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Visualization Animal Tissue: Development of a 3D E-Atlas Based on Problem-Based Learning with a Deep Learning Approach in High School

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Abstract: This study aims to develop a 3D E-Atlas based on Problem-Based Learning (PBL) and an in-depth learning approach for teaching animal tissue at the senior high school level and to evaluate its validity and practicality. The study employed a Research and Development (R&D) method using the Plomp development model, which encompasses the preliminary investigation and prototyping stages. The research participants consisted of 67 Grade 11 students from two senior high schools in Riau Province, Indonesia. Data were collected through interviews, needs analysis questionnaires, expert validation sheets, and student practicality questionnaires. The development process involved curriculum analysis, instructional analysis, interviews, needs assessment, self-evaluation, expert feasibility testing, one-to-one evaluation, small-group evaluation, learner practicality testing, and documentation. The findings indicated that the developed 3D E-Atlas achieved a very high level of validity, as reflected in an expert validation score of 97%. Furthermore, the practicality test indicated that the media was categorized as very practical, with a score of 85% in the field test. These findings suggest that the integration of interactive 3D visualization with PBL syntax and immersive learning activities may support students' learning motivation, engagement, and conceptual understanding of animal tissue. The contribution of this study lies in the development of innovative digital learning media for biology education by integrating 3D visualization technology with a student-centered learning approach to support interactive, contextualized, and meaningful 21st-century learning.

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Introduction

The transformation of 21st-century education emphasizes the importance of utilizing digital technology not only as a tool, but as an integral component in creating interactive, meaningful, and learner-centered learning experiences (Mittelmeier et al., 2018; Redecker & Punie, 2017). In this context, the integration of technology-based learning media plays an important role in enhancing the quality of learning while fostering the development of higher-order thinking skills. (Hattie & Donoghue, 2016; Sugiyono, 2020).

Biology learning is a field that relies heavily on visualization skills, especially for microscopic materials such as animal tissues, which involve complex cell structures and functions (Krell et al., 2020; Mayer, 2020). Animal tissue materials are often difficult to understand when presented solely through text or two-dimensional (2D) visualizations, resulting in poor conceptual understanding among students (Cain et al., 2020; Chen et al., 2020). These limited visual representations also contribute to low student interest and engagement in learning abstract biological concepts (Geary et al., 2019; Hughes et al., 2018).

To overcome these various problems, one step that can be taken is the advancement of digital technology visualization-based learning media that is able to display object representations in a more realistic and interactive manner (Law et al., 2019; Radianti et al., 2020). In this regard, the use of E-Atlas as an electronic learning medium is a relevant alternative because it can present information systematically through a combination of text, images, and interactive elements (Bostyn & Roets, 2022; Sun et al., 2019). Furthermore, the development of E-Atlas based on three-dimensional (3D) visualization provides a more in-depth learning experience because it allows for dynamic object exploration, such as rotation, magnification, and spatial structural observation (Geary et al., 2019; Hernandez, 2020).

Recent research shows that the use of 3D visualization in science learning significantly improves conceptual understanding and spatial abilities compared to conventional media (Tarín-Vicente et al., 2022; Quintas et al., 2020). This is due to the ability of 3D visualization to reduce cognitive load and help students build more accurate mental representations of the objects being studied (Mayer, 2020; Sweller et al., 2019). In the context of biology learning, this visualization is very important for understanding tissue structures that cannot be directly observed (Jenkinson & McGill, 2021; Tibell & Rundgren, 2019).

The incorporation of PBL with a deep learning approach is becoming increasingly relevant in modern educational contexts that emphasize comprehensive conceptual understanding (Fullan, 2020; Fung et al., 2022). Deep learning focuses on students' ability to apply knowledge in new contexts and reflect on their learning experiences (Biggs & Tang, 2018; Fullan, 2020). This approach emphasizes not only learning outcomes, but also meaningful learning experiences on a meaningful, contextual, and conscious learning process (Fullan, 2020; Fadel et al., 2019).

However, several studies show that the use of learning media in school environments still predominantly relies on traditional learning materials and has not yet adopted digital technology to its full potential in an interactive context (Schindler et al., 2017; Tondeur et al., 2020). Furthermore, the implementation of problem-based learning and immersive learning still faces various obstacles, both practical and technologically prepared (Bond, 2020; Tondeur et al., 2020). This condition indicates a discrepancy between the demands of 21st-century learning and the actual learning practices implemented in the field (Anggraini et al., 2023; Voogt et al., 2018).

