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Early Childhood Numeracy Practice Model Through Deep Learning

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Abstract: Early numeracy refers to the ability to think critically using mathematical concepts, procedures, facts, and tools to solve everyday problems in various relevant contexts for early childhood. This study aims to develop early numeracy practices for young children through deep learning approaches. The subjects of this research are 60 Kindergarten students, divided into two developmental stages: 4–5 years old and 5–6 years old. The study employed a development research method using the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation. Data was collected through observations, interviews, documentation, and numeracy performance assessments tailored to the children's cognitive stages. The data were analyzed using both qualitative techniques to evaluate the effectiveness and developmental appropriateness of the numeracy practices. The result of this study is a validated early numeracy product that aligns with children's levels of cognitive development: knowing, applying, and reasoning. This product is adapted to each age group to ensure developmental suitability. The novelty of this research lies in the implementation of early numeracy through deep learning, which integrates meaningful, mindful, and joyful learning strategies to enhance young children's mathematical understanding. Future research is recommended to explore the scalability of this model in various cultural and socio-economic contexts, as well as to examine its long-term impact on children's mathematical thinking beyond the kindergarten years.
Keywords: numeracy, deep learning, early childhood, education

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INTRODUCTION

Learning is one of the most essential things in curriculum implementation. Each level of education unit applies a learning concept by harmonizing the applicable curriculum (Kim et al., 2022; Lansey et al., 2024; Saher & Kashif, 2020). Learning at the early childhood education level aims to lay the foundation for the development of attitudes, knowledge, skills, and creativity that students need to adapt to their environment and foster further growth and development (Jati et al., 2022). Early childhood education is generally designed to facilitate children's optimal and comprehensive growth and development by their norms and life values (Mithans et al., 2023).

Through education, children are expected to develop all their potential – religious, intellectual, social, emotional, and physical, have the basics of religion that they adhere to, have expected behavioral habits, master several basic knowledge and skills according to their needs and developmental level, and have positive motivation and learning attitudes (Aulia et al., 2024;

Elvia et al., 2023; Idris et al., 2021). Concern for early childhood education shows the essence of education itself in responding to today's challenges and competition (Kristanto et al., 2023).

The concept of 21st-century education emphasizes the need for students to possess a wide range of skills and abilities necessary to face various challenges and solve social problems in daily life (Ginting et al., 2024). Learning that supports 21st-century skills is urgently needed to face these challenges (Imran et al., 2023; Varghese & Musthafa, 2021). A person's thinking skills require one stimulation activity to reach a certain level of thinking maturity(Yusnadi et al., 2020), one of which is through the introduction of numeracy from an early age.

Numeracy is the ability to think using concepts, procedures, facts, and mathematical tools to solve everyday problems in various types of contexts that are relevant to individuals as citizens of Indonesia and the world (Susilawati et al., 2024). Numeracy is interpreted as the ability possessed by a person to apply their mathematical knowledge in explaining events, solving problems, or making decisions in daily life (Zakaria et al., 2023). This can help students recognize the role of mathematics in real life, enabling them to make informed judgments and decisions and become responsible individuals who can reason and think logically (Olteanu, 2022).

The application of early childhood numeracy requires an appropriate strategy as a form of integral learning (Novita et al., 2024). The Early Childhood Phase requires an effective strategy to fulfil its developmental aspects (Wang, 2023). Experts from Montessori, Peabody, Froebel, and Ki Hajar Dewantara view early childhood as a fundamental phase for development, including cognitive development (Xu et al., 2023). Assumptions about the development of an individual's way of thinking and the complexity of its changes through neurological development and environmental development (Lopuszanska & Samardakiewicz, 2020). In Piaget's theory, cognitive development is based on the principles of structuralism and constructivism. The point of view of structuralism is evident in its perspective on the thought process, which develops through a series of developmental stages characterized by the influence of cognitive structures (Sharma et al., 2024). Meanwhile, the constructivist perspective is evident in his view of cognitive abilities as being built through interaction with the surrounding environment. Numeracy activities are closely related to the cognitive development process of each individual (Purnomo et al., 2022).

The scope of numeracy implementation is extensive, not only introducing mathematics. Numeracy skills encompass innovation skills, technology utilization skills, life skills, and problem-solving skills (Dalim et al., 2023). The concept of problem-solving, an integral element in Piaget's theory (Cerovac & Keane, 2025), can be effectively integrated into the learning of mathematics. Mathematics education that emphasizes problem-solving has the potential to foster the development of critical and creative thinking skills in students (Lukman et al., 2023). This approach aligns with Piaget's perspective, which emphasizes that children actively develop their understanding through efforts in solving problems and building knowledge independently (Debora & Pramono, 2021).

