INSECTA Vol. 7 No. 1 , 2026, pp. 105 - 114

Available online at
INSECTA
Integrative Science Education and Teaching Activity Journal
Journal homepage : https://jurnal.iainponorogo.ac.id/index.php/insecta

Article

LungLab 3D: Visualization for Integrated Science Learning of the Human Respiratory System

Annida Fatiya Ananta Sofi[1*], Naili Jauharotun Nisa'[2], Raihsa Hanipa Naya[3], Tasbi Khatuz Zumaro[4], Rahmi Faradisya Ekapti[5]

[1,2,3,4,5] UIN Kiai Ageng Muhammad Besari, Ponorogo, Indonesia

*Corresponding Address: annidafatiyaas@gmail.com

Article Info

Article history:
Received: March 25, 2026
Accepted: April 20, 2026
Published: May 31, 2026

Keywords:

3D Learning Media;
LungLab 3D;
Respiratory System;
Thematic Worksheets System

ABSTRACT

Science learning is often perceived as abstract because many concepts are difficult for students to understand concretely, especially the human respiratory system. This often affects students' motivation and understanding of the concepts being taught. Therefore, innovative and interactive learning media are needed to provide three-dimensional visualizations that make abstract concepts more concrete and engaging. To address this need, a learning medium called LungLab 3D was developed. It is a three-dimensional lung model designed to help students study the human respiratory process in a visual and hands-on way. The media not only illustrates the anatomical structure of the lungs but also demonstrates the mechanisms of inspiration and expiration, enabling students to connect theory with real biological phenomena occurring in the body. This study employed a Research and Development (R&D) approach using the 3D Thiagarajan model (1974), which consists of three main stages: define, design, and development. Product validation was conducted by four junior high school science teachers, assessing six aspects: material relevance, durability, accuracy, efficiency, aesthetics, and safety. The validation results showed an average score of 4.42 with a percentage of 88.3%, categorized as very good. Therefore, LungLab 3D is considered suitable for use in science learning and has the potential to enhance students' understanding, especially when integrated with creative thematic worksheets that promote exploration and critical thinking.

INTRODUCTION

Natural Sciences (IPA) plays a strategic role in developing scientific thinking skills while shaping students' critical, creative, and environmentally aware character. Science learning is not only focused on mastering concepts, but also on scientific processes and the development of attitudes that encourage students to think logically, analytically, and reflectively in understanding natural phenomena (Ikrimah et al., 2025). However, in practice, science learning in schools still faces various challenges, particularly in conveying abstract concepts that are difficult to observe directly.

One topic that is quite complex is the human respiratory system, as it involves anatomical structures and the functional interrelationships between organs in the processes of inspiration

and expiration. Learning that is still dominated by lecture methods and two-dimensional media makes it difficult for students to understand these processes concretely, which in turn affects their low conceptual understanding and learning motivation (Akbar et al., 2024). In addition, existing 3D learning media still have several limitations, such as only displaying anatomical models visually without simulating processes, limited interactivity (e.g., only rotation or zoom), lack of immediate feedback on student activities, and not yet being integrated with contextual learning scenarios. As a result, students tend to become passive observers rather than active participants in the learning process. This limitation indicates that the learning media used have not been able to represent biological processes comprehensively.

According to constructivist theory, knowledge is built through meaningful learning experiences rather than simply transferred from teacher to students (Nabiila Tsuroyya Azzahra et al., 2025). Therefore, learning media are needed to bridge abstract concepts with realities that are easier for students to understand (Wang et al., 2024).

Several studies show that the use of interactive media can increase cognitive engagement and conceptual understanding (R. Ampel et al., 2025), as well as help students better understand anatomical structures (Moro et al. 2021; Mawadah et al. 2023). Three-dimensional visualization has also been proven to contribute to improving spatial thinking skills and the internalization of science concepts. However, the effectiveness of media largely depends on the suitability of the instructional design used (Reski&Fadilah 2024; Wang et al. 2024), thus requiring innovations that are not only visual but also interactive, contextual, and based on experiential learning.

