



Development and effectiveness of a physical activity-based REGMAP learning model to enhance biological literacy and scientific communication skills among secondary school students

Desarrollo y eficacia de un modelo de aprendizaje REGMAP basado en actividad física para mejorar la alfabetización biológica y las habilidades de comunicación científica entre estudiantes de secundaria

Authors

Fahmil Ikhsan Taharu ¹
Susriyati Mahanal ²
Munzil ³

^{1,2,3}Universitas Negeri Malang,
Indonesia

Corresponding author:
Susriyati Mahanal
Email:
susriyati.mahanal.fmipa@um.ac.id

Received: 03-05-26
Accepted: 05-05-26

How to cite in APA

Taharu, F. I., Mahanal, S., & Munzil, M. (2026). Development and effectiveness of a physical activity-based REGMAP learning model to enhance biological literacy and scientific communication skills among secondary school students. *Retos*, 80, 620-628. <https://doi.org/10.47197/retos.v80.119374>

Abstract

Introduction: Biology learning often emphasizes cognitive understanding while neglecting physical activity, limiting engagement, conceptual understanding, and scientific communication.

Objective: This study aims to develop and examine the effectiveness of a physical activity-based REGMAP learning model in enhancing biological literacy and scientific communication skills.

Methodology: A mixed-methods one-group pretest-posttest design involved 30 secondary school students. The intervention consisted of eight sessions integrating REGMAP with movement-based activities such as exploratory movement, kinesthetic modeling, and role-play. Data were collected through tests, observation, and questionnaires, and analyzed using the Wilcoxon Signed Ranks Test and descriptive analysis.

Results: Significant improvements were found ($p < .05$) in biological literacy (52.3–68.7) and scientific communication (54.1–70.5), with increased engagement and participation.

Conclusions: The integration of physical activity into the REGMAP model was associated with improvements in biological literacy and scientific communication skills among the study sample, indicating the potential of active and embodied learning approaches.

Keywords

Physical activity; REGMAP model; biological literacy; scientific communication; movement-based learning; secondary education.

Resumen

Introducción: El aprendizaje de la biología suele priorizar la comprensión cognitiva, descuidando la actividad física, lo que limita la participación, la comprensión conceptual y la comunicación científica.

Objetivo: Este estudio busca desarrollar y examinar la efectividad de un modelo de aprendizaje REG-MAP basado en la actividad física para mejorar la alfabetización biológica y las habilidades de comunicación científica.

Metodología: Se utilizó un diseño pre-post con un solo grupo y métodos mixtos, con la participación de 30 estudiantes de secundaria. La intervención consistió en ocho sesiones que integraron REGMAP con actividades basadas en el movimiento, como el movimiento exploratorio, el modelado cinestésico y la dramatización. Los datos se recopilaban mediante pruebas, observación y cuestionarios, y se analizaron utilizando la prueba de rangos con signo de Wilcoxon y análisis descriptivo.

Resultados: Se observaron mejoras significativas ($p < 0,05$) en la alfabetización biológica (52,3–68,7) y la comunicación científica (54,1–70,5), con un mayor compromiso y participación.

Conclusiones: La integración de la actividad física en el modelo REGMAP se asoció con mejoras en la alfabetización biológica y las habilidades de comunicación científica entre la muestra del estudio, lo que indica el potencial de los enfoques de aprendizaje activo y corporal.

Palabras clave

Actividad física; modelo REGMAP; alfabetización biológica; comunicación científica; aprendizaje basado en el movimiento; educación secundaria.

Introduction

Biology learning plays a crucial role in developing students' understanding of scientific concepts and their ability to interpret natural phenomena (Sembiring & Yusuf, 2025). One of the key goals of biology education is to foster biological literacy, which includes the ability to understand, apply, and communicate scientific knowledge in real-life contexts (Semilarski & Laius, 2021). In addition to conceptual understanding, students are also expected to develop scientific communication skills, enabling them to express ideas, present arguments, and engage in scientific discussions effectively (Murphy, et al., 2018). However, in many educational settings, biology learning still emphasizes cognitive and theoretical aspects, often neglecting the development of communication skills and meaningful engagement (Adamu & Adamu, 2025).

