

# IMPLEMENTATION OF A PROBLEM-BASED LEARNING MODEL VIEWED FROM STUDENTS' LEARNING STYLES ON STUDENTS' MATHEMATICAL PROBLEM SOLVING

Mapeni<sup>1,a\*</sup>, Rahmad Bustanul Anwar<sup>1,b</sup>, Dwi Rahmawati<sup>1,c</sup>,  
Cornelia Victoria Anghel<sup>2,d</sup>

<sup>1</sup>Postgraduate Program in Mathematics Education, University  
Muhammadiyah Metro

<sup>2</sup> Faculty of Resita Engineering Science, Technical University of Cluj-  
Napoca, Romania

Jl. Gatot Subroto No 100, Yosodadi, Kecamatan Metro Timur,  
Kota metro, Lampung

E-Mail: <sup>a\*</sup>fennyyoung90@gmail.com, <sup>b</sup>rarachmadia@gmail.com,  
<sup>c</sup>dwirahmawati1083@gmail.com, <sup>d</sup> cornelia.anghel@ubbcluj.ro

## Abstract

*Students' mathematical problem-solving ability remains a challenge in secondary education, particularly due to the dominance of teacher-centered conventional methods. This study aims to analyze the effectiveness of the Problem Based Learning (PBL) model in relation to students' learning styles (visual, auditory, and kinesthetic) on mathematical problem-solving skills. A quantitative approach with a quasi-experimental design was employed, involving 60 eleventh-grade students divided into experimental (PBL) and control (conventional) groups. Research instruments included a problem-solving test and a learning style questionnaire, with data analyzed using Two-Way ANOVA. The results revealed that: (1) there were significant differences in problem-solving abilities based on students' learning styles; (2) the PBL model was more effective than the conventional model; and (3) a significant interaction existed between learning models and learning styles in influencing students' problem-solving performance. Therefore, implementing PBL in alignment with students' learning styles is proven to enhance the effectiveness of mathematics instruction in secondary schools.*

**Keywords:** *Problem Based Learning, learning styles, problem-solving, mathematics instruction*

## 1. INTRODUCTION

The development of science, technology, and information in the 21st century has brought significant impacts across various aspects of life, particularly in the field of education. The quality and competitiveness of a nation are determined by the quality of its human resources, which can be shaped through an effective education system [1]. In this context, 21st-century learning emphasizes students' ability to seek knowledge from diverse sources, formulate problems, think analytically, and collaborate in solving problems [2].

Problem-solving ability is crucial in mathematics education. According to the National Council of Teachers of Mathematics [3], problem-solving is regarded as a key standard. Students are not only expected to memorize formulas but also to understand mathematical concepts and apply them to solve complex, contextual problems. Nevertheless, the Programme for International Student Assessment report indicates that Indonesian students' mathematics performance remains below the international average, with a score of 366 compared to the benchmark of 500 [4], [5]. This reflects the low level of Indonesian students' mathematical problem-solving ability. Specifically, the problem-solving ability of students at public senior high schools (SMA Negeri) in Lampung Province is still categorized as moderate, with indicator achievement ranging from 40% to 70% having met the minimum standard. Meanwhile, in Bandar Lampung City, students' problem-solving ability remains in the moderate category, with indicator achievement of only 1-20%, although this represents a 10.08% increase compared to last year's score for students who have already reached the minimum competency level (Rapor Mutu Pendidikan, 2023). Observations at SMA Negeri 11 Bandar Lampung also reveal that many students experience difficulties in solving

contextual mathematics problems. The teaching process is still dominated by conventional, teacher-centered methods, thereby limiting students' opportunities to be active, think critically, and collaborate [6]. As a result, students rely heavily on memorization and struggle to apply mathematical concepts to real-life situations.

One alternative believed capable of addressing this issue is Problem-Based Learning (PBL). PBL places real-world problems at the core of learning, encouraging students to actively investigate, think critically, and collaborate in finding solutions (Syamsinar, 2023). Furthermore, the implementation of differentiated instruction based on visual, auditory, and kinesthetic learning styles is expected to enhance the effectiveness of PBL. Therefore, integrating PBL with differentiated instruction can optimize students' mathematical problem-solving abilities.