Children must learn numeracy from an early age because it serves as a strong predictor of future academic success, cognitive development, and social adaptability (Novita et al., 2024). Early math skills are a more powerful predictor of later academic achievement than early reading or socio-emotional skills (Little et al., 2021). Without a strong foundation in numeracy, children are more likely to struggle academically, require special education support, and face long-term social and economic disadvantages. Globally, UNESCO has reported that six in ten children are unable to perform basic math operations by the end of primary school, highlighting a global learning crisis (Hinzen et al., 2025). In Indonesia, data from the Ministry of Education shows that only around 60% of Grade 3 students meet the minimum competency standards in mathematics, indicating serious early numeracy challenges, (Doz, 2021; Nugraheni & Marsigit, 2021; Xu et al., 2023). These findings underscore the urgency of prioritizing early numeracy development as a fundamental part of holistic education.

Early childhood learning can be categorized into three approaches: independent learning, guided learning, and supportive learning. (Wynberg et al., 2022). Free learning emphasizes less structured learning activities and unrestricted freedom of play (Buldu, 2022). Guided learning is

influenced by the various behaviors of teachers in controlling children's learning activities. In contrast, conducive learning aims to strike a balance between the freedom to actively explore and the need to limit children's activities to ensure their safety when learning (Wulan & Syaleh, 2023). In implementing the right learning model, educators need to master other approaches (Bhagwonparsadh & Pule, 2024). For example, knowledge of holistic approaches, techniques involve children in determining learning (Kroufek & Nepraš, 2023; Norwich et al., 2022), positioning education as a facilitator (Mathisen et al., 2023) prioritizing the child's authentic work (Damjanovic & Ward, 2024), and the absence of a particular order or linear way of thinking (Michinov & Michinov, 2020), including deep learning.

Deep learning is closely related to constructivist learning theory, which enhances the learning process and fosters interaction with others (Mei et al., 2023). Deep learning occurs when students are challenged and motivated by real-world problems that use interdisciplinary knowledge through an inquiry learning approach (Scott & White, 2024). Deep Learning is a development of various alternative approaches that build upon previous student-centered approaches, such as Problem-Based Learning, Flipped Classroom, and Formative Assessment, among others (Tan, 2024). Thus, it can be demonstrated that deep learning is an approach that tailors its focus to students according to their uniqueness and characteristics.

In-depth learning in PAUD does not mean teaching complex or academic concepts (*Ministry of Education and Culture*, 2025). Instead, it is an approach that respects the child's natural way of learning: through play, exploration, and discovery. Early Childhood is naturally characterized by high curiosity, and children in this stage always ask "why" about the world around them. They also enjoy exploring and trying new things (Yeler, 2022). This nature is very much in line with the principles of Deep Learning.

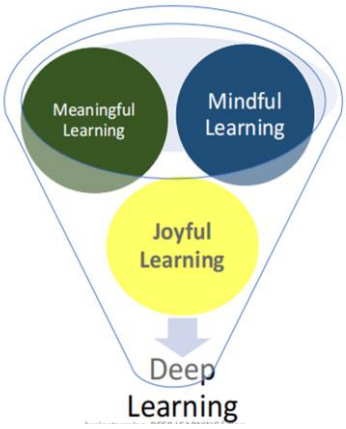


Figure 1. Concept of deep learning

The concept of meaningful learning is meaningful learning (Vargas-Hernández & Vargas-González, 2022), mindful learning is mindful learning (Brito & Sellman, 2022), and joyful learning is fun learning (Anggoro et al., 2022). Deep Learning respects the natural way children learn (Pan et al., 2023) by providing hands-on experiences, time for exploration, and opportunities to play and discover, helping children build a strong foundation of understanding and a love of learning early on (Lloyd et al., 2024).

METHOD

This research employs a development model, commonly referred to as Research and Development (R&D), as described by Rahmawati & Cintamulya, (2025). Development research is a method used to produce a specific product and evaluate its effectiveness (Sugiyono, 2015). The development model adopted in this study is the ADDIE model, which includes five stages: Analyze, Design, Development, Implementation, and Evaluation (Khiftiyah & Nilamsari, 2022; Nurhasanah et al., 2022).

In this research, the ADDIE model was applied to develop educational media on disaster mitigation through a structured and gradual process. Disaster mitigation was chosen as the focus due to the unpredictable and often severe impact of natural disasters, particularly in disaster-prone areas. Therefore, increasing awareness and preparedness through education is essential to reduce risks and losses. By integrating disaster mitigation into educational media, learners—especially young children—can acquire essential knowledge and skills to respond appropriately before, during, and after a disaster.

The learning content developed focuses on early numeracy based on a deep learning approach. The ADDIE model was selected due to its strength in providing a systematic development process. Each phase includes evaluation and revision components, ensuring a high level of validity for the resulting product. Additionally, the model is relatively simple, yet structured and systematic in its implementation (El Kharki et al., 2021; Rahmawati & Cintamulya, 2025; Sulistyaningrum et al., 2023). It also enables the creation of learning media that can be utilized in both face-to-face and online learning environments (Adeoye et al., 2024; Arfianti et al., 2021).

