

Effectiveness of the AR-based EASI (exposure analogy social action impact writing) learning model on conceptual understanding of human motion systems in elementary schools

Hillman Arif¹, Dyah Lyesmaya^{1*}, Ayi Abdurahman¹, Entit Puspita¹, Imam Robandi²

¹Universitas Nusa Putra, Jl. Raya Cibolang Cisaat, Sukabumi, West Java, 43152, Indonesia

²Institut Teknologi Sepuluh Nopember, Jl. Raya ITS, Surabaya, East Java, 60111, Indonesia
dyah.lyesmaya@nusaputra.ac.id*

Abstract: Teaching abstract science concepts like the human motion system remains challenging in elementary schools. This study compared four learning models to improve students' conceptual understanding: AR-integrated EASI, EASI without AR, AR-only, and conventional lecture–discussion. Using a quasi-experimental design, 120 sixth-graders from four Indonesian elementary schools were tested using SOLO Taxonomy-based instruments. Data were analyzed via ANOVA and Tukey HSD tests. Results showed significant differences among groups ($p = 0.000$). The EASI+AR model yielded the highest improvement ($N\text{-Gain} = 0.7287$) and significantly outperformed AR-only and conventional models. AR alone did not significantly enhance understanding. In conclusion, technology integration requires a solid pedagogical framework like EASI to effectively boost conceptual understanding. Practically, these findings imply that educators and curriculum developers must prioritize pedagogically-driven technology rather than standalone digital tools to optimize elementary science learning.

Keywords: EASI learning model; augmented reality (AR); human motion system; elementary school; SOLO taxonomy

Introduction

Education in the 21st century demands learning models that cultivate critical thinking, creativity, and robust scientific literacy. In Indonesia, achieving this goal remains a significant challenge, as evidenced by the nation's performance in international assessments. The 2018 PISA results placed Indonesia 71st out of 79 countries in science, with an average score significantly below the OECD average (OECD, 2019). This persistent gap underscores a fundamental issue in students' conceptual understanding of basic science at the elementary level, a concern echoed by national studies reporting low comprehension rates and prevalent misconceptions in topics such as the human motion system (Fauziah et al., 2024; Novanto et al., 2023). Strengthening this foundational understanding is urgent, not only for academic progression but also to prepare students for a future where the majority of jobs will require strong scientific and digital competencies (Economic Forum, 2023).

The human motion system is a prime example of an essential yet challenging topic in elementary science. Its abstract nature, involving hidden microscopic structures and dynamic physiological processes, makes it difficult for students to grasp using traditional methods. Conventional lecture-discussion approaches and static two-dimensional media often fail to convey the three-dimensional, interactive nature of bones, joints, and muscles. This pedagogical shortfall leads to widespread misconceptions; preliminary research in the local context of Cibadak District, for instance, revealed that over 70% of sixth-grade students held

misunderstandings about joint types and muscle functions (Meilindawati et al., 2023). This clear disconnect between the complexity of the material and the methods used to teach it creates a pressing need for more interactive, visual, and student-centered learning strategies.

AR strongly supports a constructivist-based learning approach because it allows students to build on their own. Previous research has shown that AR significantly contributes to conceptual understanding, supports active learning processes, and improves student participation in scientific literacy activities (Akçayır & Akçayır, 2017; Cheng & Tsai, 2013; Ibáñez & Delgado-Kloos, 2018). In response to this need, Augmented Reality (AR) technology has emerged as a powerful tool for visualization. By superimposing interactive 3D models onto the real world, AR can make abstract biological concepts tangible and explorable. Previous research supports its potential to enhance engagement and learning outcomes in science education (Habibi & Sulistyanto, 2016; Nauko & Amali, 2021). However, scholars caution that technology alone does not guarantee deep conceptual learning; it functions most effectively when integrated within a sound pedagogical framework that guides students toward meaningful knowledge construction (Henne et al., 2024; Hsu et al., 2023). This highlights the critical distinction between merely using technology and designing technology-enhanced learning.

