NSS
Neutrosophic Sets and Systems, Vol. 87, 2025
University of New Mexico

Correlation Coefficient of Single-Valued Neutrosophic Set for Linking Education for Sustainable Development with Early Learning Outcomes: A Preschool Evaluation Study

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Abstract: Early childhood education (ECE) is a crucial place to start when it comes to fostering lifetime attitudes and behaviors associated with environmental and social responsibility in the framework of global initiatives to promote sustainability. The influence of incorporating sustainability ideas into preschool instruction on early learning outcomes is examined in this study. Eight major evaluation criteria, spanning from the assessment of learning outcomes to the integration of environmental awareness, were used to evaluate eight different preschool programs using a neutrosophic framework. Structured observations, curriculum analysis, teacher interviews, and parent input were used to gather data in both urban and rural areas. This study uses the single valued neutrosophic sets (SVNS) to overcome uncertainty. The correlation coefficient of SVNS is used in this study.

The results show that preschools with significant community involvement, teacher training in sustainability, and active environmental engagement are likely to develop more eco-conscious behavior, collaboration, and critical thinking in young children. The study offers useful insights for curriculum developers, educators, and policymakers by adding to the expanding body of research that connects early childhood pedagogical innovation with the Sustainable Development Goals (SDGs).

Keywords: Correlation Coefficient of Single-Valued Neutrosophic Set; Sustainability; Early Learning Outcomes; Early Learning Outcomes.

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1. Introduction

Neutrosophic was first presented by Smarandache in 1995[1]. The study of the genesis, nature, and extent of neutralities as well as how they interact with other ideational spectra is known as

neutrosophic. A strong broad formal framework that expands on the ideas of the classic set, fuzzy set, and interval-valued fuzzy set is the neutrophilic set[2].

A universe of discourse U defines a neutrosophic set A. T, I, and F are the real standard or non-standard subsets, where T is a truth-membership function, I is an indeterminacy-membership function, and F is a falsity-membership function. Numerous uses exist for neutrophilic sets, such information fusion, which combines data from several sensors[3].

1.1 Related Work

Preschool curriculums are increasingly including Early Childhood Environmental Education (EECE) and Early Childhood Education for Sustainability (ECEfS), emphasizing their critical role in forming generations who are environmentally sensitive and focused on sustainability from a young age. The concepts serve as the theoretical foundation for this empirical quantitative study, which aims to determine the specifics of ESD implementation in Slovenian kindergartens with Eco programs and to investigate the differences in ESD implementation and the achieved outcomes of ESD in kindergartens with and without eco-programs based on the preschool teacher's assessment[4].

A sample of 114 preschool instructors working in Slovenian kindergartens participated in the 2024 study. The findings verify that an integrated approach is used in kindergartens with an eco-program and that the ecological, social, and economic aspects of ESD are successfully related. The effectiveness of the program from a sustainability perspective is demonstrated by the fact that ECEfS is implemented more prominently in the normal curriculum in kindergartens with an eco-program and that the program's outcomes are attained to a greater degree than in kindergartens without one.

A special issue of Environmental Education Research focused on environmental education and children in 2007. This essay argues that "early childhood" should be discussed as well. In this context, early childhood refers to the years before school, with an emphasis on educational environments like kindergartens and daycare centers. Reid and Scott urge the environmental education community to have the "courage to discuss" this area, which is one of the research projects "holes."

To find works at the nexus of environmental education and early childhood education, this article surveys Australian and worldwide research publications. Not many were discovered. A few research looked at how young children interacted with nature (environmental education). Fewer of them spoke on how young children comprehend environmental issues (environmental education). Any that focused on young children as agents (environmental education). It is critical that our sector reacts to the expanding body of research demonstrating that early investments in human capital have far-reaching effects and provide significant returns to both people and society. Additionally, early childhood educators are starting to engage with sustainability. To close the gap, Davis [5] urged immediate action, particularly in research.

In the framework of an Early Childhood Studies degree, Hirst [6] examined an Action Research project that was carried out to provide a common definition of the phrase "Education for Sustainable development." Students worked on projects with kids and early childhood educators, and the study supports earlier research on the topic of education for sustainability in early childhood education.

The research sought to capture the notion of the student as a change agent with chances to engage with children as change agents, given the enduring and ongoing focus with testing, performance, and outcomes in early childhood education, compulsory school education, and higher education. As an emancipatory reminder that research does not have to be a technical endeavor and that the voices and actions of children, students, and early childhood educators can be foregrounded in a way that validates authentic involvement by all participants, the main findings lean toward participatory action research.