Previous studies have shown that the development of E-Atlas in biology learning has high potential to improve students' conceptual understanding, motivation, and learning engagement (Lin et al., 2020; Wang et al., 2025). Even so, previous studies have demonstrated the potential of three-dimensional (3D) visualization to facilitate the understanding of complex biological and anatomical structures by providing interactive representations of spatial relationships (Moro et al., 2021; Radianti et al., 2020). In addition, the integration of 3D visualization with problem-based learning (PBL) has been shown to improve students’ learning performance, learning interest, classroom interaction, and satisfaction compared with conventional teaching approaches (Sun et al., 2022). However, existing studies have predominantly examined 3D visualization or its integration with PBL as separate instructional components, while the integration of interactive 3D visualization, PBL, and a deep learning approach within a single biology learning medium remains limited. The novelty of the present study lies in the development of an interactive E-Atlas 3D that integrates 3D visualization, PBL syntax, and deep learning principles to facilitate meaningful, mindful, and reflective learning experiences in biology. This integrated design distinguishes the proposed E-Atlas 3D from previous learning media and provides a more comprehensive approach to supporting students’ conceptual understanding of biological structures.

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This situation also indicates that biology learning in schools still faces serious challenges in facilitating optimal understanding of abstract concepts. If this problem is not addressed promptly, students are at risk of misconceptions, low critical thinking skills, and underdevelopment of the 21st-century competencies required by the Independent Curriculum. Therefore, innovative educational media are required not only to visualize concepts concretely but also support active and in-depth learning through the integration of digital technology and innovative learning models.

Based on the preliminary study, several problems were identified in biology learning. The learning media used were not sufficiently varied and were still dominated by printed textbooks, worksheets (LKS), and PowerPoint presentations. Students also experienced difficulties in understanding biology materials, particularly Animal Tissue, while the learning process tended to rely on the inquiry learning model. Although the Independent Curriculum had been implemented, its principles of Deep Learning had not been fully applied. Furthermore, the analysis of biology materials showed that Animal Tissue had the lowest average score, namely 83. These findings indicate the need for more interactive learning media, as supported by the needs analysis questionnaire, in which 79% of students agreed with the development of a 3D E-Atlas for Animal Tissue based on Problem-Based Learning (PBL) with a Deep Learning approach. Furthermore, the utilization of instructional media in schools is still dominated by two-dimensional visualizations so that it has not been able to support students' conceptual understanding optimally, therefore, it is necessary to develop innovative instructional media that are able to visualize the material more concretely while supporting a learning approach oriented towards the development of high-level thinking skills.

Therefore, this study aims to determine the level of validity and practicality of 3D E-Atlas based on Problem Based Learning with an in-depth learning approach on animal tissue material for grade XI high school. The creation of this media is believed to be able to provide a solution to overcome students' learning difficulties, improve conceptual understanding, and support the implementation of more interactive, meaningful learning that meets the demands of 21st-century education. This study is also expected to contribute to the advancement of digital technology-based learning media in biology education, particularly in the use of 3D visualization integrated with innovative learning models and approaches.

Research Method

This study employed a Research and Development (R&D) approach aimed at producing a 3D E-Atlas learning product on animal tissue material integrated with the PBL model and the Deep Learning approach.. The R&D method is widely used in educational research because it allows for the systematic development and validation of learning products to enhance the quality of the learning process (Plomp, Nieveen & Folmer, 2013; Sugiyono, 2020).

This product development uses the Plomp model with three main phases as a foundation, namely: (1) the Preliminary Phase, (2) the Prototyping Phase, and (3) the Assessment Phase (Plomp, Nieveen & Folmer, 2013). However, this research was limited to the prototype stage, focusing on the design, validation, and practicality testing of the product due to time and resource constraints. This model was chosen because it has systematic steps in solving learning problems through an iterative design and evaluation process. This research was conducted in two senior high schools in Riau Province in the 2025/2026 academic year. The research sample consisted of 31 students in grade XI.6 from SMAN 2 Siak Hulu and 36 students in grade XI.3 from SMAN 3 Siak Hulu, resulting in a total sample

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of 67 students. This sample selection aimed to obtain relevant data according to the research needs.