Traditional instructional approaches tend to rely heavily on lecture-based methods and textbook-oriented activities, which may limit students' active participation and reduce opportunities for collaborative learning (Isnaeni, et al., 2026). As a result, students often struggle to connect scientific concepts with real-world applications and face difficulties in articulating their understanding (Bouillion & Gomez, 2001). This issue highlights the need for innovative learning models that not only promote conceptual understanding but also support active engagement and communication (Grabinger & Dunlap, 2002).

In recent years, physical activity has gained increasing attention as an important component in the learning process (Padial-Ruz et al., 2022). Research suggests that integrating movement into learning can enhance students' cognitive performance, motivation, and social interaction through embodied learning processes (Kosmas & Zaphiris, 2023). Embodied learning emphasizes the role of physical experience in shaping cognitive understanding, where students actively construct knowledge through interaction with their environment (Fugate, Macrine & Cipriano, 2019). Movement-based learning activities, such as role-play, simulation, and exploratory tasks, have been shown to improve engagement, deepen understanding, and support the development of communication skills (Devereaux, & Goodill, 2025).

Despite its potential, the integration of physical activity into academic learning, particularly in biology education, remains limited (Saputra et al., 2026). Many instructional models have not fully incorporated movement-based strategies as a core component of the learning process (Aloizou et al., 2025). In this context, the REGMAP learning model consisting of Reading, Generate, Materials, and Publish offers a structured approach that encourages students to actively construct knowledge, develop learning materials, and communicate their understanding. However, previous implementations of REGMAP have primarily focused on cognitive and collaborative aspects, with minimal integration of physical activity.

Therefore, integrating physical activity into the REGMAP model presents a promising approach to enhance both biological literacy and scientific communication skills. By combining cognitive, social, and physical dimensions of learning, this approach is expected to create a more engaging and meaningful learning experience. The novelty of this study lies in: (1) integrating movement-based learning into the REGMAP model; (2) applying an embodied learning approach in biology education; and (3) empirically examining its effectiveness in improving biological literacy and scientific communication skills.

To operationalize the integration of physical activity within the REGMAP model, several types of movement-based activities were considered appropriate, including exploratory walking, kinesthetic modeling, collaborative role-play, and group-based interaction tasks. Exploratory walking enables students to directly observe biological phenomena in their environment, thereby strengthening contextual understanding and inquiry skills. Kinesthetic modeling allows students to represent abstract biological processes such as cell division or ecological interactions through body movement, making complex concepts more concrete and easier to understand. Collaborative role-play encourages students to simulate scientific situations, fostering active participation and enhancing scientific communication through social interaction. Additionally, group-based physical tasks promote cooperation, engagement, and peer learning. These activities were selected because they align with the principles of embodied learning, where cognitive understanding is reinforced through physical experience, ultimately supporting both biological literacy and scientific communication skills. Based on these considerations, this study aims to develop and examine the effectiveness of a physical activity-based REGMAP learning

model in enhancing students' biological literacy and scientific communication skills in secondary education.

Method

This study employed a mixed-methods approach using a one-group pretest–posttest design to examine the effectiveness of a physical activity-based REGMAP learning model (Jong, et al., 2020). This design allows the assessment of changes in students' biological literacy and scientific communication skills before and after the intervention (Susanto, 2017). The integration of quantitative and qualitative data provides a more comprehensive understanding of both learning outcomes and student engagement during the intervention (Baddane & Ennam, 2024).

This study is considered exploratory in nature, as it investigates the integration of physical activity into the REGMAP learning model, an approach that remains limited in current literature, particularly among secondary school students. A review of existing studies indicates that while the REGMAP model has been applied to enhance cognitive and collaborative learning outcomes, its combination with structured physical activity has not been widely examined. Therefore, this study aims to explore the potential of this integration and provide initial empirical evidence regarding its effectiveness in improving biological literacy and scientific communication skills.