The EASI (Exposure, Analogy, Social Action, Impact Writing) learning model offers such a framework. Developed initially to foster literacy and character through visual analogy (Lyesmaya et al., 2023), its constructivist stages are highly adaptable to science education. Rooted in Vygotsky's social constructivism, the EASI model systematically guides learners through four progressive phases within their Zone of Proximal Development (ZPD). The Exposure phase stimulates students' cognitive curiosity by confronting them with authentic scientific phenomena. This is followed by the Analogy phase, which serves as a cognitive scaffold where abstract concepts are mapped onto familiar concrete structures to minimize misconceptions. In the Social Action phase, students engage in collaborative dialogic inquiry to socially co-construct and validate their understanding. Finally, the Impact Writing phase promotes metacognitive reflection, anchoring the newly acquired knowledge into long-term memory through structured expressive writing. Recent literature highlights that such multi-phased constructivist scaffolds are critical for building deep conceptual understanding in science education. The Analogy stage, in particular, aligns seamlessly with AR's strength in providing dynamic visual comparisons, as integrating interactive visualization within structured pedagogical stages prevents cognitive overload and enhances spatial representation (Ibáñez & Delgado-Kloos, 2018).

While both AR and EASI show individual promise, a significant research gap exists. Empirical studies investigating the synergistic integration of the EASI pedagogical model with AR technology in elementary science are notably absent. Furthermore, there is a lack of comparative evidence on whether the pedagogical model, the technology, their combination, or conventional methods are most effective for building conceptual understanding. To address this gap, this study aims to investigate and compare the effectiveness of four distinct instructional approaches on sixth-grade students' conceptual understanding of the human motion system: (1) the integrated AR-based EASI model, (2) the EASI model without AR, (3)

AR technology used independently, and (4) the conventional lecture-discussion method. By doing so, this research seeks to provide evidence-based insights into optimal learning design, contributing to the theory and practice of hybrid pedagogy in elementary science education.

Method

This study employed a quantitative approach with a quasi-experimental design to examine the effectiveness of four learning interventions on sixth-grade students' conceptual understanding of the human motion system. The study involved four groups: (1) the EASI model integrated with Augmented Reality (AR), (2) the EASI model without AR, (3) AR technology only, and (4) a conventional lecture-discussion method as the control group. Conducted in Cibadak District, Sukabumi Regency, West Java, Indonesia, the study included 120 sixth-grade students selected through purposive and cluster random sampling techniques. Data were collected using a conceptual understanding test developed based on the SOLO (Structure of the Observed Learning Outcome) Taxonomy, which assesses students' understanding across hierarchical cognitive levels, ranging from simple identification to extended abstract thinking (Biggs & Collins, 1982). The instrument was validated by experts and demonstrated acceptable reliability, with a Cronbach's Alpha coefficient exceeding 0.70, indicating satisfactory internal consistency (Papanastasiou et al., 2019). An observation sheet was also employed to monitor the fidelity of the intervention implementation.

The research procedure began with a pretest administered to all participants to measure their initial conceptual understanding. Subsequently, each group received a different learning intervention over a four-week period. The EASI+AR group followed the stages of Exposure, Analogy, Social Action, and Impact Writing supported by AR-based 3D visualizations, while the EASI-only group implemented the same pedagogical framework using conventional visual media. The AR-only group used AR technology without structured EASI guidance, whereas the control group received conventional instruction. Following the intervention, a posttest was administered to evaluate students' final conceptual understanding. Data analysis involved descriptive statistics and the calculation of N-Gain scores to determine learning improvement. Before hypothesis testing, the assumptions of normality and homogeneity were examined, followed by a One-Way ANOVA and Tukey's HSD post hoc test to identify significant differences among the four groups. All statistical analyses were performed using SPSS software.