Data collection was carried out through observation, interviews, documentation, and early numeracy performance assessments. These techniques were used to gather information about learner needs, age-appropriate media design, and the effectiveness of the developed product. The research involved 60 early childhood students from kindergarten, divided into two age groups: 4– to 5–year–olds and 5– to 6–year–olds.

To ensure data validity, both source triangulation and method triangulation techniques were used. Source triangulation was conducted by comparing data from teachers, students, and learning documents. Method triangulation involved combining observations, interviews, documentation, and tests to provide a comprehensive and corroborative understanding of the research. Additionally, expert judgment was employed during the design and development stages to validate the content, language, and visual aspects of the media in accordance with the developmental characteristics of early childhood learners.

Data analysis employed both qualitative and quantitative descriptive methods. Qualitative data were analysed through stages of data reduction, data display, and conclusion drawing. Quantitative data were analyzed by comparing the results of pretests and posttests on early numeracy, using the percentage of score improvement as an indicator of product effectiveness.

RESULTS AND DISCUSSION

The deep learning method offers a hands-on experience, allowing for exploration and encouraging full involvement from each child in the learning process. This research was carried out at Lestari Mulyo Pucakwangi Pati Kindergarten. The development of deep learning practice media is carried out using the ADDIE development model, which consists of five stages of development, namely: (1) analysis stage, (2) design stage, (3) development stage, (4) implementation stage, and (5) evaluation stage.

This sub-chapter explains the design of early numeracy practices using deep learning media. Design and development of disaster education media by the product development model used in the research on the development of in-depth learning media practices in early numeracy. The stages in the implementation of development research are as follows.

1. Analysis stage
   Analysis of the condition of Kindergarten Lestari Mulyo Pucakwangi Pati. Learning is still conventional. A situation analysis was conducted to achieve optimal results in mapping the needs of initial numeracy practice using the deep learning method.
2. Design Stage
   Building on the analysis of the initial numeracy practice's needs, an appropriate design needs to be implemented that targets these needs. Design of in-depth learning methods in early childhood numeracy practice.

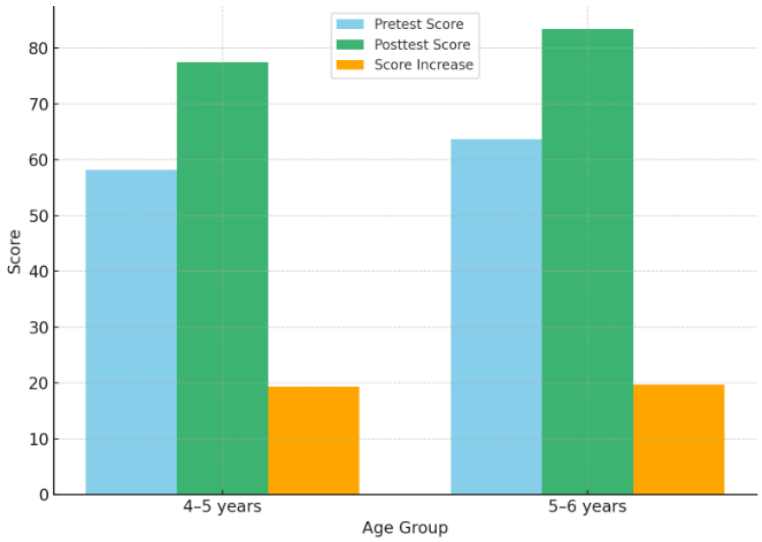
3. Development Stage
   Development of deep learning implementation design to meet the needs of continuous education. Development was carried out to determine the optimal formula for the initial numeracy practice model, utilizing deep learning, based on the child's developmental age and the level of numeracy implementation.
4. Implementation stage
   The right level of numeracy has been tailored to the child's age and development. Each initial numeracy practice is adjusted to the child's developmental level. Deep learning media is the ideal approach to implementing it according to these stages of development.

   The implementation stage focused on applying early numeracy practices using deep learning media that had been developed and aligned with children's cognitive development stages. Each numeracy activity was tailored to the age and cognitive abilities of the children, specifically targeting two age groups: children aged 4–5 years and those aged 5–6 years.

   The implementation trial was conducted in Kindergarten Lestari Mulyo, Pucakwangi, Pati, involving 60 early childhood learners, divided equally between the two age groups. The aim was to assess the effectiveness of the early numeracy practice model through quantitative analysis.