The participants consisted of 30 secondary school students selected through purposive sampling based on their participation in biology learning and willingness to be involved in the study. The students were enrolled in a public secondary school and had relatively moderate levels of biological literacy and scientific communication skills based on initial classroom assessments. All participants were involved throughout the intervention process.

The intervention was conducted through eight structured learning sessions using the REGMAP model (Reading, Generate, Materials, and Publish) integrated with physical activity. Each session lasted approximately 70 minutes and followed three main phases: (1) introduction and warm-up activity, (2) core learning integrated with movement-based tasks, and (3) reflection and feedback.

Physical activity was systematically embedded in each phase to support embodied learning and active participation. The activities included exploratory movement during the reading phase to observe biological phenomena, kinesthetic modeling to represent biological processes, collaborative role-play to simulate scientific situations, and group-based physical interaction tasks to enhance communication and teamwork.

The REGMAP stages were implemented as follows:

1. **Reading:** Students explored biological concepts through guided reading combined with movement-based observation activities.
2. **Generate:** Students generated ideas and discussed concepts through interactive and physically engaging group activities.
3. **Materials:** Students developed learning materials or models using hands-on and kinesthetic approaches.
4. **Publish:** Students presented their findings through oral presentations, demonstrations, and role-play activities involving physical expression.

Data were collected using multiple instruments to ensure data triangulation:

1. **Biological Literacy Test:** A structured test measuring students' understanding, application, and interpretation of biological concepts.
2. **Scientific Communication Skills Rubric:** An assessment rubric evaluating clarity of explanation, argumentation, and presentation skills.
3. **Observation Sheets:** Used to assess students' engagement, participation, and interaction during learning activities.

4. Questionnaires: Used to gather students' perceptions of the learning process and physical activity integration.

All instruments were validated by experts in biology education and educational psychology. The reliability of the instruments was confirmed with a Cronbach's alpha coefficient above 0.80, indicating high internal consistency.

Quantitative data from pretest and posttest scores were analyzed using the Wilcoxon Signed Ranks Test to determine significant differences after the intervention. Effect size was also calculated to assess the magnitude of the intervention's impact. Qualitative data from observations and questionnaires were analyzed descriptively to support and enrich the quantitative findings, particularly in relation to student engagement, participation, and communication behavior.

Ethical Considerations

Ethical approval for this study was obtained from Muhammadiyah University of Buton. Informed consent was obtained from all participants and their schools prior to data collection. Participation was voluntary, and the confidentiality of all data was strictly maintained throughout the research process.

Results

Improvement in Biological Literacy

The analysis of pretest and posttest scores revealed a consistent improvement in students' biological literacy following the implementation of the physical activity-based REGMAP learning model. As presented in Table 1, the mean biological literacy score increased from 52.3 (moderate category) in the pretest to 68.7 (high category) in the posttest. All participants demonstrated positive gains, indicating that the intervention effectively enhanced students' understanding, application, and interpretation of biological concepts. These findings should be interpreted with caution due to the relatively small sample size, which limits the generalizability of the results.

Table 1. Pretest and Posttest Biological Literacy Scores (N = 30)

No	Indicator	Pretest Mean	Posttest Mean	Gain
1	Concept Understanding	53.1	69.4	+16.3
2	Application of Concepts	51.2	67.8	+16.6
3	Interpretation of Data	52.6	68.9	+16.3
	Overall Mean	52.3	68.7	+16.4

Improvement in Scientific Communication Skills

Similarly, students' scientific communication skills showed significant improvement after the intervention. As shown in Table 2, the mean score increased from 54.1 (moderate category) to 70.5 (high category). Students demonstrated better clarity in explaining concepts, improved argumentation, and greater confidence in presenting scientific ideas.