The development of the 3D E-Atlas was carried out through two main stages in the Plomp model: the Preliminary Phase and the Prototyping Phase. The Preliminary Phase aimed to identify needs and formulate the basis for product development through several activities. First, a curriculum analysis was conducted to examine the suitability of learning outcomes, learning objectives, and the application of in-depth learning principles in the Independent Curriculum. Second, a learning analysis was conducted to identify problems in biology learning, particularly in the animal tissue material that was difficult to understand due to limited visual media. Next, interviews were conducted with teachers and students to determine learning conditions, media use, and obstacles faced. In addition, a needs analysis questionnaire was also conducted, with the results showing that 79% of students agreed with the development of the 3D E-Atlas as a learning medium. The results of all activities at this stage were then used as the basis for designing the 3D E-Atlas product. This research was conducted with due regard to research ethics principles, in which all students participated voluntarily and had obtained permission from the school and relevant teachers. The data obtained was reated as confidential and used exclusively for research purposes.

The Prototyping Phase aims to develop and refine the product through formative evaluation based on Tessmer's stages (Plomp, Nieveen & Folmer, 2013). At this stage, the researcher first conducted a Self-Evaluation, which is an initial assessment of the product to identify any errors and deficiencies that still exist in the 3D E-Atlas. Next, an Expert Review was conducted involving five validators, consisting of one material expert, one media expert, and three learning experts. This validation process includes an assessment of content aspects, learning design, and media display to ensure the developed product is valid for use. After the validity test sheet is presented, the data from the validity test sheet were analyzed using the following formula sheet will be analyzed using the following formula:

$$V = \frac{\text{TSe}}{\text{TSh}} x\ 100\%$$

Description :
V : Validity
TSe : Total validity score from validator
TSh : Total maximum expected score

One-to-One Evaluation was conducted after the validation stage by involving three students to assess the clarity, readability, and ease of use of the product. The next stage was Small Group Evaluation, which involved five students to assess the practicality of using the product in learning activities. The final stage was a Field Test conducted in one class at each of two schools, involving a total of 68 students, to measure the level of practicality of using the E-Atlas 3D in actual learning conditions. Through this series of stages, it is hoped that the developed product will be more effective, practical, and in accordance with learning needs. Determining the percentage interval for the PBL-based E-Atlas 3D learning media with the Deep Learning approach, the student readability sheet uses the following formula:

$$P = \frac{F}{N}$$

Description:
P : Percentage sought
F : Answer Frequency
N : Number of samples

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The product produced in this study is a 3D E-Atlas on animal tissue material, designed as an interactive digital learning medium. This product has several key characteristics, namely presenting three-dimensional (3D) visualizations of animal tissue structures, making it easier for students to understand abstract concepts. In addition, the 3D E-Atlas is equipped with interactive features such as zoom, rotation, and labels that allow users to explore the material in more depth. This product is also integrated with Problem-Based Learning (PBL) syntax, thus supporting active and contextual problem-based learning. In addition, the 3D E-Atlas is designed to accommodate the principles of deep learning, namely understanding, applying, and reflecting. The material presented in this product has been adjusted to the learning outcomes of grade XI high school in the Independent Curriculum.

The instruments used included several types. First, an interview guide was used to obtain data related to learning conditions from teachers and students. Second, a needs analysis questionnaire aimed to determine students' needs for learning media. Third, an expert validation sheet was used to assess the product's validity based on material, learning, and media aspects. Furthermore, a practicality questionnaire was used to assess students' ease of use of the product. Finally, documentation was used as supporting data presented in the form of documents and activities that took place during the research.

Data analysis was conducted descriptively using qualitative and quantitative approaches. Qualitative analysis was used to process interview and observation data through the processes of data reduction, data presentation, and drawing conclusions. Meanwhile, quantitative analysis was employed to evaluate the validity and practicality of the developed product.

Table 1. Criteria for evaluating the validity of the developed product based on intervals

Interval	Criteria
76%-100%	Highly Valid
51%-75%	Valid
26%-50%	Fairly Valid
0%-25%	Not Valid

Sumber : (Sugiyono, 2020)

Table 2. Criteria for evaluating the practicality of the developed product based on intervals

Interval	Criteria
85% - 100%	Very Practical
69% - 84%	Practical
53% - 68%	Fairly Practical
37% - 52%	Less Practical
20% - 36%	Not Practical

Sumber : (Sugiyono, 2020)

Results and Discussion

This research produces a 3D E-Atlas based on PBL with a Deep Learning approach specifically designed for the topic of Animal Tissues. This research uses “the implementation of the Plomp development model through the prototype stage, where each stage plays an important role in maintaining the quality of the E-Atlas. In the analysis phase, Researchers conducted literature reviews and field research to identify various problems through observations and interviews with educators and students. The results show that the media used in the learning process is still limited in variety, such as printed books/packages, activity sheets, and PowerPoint presentations.