   A pretest-posttest design was used to measure numeracy development. The pretest assessed children's initial numeracy skills before using the deep learning media, while the posttest evaluated their skills after the intervention. The results showed a significant improvement in numeracy abilities across both age groups:

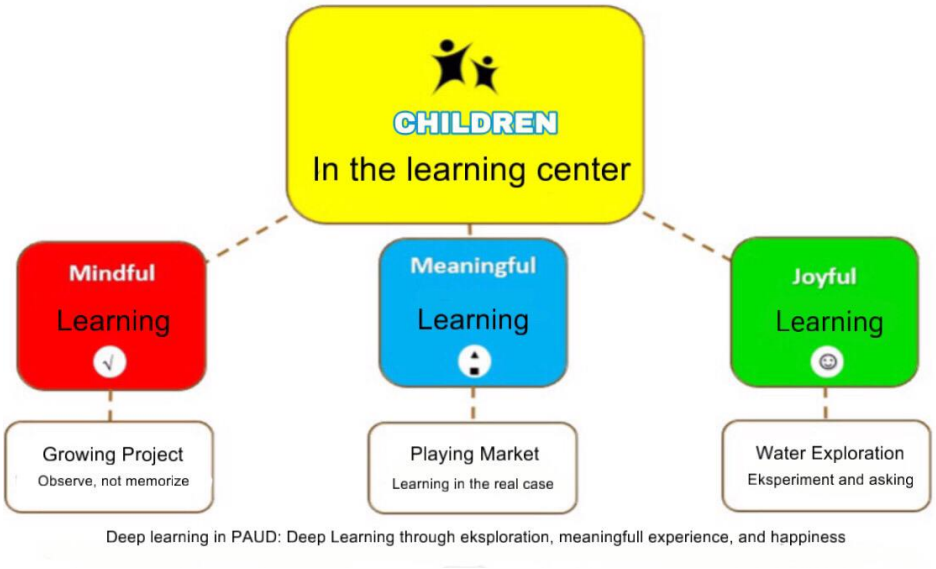
Table 1. Comparison of Pretest, Posttest, and Score Increase in Early Numeracy Practice



These results indicate that the deep learning-based early numeracy practices were effective in enhancing children's understanding of numeracy. Additionally, observational data collected during implementation revealed increased engagement, curiosity, and joyful participation, notably when learning activities incorporated storytelling, games, and hands-on materials. The media developed proved suitable and accessible for early childhood learners across both age categories.

5. Evaluation Stage
   Evaluation is carried out at each level of initial numeracy practice. The evaluation was carried out comprehensively, encompassing the readiness of Human Resources (HR), learning planning, the three aspects of deep learning, and children's readiness to learn.

Figure 2. Deep learning in childhood education



Numeracy is not only about arithmetic, but also about the application of mathematical concepts in everyday life. Here are three levels of thinking processes in early childhood numeracy (Johnston & Bull, 2022; Khasanah & Purnamasari, 2023; Maharani et al., 2024; Novita et al., 2024).

1. Understanding (Knowing). These basic levels include:
   a. Remembering the math facts
   b. Identify basic conceptsPerform simple calculations
2. Applying. At the intermediate level, students are expected to:
   a. Applying mathematical concepts in real-life situations
   b. Solve problems of daily routine
   c. Using the math procedures that have been learned
3. Reasoning. The highest level in numeracy includes:
   a. Complex data analysis
   b. Non-routine troubleshooting
   c. Provide a mathematical justification for a given solution

Table 1. Early Numeracy Practice at the age of 4 – 6 years in deep learning According to the level of thinking (cognition)

Numeracy Level	**Practice Age 4 – 5 years old**	**Practice Age 5 – 6 years**
Knowing	Songs with simple vocabulary Counting by objects according to the topic	Songs with more complex vocabulary
Applying	Counting by objects according to the topic Getting to know the numbers 1 - 10 with consumables Getting to know numbers with APE media	Counting objects with various subtopics Getting to know the numbers 11 – 20 with consumables Getting to know the numbers with various APE media
Reasoning	Use numbers to count from 1 to 10 and compare the number of objects.	Use numbers to count 11 - 20 and compare the number of objects.

Numeracy Level	Practice Age 4 – 5 years old	Practice Age 5 – 6 years
		Sort objects by number, size, and color

Table 2. Strategies to improve higher numeracy levels through deep learning.

Deep Learning	Reflection
Meaningful Learning	Help learners evaluate their thought processes.
Mindful Learning	Students become independent learners, active and able to regulate themselves. Ability to apply knowledge
Joyful Learning	Be happy in learning and provide a comfortable learning environment for students.

Teaching numeracy through deep learning is essential for building meaningful and developmentally appropriate experiences (Winarno et al., 2024). Deep learning involves a sequence of pedagogical steps: activating prior knowledge, exploring numerical concepts through contextual problem-solving, deepening understanding with reflection and collaboration, applying concepts across situations, and engaging in formative evaluations that focus on student thinking (Reilly & Reeves, 2024).