Table 2. Pretest and Posttest Scientific Communication Skills (N = 30)

No	Indicator	Pretest Mean	Posttest Mean	Gain
1	Clarity of Explanation	55.0	71.2	+16.2
2	Scientific Argumentation	53.7	69.8	+16.1
3	Presentation Skills	53.6	70.5	+16.9
	Overall Mean	54.1	70.5	+16.4

Statistical Analysis

To determine the significance of the observed improvements, the Wilcoxon Signed Ranks Test was conducted. The results indicated that all students showed positive ranks, with no negative ranks or ties, suggesting a consistent increase in both biological literacy and scientific communication scores.

Table 3. Wilcoxon Signed Ranks Test Results

Variable	N	Mean Rank	Sum of Ranks	Z	p-value	Effect Size (r)
Biological Literacy	30	15.50	465.00	-4.782	.000	0.87
Scientific Communication	30	15.50	465.00	-4.901	.000	0.89

The analysis revealed statistically significant differences between pretest and posttest scores for both variables ($p < .05$). The effect sizes ($r = 0.87$ and $r = 0.89$) indicate a large effect, demonstrating that the intervention had a substantial impact on students' learning outcomes.

Observational Findings

In addition to quantitative improvements, observational data revealed meaningful changes in students' learning behaviors during the intervention. Students became more actively engaged in the learning process, particularly during movement-based activities such as kinesthetic modeling and role-play. These activities encouraged collaboration, increased participation, and facilitated more dynamic classroom interactions.

Students also demonstrated greater confidence in expressing ideas, asking questions, and participating in group discussions. Physical activity appeared to create a more interactive and supportive learning environment, allowing students to connect biological concepts with real-life experiences through embodied learning.

Summary of Findings

Overall, the results indicate that the physical activity-based REGMAP learning model significantly improved both biological literacy and scientific communication skills. The combination of cognitive, social, and physical learning processes contributed to increased engagement, deeper understanding, and enhanced communication abilities among students. These findings highlight the effectiveness of integrating movement-based learning into biology education to support holistic student development.

Discussion

This study aimed to develop and examine the effectiveness of a physical activity-based REGMAP learning model in enhancing students' biological literacy and scientific communication skills. The findings demonstrated a statistically significant improvement in both variables, supported by large effect sizes (Muhammad, Jafar & Gwanji, 2025). These results indicate that the integration of physical activity into the REGMAP model provides a meaningful contribution to improving students' cognitive and communicative competencies in biology learning (Siswati, et al., 2026).

The significant increase in biological literacy scores suggests that the REGMAP model effectively supports students in understanding, applying, and interpreting biological concepts (Sembiring & Yusuf, 2025). Unlike traditional instruction that tends to be teacher-centered, the REGMAP approach encourages students to actively engage in reading, generating ideas, developing learning materials, and publishing their understanding (Oo, Habók & Józsa, 2023). This active learning process aligns with constructivist learning theory, which emphasizes that knowledge is constructed through active participation and interaction (Hood, 2017). The addition of physical activity further strengthens this process by enabling students to experience concepts through bodily engagement, making learning more concrete and meaningful (Ennis, 2017).

Furthermore, the improvement in scientific communication skills indicates that students became more capable of expressing ideas, constructing arguments, and presenting scientific information clearly (Chung, et al., 2016). The "Publish" stage in the REGMAP model played a critical role in facilitating this development, as students were required to communicate their understanding through presentations and collaborative discussions. When combined with movement-based activities such as role-play and group interaction, students were encouraged to engage more actively, resulting in increased confidence and communication effectiveness (Naili, Hiba & Ayad, 2025).

From the perspective of embodied learning, the findings support the idea that physical activity enhances cognitive processes by integrating sensory, motor, and social experiences (Mavilidi, et al., 2018). Movement-based learning activities, such as kinesthetic modeling and exploratory tasks, allowed students to visualize abstract biological concepts and connect them with real-world phenomena (Aloizou et al., 2025). This approach not only improved conceptual understanding but also increased student engagement and motivation, as reflected in the observational findings (Cents-Boonstra et al., 2021).