Based on these problems, LungLab 3D media was developed as an interactive learning tool to help students understand the human respiratory system more concretely. This media presents lung structures along with inspiration and expiration mechanisms through dynamic simulations that can be manipulated by users, allowing students to observe, explore, and understand the relationships between organs more deeply (Pradityatama et al., 2023).

LungLab 3D is designed as an exploratory and contextual learning medium. The term *Lung* indicates a focus on the human respiratory system (Zulia&Alimah, 2023). While *Lab* represents scientific exploration activities similar to laboratory practice (Sapriati et al., 2023). Compared to previous 3D media, LungLab 3D offers several key advantages: (1) it provides real-time simulations of physiological processes (inspiration and expiration), showing changes in lung volume, diaphragm movement, and airflow simultaneously; (2) it offers a high level of interactivity, where users can not only rotate objects but also trigger simulations, select specific organs, and view functional explanations directly; (3) it includes feedback features that allow students to immediately identify errors or misconceptions; (4) it integrates problem-based or real-life contextual learning scenarios, enabling concepts to be learned in meaningful contexts; and (5) it supports independent exploration, encouraging students to conduct simple inquiry activities similar to digital laboratory experiences. Visualization helps transform abstract concepts into more concrete forms that are easier to understand (Evanjeli et al., 2024). While also supporting the integration of science concepts in a unified manner (Hayyuna et al., 2023). The respiratory system material is chosen because it is directly related to human life and health (Drevet et al., 2025).

The development of this media is based on multimedia learning theory, which emphasizes the importance of combining text, images, and animations to enhance learning effectiveness (Faisal et al., 2024). Also supported by experiential learning approaches that require active student involvement (Sagitarini et al., 2020). In addition, the use of interactive media aligns with the advancement of educational technology in the Industrial Revolution 4.0 era, which promotes more innovative and student-centered learning (Sun et al. 2022; Rohmatulloh et al. 2022).

In the context of science learning, the use of LungLab 3D is expected to provide a solution to students' low understanding of the human respiratory system. This media allows

students to interact directly with learning models, thereby improving conceptual understanding while also supporting the STEAM approach (Akbar et al., 2024).

The novelty of this research lies in the development of a learning medium that integrates interactive visualization, dynamic simulation, and contextual as well as experiential learning approaches. The advantages of LungLab 3D compared to previous media lie in its ability to present real-time respiratory processes, provide independent exploration features, and connect concepts with real-life situations. This media is also adapted to the cognitive development stage of junior high school students, who are in the concrete operational stage, so it is expected to create more meaningful learning experiences..

Overall, the development of LungLab 3D is expected to contribute to improving the quality of science learning through a more interactive, contextual, and student-centered approach, as well as supporting the transformation of education to be more adaptive to 21st-century technological advancements. Therefore, the objective of this study is to develop LungLab 3D as a learning media, evaluate its feasibility through expert validation, identify aspects that need improvement, and analyze its effectiveness in improving students' conceptual understanding of the human respiratory system.

METHODS

This study employs a Research and Development (R&D) methodology aimed at developing and testing the feasibility of an innovative educational media product. The product developed in this study is the three-dimensional educational media tool LungLab 3D, which covers the human respiratory system. The R&D methodology was chosen because it allows researchers to produce an educational product while simultaneously testing its validity and feasibility before it is used in the learning process (Gustiani, 2019). The development model used in this study is the 3D model, which consists of three main stages: define, design, and development. This model was chosen because it is considered effective and systematic in producing learning products whose feasibility can be tested before they are applied in the learning process (Manalu, 2024).

The use of three-dimensional media in learning is also considered effective in helping to visualize abstract concepts in a more concrete and interactive way. Three-dimensional media allow students to observe objects through representations with length, width, and height, making concepts that were previously difficult to grasp theoretically easier to understand through visual and hands-on experiences. Furthermore, the use of 3D media has been shown to enhance conceptual understanding, student engagement, and learning outcomes in science education (Siregar et al., 2022).