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The first stage of Preliminary Research conducted was curriculum analysis, learning analysis, teacher and student interviews, and a needs questionnaire. Findings from the field study showed: 1) learning outcomes in learning have used the independent curriculum but have not fully implemented the principles of Deep Learning; 2) KKTP in biology subjects was set at 76, but student learning outcomes in visual materials were relatively lower than other materials; 3) Biology learning has implemented the Independent Curriculum with a Deep Learning approach, but the Animal Tissue material is still difficult to understand because learning is dominated by the inquiry model and limited laboratory facilities and visual media in displaying microscopic objects clearly; 4) the findings derived from the analysis of the student needs questionnaire obtained data that 79% of students agreed with the development of teaching materials in the form of PBL-based 3D E-Atlas with a Deep Learning approach on the Animal Tissue material. From these findings, it can be seen that students need the use of interactive visual media that can increase student motivation and interest in learning because it can create a more engaging and meaningful learning experience (Mayer, 2020; Sugiyono, 2020).

In the development phase, researchers integrated the Problem Based Learning model combined with the Deep Learning approach into the 3D E-Atlas, ensuring that PBL syntax, Deep Learning principles, and learning experiences were embedded in its structure (Figure 1). The E-Atlas platform is structured for each session, tailored to the teaching module, instructional objectives, and desired learning outcomes. Various studies have found that increasing student interest in learning can be achieved by utilizing innovative, diverse, engaging, and contextual learning materials and models that adapt to learner needs (Fahmi et al., 2021; Imam Suja et al., 2022). Utilizing the 3D E-Atlas for practical learning activities deemed valuable and useful by learners can generate and maintain situational interest. Therefore, the E-Atlas, designed to align with educators' teaching modules and subtopics on Animal Tissues, enhances the accessibility and practicality of this platform for both teachers and students.

Figure 1. Example of Product Development Design

The 3D E-Atlas concept, based on PBL and a Deep Learning approach, is embedded in every activity displayed in the E-Atlas (Figure 2). The first step in the PBL process is orienting students to the problem. This phase targets increasing curiosity, stimulating motivation, and encouraging students to discover and examine problems. Through the provision of structured guidance, implementing an approach focused on material mastery, and strengthening teamwork, instructors can maximize the efficacy of Problem Based Learning and accelerate learner success in completing problem-solving tasks (Chung, 2019; Nitisiri et al., 2023). The presentation of E-Atlas at the stage of organizing students in syntax describes the steps in which educators provide instructions or guidelines for group formation, so that learners can work practically, both individually and in groups. In this phase, learners are assigned to digest and examine the problems presented in the problem orientation stage in

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syntax, then continue with problem formulation according to the results of their analysis. The goal is for learners to collaborate effectively, share responsibilities and develop structured strategies to solve problems independently and analytically.

Figure 2. Example of a PBL-Based 3D E-Atlas Display with a Deep Learning Approach

The next syntax accommodates both independent and collaborative investigations. This phase targets the acquisition of relevant information and supporting data to overcome identified problems, with students actively participating in defining the problem formulation. In this phase, students are encouraged to formulate a systematic strategy for solving problems. This aligns with research findings showing that planning and implementing investigations require valid reference sources to ensure the success of group investigations (Dualom, 2021). The E-Atlas's development and presentation syntax reflects the research process, with the results documented and presented in a PowerPoint presentation. The E-Atlas platform plays a role in honing critical thinking and teamwork skills and broadening learners’ understanding through group evaluation and reflection (Kamal et al., 2024).

The final stage, analysis and evaluation, marks the final stage of the research process, during which students evaluate and reflect on their work. These prompts guide them in evaluating the research process while encouraging discussion and feedback between educators and students. This interaction not only maximizes classroom engagement but also strengthens students' understanding and engagement in the learning process. Assessment and reflection at the end of the lesson are crucial for increasing engagement and improving outcomes in writing and other academic assignment (Mills et al., 2020).