In addition, the integration of physical activity contributed to improved social interaction and collaboration among students (Huang, 2024). The results showed that students became more participative, interactive, and responsive during group activities. Physical engagement appears to create a more dynamic and supportive learning environment, where students feel more comfortable sharing ideas and working collaboratively (Bower, Lee & Dalgarno, 2017). This finding is consistent with previous research highlighting the role of physical activity in promoting social bonding and cooperative learning.

This study also contributes to the growing body of research in physical education and educational psychology by demonstrating that physical activity can be effectively integrated into academic subjects such as biology (Asih, Suwono & Hastuti, 2026). From a practical perspective, the findings suggest that teachers should consider incorporating structured physical activities into their instructional design. The REGMAP model offers a flexible framework that can be adapted to various learning contexts, allowing educators to integrate cognitive, social, and physical elements in a balanced manner. This approach is particularly relevant for secondary school students, who benefit from interactive and experiential learning environments (Fitrianto & Saif, 2024).

However, this study has several limitations. The use of a one-group pretest–posttest design without a control group limits the ability to make causal inferences. Additionally, the sample size was relatively small and limited to a single educational context, which may affect the generalizability of the findings. Future research is recommended to employ experimental designs with control groups, larger sample sizes, and diverse educational settings. Further studies could also explore the long-term impact of physical activity-based learning on students' academic performance and other skills such as critical thinking and creativity.

Despite the positive findings, this study has limitations, particularly the small sample size, which restricts the generalizability of the results. Therefore, the findings should be considered preliminary and interpreted cautiously within the context of the study sample. In conclusion, the findings of this study highlight that integrating physical activity into the REGMAP learning model provides a comprehensive and effective approach to enhancing biological literacy and scientific communication skills. By combining cognitive, social, and embodied learning processes, this model creates a more engaging, interactive, and meaningful learning experience for students.

Conclusions

This study suggests that the physical activity-based REGMAP learning model has the potential to enhance students' biological literacy and scientific communication skills within the study sample. The findings indicate improvements in students' ability to understand, apply, and interpret biological concepts, as well as to express and communicate scientific ideas more clearly. However, as an exploratory study, these results should be interpreted with caution and cannot be generalized beyond the sample involved.

The integration of physical activity appears to contribute to increased engagement, collaboration, and meaningful learning experiences through embodied learning processes. Students demonstrated greater participation and confidence in communicating scientific ideas, suggesting the potential value of movement-based learning in supporting both cognitive and communicative outcomes.

Nevertheless, this study is limited by the use of a one-group design, a relatively small sample size, and a non-random sampling method, which restrict the generalizability and precision of the findings. Therefore, future research is strongly recommended to involve larger and more diverse samples and to em-

ploy more rigorous sampling techniques, such as simple random sampling, as well as more robust experimental designs. In this regard, the present study provides an initial trend that warrants further investigation into the integration of physical activity within the REGMAP learning model.

Acknowledgements

Researchers with the Indonesian Education Scholarship (BPI) Registration Number (202231103589), would like to thank the funding this research received from the Indonesian Education Scholarship (BPI), enter for Higher Education Funding and Assessment (PPAPT) under the Ministry of Education and Technology, and the Indonesian Endowment Fund for Education Agency (LPDP).