The definition phase was conducted to identify needs and issues in the science learning process, particularly regarding the human respiratory system. During this phase, several analytical activities were carried out, including a curriculum analysis to align the material with learning outcomes, an analysis of student characteristics to determine the need for visualizations of abstract concepts, and an analysis of actual learning conditions in the classroom. The results of the analysis indicate that many students struggle to understand the mechanisms of inhalation and exhalation because these processes cannot be directly observed and are only explained through two-dimensional media. Therefore, learning media capable of visualizing the functioning of the respiratory system in a more concrete, realistic, and interactive manner is required (Qolbyatin et al., 2023).

The design phase aims to design the educational media to be developed. During this phase, the form and structure of the LungLab 3D media are designed; this consists of a three-dimensional lung model that displays the parts of the human respiratory system, such as the trachea, bronchi, bronchioles, alveoli, and diaphragm, as well as the mechanisms of inspiration and expiration. The design of the educational media at this stage aims to produce a systematic product design before the development process begins (Sugiyono, 2019). In the media design

process, the researcher considered several important aspects, such as the appropriateness of the material, safety of use, durability of the materials, efficiency of use, and aesthetic appeal to ensure the media is engaging and easy for students to use. These aspects are crucial components in the development of educational media to ensure the resulting media is not only visually appealing but also effective in supporting students' learning process (Arsyad, 2019).

The development phase involves product development and validation by experts. During this phase, the LungLab 3D learning media is created based on the design developed in the previous phase. Once the product is completed, an expert validation process is conducted to assess the suitability of the developed learning media. Validation was conducted by four junior high school/MTs science teachers with experience in science education and the use of learning media in the classroom. The involvement of expert validators in the development research aimed to ensure that the resulting product is of high quality and suitable for use in the learning process (Sugiyono, 2019).

The assessment was conducted using a validation questionnaire designed as a survey with a 1–5 Likert scale, ranging from "strongly disagree" (1), "disagree" (2), "somewhat agree" (3), "agree" (4), to "strongly agree" (5). The use of the Likert scale in educational research instruments is widely employed to systematically and measurably assess respondents' attitudes, perceptions, and evaluations of a subject (Riduwan, 2018). The validation instrument in this study consists of 18 items covering six evaluation aspects: content appropriateness, media durability, accuracy of form and function, efficiency of use, aesthetic appeal, and safety of media use. Each aspect comprises several indicators designed to comprehensively assess the quality of the learning media. Before being used in the product validation process, the questionnaire instrument first underwent a content validity validation process by science education experts to ensure that each statement item aligned with the assessment indicators for educational media. Content validity aims to ensure that the instrument used is truly capable of measuring the aspects intended for assessment and possesses a high level of clarity and relevance (Riduwan, 2018).

During the media design and development process, the researchers also utilized several supporting software tools. The visual design of the media was created using the graphic design application Canva, while the product documentation and user guide were prepared using Microsoft PowerPoint. The use of this software helped produce media that was more systematic, engaging, and easy for students to understand (Permatasari & Wahyudi, 2021).

Validation data were analyzed using quantitative descriptive methods by calculating average scores and feasibility percentages. The formula used to calculate feasibility percentage is:

$$P = \frac{Score\ obtained}{Maximum\ score} \times 100\%$$

Feasibility percentage results are categorized based on Riduwan's (2018) guidelines: 81-100% (very good), 61-80% (good), 41-60% (sufficient), 21-40% (poor), and 0-20% (very poor). Based on the analysis results, LungLab 3D media obtained an average score of 4.42 with a feasibility percentage of 88.3%, included in the very good category, so it is declared feasible for use in science learning.