Didartita & Irwandi, (2019) stated that the visual learning style has the greatest influence on learning outcomes. The study by Kinanthi et al., (2023) concluded that the differentiated learning process using Problem-Based Learning (PBL) in mathematics instruction showed improvement [7]. According to Wijayanti & Kristiyowati, (2024), the findings indicate that instruction using the Problem-Based Learning model with a differentiation approach based on learning styles is proven effective [8]; the auditory learning style significantly affects how students receive and process information. Students who learn through listening tend to better understand material delivered verbally. This is consistent with findings that the direct instruction model, which emphasizes verbal interaction, can enhance learning outcomes for students with an auditory learning style [9].

Based on the above discussion, this study aims to examine the implementation of the Problem-Based Learning model in relation to

---

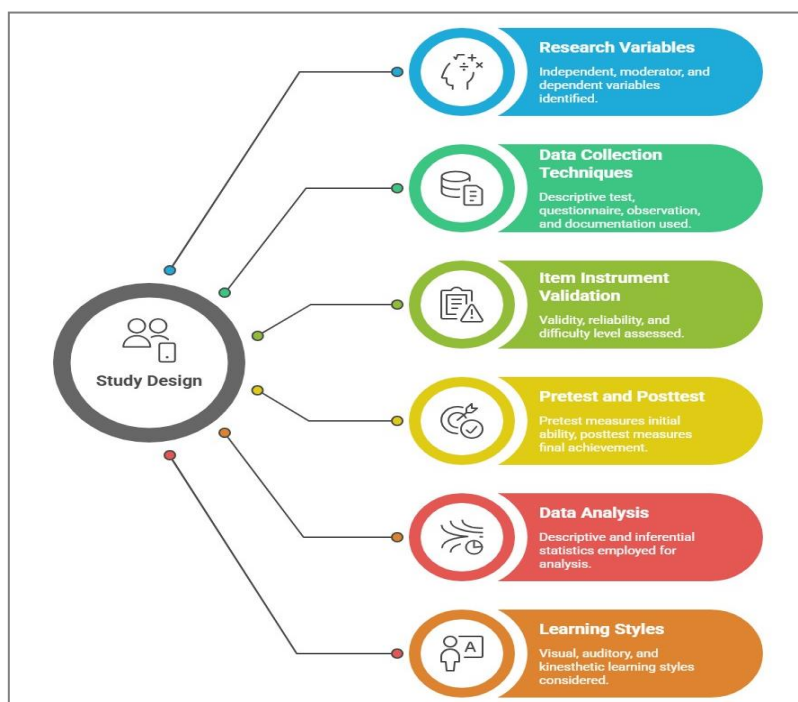
students' learning styles and its impact on mathematical problem-solving ability.

## **2. RESEARCH METHODS**

This study employed a quantitative approach with a quasi-experimental design, specifically a Non-Equivalent Control Group Design. Two student groups were selected: an experimental group that received instruction using the Problem-Based Learning (PBL) model and a control group taught using conventional methods. Both groups were administered pretests and posttests to measure improvements in problem-solving ability [10].

The research population consisted of all senior high school students in Bandar Lampung City during the 2025/2026 academic year. The sample was selected using stratified random sampling based on school performance levels—high, medium, and low. From these schools, six classes were chosen, comprising three experimental classes and three control classes. Each group was then further classified according to students' learning styles (visual, auditory, kinesthetic) [11].

The research variables included: (1) independent variable: instructional model (PBL vs. conventional), (2) moderator variable: learning style (visual, auditory, kinesthetic), and (3) dependent variable: mathematical problem-solving ability. Problem-solving ability was measured using four indicators: understanding the problem, devising a plan, carrying out the plan, and looking back at the solution [12].



**Figure 1.** Research procedure and data analysis workflow

Data collection techniques included: (1) a descriptive test, (2) a learning styles questionnaire, (3) classroom learning activity observation, and (4) documentation. Research instruments consisted of a problem-solving test containing six descriptive questions on matrix topics, validated by experts; a Likert-scale learning styles questionnaire; and a learning activity observation sheet.

#### **Item Instrument Validation**

- Validity testing was assessed by comparing the test items with the instructional materials that had been taught.
- For the questionnaire, validity was evaluated through expert judgment and item-total correlation analysis.
- Reliability testing refers to consistency. An instrument is considered reliable if it produces the same results when administered to the same group on different occasions or at different times.
- Item Difficulty level analysis was conducted to determine whether each test item was difficult and to identify students'

ability levels specifically, whether they were able to answer the item correctly.