Results and Discussion

The pretest and posttest scores for conceptual understanding were analyzed using descriptive statistics and N-Gain calculations. The results indicated varied levels of improvement across the four treatment groups, as summarized in Table1.

Table 1. Descriptive Statistics and N-Gain Scores of Conceptual Understanding

Group	Pretest Mean	Posttest Mean	N-Gain Score	Category
EASI + AR	55.3	87.8	0.7287	High
EASI without AR	55.5	80.5	0.5801	Medium
AR Only	55.2	75.2	0.4712	Medium
Conventional Method	55.0	74.7	0.4496	Medium

The EASI+AR group achieved the highest improvement with an N-Gain of 0.7287 (high category), followed by the EASI without AR group (0.5801, medium). The AR-only and conventional groups showed medium gains (0.4712 and 0.4496, respectively). These findings suggest that while AR or EASI alone contribute to learning, their integration yields the most substantial conceptual gains.

A one-way ANOVA was conducted on the N-Gain scores to determine whether there were statistically significant differences between the four groups. The assumption of homogeneity of variance was met (Levene’s test, $p = 0.131$), and the Shapiro-Wilk test confirmed normality of residuals ($p > 0.05$). The ANOVA results revealed a significant difference among the groups, $F(3, 116) = 8.413, p = 0.000$.

To identify specific pairwise differences, a post hoc Tukey HSD test was performed. The results are presented in Table2

Table 2. Post Hoc Tukey HSD Test Results for N-Gain Scores

Comparison	Mean Difference	p-value	Significance
EASI+AR vs. EASI no AR	0.1483	0.088	No
EASI+AR vs. AR Only	0.2583	0.000	Yes
EASI+AR vs. Conventional	0.2800	0.000	Yes
EASI no AR vs. AR Only	0.1100	0.298	No
EASI no AR vs. Conventional	0.1317	0.157	No
AR Only vs. Conventional	0.0217	0.986	No

Note. The mean difference is significant at the $p < .05$ level

The post hoc analysis confirmed that the EASI+AR group significantly outperformed both the AR-only and conventional groups. However, no significant difference was found between the EASI+AR and EASI without AR groups ($p = 0.088$), indicating that while AR enhances learning, the pedagogical framework of EASI itself is robust. Notably, there were no significant differences between the AR-only and conventional groups ($p = 0.986$), suggesting that AR technology alone, without structured pedagogy, did not substantially enhance conceptual understanding beyond traditional methods.

The hierarchical pattern of effectiveness found in this study aligns with the principles of multimedia learning theory, specifically the Cognitive Theory of Multimedia Learning (CTML) proposed by Mayer (2001; 2002). The success of the EASI+AR group can be explained by

several key principles of CTML. First, the multimedia principle is met by presenting material through text (in the EASI guide) and 3D visualization (through AR). Second, the principle of spatial and temporal contiguity is realized by presenting verbal and visual information directly and simultaneously integrated in the AR experience, minimizing unnecessary cognitive load. Third, the interactive AR experience facilitates the principle of generative processing, where students actively construct mental models by manipulating 3D objects. This explains why EASI+AR is superior to EASI alone, as EASI alone relies more on verbal processing and imagination, whereas EASI+AR provides concrete visual and interactive support for constructing these mental models. Furthermore, the failure of the AR alone group also aligns with Mayer's warning that multimedia technology will only be effective if it is designed to fit the way the human mind works. Without an EASI pedagogical guide serving as an instructional framework, AR content risks overloading working memory with disorganized information, thus failing to support meaningful learning. Furthermore, these findings strengthen the validity of the EASI model as a practical embodiment of the principles of social constructivism.