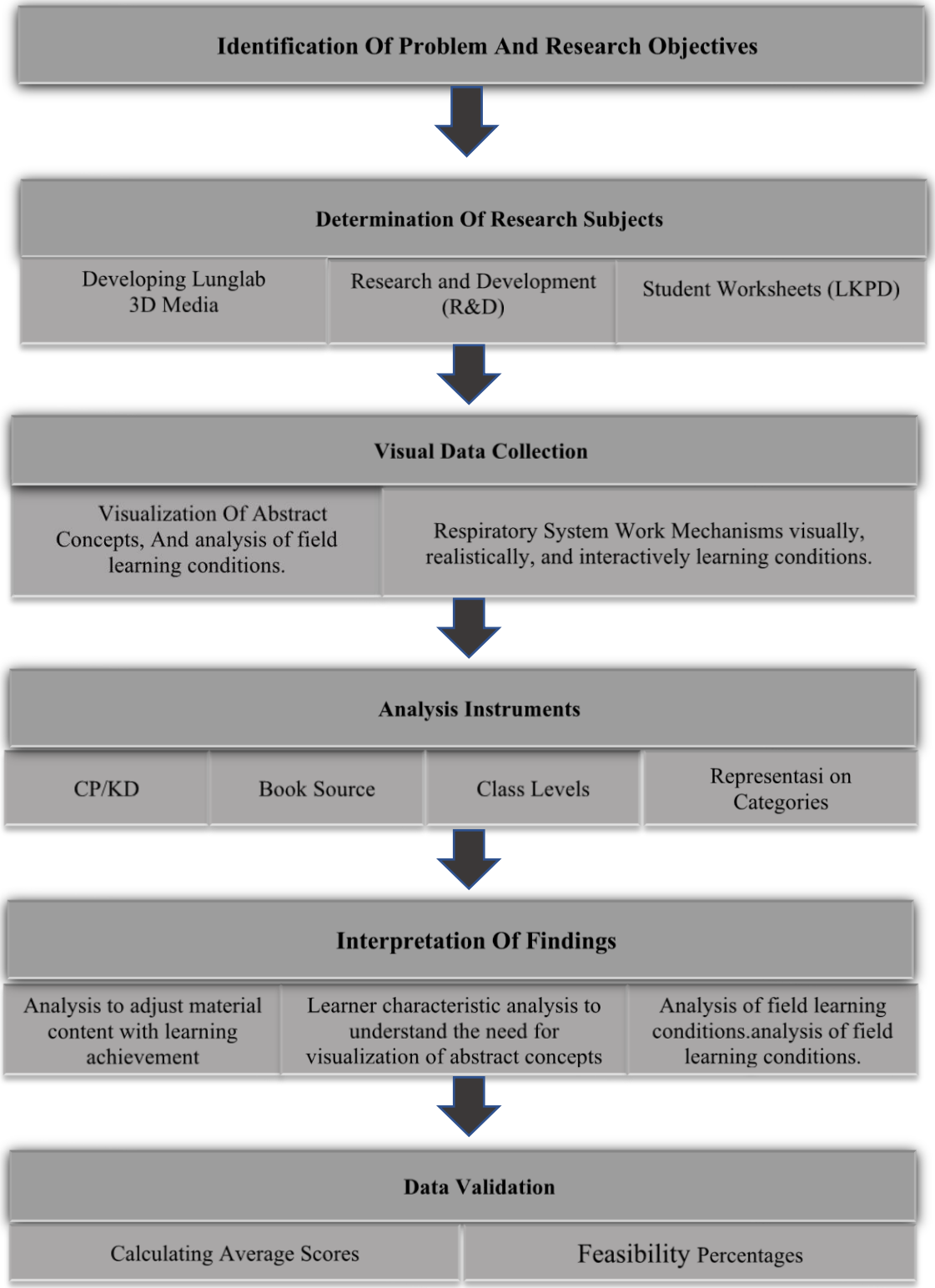


Figure 1. Research Flowchart

The research process for developing the LungLab 3D educational media began with identifying the problem and defining the research objectives related to students' difficulties in understanding the abstract concepts of the human respiratory system. Next, a needs analysis was conducted, encompassing curriculum analysis, analysis of student characteristics, and analysis of on-site learning conditions to determine the appropriate educational media needs. Based on these findings, the researcher collected data and references from textbooks, learning outcomes, and relevant scientific literature to serve as the foundation for media design. The

next stage involved the design and development of the LungLab 3D media, which visually and interactively displays the structure of respiratory organs and the mechanisms of inspiration and expiration, accompanied by the creation of Student Worksheets (LKPD) to support learning activities. After the media was developed, it was validated by four junior high school/MTs science teachers serving as expert validators using an evaluation questionnaire. The validation data was then analyzed by calculating the average score and the percentage of suitability, which was subsequently interpreted to determine the level of suitability of the LungLab 3D media as a science learning medium for the human respiratory system.