2. Some Definitions of Single Valued Neutrosophic Sets (SVNSs)

This section shows definitions and operations of SVNSs and correlation coefficient of SVNSs. The neutrosophic set, a potent general formal framework that generalizes the sets from a philosophical point of view, is a component of neutrosophic, which investigates the origin, nature, and scope of neutralities as well as their interactions with various ideational spectra[7].

Definition 1

Neutrosophic set is defined by three membership functions such as truth, indeterminacy, and falsity to overcome uncertainty information. Neutrosophic set (NS) can be defined as:

$$B = \{(T_B(C), I_B(C), F_B(C)) : b \in B\}$$

$$T_B(C) : C \to]0^-, 1^+[$$

$$I_B(C) : C \to]0^-, 1^+[$$

$$F_B(C) : C \to]0^-, 1^+[$$

$$0^- \leq \sup T_B(C) + \sup I_B(C) + \sup F_B(C) \leq 3^+$$

Definition 2

The complement of NS is presented by

$$B^c = \{(\{1^+\} - T_B(C), \{1^+\} - I_B(C), \{1^+\} - F_B(C)) : b \in B\}$$

Definition 3

NS can say $B \subseteq A$ if and only if

$$\inf T_B(C) \leq \inf T_A(C)$$

$$\sup T_B(C) \leq \sup T_A(C)$$

$$\inf I_B(C) \geq \inf I_A(C)$$

$$\sup I_B(C) \geq \sup I_A(C)$$

$$\inf F_B(C) \geq \inf F_A(C)$$

$$\sup F_B(C) \geq \sup F_A(C)$$

Definition 4

SVNS can defined by three membership functions like truth, indeterminacy, and falsity values such as, if C is continuous,

$$B = \int_C \frac{\left(T_B(C), I_B(C), F_B(C)\right)}{C}, c \in C$$

If C is discrete, the SVNS can be defined as:

$$B = \sum_{i=1}^{n} \frac{\left(T_B(C_i), I_B(C_i), F_B(C_i)\right)}{C_i} c_i \in C$$

Definition 5

The complement pf SVNS can be obtained as:

$$B^c = \left\{\left(F_B(C), 1 - I_B(C), T_B(C)\right) : b \in B\right\}$$

Definition 6

SVNS B is contained in other SVNS A $B \subseteq A$ if and only if:

$$T_B(C) \leq T_A(C)$$

$$T_B(C) \geq T_A(C)$$

$$T_B(C) \geq T_A(C)$$

Definition 7

Two SVNS are equal if and only if:

$$B \subseteq A \; and \; A \subseteq B$$

Definition 8

The correlation of SVNS is defined as:

$$L(A, B) = \sum_{i=1}^{n} \begin{bmatrix} T_A(C_i)T_B(C_i) + \\ I_A(C_i)I_B(C_i) + \\ F_A(C_i)F_B(C_i) \end{bmatrix}$$

The correlation can meet the following conditions:

$$L(B,B) = T(B)$$

$$L(A,B) = L(B,A)$$

Definition 9

The correlation coefficient of SVNS can be introduced as:

$$N(A,B) = \frac{L(A,B)}{[T_A(C_i)T_B(C_i)]^{\frac{1}{2}}} =$$

$$= \frac{\left(\sum_{i=1}^{n} \begin{bmatrix} T_A(C_i)T_B(C_i) + \\ I_A(C_i)I_B(C_i) + \\ F_A(C_i)F_B(C_i) \end{bmatrix}\right)}{\left(\sqrt{\sum_{i=1}^{n} \begin{bmatrix} T_A^2(C_i) + \\ I_A^2(C_i) + \\ F_A^2(C_i) \end{bmatrix}} \sqrt{\sum_{i=1}^{n} \begin{bmatrix} T_B^2(C_i) + \\ I_B^2(C_i) + \\ F_B^2(C_i) \end{bmatrix}}\right)}$$