The effectiveness of both stand-alone and AR-enhanced EASI groups demonstrates that the EASI framework successfully creates ideal conditions for students to actively construct knowledge. The Exposure and Analogy stages align with Vygotsky's concept of the tools of the mind, where learning resources (including analogies and AR) serve as tools for achieving understanding within students' Zone of Proximal Development (ZPD). Furthermore, the Social Action stage directly reflects the core of Vygotsky's social constructivism, namely that learning is a social and collaborative process in which knowledge is built through interactions with others. Finally, the Impact Writing stage represents a moment of internalization and consolidation of knowledge, where understanding that has been socially and cognitively constructed is formalized through writing. Thus, the relative success of the EASI and EASI+AR groups not only demonstrates the effectiveness of technology integration but, more fundamentally, validates the strength of the EASI model itself as a learning design aligned with how humans naturally learn: through the process of constructing knowledge from concrete experiences, social interactions, and reflection. The findings of this study underscore the importance of pedagogically driven technology integration in science education. The superior performance of the EASI+AR group can be attributed to the synergy between the constructivist stages of the EASI model and the immersive visualizations afforded by AR. During the Analogy phase, students interacted with 3D AR models of bones, joints, and muscles, enabling them to form dynamic mental models of abstract concepts a process aligned. This integration facilitated generative processing, in which students actively construct knowledge through interactive visual manipulation.

In contrast, the AR-only group, while engaged, lacked a structured framework to connect visual exploration with deeper conceptual reasoning. This aligns with Henne et al. (2024), who caution that technology without pedagogical guidance can lead to shallow engagement rather than meaningful learning. The moderate success of the EASI-without-AR group further highlights the strength of the pedagogical model itself, particularly its emphasis on social action and reflective writing, which encourage the consolidation and transfer of knowledge, consistent with Vygotsky's (1980) social constructivism.

The lack of significant differences between the AR-only and conventional groups suggests that simply providing advanced visualization tools does not automatically improve conceptual understanding. This challenges the assumption that digital tools alone can transform learning outcomes and reinforces the need for a teacher-led pedagogical framework.

Theoretically, this study validates the Cognitive Theory of Multimedia Learning (Mayer, 2002) and Social Constructivism (Vygotsky, 1980) in the context of AR-integrated pedagogy. The EASI model operationalizes these theories through its structured stages of Exposure, Analogy, Social Action, and Impact Writing, which provide a clear instructional framework that guides students from concrete experiences to abstract conceptualizations. Practically, this study recommends that educators adopt the AR-based EASI model.

Conclusion

This study aimed to investigate the effectiveness of the AR-based EASI (Exposure–Analogy–Social Action–Impact Writing) learning model in enhancing elementary students' conceptual understanding of the human motion system. The results showed a significant difference in conceptual improvement among the four treatment groups ($p = 0.000$). The EASI+AR group achieved the highest N-Gain score (0.7287, high category) and was significantly superior to the AR-only and conventional groups. The EASI model without AR also showed good effectiveness (N-Gain = 0.5801, medium), while AR used alone did not significantly differ from conventional lecture-discussion methods.

These findings confirm that the pedagogical integration of the EASI model with AR technology is the most effective approach for teaching abstract science concepts. The study underscores that technology alone does not guarantee deep learning; its effectiveness depends on its integration within a sound pedagogical framework that actively guides students through structured, meaningful, and socially interactive learning processes.

Acknowledgment

The authors would like to thank the supervisors from the Master of Pedagogy Program at Universitas Nusa Putra for their guidance and support throughout this study. We also extend our gratitude to the principals, teachers, and sixth-grade students of the participating elementary schools in Cibadak District for their cooperation and enthusiasm during the research implementation. Special thanks are due to the educational technology unit of the university for providing technical assistance with AR development and implementation

References

- Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20, 1–11.
- Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (2001). *Taxonomy for Assessing a Revision of Bloom's Taxonomy of Educational Objectives*. Longman. <https://www.uky.edu/~rsand1/china2018/texts/Anderson-Krathwohl - A taxonomy for learning teaching and assessing.pdf>