The learning style questionnaire was developed based on the following indicators:

- **Visual:** Learns through images or visual media; understands position, numbers, and shapes well; neat and organized; less disturbed by sounds; and has difficulty following verbal instructions.
- **Auditory:** Learns more effectively through listening; excels in oral activities; sensitive to sounds or music; easily distracted by noise; but generally weaker in visual tasks.
- **Kinesthetic:** Prefers learning through physical activity; highly attuned to body language; highly active and enjoys hands-on experiences; but typically less neat and weaker in verbal expression.

The data were analyzed using descriptive and inferential statistics. Two-way ANOVA (Two-Way ANOVA) was employed to examine the effects of the instructional model and learning style, as well as their interaction, on students' problem-solving ability [2]. The hypothesis testing procedure was as follows:

a. **Formulating the hypotheses:**

$H_0$  = The sample comes from a population that is normally distributed.

$H_1$  = The sample does not come from a population that is normally distributed.

b. **Decision-making criteria:**

Accept  $H_0$  if the probability value (p-value) is greater than  $\alpha$  (0.05); reject  $H_0$  if the p-value is less than or equal to 0.05.

c. **Interpretation of results:**

The test was conducted to determine:

- a. Differences in problem-solving ability based on learning styles (visual, auditory, kinesthetic).

- b. Differences in problem-solving ability based on instructional model (conventional vs. PBL).
- c. The presence of an interaction effect between learning style and instructional model on students' mathematical problem-solving ability.

### **3. RESULTS AND DISCUSSION**

In this research, the participants were divided into two groups: a control group taught using conventional methods and an experimental group of Grade XI students taught using the Problem-Based Learning (PBL) model, each consisting of 30 students [13]. Several tests were conducted as follows:

#### **a. Initial Ability Test**

Prior to the treatment, an initial problem-solving ability test was administered to both groups (control and experimental) using an independent samples t-test. The normality test results indicated that the data from both classes were normally distributed, with significance values greater than 0.05. The homogeneity test also confirmed that the variances of the two groups were homogeneous. Subsequently, the t-test results showed no significant difference in the initial problem-solving abilities between the two groups. This indicates that both groups had equivalent baseline abilities before the intervention was applied [14].

#### **b. Hypothesis Testing**

After the treatment was implemented, hypothesis testing was conducted using Two-Way ANOVA to examine the effects of learning style, instructional model, and their interaction on students' problem-solving ability.

The test results revealed the following:

a. Distribution of Students' Learning Styles

Tabel 1. Result of Students' Learning Style Indicators

Class	Visual	Auditory	Kinesthetic	Total
XI-1 (PBL)	12	9	9	30
XI-3	11	10	9	30
<b>Total</b>	<b>23</b>	<b>19</b>	<b>18</b>	<b>60</b>

b. Average Problem-Solving Scores

Tabel 2. Average Problem-Solving Scores

Learning Style	PBL (XI-1)	Conventional (XI-3)
Visual	85.4	76.2
Auditory	83.1	74.7
Kinesthetic	86.3	75.8
<b>Average</b>	<b>84.93</b>	<b>75.57</b>

c. Statistical Test (T-test) Hypotheses:

H0: There is no difference between the PBL and conventional models.

H1: There is a difference between the PBL and conventional models.

The results of the t-test calculation:  $t_{\text{count}} = 3.94$ ,  $t_{\text{table}} (df=58, \alpha=0.05) = 2.00$  Because  $t_{\text{count}} > t_{\text{table}}$ , then H0 is rejected. This means that there is a significant difference between the two learning models.

The Interaction Table of Learning Styles and Instructional Models further supports this result:

### **a. Visual Learning Style**

Students with a visual learning style taught using the PBL model obtained the highest average score (85.4) compared to visual learners in the conventional class (76.2). Visual learners tend to understand information through sight, such as images, diagrams, tables, colors, and symbols. They typically prefer visual learning media, including instructional videos, animations, color-coded notes, and concept maps or graphic organizers [15].

#### **1) In the Conventional Model:**

In the conventional model, which predominantly relies on lectures and problem exercises without strong visual support, visual learners receive insufficient stimulation aligned with their learning style. This results in lower conceptual understanding, as there is minimal visualization of matrix structures, row operations, or the process of matrix inversion.

#### **2) IN the PBL Model:**

The PBL model encourages students to think actively and independently by seeking solutions to contextual problems. During this process, students frequently use visual media — such as constructing diagrams of matrix operations, sketching calculation steps, or watching video explanations of matrix concepts. This significantly supports visual learners and leads to a notable improvement in learning outcomes.