The application of deep learning in the 3D E-Atlas of Animal Tissues is seen through meaningful, conscious, and enjoyable learning activities by linking the material to real-life problems based on Problem Based Learning (PBL), such as cases of epithelial tissue regeneration, ligament injuries, and muscle and nerve disorders. Through discussion, investigation, collaboration, and reflection activities, students are encouraged to understand, apply, then think about the concept contextually to create more meaningful learning and be conducive to expanding critical thinking skills. In addition, interactive 3D visualizations in the E-Atlas facilitate students’ understanding of the structure of animal tissues in a more concrete and interesting way so that the learning experience becomes more effective. Deep learning emphasizes the active involvement of students in building knowledge through authentic learning experiences that are relevant to everyday life to improve conceptual understanding and problem-solving skills of students (Sari & Nugroho, 2021; Rahmawati, 2025).

The PBL-based e-Atlas with a Deep Learning approach that has been developed was then further evaluated through a validity test by experts, One to One Evaluation, Small Group Evaluation and Field Test. The validity test by experts ensured the suitability of the instructional content, design aspects, PBL procedures, and the Deep Learning approach,

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while the response test assessed the level of understandability and usability of the e-Atlas for students. The data from the validity results by media experts are presented in Figure 3.

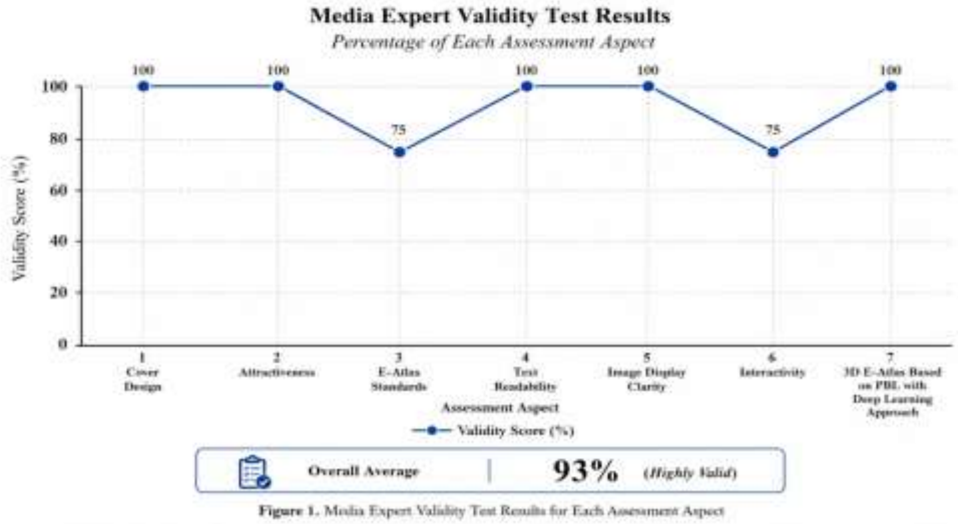

Figure 3. Results of Media Expert Validity Test

Looking at the data in Figure 3, The results of the validity assessment conducted by the media validator indicated that the 3D E-Atlas possessed a high level of quality, achieving an average validity score of 93%, classified as very valid. All key aspects, including cover design, display elegance, text readability, clarity of image presentation, and the PBL-based 3D E-Atlas with a Deep Learning approach, successfully achieved a full score of 100%. However, the standard aspect of the E-Atlas and the interactive aspect obtained a score of 75%, which indicates certain limitations in the E-Atlas, especially in its interactive capabilities which are still less attractive. Overall, the developed E-Atlas is considered interesting and effective for use as an interactive learning medium. This finding is consistent with the view of Nurrita (2018) Tafonao (2018) who stated that interesting and interactive learning media can increase learning motivation and help students understand the material more practically. In addition, the implementation of the Problem Based Learning model and the deep learning approach in learning media can foster critical thinking among students, actively solve problems, and understand concepts more meaningfully, thus impacting on improving student learning outcomes (Anggraini et al., 2023; Rahmawati, 2025). Validity testing conducted by material experts is likewise a significant component in developing a PBL-based E-Atlas with a Deep Learning approach, as it facilitates students' understanding of Animal Tissues. The findings of the study validity testing the evaluation results provided by subject matter experts are shown in Table 3.