- Biggs, J. B., & Collins, K. (1982). *Evaluating The Quality Of Learning: The SOLO Taxonomy*. Academic Press.
- Cheng, K.-H., & Tsai, C.-C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of Science Education and Technology*, 22(4), 449–462.
- Creswell, J. W. (2023). *Research design Research design*. In *Research in Social Science: Interdisciplinary Perspectives*.
- Economic Forum, W. (2023). *Future of Jobs Report 2023*. In *The Future Of Homo*. <https://doi.org/10.1142/11458>
- Fauziah, A., Hasibuan, M. F., & Yendrawaty. (2024). Meningkatkan Hasil Belajar Murid Pada Pelajaran Ipa Dengan Menggunakan Model Pembelajaran Visual, Auditori, Kinestheti(Vak) Pada Materi Sistem Gerak Manusia Di Kelas Vi Sd Negeri 067241 Medan Denai. *Didaktik : Jurnal Ilmiah PGSD FKIP Universitas Mandiri*, 10, 1–23.
- Habibi, C., & Sulistyanto, S. H. (2016). Pengembangan Media Augmented Reality Sebagai Alat Bantu Edukasi Pada Pembelajaran Sistem Pernafasan Manusia.
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74. <https://doi.org/10.1119/1.18809>
- Henne, A., Syskowski, S., Krug, M., Möhrke, P., Thoms, L. J., & Huwer, J. (2024). How to Evaluate Augmented Reality Embedded in Lesson Planning in Teacher Education. *Education Sciences*, 14(3). <https://doi.org/10.3390/educsci14030264>
- Hsu, H. P., Cheah, Y. H., & Hughes, J. E. (2023). A Case Study of a Secondary Biology Teacher’s Pedagogical Reasoning and Action with Augmented Reality Technology. *Education Sciences*, 13(11). <https://doi.org/10.3390/educsci13111080>
- Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, 123, 109–123.
- Lyesmaya, D., Musthafa, B., Sunendar, D., Rahman, & Fahrurrozi, F. (2023). The E-A-S-I (Exposure-Analogy Visual-Social Action-Impact Writing) Learning Model: Improving Reflective Writing Skills and Developing Values in Elementary School through Wayang Sukuraga. *PrimaryEdu : Journal of Primary Education*, 7(2), 254–265. <https://doi.org/10.22460/pej.v7i2.4124>
- Mayer, R. E. (2002). *Multimedia Learning*. In *Encyclopedia of the Sciences of Learning* (Vol. 41). https://doi.org/10.1007/978-1-4419-1428-6_285
- Meilindawati, R., Zainuri, Z., & Hidayah, I. (2023). Penerapan Media Pembelajaran Augmented Reality (Ar) Dalam Pembelajaran Matematika. *Jurnal E-DuMath*, 9(1), 55–62. <https://doi.org/10.52657/je.v9i1.1941>
- Nauko, Y. S., & Amali, L. N. (2021). Pengenalan Anatomi Tubuh Menggunakan Teknologi Augmented Reality Berbasis Android. *Jambura Journal of Informatics*, 3(2), 66–76. <https://doi.org/10.37905/jji.v3i2.11720>
- Novanto, Y. S., Djudin, T., T, A. Y., Basith, A., & Murdani, E. (2023). Kemampuan Pemahaman Konsep Ipa Pada Murid Sekolah Dasar Berdasarkan Gender. *JPDI (Jurnal Pendidikan Dasar Indonesia)*, 8(1), 43. <https://doi.org/10.26737/jpdi.v8i1.4260>
- OECD. (2019). *What Students Know And Can Do: Vol. I*. <https://doi.org/10.1787/5f07c754-en>
- Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students’ twenty-first century skills. *Virtual Reality*, 23(4), 425–436. <https://doi.org/10.1007/s10055-018-0363-2>
- Vygotsky, L. S. (1980). *Mind in Society*. Harvard University Press. <https://doi.org/10.2307/j.ctvjf9vz4>