RESULTS AND DISCUSSION

This study presents the findings from the validation of the LungLab 3D learning media, conducted by four expert validators at the development stage, all of whom are junior high school science teachers. Data were collected using assessment questionnaires covering six main aspects: (1) material suitability, (2) media durability, (3) accuracy of form and function, (4) usage efficiency, (5) display aesthetics, and (6) usage safety. These aspects were selected to provide a balanced evaluation of the media in terms of both pedagogical relevance and technical quality. In addition, they reflect the importance of ensuring that a learning medium is not only conceptually accurate but also practical and usable in real classroom situations.

The collected data were analyzed using descriptive quantitative techniques to determine the feasibility level of the media. The results show that LungLab 3D obtained an average score of 4.42 with a feasibility percentage of 88.3%, which falls into the "Very Good" category based on Riduwan's (2012) criteria. This indicates that LungLab 3D meets the essential requirements to be used as a science learning medium, particularly for topics that tend to be abstract. Beyond the numerical results, this also suggests that the media is capable of presenting complex concepts in a way that is easier for students to understand. In line with the problems outlined in the introduction, these findings highlight the potential of LungLab 3D in supporting students' understanding of the human respiratory system through more concrete and interactive visualization.

The detailed results of the validation are presented in Table 1.

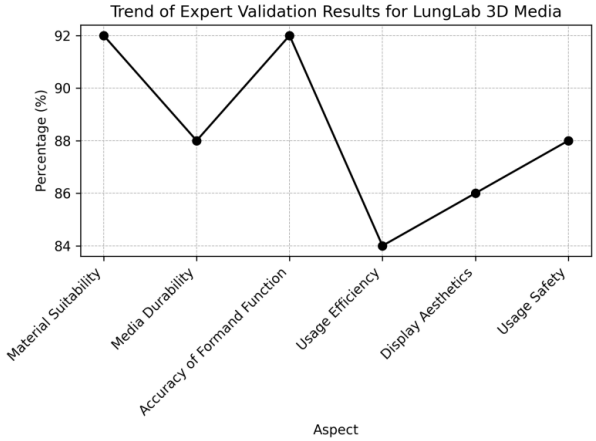
Table 1. Results of LungLab 3D Media Validation by Experts

No	Aspect	Average Score	Percentage (%)	Category
1	Material Suitability	4.6	92	Very Good
2	Media Durability	4.4	88	Very Good
3	Accuracy of Form and Function	4.6	92	Very Good
4	Usage Efficiency	4.2	84	Good
5	Display Aesthetics	4.3	86	Good
6	Usage Safety	4.4	88	Very Good
Overall Average		**4.42**	**88.3**	**Very Good**

Source: Data analysis results (2025)

The distribution of these results is further illustrated in Figure 2.

Figure 2. Graph of LungLab 3D Media Validation Results by Experts



A closer look at each aspect shows that material suitability and accuracy of form and function received the highest scores, both reaching 92%. This indicates that the content presented in LungLab 3D is not only scientifically accurate but also visually represented in a way that closely reflects real structures and processes. Such alignment is important to minimize misconceptions, particularly when students are dealing with abstract concepts such as the mechanisms of inhalation and exhalation. Meanwhile, media durability and usage safety also show strong results, each scoring 88%, indicating that the media is sufficiently robust and safe for repeated use in classroom activities that involve direct interaction.

In contrast, usage efficiency (84%) and display aesthetics (86%) show slightly lower values compared to the other aspects, although they still fall within the "good" category. This suggests that, while the media is already feasible to use, there is still room for improvement, particularly in terms of ease of use and visual appeal. For instance, simplifying how the media is used or enhancing its visual design could make it more intuitive and engaging for students.

