., Mousa , M.M., Erkan , I., and Rahman , M. (2021). Applications of SWOT analysis: An integrative review of the literature. Journal of Global Business Insights , 6(1), 54-72.
[12] Yusuf , M., Saiyed , R., & Sahala , J. (December 2022). SWOT analysis in the development of the relationship marketing program. In Proceedings of the International Conference on Economics and Business (Vol. 1, No. 2, pp. 573-588).
[13] Longsheng , C., Shah , S.A.A., Solangi , Y.A., Ahmad, M., & Ali, S. (2022). A multi-criteria integrated SWOT analysis on the implementation of sustainable waste-to-energy in Pakistan. Renewable Energy, 195, 1438-1453.
[14] Farrokhnia, M., Banihashem , S.K., Noroozi, O., & Wals , A. (2024). A SWOT Analysis of ChatGPT : Implications for Educational Practice and Research. Innovations in International Education and Teaching, 61(3), 460-474.
[15] Vázquez, ML, Hernández, JH, Batista- Hernández, N.., Salvatierra, JAA, and Baryolo, O. G. (2018). A framework for PEST analysis based on fuzzy decision maps. Spaces, 39, 13.
[16] Matović, I.M. (September 2020). PESTEL analysis of the external environment as a success factor for a startup. In Proceedings of the ConScienS conference (pp. 96-102). Scientia Research Institute Moralitas.
[17] Cox, J. (2021). The higher education environment driving academic library strategy: A political, economic, social and technological (PEST) analysis. The Journal of Academic Librarianship, 47, 102219.
[18] Batista- Hernández, N., Vega, JAF, Cuzco, NEU and Merchán, MMF (2020). Neutrosophic Method for making decisions on procedure of tender for the acquisition of goods and services in public procurement. Neutrosophic Computing and Machine Learning, 11, 1-8.
[19] Batista- Hernández, N., Leyva- Vázquez, MY, González- Caballero, E., Cruzaty, LEV, Ortega- Chávez, W., and Smarandache , F. (2021). A new method for assessing entrepreneurial competence in university students using plitogenic numbers and SWOT analysis. International Journal of Fuzzy Logic and Intelligent Systems, 21, 280-292.
[20] Obbineni , J., Kandasamy , I., Vasantha , W.B., & Smarandache , F. (2023). Combining SWOT analysis and neutrosophic cognitive maps for multi-criteria decision making: A case study of organic farming in India. Soft Computing , 27, 18311-18332.
[21] Mohamed, Z., Ismail, MM, & Abd El- Gawad , AF (2023). Analysis Impact of Intrinsic and Extrinsic Motivation on Job Satisfaction in Logistics Service Sector: An Intelligent Neutrosophic Model. *Neutrosophic Systems With Applications* , *4* , 43-52. https://doi.org/10.61356/j.nswa.2023.20
[22] Mohamed, M., & Sallam , K.M. (2023). Leveraging Neutrosophic Uncertainty Theory toward Choosing Biodegradable Dynamic Plastic Product in Various Sands. *Neutrosophic Systems With Applications* , *5* , 1-9. https://doi.org/10.61356/j.nswa.2023.23
[23] Dhouib , S. (2021). Optimization of the salesman problem on a single-valued triangular neutrosophic number using the dhouib-matrix-TSP1 heuristic. International Journal of Engineering, 34, 2642-2647.
[24] Kumar , S. Edalatpanah , S. (2020). A new classification function for the triangular neutrosophic number and its application in integer programming. Journal of International Journal of Neutrosophic Science, 4(2), 82-92.
[25] Mathew, L.P. and Sebastian , L. (June 2023). An introduction to single-valued neutrosophic fuzzy numbers, trapezoidal single-valued neutrosophic fuzzy numbers, and triangular single-valued neutrosophic fuzzy numbers. In Proceedings of the AIP conference (Vol. 2875, No. 1). AIP Publication.
[26] Abd El- khalik , W. (2022) " **A Machine Learning Approach for Improved Thermal Comfort Prediction in Sustainable Built Environments** ", *Sustainable Machine Intelligence Journal* , 1, pp. (2):1–8. doi:10.61185/SMIJ.2022.11101 .
[27] Sleem , A. (2022) " **Empowering Smart Farming with Machine Intelligence: An Approach for Plant Leaf Disease Recognition** ", *Sustainable Machine Intelligence Journal* , 1, pp. (3):1–11. doi:10.61185/SMIJ.2022.1013

[28] A. Metwaly , A. and Elhenawy , I. (2023) " **Sustainable Intrusion Detection in Vehicular Controller Area Networks using Machine Intelligence Paradigm** ", *Sustainable Machine Intelligence Journal* , 4, pp. (4):1–12. doi:10.61185/SMIJ.2023.44104

[29] Salem, S. (2023) " **An Improved Binary Quadratic Interpolation Optimization for 0-1 Knapsack Problems** ", *Sustainable Machine Intelligence Journal* , 4, pp. (1):1–11. doi:10.61185/SMIJ.2023.44101 .

[30] A. Metwaly , A., Sleem , A. and Elhenawy , I. (2023) " **Integrating Machine Intelligence to Estimate PM2.5 Concentration for Sustainable Urban Air Quality Management** ", *Sustainable Machine Intelligence Journal* , 4, pp. (6):1–8. doi:10.61185/SMIJ.2023.44106 .

[31] Mohamed, M. (2023) " **Agricultural Sustainability in the Age of Deep Learning: Current Trends, Challenges, and Future Trajectories** ", *Sustainable Machine Intelligence Journal* , 4, pp. (2):1–20. doi:10.61185/SMIJ.2023.44102 .

[32] El- Douh , A. (2023) " **A Neutrosophic Multi-Criteria Model for Evaluating Sustainable Soil Enhancement Methods and their Cost Implications in Construction** ", *Sustainable Machine Intelligence Journal* , 5, pp. (1):1–11. doi:10.61185/SMIJ.2023.55101 .

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