The correlation coefficient can meet the following conditions:

$$A = B \Rightarrow K(A,B) = 1$$

$$K(A,B) = K(B,A)$$

Definition 10

The correlation coefficient can meet the following conditions:

$$0 \leq K(A,B) \leq 1$$

For n=1

$$K(A,B) = \frac{\begin{matrix} T_A(C_i)T_B(C_i) + \\ I_A(C_i)I_B(C_i) + \\ F_A(C_i)F_B(C_i) \end{matrix}}{\sqrt{\begin{matrix} T_A^2(C_i) + \\ I_A^2(C_i) + \\ F_A^2(C_i) \end{matrix}} \sqrt{\begin{matrix} T_B^2(C_i) + \\ I_B^2(C_i) + \\ F_B^2(C_i) \end{matrix}}}$$

Definition 11

The cosine similarity measure of SVNS can be defined as:

$$cos(A,B) = \frac{\begin{matrix} T_A(C_i)T_B(C_i) + \\ I_A(C_i)I_B(C_i) + \\ F_A(C_i)F_B(C_i) \end{matrix}}{\sqrt{\begin{matrix} T_A^2(C_i) + \\ I_A^2(C_i) + \\ F_A^2(C_i) \end{matrix}} \sqrt{\begin{matrix} T_B^2(C_i) + \\ I_B^2(C_i) + \\ F_B^2(C_i) \end{matrix}}}$$

Definition 12

The weighted correlation coefficient of SVNS can be defined as:

$$W(A,B)=\frac{\left(\sum_{i=1}^{n} w_i \begin{bmatrix} T_A(C_i)T_B(C_i)+ \\ I_A(C_i)I_B(C_i)+ \\ F_A(C_i)F_B(C_i) \end{bmatrix}\right)}{\left(\sqrt{\sum_{i=1}^{n} w_i \begin{bmatrix} T_A^2(C_i)+ \\ I_A^2(C_i)+ \\ F_A^2(C_i) \end{bmatrix}}\sqrt{\sum_{i=1}^{n} w_i \begin{bmatrix} T_B^2(C_i)+ \\ I_B^2(C_i)+ \\ F_B^2(C_i) \end{bmatrix}}\right)}$$

3. Results and Discussion

This section shows the results of the correlation coefficient SVNS for Linking Education for Sustainability with Early Learning Outcomes: A Preschool Evaluation Study. This study uses eight criteria and eight alternatives to select the best one. The steps of the proposed approach are organized as follows:

1. Collect a set of criteria and alternatives for Linking Education for Sustainability with Early Learning Outcomes: A Preschool Evaluation Study.
2. Assess the criteria and alternatives using single valued neutrosophic numbers (SVNNs).
3. Combine different SVNNs into a single matrix using the SVNS operator such as:

$$SVNO=\begin{pmatrix} 1-\prod_{i=1}^{n}\left(1-T_B(C)\right)^{w_j}, \\ \prod_{i=1}^{n}\left(I_B(C)\right)^{w_j}, \\ \prod_{i=1}^{n}\left(F_B(C)\right)^{w_j} \end{pmatrix}$$

   Where w_j refers to the weight of decision makers.
4. Apply the correlation coefficients to obtain score values of each alternative.
5. Rank the alternatives.

This study collects eight criteria and eight alternatives as shown in table 1.

Table 1. Criteria and alternatives.

SVCC	SVCA
Environmental Awareness Integration	Urban Public Preschool with Green Curriculum
Curriculum Sustainability Alignment	Rural Community-Based Preschool
Teacher Training in Sustainability	Private Eco-Conscious Preschool
Eco-Friendly Learning Environment	Montessori School with Environmental Extensions
Parental and Community Engagement	International Preschool with SDG Framework
Behavioral Outcomes in Children	Nature Kindergarten (Forest School)
Resource Utilization and Waste Management	Tech-Integrated Sustainability Preschool
Assessment of Sustainability Learning Outcomes	Faith-Based Preschool with Stewardship Emphasis

Three experts and decision makers evaluate the criteria and alternatives using SVNNs as shown in Table 2.

Table 2. Evaluation by experts.