Learning progression is a continuous sequence of stages in learning (Nugroho & Hanatan, 2019; Zhou & Liang, 2023). The continuity encompasses aspects of the characteristics, breadth, and depth of learning materials that align with the child's age level. The scope of the material must be formulated based on the development of students, ensuring that the scientific concepts learned align with their development (Jad et al., 2021; Soledad et al., 2021). The implementation of learning must be aligned with students' abilities in the context of mastering tiered competencies.

CONCLUSION

The concept of 21st-century education is a demand for students to possess a variety of skills and abilities necessary to face various challenges and solve social problems in daily life. Early childhood numeracy is a form of learning material that requires good practice development. One form of practice applied is the use of the deep learning method. Deep learning encompasses three key concepts: meaningful learning, mindful learning, and joyful learning. A person's thinking skills require one stimulating activity to reach a certain level of thinking maturity. One of them is through the introduction of numeracy from an early age. The development of this initial numeracy practice includes 3 (three) levels of thinking processes, namely the level of knowing, applying, and rationalizing. These three levels are integrated with 3 three deep learning concepts. The result of the integration is the development of innovative early numeracy practices with the ADDIE method.

REFERENCES

Adeoye, M. A., Wirawan, K. A. S. I., Pradnyani, M. S. S., & Septiarini, N. I. (2024). Revolutionizing education: Unleashing the power of the ADDIE model for effective teaching and learning. *JPI (Jurnal Pendidikan Indonesia)*, *13*(1), 202–209.

Anggoro, S., Widodo, A., Thoe, N. K., & Cyril, N. (2022). Promoting Nature of Science Understanding for Elementary School through Joyful Learning Strategy. *Journal of Pedagogy and Education Science*, *1*(02). https://doi.org/10.56741/jpes.v1i02.77

Arfianti, D., Retnowati, R., & Awaludin, M. T. (2021). Development of E-Magazine Materials for Disaster Mitigation Outbreak to Increase Preparedness of High School Students. *Journal Of Biology Education Research (JBER)*, *2*(2). https://doi.org/10.55215/jber.v2i2.3652

Aulia, I., Al Idrus, S. A. J., & Mustafa, P. S. (2024). Pembinaan Kecerdasan Spiritual dan Emosional Melalui Kegiatan Ekstrakurikuler Pramuka Siswa Kelas IV di SDN 26 Cakranegara. *Journal of Science and Education Research*, *3*(2), 17–23.

Bhagwonparsadh, Y., & Pule, K. G. (2024). The effects of educators' mathematics pedagogical content knowledge on the mentoring of grade 12 students using problem-based learning. *Journal of Culture and Values in Education*, *7*(1), 99–117.

Brito, R. , J. S., & Sellman, E. (2022). From instrumental to integral mindfulness: Toward a more holistic and transformative approach in schools. *Studies in Philosophy and Education*, *41*(1), 91–109.

Buldu, E. (2022). Understanding the Value of Play: Recasting Playful Learning by Early Childhood Teachers. *Open Journal for Educational Research*, *6*(1). https://doi.org/10.32591/coas.ojer.0601.05057b

Cerovac, M., & Keane, T. (2025). Early insights into Piaget's cognitive development model through the lens of the Technologies curriculum. *International Journal of Technology and Design Education*, *35*(1), 61–81.

Dalim, S. F., Syed Aris, S. R., Hoon, T. S., Nadzri, F. A., Deni, S. M., Yahya, N., & Si, E. M. (2023). Framework for Numeracy and Digital Skills Attributes in Higher Education. *Research in Social Sciences and Technology*, *8*(3). https://doi.org/10.46303/ressat.2023.18

Damjanovic, V., & Ward, J. (2024). Exploring inquiry-based STEM in preschool: The treehouse project. *School Science and Mathematics*, *124*(5). https://doi.org/10.1111/ssm.12640

Debora, R., & Pramono, R. (2021). Implementation of STEM Learning Method to Develop Children's Critical Thinking and Problem Solving Skills. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *6*(3). https://doi.org/10.31004/obsesi.v6i3.1722

Doz, D. (2021). Students' Mathematics Achievements: A Comparison between Pre-and Post-COVID-19 Pandemic. *Education and Self Development*, *16*(4). https://doi.org/10.26907/esd.16.4.04

El Kharki, K., Berrada, K., & Burgos, D. (2021). Design and implementation of a virtual laboratory for physics subjects in moroccan universities. *Sustainability (Switzerland)*, *13*(7). https://doi.org/10.3390/su13073711

Elvia, R., Emiola, A. G., & Quynh, P. T. N. (2023). The Relationship Between Students' Attitudes Towards Geography Lessons and Learning Motivation and Geography Learning Achievement. *Journal of Social Knowledge Education (JSKE)*, *4*(4). https://doi.org/10.37251/jske.v4i4.760

Ginting, D. A., Suprayetno, E., Marpaung, F. D. N., & Hasan, M. (2024). Pelatihan Implementasi Model Pembelajaran Problem Based-Learning Bagi Guru SMP Swasta Mulia Hamparan Perak. *JURNAL ABDIMAS MADUMA*, *3*(1), 1–8.