Taken together, these results reinforce the relevance of three-dimensional learning media in addressing the limitations of conventional two-dimensional instruction, as discussed earlier in the introduction. In this context, LungLab 3D serves as a bridge between abstract scientific concepts and students' concrete understanding. By presenting the respiratory system in a more visual and interactive way, the media helps students form clearer mental representations. This finding is consistent with previous studies highlighting the role of 3D visualization in improving spatial ability and conceptual understanding (Mawadah et al., 2023; Moro et al., 2021).

From an instructional perspective, LungLab 3D reflects the principles of multimedia and experiential learning. The combination of text, visuals, and hands-on interaction encourages students to engage more actively in the learning process (Faisal et al., 2024; Sagitarini et al., 2020). Rather than passively receiving information, students are given opportunities to explore and interact directly with the learning material. This aligns with constructivist learning theory, which views knowledge as something that is actively built through experience and interaction (Nabiila Tsuroyya Azzahra et al., 2025). In this context, LungLab 3D functions not only as a supporting tool but also as a medium that facilitates deeper and more meaningful learning.

In the context of science education, the use of three-dimensional visualization also shows potential in supporting higher-order thinking skills. When students are able to connect abstract concepts with real-life biological phenomena, their understanding becomes more contextual. This is closely related to science literacy, which emphasizes the ability to interpret and apply scientific knowledge in everyday situations (Oktaviani & Faizah, 2024). In addition, the interactive nature of the media can support processes such as analyzing, classifying, and evaluating information, which are essential components of scientific thinking (Putri&Fadly,

2022). However, these possibilities should still be seen as potential, since this study has not yet tested the effectiveness of the media directly on students.

It is important to note that this study is limited to the product development and validation stage using the 3D define, design, and development model. Therefore, the findings focus on the feasibility of the media rather than its direct impact on learning outcomes. Any claims related to improvements in learning achievement or higher-order thinking should be interpreted as potential implications that require further investigation through implementation or experimental studies. From a pedagogical perspective, the results also highlight areas for improvement. The aspects of efficiency and visual design, for example, suggest that further refinement is needed to make the media easier to use and more visually engaging. Improving these elements may help reduce cognitive load and enhance students' overall learning experience, in line with multimedia learning principles (Wang et al., 2024; Reski&Fadilah, 2024; Faisal et al., 2024). At the same time, the strong scores in durability and safety confirm that the media is well suited for repeated use in active and interactive classroom settings (Sagitarini et al., 2020).

Overall, LungLab 3D can be considered an innovative and feasible learning medium that is relevant to current educational needs. By offering a more concrete, interactive, and experience-based approach, it supports students in developing a better understanding of complex scientific concepts. At the same time, it also shows strong potential in contributing to the development of essential 21st-century skills, such as critical thinking and problem solving (Rohmatulloh et al., 2022; Sun et al., 2022).

CONCLUSION

This study resulted in the development of LungLab 3D, an innovative three-dimensional learning medium designed to support students' understanding of the human respiratory system through concrete and interactive visualization. Validation conducted by four junior high school/MTs science teachers across six assessment aspects yielded an average score of 4.42 with a feasibility percentage of 88.3%, which falls into the "Very Good" category. These findings indicate that LungLab 3D is a feasible and promising tool for science instruction, particularly in helping students grasp abstract respiratory system concepts.

In addition, LungLab 3D aligns with constructivist and multimedia learning principles and shows potential to enhance student engagement and conceptual understanding, especially when integrated into worksheet-based thematic learning and STEAM-oriented approaches. Further research is recommended to examine its effectiveness in improving students' learning outcomes, motivation, and critical thinking skills in broader instructional contexts.

AKNOWLEDGMENT

The authors would like to express sincere gratitude to the supervising lecturers for their guidance and support throughout the research process. Appreciation is also extended to the junior high school/MTs science teachers who served as expert validators and provided valuable input during the development of the LungLab 3D learning media. The authors also thank colleagues who contributed suggestions and assistance that supported the completion of this study.