Result: Average score increased from 65 (Conventional) to 85 (PBL).

### **b. Auditory Learning Style**

For auditory learners, students in the PBL class also demonstrated better results (83.1) compared to those in the conventional class (74.1). Auditory learners absorb information effectively through listening — such as hearing teacher explanations, participating in discussions, or reading aloud. They

often remember content based on how it was delivered or the speaker's tone of voice.

1) **In the Conventional Model:**

This model can sometimes suit auditory learners, as teachers primarily deliver instruction orally. However, its one-way nature causes students to quickly lose focus due to the lack of feedback or interactive discussion.

2) **In the PBL Model:**

In PBL, students engage in active group discussions, listen to peers' opinions, articulate their own ideas, and respond to questions posed by the facilitator teacher. This verbal interaction greatly assists auditory learners in comprehending and retaining concepts such as the sequence of matrix operations or solving systems of equations using matrices.

Result: Average score increased from 62 (Conventional) to 80 (PBL).

**c. Kinesthetic Learning Style**

Kinesthetic learners taught using the PBL model achieved a higher average score (86.3) compared to those in the conventional class (75.8). Kinesthetic learners learn most effectively through physical movement, direct practice, or simulation. They tend to dislike sitting for long periods, listening to lectures, or merely reading.

1) **In the Conventional Model:**

This approach involves minimal physical activity. Kinesthetic learners tend to become bored and passive quickly, leading to low learning outcomes because they are not actively engaged in the learning process.

2) **In the PBL Model:**

PBL enables students to engage in hands-on practice — such as arranging matrix operations using cut-out paper, simulating matrix construction, sequencing determinant and inverse

calculations, and solving real-world case studies. These activities provide kinesthetic learners with opportunities to experience and directly experiment with the learning material.

## **DISCUSSION**

The findings of this study indicate that the implementation of the Problem-Based Learning (PBL) model, when viewed in relation to students' learning styles, significantly influences their mathematical problem-solving ability. This confirms that aligning instructional models with students' learning styles enhances their effectiveness in solving mathematics problems. The  $R^2$  value of 0.566 demonstrates that the interaction between learning style and instructional model accounts for 56.6% of the variance in students' problem-solving ability improvement.

These results are consistent with prior research. Elvi Hidayati (2022) concluded that students' mathematical problem-solving ability improved after the implementation of PBL, and that the overall mathematics learning process also improved: students became more active in completing independent tasks and better at analyzing problems. Similarly, Ningsih et al. (2023) reported enhanced learning processes, with students showing greater engagement in problem-solving, group discussions, collaborative work, worksheet (LKS) implementation, and active task participation [16].

Furthermore, the interaction between the PBL model and the kinesthetic learning style positively affected problem-solving ability. This is because Problem-Based Learning and the kinesthetic learning style mutually reinforce each other in developing problem-solving skills. PBL often involves real-world problems where students work with tangible materials or engage in hands-on activities [13], [14], [17], [18]. Kinesthetic learners, who acquire knowledge most effectively through physical activity and direct experience, thrive in

such an environment. The kinesthetic preference for learning through movement and physical manipulation aligns naturally with PBL's experiential approach, allowing these students to learn in a way that feels intuitive and meaningful. They can literally see and feel the real-world application of the mathematical concepts they study.

Students' learning styles visual, auditory, and kinesthetic represent individual differences in how learners receive, process, and internalize information, ultimately influencing their academic performance. In practice, some students grasp information more easily through listening, others through visual representation, and still others through physical interaction or movement. Learning style demonstrably affects problem-solving ability; notably, the "Auditory-Kinesthetic (AK)" combination has shown significant influence [19].

Problem-solving demands higher-order thinking and logical reasoning, and learning style plays a crucial role in shaping students' problem-solving strategies. The Problem-Based Learning (PBL) model is widely recognized as effective in fostering higher-order thinking skills because it enables students to actively explore problems, integrate theory with practice, and collaboratively seek solutions [12], [20], [21], [22].

However, the success of PBL is strongly influenced by students' internal factors, such as motivation, self-confidence, and learning style [23], [24]. This is because PBL requires students to be self-directed and proactive qualities that contrast sharply with the teacher-centered nature of conventional instruction.