Hinzen, H., Medel-Anonuevo, C., & Németh, B. (2025). Implementation of the Marrakech Framework for Action in the Context of the Sustainable Development Goals: UNESCO and Global Cooperation Frameworks. *New Directions for Adult and Continuing Education*, *2025*(185), 9–16.

Idris, M. O., Yusuf, M., Mohd Hanif, M. H., Adekunle, S. M., & Kayode, B. K. (2021). An Appraisal of the Attitudes and Achievement Motivation of Arab Postgraduate Students Towards the Learning of the English Language in Selected Malaysian Public Universities. *Asian Journal of Assessment in Teaching and Learning*, *11*(1). https://doi.org/10.37134/ajatel.vol11.1.4.2021

Imran, S., Shaheen, S., Waseem, H., & Ali, A. (2023). Transformation of 21st Century Science Skills: Perceptions of Secondary School Teachers. *Qlantic Journal of Social Sciences and Humanities*, *4*(3). https://doi.org/10.55737/qjssh.819252525

Jad, N., Raouf, K., Elkababi, K., & Radid, M. (2021). EXPLORATION OF ERRONEOUS REPRESENTATIONS OF THE CONCEPT "ENERGY" BY MOROCCAN PRIMARY SCHOOL LEARNERS. *Journal of Southwest Jiaotong University*, *56*(6). https://doi.org/10.35741/issn.0258-2724.56.6.57

Jati, K., Intaniasari, Y. S., Ningrum, R. S., Hafida, S. H. N., Utami, R. D., Ariyadi, M. Y., & Subekti, T. A. (2022). Peningkatan pemahaman pola asuh melalui sosialisasi tumbuh kembang anak untuk menciptakan generasi emas. *Buletin KKN Pendidikan*, *4*(1), 12–23.

Johnston, K., & Bull, R. (2022). Understanding educator attitudes towards and perceptions of mathematics in early childhood. *Journal of Early Childhood Research*, *20*(3). https://doi.org/10.1177/1476718X211052785

Khasanah, I., & Purnamasari, I. (2023). Role-Playing Methods: Efforts to Stimulate the Development of Early Childhood Numeracy Literacy. *Journal of Social Research*, *2*(4). https://doi.org/10.55324/josr.v2i4.776

Khiftiyah, M., & Nilamsari, W. (2022). Proses pemberdayaan perempuan melalui program usaha peningkatan pendapatan keluarga pada masa pandemi covid-19. *Jurnal Pembangunan Manusia*, *3*(1). https://doi.org/10.7454/jpm.v3i1.1024

Kim, Y., Lee, Y. H., Lee, H., & Lim, S. M. (2022). ALIGNMENT OF CONCEPTS OF MEIOSIS AMONG CURRICULUM, TEXTBOOKS, CLASSROOM TEACHING AND ASSESSMENT IN UPPER SECONDARY SCHOOL IN REPUBLIC OF KOREA. *Journal of Baltic Science Education*, *21*(2). https://doi.org/10.33225/jbse/22.21.232

Kristanto, W., Azminah, S. N., & Citrasukmawati, A. (2023). Membangun pendidikan karakter pada anak usia dini melalui permainan dingklik oglak aglik. *JECIE (Journal of Early Childhood and Inclusive Education)*, *6*(2), 254–262.

Kroufek, R., & Nepraš, K. (2023). The impact of educational strategies on primary school students' attitudes towards climate change: A comparison of three European countries. *European Journal of Science and Mathematics Education*, *11*(3). https://doi.org/10.30935/scimath/12945

Lansey, K. R., Jackson, L. , Agran, M., Ryndak, D., & Jameson, J. M. (2024). A Secondary Analysis of Jackson et al.(2022): The Impact of Educational Placement for Students with Complex Support Needs. *Research and Practice for Persons with Severe Disabilities*, *49*(3), 208–224.

Little, C. W., Lonigan, C. J., & Phillips, B. M. (2021). Differential patterns of growth in reading and math skills during elementary school. *Journal of Educational Psychology*, *113*(3). https://doi.org/10.1037/edu0000635

Lloyd, S., Jones, N., & Smith, D. (2024). Two service evaluations of LEAPlets–An early years programme for children in foster care and adoption, based on the BUSS® (Building Underdeveloped Sensorimotor Systems) Model. *Adoption & Fostering*, *48*(3–4), 471–493.