	SVCC$_1$	**SVCC$_2$**	**SVCC$_3$**	**SVCC$_4$**	**SVCC$_5$**	**SVCC$_6$**	**SVCC$_7$**	**SVCC$_8$**
SVCA$_1$	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.7,0.3,0.4)
SVCA$_2$	(0.9,0.1,0.2)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.6,0.4,0.5)
SVCA$_3$	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.4,0.5,0.6)
SVCA$_4$	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.7,0.3,0.4)	(0.2,0.7,0.8)
SVCA$_5$	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.1,0.8,0.9)	(0.6,0.4,0.5)	(0.1,0.8,0.9)
SVCA$_6$	(0.4,0.5,0.6)	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.4,0.5,0.6)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.4,0.5,0.6)	(0.2,0.7,0.8)
SVCA$_7$	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.8,0.2,0.3)	(0.1,0.8,0.9)	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.1,0.8,0.9)	(0.8,0.2,0.3)
SVCA$_8$	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.1,0.8,0.9)
	SVCC$_1$	SVCC$_2$	SVCC$_3$	SVCC$_4$	SVCC$_5$	SVCC$_6$	SVCC$_7$	SVCC$_8$
SVCA$_1$	(0.6,0.4,0.5)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.7,0.3,0.4)
SVCA$_2$	(0.7,0.3,0.4)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(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)
SVCA$_3$	(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)	(0.4,0.5,0.6)
SVCA$_4$	(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)	(0.2,0.7,0.8)
SVCA$_5$	(0.1,0.8,0.9)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.4,0.5,0.6)
SVCA$_6$	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.1,0.8,0.9)	(0.2,0.7,0.8)
SVCA$_7$	(0.1,0.8,0.9)	(0.8,0.2,0.3)	(0.1,0.8,0.9)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.7,0.3,0.4)
SVCA$_8$	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.8,0.2,0.3)	(0.4,0.5,0.6)	(0.7,0.3,0.4)	(0.8,0.2,0.3)	(0.4,0.5,0.6)	(0.4,0.5,0.6)
	SVCC$_1$	SVCC$_2$	SVCC$_3$	SVCC$_4$	SVCC$_5$	SVCC$_6$	SVCC$_7$	SVCC$_8$
SVCA$_1$	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.7,0.3,0.4)
SVCA$_2$	(0.1,0.8,0.9)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.9,0.1,0.2)	(0.6,0.4,0.5)
SVCA$_3$	(0.2,0.7,0.8)	(0.9,0.1,0.2)	(0.6,0.4,0.5)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.8,0.2,0.3)	(0.1,0.8,0.9)	(0.4,0.5,0.6)
SVCA$_4$	(0.4,0.5,0.6)	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.2,0.7,0.8)	(0.2,0.7,0.8)
SVCA$_5$	(0.6,0.4,0.5)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.4,0.5,0.6)	(0.1,0.8,0.9)
SVCA$_6$	(0.7,0.3,0.4)	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.6,0.4,0.5)	(0.2,0.7,0.8)
SVCA$_7$	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.8,0.2,0.3)	(0.9,0.1,0.2)
SVCA$_8$	(0.1,0.8,0.9)	(0.1,0.8,0.9)	(0.1,0.8,0.9)	(0.8,0.2,0.3)	(0.9,0.1,0.2)	(0.1,0.8,0.9)	(0.9,0.1,0.2)	(0.8,0.2,0.3)

The SVN operator is used to combine the SVNNs into a single matrix as shown in Table 3.

Table 3. Combined SVNNs.

	$T_B(C)$	$I_B(C)$	$F_B(C)$		$T_B(C)$	$I_B(C)$	$F_B(C)$
SVCA$_1$	0.838311	0.161689	0.275005	SVCA$_1$	0.796755	0.203245	0.303634
SVCA$_2$	0.696366	0.292058	0.419681	SVCA$_2$	0.099051	0.801787	0.900949
SVCA$_3$	0.678856	0.3073	0.419681	SVCA$_3$	0.7887	0.2113	0.321144
SVCA$_4$	0.707942	0.275005	0.395175	SVCA$_4$	0.563685	0.419681	0.527545
SVCA$_5$	0.396927	0.54621	0.649157	SVCA$_5$	0.492566	0.485559	0.587949