REFERENCES

Akbar, M. N., Mardin, H., Mangge, A. Z., & Daud, P. S. (2024). An exploratory study of augmented reality for teaching the human skeletal system at SMA Negeri 1 Suwawa. *Jurnal Pendidikan Sains*, X(2), 133–140.

Ampel, R., Harahap, F., Suriani, N. W., & Rungkat, J. A. (2025). Pengaruh media pembelajaran interaktif berbasis Wordwall terhadap hasil belajar siswa pada materi sistem pernapasan manusia di SMP Negeri 1 Tombulu. *Jurnal Wahana Didaktika*, 23(2), 238–251.

Arikunto, S. (2005). *Prosedur penelitian: Suatu pendekatan praktik*. Jakarta: Rineka Cipta.
Arsyad, Azhar. (2019). *Media Pembelajaran*. Depok: Rajawali Press.
Brumpt, E., Bertin, E., Tatu, L., & Louvrier, A. (2023). 3D printing as a pedagogical tool for teaching normal human anatomy: A systematic review. *BMC Medical Education*, 23(1), 783. https://doi.org/10.1186/s12909-023-04512-6
Drevet, G., Soldea, V., Gouttard, S., Virely, M., Maury, J., & Tronc, F. (2025). Contribution of 3D visualization and printing in teaching lung segments anatomy. *3D Printing in Medicine*, 11(25), 1–9.
Evanjeli, C., Fitri, N. A., & Arafat, Y. (2024). Augmented reality-based 3D technology learning media for human respiratory organs. *Journal of Artificial Intelligence and Engineering Applications*, 3(2), 579–583.
Faisal, M., Ramdhani, L., & Hardyanti. (2024). Pengaruh penggunaan media animasi terhadap hasil belajar dan motivasi belajar siswa. *JPK: Jurnal Pendidikan dan Kebudayaan*, 1(4), 18–22.
Gustiani, S. (2019). Research and development (R&D) method as a model design in educational research and its alternatives. *Holistics (Hospitality and Linguistics): Jurnal Ilmiah Bahasa Inggris*, 11(2). https://jurnal.polsri.ac.id/index.php/holistic/article/view/1849
Hayyuna, R., Kurniawan, D. T., & Lestari, T. (2023). 3D AR learning media on human respiratory organs to train elementary science process skills. *IJIS Edu: Indonesian Journal of Integrated Science Education*, 5(2), 127–135.
Ikrimah, S. K., Wardatussa'idah, I., & Yudha, C. B. (2025). Analisis proses pembelajaran IPAS melalui pendekatan saintifik pada siswa kelas V di SDIT Ar-Rissalah. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, 10(2), 250–264. https://doi.org/10.23969/jp.v10i02.26886
Manalu, A. E. E. (2024). Pengembangan media 3D materi sistem pernapasan pelajaran IPA pada siswa kelas V SDN 101752 Kelambir Lima Kebun. *Prosiding Seminar Nasional PSSH*, 3(1), 98.1–98.11.
Mawadah, N. V., Ikhsan, J., Suyanta, Nurohman, S., & Rejeki, S. (2023). 3D visualization trends in science learning: Content analysis. *Jurnal Penelitian Pendidikan IPA*, 9(8), 397–403. https://doi.org/10.29303/jppipa.v9i8.3864
Moro, C., Birt, J., Stromberga, Z., Phelps, C., Clark, J., Glasziou, P., & Scott, A. M. (2021). Virtual and augmented reality enhancements to medical and science student physiology and anatomy test performance: A systematic review and meta-analysis. *Anatomical Sciences Education*, 14(3). https://doi.org/10.1002/ase.2049
Nabiila Tsuroyya Azzahra, N. T., Ali, S. N. L., & Bakar, M. Y. A. (2025). Teori konstruktivisme dalam dunia pembelajaran. *Jurnal Ilmiah Research Student*, 2(2), 64–75. https://doi.org/10.61722/jirs.v2i2.4762
Okra, R. (2023). The development of educational game-based learning media in natural science subject for elementary school students. *Jurnal Inovasi Teknologi Pendidikan*, 10(2), 122–132.
Oktaviani, N., & Faizah, U. N. (2024). The effect of science literacy skills on contextual thinking skills. *INSECTA: Integrative Science Education and Teaching Activity Journal*, 5(1), 1–10.
Permatasari, D., & Wahyudi, W. (2021). Pemanfaatan aplikasi Canva sebagai media pembelajaran kreatif dalam meningkatkan minat belajar siswa. *Jurnal Pendidikan dan Teknologi Pembelajaran*, 6(2), 78–86.
Pradityatama, M., Dharma, I. G. B. B., & Arfian, N. (2023). Interactive learning media anatomy of 3D human skull using augmented reality. *Jurnal JTIK*, 7(2), 322–327. https://doi.org/10.35870/jtik.v7i2.787