Lopuszanska, U., & Samardakiewicz, M. (2020). The Relationship between Air Pollution and Cognitive Functions in Children and Adolescents: A Systematic Review. In *Cognitive and Behavioral Neurology* (Vol. 33, Issue 3). https://doi.org/10.1097/WNN.0000000000000235

Lukman, H. S., Agustiani, N., & Setiani, A. (2023). Gamification of Mathematics Teaching Materials: Its Validity, Practicality and Effectiveness. *International Journal of Emerging Technologies in Learning (IJET)*, *18*(20). https://doi.org/10.3991/ijet.v18i20.36189

Maharani, S. D., Putri, R. I. I., Syawaliyah, A. F., & Safitri, M. L. O. (2024). Interactive learning media: literacy and numeracy limas house balaputera dewa museum in phase B. *Research and Development in Education (RaDEn)*, *4*(1), 617–629.

Mathisen, C., Bjørk, I. T., Heyn, L. G., Jacobsen, T. I., & Hansen, E. H. (2023). Practice education facilitators perceptions and experiences of their role in the clinical learning environment for nursing students: a qualitative study. *BMC Nursing*, *22*(1). https://doi.org/10.1186/s12912-023-01328-3

Mei, J., Chen, W., Li, B., Li, S., & Zhang, J. (2023). Visualization of computer-supported collaborative learning models in the context of multimodal data analysis. *3C Empresa. Investigación y Pensamiento Crítico*, *12*(01). https://doi.org/10.17993/3cemp.2023.120151.87-109

Michinov, N., & Michinov, E. (2020). Do Open or Closed Postures Boost Creative Performance? The Effects of Postural Feedback on Divergent and Convergent Thinking. *Psychology of Aesthetics, Creativity, and the Arts*. https://doi.org/10.1037/aca0000306

Ministry of Education and Culture. (2025). Deep Learning Guide. https://bpmpkaltara.kemdikbud.go.id/wp-content/uploads/2025/02/nasmik-deep-learning-2025-full_10-feb.pdf

Mithans, M., Lipovec, Ž., & Ograjšek, S. (2023). Teacher's Work with Children with Special Needs in Kindergarten. *Pedagoška Obzorja*, *38*(1), 96–111.

Norwich, B., Moore, D., Stentiford, L., & Hall, D. (2022). A critical consideration of 'mental health and wellbeing' in education: Thinking about school aims in terms of wellbeing. *British Educational Research Journal*, *48*(4). https://doi.org/10.1002/berj.3795

Novita, S., Anindhita, V., Wijayanti, P. A. K., Santoso, L. A. B., La Batavee, H., Tampubolon, A. F. J., & Syafitri, A. N. (2024). Relationship Between Numeracy and Vocabulary Skills in Indonesian Preschool Children and the Impacts of Learning Environments. *International Journal of Early Childhood*, *56*(2). https://doi.org/10.1007/s13158-023-00356-z

Nugraheni, L. P., & Marsigit, M. (2021). Realistic mathematics education: An approach to improve problem solving ability in primary school. *Journal of Education and Learning (EduLearn)*, *15*(4). https://doi.org/10.11591/edulearn.v15i4.19354

Nugroho, A. Y. U., & Hanatan, A. (2019). Learning Module for Elementary School Students Using Learning Model Based on LCM Theory. *International Journal of Educational Research Review*, *4*(1). https://doi.org/10.24331/ijere.472797

Olteanu, C. (2022). Programming, mathematical reasoning and sense-making. *International Journal of Mathematical Education in Science and Technology*, *53*(8). https://doi.org/10.1080/0020739X.2020.1858199

Pan, Q., Zhou, J., Yang, D., Shi, D., Wang, D., Chen, X., & Liu, J. (2023). Mapping Knowledge Domain Analysis in Deep Learning Research of Global Education. *Sustainability (Switzerland)*, *15*(4). https://doi.org/10.3390/su15043097

Purnomo, H., Sa'dijah, C., Hidayanto, E., Sisworo, Permadi, H., & Anwar, L. (2022). Development of Instrument Numeracy Skills Test of Minimum Competency Assessment (MCA) in Indonesia. *International Journal of Instruction*, *15*(3). https://doi.org/10.29333/iji.2022.15335a

Rahmawati, N. I., & Cintamulya, I. (2025). Validity of e-modules integrated with game-based problem-based learning to improve 21st century skills in Biology learning. *Biosfer: Jurnal Pendidikan Biologi*, *18*(1), 103–114.

Reilly, C., & Reeves, T. C. (2024). Refining active learning design principles through design-based research. *Active Learning in Higher Education*, *25*(1). https://doi.org/10.1177/14697874221096140

Saher, S., & Kashif, N.-. (2020). Analysis of Alignment between National Curriculum of Education and Textbooks at Higher Secondary Level in Punjab-Pakistan. *Review of Economics and Development Studies*, *6*(3). https://doi.org/10.47067/reads.v6i3.256

Scott, E. K., & White, B. R. (2024). An empirical study of cultivating innovative practice abilities in an interdisciplinary education environment in Australia. *Research and Advances in Education*, *3*(5), 53–63.