Table 3. Results of Expert Assessment of Learning Content

No	Aspects	Validity Results (%)	Description
1)	Coherence	100	Highly Valid
2)	Depth/complexity of the material	100	Highly Valid
3)	Suitability of the material	100	Highly Valid
4)	Accuracy of the material	100	Highly Valid
	Average	**100**	**Highly Valid**

Referring to Table 3, The outcomes of the assessment material expert validity test indicate that the PBL-based E-Atlas with a deep learning approach achieved very practical quality with an average score of 100% and was categorized as very valid. This means that the material contained in the E-Atlas is in accordance with the instructional objectives and is conducive to helping learners understand the concept of animal tissue. Material that is structured coherently and accurately can help students understand the relationships between concepts, thus making the learning process more effective. This finding is in line with the opinion that the quality of practical learning materials must meet the aspects of content suitability, conceptual accuracy, and material integration in order to improve student understanding (Magdalena et al., 2020; Puspitasari & Hanif, 2019). Furthermore, the use of the PBL model in learning activities can also support the development of critical thinking skills in students, problem-solving skills, and independence in learning through a contextual and meaningful learning process. (Sari & Nugroho, 2021; Nugraha & Suherdi, 2021).

Validity testing was also conducted by learning experts to ensure that the PBL-based E-Atlas with its in-depth learning approach aligns with the learning process and objectives. Validity testing aims to assess the suitability of learning models and strategies to increase student engagement and understanding in the learning process (Rahmawati, 2025; Ghazali et al., 2021). The results of the learning expert validity test are presented in Table 4.

Table 4. Results of the Learning Expert Validity Test

No	Aspects	Validator 1	Validator 2	Validator 3	Description
1)	Appearance	100	100	100	Highy Valid
2)	Clarity of learning objectives	100	100	100	Highy Valid
3)	Alignment of learning objectives with CP	100	100	100	Highy Valid
4)	Suitability of material with learning objectives	100	100	75	Highy Valid
5)	Systematic, smooth, and clear logic	75	100	100	Highy Valid
6)	E-Atlas 3D based on PBL with a Deep Learning approach	100	100	100	Highy Valid
7)	Language	100	100	100	Highy Valid
8)	Readability	75	100	100	Highy Valid
9)	Ease of understanding	100	100	100	Highy Valid
	Average		**98**		**Highy Valid**

As seen from Table 2, the results of the validity research conducted by learning experts revealed that the PBL-based E-Atlas with a deep learning approach obtained an average score of 98% with a very valid classification. Most assessment aspects, such as appearance, clarity of learning objectives, appropriateness of material, language, and ease of understanding, obtained a score of very practical. This indicates that the developed E-Atlas is appropriate for learning needs and is able to support the learning process effectively. However, several aspects received a score of 75%, particularly the suitability of the material with the learning objectives, content organization, and readability. The validators suggested improving the alignment of the material with the learning objectives, refining the content sequence, and adjusting the text presentation. These suggestions were addressed through subsequent revisions to improve the clarity and readability of the E-Atlas 3D. In general, the successfully developed E-Atlas is considered suitable for use in the learning process considering its capacity to combine the Problem-Based Learning model with the Deep Learning approach effectively and optimally. Research findings by Rahmawati & Atmojo, (2021) and Meldrawati et al. (2021) explain that the Problem-Based Learning model can improve students' activeness, critical thinking skills, and conceptual understanding.

Based on the results of One-to-One Evaluation interviews with students, the PBL-based E-Atlas with an in-depth learning approach received very positive responses from students. Most students stated that the E-Atlas display was attractive, easy to understand, and had a combination of colors, images, and 3D representations that helped in understanding the material on animal tissues. In addition, clear instructions for use and coherent presentation of the material made it easier for students to use the E-Atlas independently. Students also revealed that the application of PBL stages in E-Atlas was able to maximize curiosity, arouse motivation in learning, and strengthen understanding of concepts in greater depth. The interview results showed that the developed E-Atlas was practical to use and was able to create a more interactive and enjoyable learning experience for students. Based on the statements of Nurrita (2018) and Tafonao (2018), the use of interesting and interactive learning media has the potential to increase enthusiasm for learning and is conducive to facilitating students' understanding of the material. In addition, the use of the Problem Based Learning model in learning media can encourage students to be more active, think critically, and learn independently through contextual problem solving. In addition to conducting expert validity tests, the researchers also conducted practicality tests on students after using the PBL-based 3D E-Atlas with a Deep Learning approach. After using the 3D E-Atlas, the researchers asked students to complete a practicality test questionnaire. The results of the practicality test by students can be seen in Table 6.