References

- Adamu, M. A., & Adamu, S. (2025). Examining Biology practical engagement through the lens of constructivist and experiential learning theories. *Aminu Kano Academic Scholars Association Multi disciplinary Journal*, 2(5), 55-67. <https://doi.org/10.64726/5srdc432>
- Aloizou, V., Linardatou, S., Boloudakis, M., & Retalis, S. (2025). Integrating a movement-based learning platform as core curriculum tool in kindergarten classrooms. *British Journal of Educational Technology*, 56(1), 339-365. <https://doi.org/10.1111/bjet.13511>
- Asih, T., Suwono, H., & Hastuti, US (2026). Effects of a movement-based physical education program supported by artificial intelligence through a virtual nature reserve on ecological literacy and inquiry skills. *Retos*, 78, 705-717. <https://doi.org/10.47197/retos.v78.118848>
- Baddane, K., & Ennam, A. (2024). Measuring pedagogical transformation: A quantitative analysis of critical thinking integration in literary criticism for heightened student engagement and learning outcomes. *International Journal of Linguistics, Literature and Translation*, 7(1), 39-50. <https://doi.org/10.32996/ijllt.2024.7.1.4>
- Bouillion, L. M., & Gomez, L. M. (2001). Connecting school and community with science learning: Real world problems and school-community partnerships as contextual scaffolds. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 38(8), 878-898. <https://doi.org/10.1002/tea.1037>
- Bower, M., Lee, M. J., & Dalgarno, B. (2017). Collaborative learning across physical and virtual worlds: Factors supporting and constraining learners in a blended reality environment. *British Journal of Educational Technology*, 48(2), 407-430. <https://doi.org/10.1111/bjet.12435>
- Cents-Boonstra, M., Lichtwarck-Aschoff, A., Denessen, E., Aelterman, N., & Haerens, L. (2021). Fostering student engagement with motivating teaching: An observation study of teacher and student behaviours. *Research Papers in Education*, 36(6), 754-779. <https://doi.org/10.1080/02671522.2020.1767184>
- Chung, Y., Yoo, J., Kim, S. W., Lee, H., & Zeidler, D. L. (2016). ENHANCING STUDENTS' COMMUNICATION SKILLS IN THE SCIENCE CLASSROOM THROUGH SOCIOSCIENTIFIC ISSUES. *International Journal of Science and Mathematics Education*, 14(1), 1-27. <https://doi.org/10.1007/s10763-014-9557-6>
- Ennis, C. D. (2017). Educating students for a lifetime of physical activity: Enhancing mindfulness, motivation, and meaning. *Research quarterly for exercise and sport*, 88(3), 241-250. <https://doi.org/10.1080/02701367.2017.1342495>
- Devereaux, C., & Goodill, S. W. (2025). Innovations in dance/movement therapy education: Simulation lab applications. *The Arts in Psychotherapy*, 102387. <https://doi.org/10.1016/j.aip.2025.102387>
- Fitrianto, I., & Saif, A. (2024). The role of virtual reality in enhancing Experiential Learning: a comparative study of traditional and immersive learning environments. *International Journal of Post Axial: Futuristic Teaching and Learning*, 97-110. <https://doi.org/10.59944/postaxial.v2i2.300>
- Fugate, J. M., Macrine, S. L., & Cipriano, C. (2019). The role of embodied cognition for transforming learning. *International Journal of School & Educational Psychology*, 7(4), 274-288. <https://doi.org/10.1080/21683603.2018.1443856>