Sharma, P., Adamopoulos, I., Syrou, N., Budhathoki, C. B., & Thapa, P. (2024). The impact of health-caregivers emotional nurturance on cognitive development in preschoolers: A nationwide public health cross-sectional study. *Electronic Journal of General Medicine*, *22*(3), 1–10.

Soledad, M., Andrade-Vargas, L., Rivera, D., & Castro, M. (2021). Trends for the Future of Education Programs for Professional Development. *Sustainability*, *13*(13), 7244–7250.

Sugiyono, S. (2015). *Qualitative, quantitative, and R&D research methods*. Alfabeta.

Sulistyaningrum, D. A., Wibawanto, H., & Purwanti, E. (2023). Developing a Google Classroom Training Model for Elementary School Teachers. *Innovative Journal of Curriculum and Educational Technology*, *12*(1). https://doi.org/10.15294/ijcet.v12i1.65869

Susilawati, E., Muslim, S., Khaerudin, K., & Yansyah, F. (2024). The potency of the adaptive cooperative learning model in strengthening numeracy performance of secondary school

students: Education policy insights. *Edelweiss Applied Science and Technology*, *8*(6), 8934–8944.

Tan, J. (2024). Exploring the Optimization Model of University English Blended Teaching Mode Combined with Deep Learning. *Journal of Electrical Systems*, *20*(6s), 1682–1694.

Vargas-Hernández, J. G., & Vargas-González, O. C. (2022). Strategies for meaningful learning in higher education. *Journal of Research in Instructional*, *2*(1). https://doi.org/10.30862/jri.v2i1.41

Varghese, J., & Musthafa, M. A. (2021). Why the Optimism Misses? An Analysis on the Gaps and Lags of Teachers' Perceptions of 21st Century Skills. *Shanlax International Journal of Education*, *10*(1). https://doi.org/10.34293/education.v10i1.4322

Wang, X. (2023). A Study of Early Childhood Teachers' Professional Development and Teaching Effectiveness Enhancement from the Perspective of Educational Psychology. *Contemporary Education and Teaching Research*, *4*(8). https://doi.org/10.61360/bonicetr232014330806

Winarno, W., Muchtarom, M., & Fauziyah, H. (2024). Readiness and efforts of civics teachers in developing literacy and numeracy skills. *Journal of Education and Learning (EduLearn)*, *18*(4), 1209–1223.

Wulan, D. S. A., & Syaleh, M. (2023). The Influence of Education Management on Learning Motivation in Early Childhood. *Journal Management of Sport*, *1*(2), 64–71.

Wynberg, E. R., Boland, A., Raijmakers, M. E. J., & van der Veen, C. (2022). Towards a Comprehensive View of Object-Oriented Play. In *Educational Psychology Review* (Vol. 34, Issue 1). https://doi.org/10.1007/s10648-021-09608-7

Xu, T., Wu, X., Sun, S., & Kong, Q. (2023). Cognitive diagnostic analysis of students' mathematical competency based on the DINA model. *Psychology in the Schools*, *60*(9). https://doi.org/10.1002/pits.22916

Yeler, G. (2022). ASSOCIATION OF LEARNING SPACES WITH NATURE: THE EXAMPLE OF KIRKLARELİ ZÜBEYDE HANIM KINDERGARTEN. *Kirklareli University Journal of Engineering and Science*, *8*(2), 211–228.

Nurhasanah, Y., Khairunisa, Y., & Kuswoyo, D. (2022). Development of Interactive Digital Learning Multimedia Applications as Independent Learning Module in 2-Dimensional Game Programming Courses. *JTP - Jurnal Teknologi Pendidikan*, *24*(3). https://doi.org/10.21009/jtp.v24i3.29769

Yusnadi, Y., Rosdiana, R., & Anifah, A. (2020). The Development of Teaching Materials for the Principles of Nonformal Education Based on Higher Order Thinking Skills on The Subject of Tasks and Population Goals of Non Formal Education. *Budapest International Research and Critics in Linguistics and Education (BirLE) Journal*, *3*(1). https://doi.org/10.33258/birle.v3i1.826

Zakaria, M. H., Rakhmawati, N. D., Endahwuri, D., & Wibisono, A. (2023). Numeracy Literacy Skills of Introverted and Extroverted Students in Solving Linear Program Problems. *Hipotenusa : Journal of Mathematical Society*, *5*(1). https://doi.org/10.18326/hipotenusa.v5i1.9029

Zhou, J., & Liang, D. (2023). A New Methodology of Knowledge Point Sequence Generation and Learning Path Recommendation by Knowledge Reasoning. *International Journal of Emerging Technologies in Learning*, *18*(13). https://doi.org/10.3991/ijet.v18i13.41915