Putri, E. A., & Fadly, W. (2022). Analysis of student's rational thinking ability in a career perspective in the field of STEM. *INSECTA: Integrative Science Education and Teaching Activity Journal*, 3(2), 127–139.

Qolbyatin, N. A., Septaria, K., & Wulandari, S. A. (2023). Quartet learning media and student argumentation. *INSECTA: Integrative Science Education and Teaching Activity Journal*, 4(2), 138–150. https://doi.org/10.21154/insecta.v4i2.7012

Reski, S. H., & Fadilah, M. (2024). Analisis media pembelajaran terhadap beban kognitif peserta didik pada pembelajaran biologi. *Jurnal Bioshell*, 13(1), 11–16. https://doi.org/10.56013/bio.v13i1.2773

Riduwan. (2018). *Skala pengukuran variabel-variabel penelitian*. Bandung: Alfabeta.

Rohmatulloh, G., Siregar, N. F., Widodo, A., & Artikel, I. (2022). Inovasi media pembelajaran tiga dimensi berbasis teknologi pada pembelajaran biologi. *BIODIK: Jurnal Ilmiah Pendidikan Biologi*, 8(4), 139–146.

Sagitarini, N. M. D., Ardana, I. K., & Asri, I. G. A. A. S. (2020). Model experiential learning berbantuan media konkret berpengaruh terhadap kompetensi pengetahuan IPA. *Jurnal Ilmiah Pendidikan dan Pembelajaran*, 4(2), 315–327.

Sapriati, A., Suhandoko, A. D. J., Yundayani, A., Karim, R. A., Kusmawan, U., Adnan, A. H. M., & Suhandoko, A. A. (2023). The effect of virtual laboratories on improving students' self-regulated learning. *Education Sciences*, 13, 1–13.

Siregar, N. F., Rohmatulloh, G., Riandi, R.,&Widodo, A. (2022). Inovasi media pembelajaran 3 dimensi berbasis teknologi pada pembelajaran biologi:(Technology-based 3 dimensional learning media innovation in biology learning). *Biodik*, *8*(4), 139-146.

Sugiyono. (2019). *Metode penelitian pendidikan: Pendekatan kuantitatif, kualitatif, kombinasi, R&D dan penelitian pendidikan*. Bandung: Alfabeta.

Sun, M., Chu, F., Gao, C., & Yuan, F. (2022). Application of three-dimensional visualization with problem-based learning. *BMC Medical Education*, 22(1), 1–8. https://doi.org/10.1186/s12909-022-03931-5

Wang, J., Li, W., Dun, A., Zhong, N., & Ye, Z. (2024). 3D visualization technology for learning human anatomy. *BMC Medical Education*, 24(1), 1–13. https://doi.org/10.1186/s12909-024-05403-4

Ye, Z., Dun, A., Jiang, H., Nie, C., Zhao, S., Wang, T., & Zhai, J. (2020). The role of 3D printed models in teaching human anatomy. *BMC Medical Education*, 20(1), 335. https://doi.org/10.1186/s12909-020-02189-6

Zulia, R., & Alimah, S. (2023). The replica of human respiration system to improve students' interpretation skill. *Biosfer: Jurnal Pendidikan Biologi*, 16(2), 232–243.