- Grabinger, S., & Dunlap, J. C. (2002). *Problem-based learning as an example of active learning and student engagement: Invited talk. In International Conference on Advances in Information Systems* (pp. 375-384). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-36077-8_39
- Hood Cattaneo, K. (2017). Telling active learning pedagogies apart: From theory to practice. *Journal of new approaches in educational research*, 6(2), 144-152.
- Huang, D. (2024). Research on the Relationship Between School Physical Education and Students' Comprehensive Development. *International Journal of Educational Teaching and Research*, 1(2). <https://doi.org/10.70767/ijetr.v1i2.307>
- Isnaeni, I., Nuraedah, N., Haliadi, H., & Nongtji, M. (2026). Implementation of Student Centered Learning in History Class: A Qualitative Study at SMA Lab School Untad Palu. *Journal of Educational Sciences*, 10(4), 319-335. <https://doi.org/10.31258/jes.10.4.p.319-335>
- Jong, S. T., Croxson, C. H., Guell, C., Lawlor, E. R., Foubister, C., Brown, H. E., & Corder, K. (2020). Adolescents' perspectives on a school-based physical activity intervention: A mixed method study. *Journal of sport and health science*, 9(1), 28-40. <https://doi.org/10.1016/j.jshs.2019.06.007>
- Kosmas, P., & Zaphiris, P. (2023). Improving students' learning performance through Technology-Enhanced Embodied Learning: A four-year investigation in classrooms. *Education and Information Technologies*, 28(9), 11051-11074. <https://doi.org/10.1007/s10639-022-11466-x>
- Mavilidi, M. F., Ruiters, M., Schmidt, M., Okely, A. D., Loyens, S., Chandler, P., & Paas, F. (2018). A narrative review of school-based physical activity for enhancing cognition and learning: The importance of relevancy and integration. *Frontiers in psychology*, 9, 2079. <https://doi.org/10.3389/fpsyg.2018.02079>
- Muhammad, B., Jafar, U., & Gwanji, S. A. (2025). Effect of Activity-Based Instruction on the Self-Efficacy of Secondary School Biology Students in the Gumel Education Zone, Jigawa State, Nigeria. *Journal of Education, Communication, and Digital Humanities*, 3(1), 15-25. <https://doi.org/10.5281/zenodo.18077164>
- Murphy, P. K., Greene, J. A., Allen, E., Baszczewski, S., Swearingen, A., Wei, L., & Butler, A. M. (2018). Fostering high school students' conceptual understanding and argumentation performance in science through Quality Talk discussions. *Science education*, 102(6), 1239-1264. <https://doi.org/10.1002/sce.21471>
- Naili, R. S., Hiba, B., & Ayad, H. (2025). The Effectiveness of Movement-Based Activities on Vocabulary Retention among First-Year Middle School EFL Learners. dspace.univ-jijel.dz:8080/xmlui/handle/123456789/15692
- Oo, T. Z., Habók, A., & Józsa, K. (2023). Qualifying method-centered teaching approaches through the reflective teaching model for reading comprehension. *Education Sciences*, 13(5), 473. <https://doi.org/10.3390/educsci13050473>
- Padial-Ruz, R., García-Molina, R., González Valero, G., & Ubago-Jiménez, J. L. (2022). Actividad física y movimiento integrados en la enseñanza de una segunda lengua desde una edad temprana: una revisión sistemática (Physical activity and movement integrated into the second language teaching from an early age: a systematic review). *Retos*, 44, 876-888. <https://doi.org/10.47197/retos.v44i0.91506>
- Saputra, AA, Arizona, A., Asih, T., Arifin, MZ, & Saputra, R. (2026). Eco-pedagogical physical activity program based on the cultural landscapes of Lampung to improve students' moral and environmental awareness. *Retos*, 78, 114-125. <https://doi.org/10.47197/retos.v78.118210>
- Sembiring, D. A. E. P., & Yusuf, M. (2025). How do students understand biological concepts? A study on science literacy in basic education. *Jurnal Sinar Edukasi*, 6(03), 207-222. <https://doi.org/10.61346/jse.v6i03.289>
- Semilariski, H., & Laius, A. (2021). Exploring Biological Literacy: A Systematic Literature Review of Biological Literacy. *European Journal of Educational Research*, 10(3), 1181-1197. <https://eric.ed.gov/?id=EJ1307679>
- Siswati, B. H., Nugroho, A. H., Nurullah, A. F., Zahra, N. F. A., & Llave, A. L. A. R. (2026). Remap-GI in Biology Learning: Enhancing Creative Thinking and Cognitive Outcomes on Biodiversity Topics. *Al Jahiz: Journal of Biology Education Research*, 7(1), 21-34. <https://doi.org/10.32332/al-jahiz.v7i1.11610>

Susanto, H. (2017). Enhancement of students' biological literacy and critical thinking of biology through socio-biological case-based learning. *Jurnal Pendidikan IPA Indonesia*, 6 (2). <https://doi.org/10.15294/jpii.v6i2.9622>

Authors' and translators' details:

Fahmil Ikhsan Taharu
Susriyati Mahanal
Munzil

fahmil.ikhsan.2203419@students.um.ac.id
susriyati.mahanal.fmipa@um.ac.id
munzil.fmipa@um.ac.id

Author
Corresponding Author
Author