#### 4. CONCLUSION AND RECOMMENDATIONS

Based on the analysis and discussion, this study concludes that the Problem-Based Learning (PBL) model is significantly more effective than conventional methods in enhancing students' mathematical problem-solving ability. The most substantial improvement was observed among visual learners, followed by auditory and kinesthetic learners. This indicates that implementing PBL tailored to students' learning styles optimizes both learning outcomes and critical thinking skills. However, this study did not deeply examine external factors such as socioeconomic background, learning motivation, or family support. Additionally, the nuanced interaction between learning styles and the PBL model warrants further investigation.

Teachers are encouraged to implement PBL adapted to students' learning styles to make instruction more effective and meaningful. Schools should provide professional development for teachers in designing varied, problem-based learning activities. Future researchers are advised to explore affective and motivational dimensions and to conduct studies on a larger scale to yield more comprehensive and generalizable findings.

#### REFERENCES

- [1] S. Huda, L. Anggraini, R. Saputri, M. Syazali, and R. Umam, "Learning model to improve the ability to understand mathematical concepts," *Prisma*, vol. 173, no. 2, pp. 173-181, 2019, [Online]. Available: <https://jurnal.unsur.ac.id/prisma>
- [2] S. Sumarni *et al.*, "Behavior in early childhood (2-3) years: A case study on the use of gadgets in social environments," *Int. J. Innov. Creat. Chang.*, vol. 8, no. 8, pp. 384-404, 2019.
- [3] M. Munifah, A. N. Romadhona, I. Ridhona, R. Ramadhani, R. Umam, and H. S. Tortop, "How to Manage Numerical Abilities in Algebra Material?," *Al-Jabar J. Pendidik. Mat.*, vol. 10, no. 2, pp. 223-232, 2019.
- [4] M. U. Ridwanulloh, S. Huda, and R. Umam, "Innovative Leadership Management: The Pattern of School Quality Development at SMP Muhammadiyah 2 Inovasi Malang," *Progres. J. Pemikir. dan Pendidik. Islam*, vol. 11, no. 01, pp. 25-42, 2022,

doi: 10.22219/progresiva.v11i01.20742.

- [5] M. Yasin, S. Huda, F. G. Putra, M. Syazali, R. Umam, and S. Widyawati, "IMPROVE Learning Model and Learning Independence: Influence and Interaction on Mathematics Problem-Solving Abilities in Islamic Boarding School IMPROVE Learning Model and Learning Independence: Influence and Interaction on Mathematics Problem-Solving Ab," *J. Phys. Conf. Ser.*, vol. 1467, p. 012003, 2020, doi: 10.1088/1742-6596/1467/1/012003.
- [6] S. Huda, Suherman, Komarudin, M. Syazali, and R. Umam, "The Effectiveness of Al-Qurun Teaching Model ( ATM ) Viewed from Gender Differences: The Impact on Mathematical Problem-Solving Ability The Effectiveness of Al-Qurun Teaching Model ( ATM ) Viewed from Gender Differences: The Impact on Mathematical Probl," *J. Phys. Conf. Ser.*, vol. 1467, p. 012001, 2020, doi: 10.1088/1742-6596/1467/1/012001.
- [7] F. G. Putra *et al.*, "Mathematical representation: a bibliometric mapping of the research literature (2013 - 2022)," *Infin. J. Math. Educ.*, vol. 13, no. 1, pp. 1-26, 2024, doi: 10.22460/infinity.v13il.p1-26.
- [8] T. Sriyakul, R. Umam, and K. Jermsittiparsert, "Supplier Relationship Management , TQM Implementation , Leadership and Environmental Performance: Does Institutional Pressure Matter," *Int. J. Innov. Creat. Chang.*, vol. 5, no. 2, pp. 211-227, 2019.
- [9] A. Saregar *et al.*, "International Journal of Educational Methodology Natural Disaster Education in School: A Bibliometric Analysis with a Detailed Future Insight Overview," *Int. J. Educ. Methodol.*, vol. 8, no. 4, pp. 743-757, 2022, doi: 10.12973/ijem.8.4.743.
- [10] S. Sumarni, R. Ramadhani, Y. Sazaki, R. Tria, W. D. Andika, and A. E. Prasetyo, "Development of " Child Friendly ICT " Textbooks to Improve Professional Competence of Teacher Candidates : A Case Study of Early Childhood Education Program Students To cite this article: Sumarni , S ., Ramadhani , R ., Sazaki , Y ., Astika , R , T ., An," *J. Educ. Gift. Young Sci.*, vol. 7, no. 3, pp. 643-658, 2019, doi: 10.17478/jegys.596095.
- [11] R. Prastowo, S. Huda, R. Umam, K. Jermsittiparsert, and A. Eko, "Academic Achievement and Conceptual Understanding of Electrodynamics: Applications Geoelectric Using Cooperative Learning Model," *J. Ilm. Pendidik. Fis. Al-Biruni*, vol. 8, no. 2, pp. 165-175, 2019, doi: 10.24042/jipfalbiruni.v0i0.4614.
- [12] A. G. Picciano, "Theories and frameworks for online education:

- Seeking an integrated model," *Online Learn. J.*, vol. 21, no. 3, pp. 166-190, 2017, doi: 10.24059/olj.v21i3.1225.
- [13] R. Diani, H. Herliantari, I. Irwandani, A. Saregar, and R. Umam, "Search, Solve, Create, and Share (SSCS) Learning Model: The Impact on the Students' Creative Problem-Solving Ability on the Concept of Substance Pressure," *J. Penelit. Fis. dan Apl.*, vol. 9, no. 1, p. 65, 2019, doi: 10.26740/jpfa.v9n1.p65-77.
- [14] S. Huda *et al.*, "Islamic education in supply chain system by prioritizing manners as a success factor of millennial generation on socializing," *Int. J. Supply Chain Manag.*, vol. 9, no. 2, pp. 853-863, 2020.
- [15] N. Nuryadi and I. Kholifa, "Etnomatematika: Eksplorasi gamelan Jawa karawitan dengan pendekatan science, technology, engineering, and mathematics (STEM)," *J. Pendidik. Surya Edukasi*, vol. 6, no. 2, pp. 140-148, 2020, doi: 10.37729/jpse.v6i2.6810.
- [16] S. Wongsu and K. Cojorn, "Enhancing the Students' Problem-Solving Skills through Situation-Based Learning with the Six Thinking Hats Technique," *J. Adv. Sci. Math. Educ.*, vol. 4, no. 2, pp. 95-112, 2024, doi: 10.58524/jasme.v4i2.447.
- [17] A. Rozikin, S. Suherman, F. Farida, and R. Tasca, "Investigating the relationship between environmental literacy and mathematical literacy toward computer self-efficacy in secondary school," *J. Adv. Sci. Math. Educ.*, vol. 4, no. 2, pp. 61-70, 2021, doi: 10.58524/jasme.v4i2.363.
- [18] Nuryadi, "Pendidikan Matematika Berbasis Etnomatematika Di Era 4.0," *Pros. Konf. Pendidik. Nas. "Strategi dan Implementasi Pendidik. Karakter pada Era Revolusi Ind. 4.0,"* vol. 2, no. 1, pp. 5-12, 2020.
- [19] N. Aisya, I. Ibrohim, S. Mahanal, and H. Maghfiroh, "The effect of reading questioning answering integrated with creative problem solving on critical thinking," *JPBI (Jurnal Pendidik. Biol. Indones.)*, vol. 9, no. 2, pp. 198-205, 2023, doi: 10.22219/jpbi.v9i2.25718.
- [20] I. License, "Virtual Laboratories In Science Education : Unveiling Trajectories , Themes , and Emerging Paradigms (2013-2023)," *J. Balt. Sci. Educ.*, vol. 23, no. 5, pp. 990-1009, 2024.
- [21] V. Eloranta, E. Hakanen, and C. Shaw, "Teaching for paradigm shifts: Supporting the drivers of radical creativity in management education," *Educ. Res. Rev.*, vol. 45, no. September, p. 100641, 2024, doi: 10.1016/j.edurev.2024.100641.
- [22] H. Gruber, "New section 'Discourses and Rejoinders' in the Journal Educational Research Review," *Educ. Res. Rev.*, vol. 44, no. August, 2024, doi: 10.1016/j.edurev.2024.100626.
-

- [23] A. V. Oje, N. J. Hunsu, and L. Fiorella, "A systematic review of evidence-based design and pedagogical principles in educational virtual reality environments," *Educ. Res. Rev.*, vol. 47, no. February, p. 100676, 2025, doi: 10.1016/j.edurev.2025.100676.
- [24] K. Noura, "Preparing for the Future of Education : Adapting to the Technological Revolution and the World of Work," *Smart Soc. Community Serv. Empower. J.*, vol. 4, no. 2, pp. 55-69, 2024.