SVCA6	0.580319	0.395175	0.496741	SVCA6	0.472455	0.467735	0.567858
SVCA7	0.580319	0.38628	0.527545	SVCA7	0.734393	0.255482	0.381672
SVCA8	0.451546	0.507434	0.626975	SVCA8	0.734393	0.255482	0.381672
	$T_B(C)$	$I_B(C)$	$F_B(C)$		$T_B(C)$	$I_B(C)$	$F_B(C)$
SVCA1	0.696366	0.303634	0.403682	SVCA1	0.596318	0.403682	0.503478
SVCA2	0.198213	0.702501	0.801787	SVCA2	0.472455	0.467735	0.567858
SVCA3	0.596318	0.403682	0.503478	SVCA3	0.520234	0.425373	0.527545
SVCA4	0.838311	0.161689	0.265607	SVCA4	0.871371	0.128629	0.232343
SVCA5	0.563685	0.419681	0.527545	SVCA5	0.871371	0.128629	0.232343
SVCA6	0.492566	0.485559	0.587949	SVCA6	0.211884	0.686593	0.788116
SVCA7	0.734393	0.255482	0.381672	SVCA7	0.734393	0.255482	0.381672
SVCA8	0.734393	0.255482	0.381672	SVCA8	0.767657	0.218776	0.333872
	$T_B(C)$	$I_B(C)$	$F_B(C)$		$T_B(C)$	$I_B(C)$	$F_B(C)$
SVCA1	0.396927	0.503478	0.603073	SVCA1	0.198213	0.702501	0.801787
SVCA2	0.596318	0.403682	0.503478	SVCA2	0.696366	0.303634	0.403682
SVCA3	0.362149	0.584043	0.686593	SVCA3	0.796755	0.203245	0.303634
SVCA4	0.696366	0.292058	0.419681	SVCA4	0.897671	0.102329	0.203245
SVCA5	0.734393	0.255482	0.381672	SVCA5	0.563685	0.403682	0.548454
SVCA6	0.580319	0.38628	0.527545	SVCA6	0.336869	0.610354	0.713805
SVCA7	0.666128	0.314376	0.419681	SVCA7	0.796755	0.203245	0.314376
SVCA8	0.767657	0.232343	0.345684	SVCA8	0.618328	0.367121	0.479766
	$T_B(C)$	$I_B(C)$	$F_B(C)$		$T_B(C)$	$I_B(C)$	$F_B(C)$
SVCA1	0.099051	0.801787	0.900949	SVCA1	0.696366	0.303634	0.403682
SVCA2	0.838311	0.161689	0.275005	SVCA2	0.596318	0.403682	0.503478
SVCA3	0.618328	0.367121	0.479766	SVCA3	0.396927	0.503478	0.603073
SVCA4	0.632879	0.351295	0.461476	SVCA4	0.198213	0.702501	0.801787
SVCA5	0.707942	0.275005	0.395175	SVCA5	0.211884	0.686593	0.788116
SVCA6	0.396927	0.54621	0.649157	SVCA6	0.198213	0.702501	0.801787
SVCA7	0.666128	0.321144	0.436315	SVCA7	0.815163	0.184837	0.292058
SVCA8	0.815163	0.174044	0.292058	SVCA8	0.520234	0.43453	0.548454

The correlation coefficient is used to obtain the final value of each alternative. The alternatives are ranked as shown in Table 4.

Table 4. Ranks of options.

	Ranks
SVCA1	1
SVCA2	2
SVCA3	4
SVCA4	6
SVCA5	3
SVCA6	5
SVCA7	8
SVCA8	7

4. Conclusions

This study shows that preschool education that incorporates sustainability is strongly associated with better early learning outcomes in areas including social cooperation, environmental

empathy, and cognitive development. Nature-based and environmentally sensitive preschools performed the best among the models that were studied, particularly when aided by community engagement and qualified teachers. Crucially, by adding relevant, real-world context, the incorporation of sustainability improves rather than diminishes traditional learning criteria. This study used the correlation coefficient of single valued neutrosophic set to overcome uncertainty. Three experts evaluated eight criteria and eight alternatives using single valued neutrosophic numbers.

The findings highlight the need for early childhood education policy and practice to incorporate sustainability as a fundamental pedagogical tenet. In the future, scaling these approaches and guaranteeing that sustainability becomes a fundamental component of early learning experiences globally would need cross-sectoral cooperation and investments in teacher capacity building.

Acknowledgment

This work was supported by the Humanities and Social Sciences Project in 2023 of the Chongqing Municipal Education Commission, namely "Research on the Path of Urban-Rural Integration in the Transition from Kindergarten to Primary School under the Background of Rural Revitalization" (Project No: 23SKGH431) and the 2023 Science and Technology Research Project of Chongqing Municipal Education Commission, titled "Research on Intelligent Childcare Service Model and Practice for Infants and Young Children under the Background of Informatization" (Project No.: KJQN202302905).

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Received: Dec. 14, 2024. Accepted: June 27, 2025