Table 6. Results of Student Practicality Test

No	Aspects	Small Group Evaluation (%)	Description	Field Test (%)	Description
1.	E-Atlas 3D Design	92	Very Practical	84	Practical
2.	Text Readability	93	Very Practical	82	Practical
3.	Presentation Clarity	95	Very Practical	85	Very Practical
4.	Image Quality	94	Very Practical	85	Very Practical
5.	Font Use	91	Very Practical	85	Very Practical
6.	Language Use	87	Very Practical	84	Practical
7.	Coherence	95	Very Practical	85	Very Practical
8.	Presentation of material	94	Very Practical	83	Practical
9.	Motivation	89	Very Practical	86	Very Practical
10.	E-Atlas 3D based PBL with Deep Learning approach	96	Very Practical	86	Very Practical
	Average	92	Very Practical	85	Very Practical

Evaluation on small groups revealed that the E-Atlas 3D tool obtained an average score of 92% and was included in the Very Practical category.. This value indicates that the developed media has met the practicality aspect from the students' perspective. The aspect with the highest score was the E-Atlas 3D indicator with a deep learning approach at 96%, which indicates that the media is able to help students understand the material more meaningfully through three-dimensional visualization and interactive learning experiences. In addition, the aspects of clarity of presentation, material sequence, and presentation of the material also received high scores, so that students found the material easy to understand and interesting to learn. The use of communicative language, an attractive design display, and practical image quality also support students' comfort in using the learning media. These findings indicate that E-Atlas 3D is not only visually appealing, but also effective in increasing student engagement during the learning process. Theoretically, interactive and visual-based learning media can improve students' learning experiences, motivation, and conceptual understanding because they provide more active and in-depth learning opportunities (Rahmawati, 2025; Sari & Nugroho, 2021).

Based on the field test results, the E-Atlas 3D media obtained an average percentage of 85% with a Very Practical category. These results indicate that the developed media is practical for use in learning on a wider scale. The highest score of 86% in the motivation aspect and 3D E-Atlas indicators with a deep learning approach demonstrates the media's ability to increase students' interest in learning while fostering a deeper understanding of the material through contextual and interactive learning experiences. Meanwhile, aspects of text readability, language use, and media design also received practical assessments, indicating that the media is easy to use and understand by students. Although there were some aspects that experienced a slight decline compared to the small group evaluation stage, the overall results still show that E-Atlas 3D is valid and practical for use as a learning medium. This confirms that the application of interactive visual-based digital media is able to produce a more engaging learning experience, maximize the active involvement of students, and encourage the formation of in-depth learning in the learning process in the modern era. (Nirmalawaty et al., 2021; Pratama et al., 2020). The interactive features of the 3D E-Atlas, including zooming, rotation, and labeling, enable students to actively explore animal tissue structures from different perspectives, thereby stimulating curiosity and situational interest. This interactive exploration helps students understand the relationships between tissue structures and their functions rather than merely memorizing concepts. Furthermore, the integration of the E-Atlas 3D with PBL and the Deep Learning approach encourages students to apply their understanding to contextual problems through active exploration, application, and reflection, supporting deeper understanding of the learning material.

Conclusion

This study successfully produced a PBL-based 3D E-Atlas using a Deep Learning approach, containing animal tissue material. The assessment results showed very high validity, with an average score of 97% from all expert validators. Practicality testing involving students also showed a very high level of satisfaction, with an average score of 85%, indicating ease of use, material clarity, and visual attractiveness. The interactive 3D visualization helps students understand complex and abstract animal tissue structures more clearly, reducing the cognitive effort needed to construct mental representations of biological concepts. This supports students in connecting tissue structures with their functions and understanding concepts beyond memorization. The integration of PBL and Deep Learning was implemented through five PBL syntax sequences, three basic principles, and three Learning Experiences.

Recommendation

This study recommends the use of a PBL-based 3D E-Atlas with a Deep Learning approach to actively engage students in learning. Its implementation should be supported by problem-based activities, guided 3D exploration, group discussion, and reflection, along with clear instructions and effective classroom time management. Adequate digital devices and stable internet access should also be ensured. Future researchers are encouraged to evaluate the effectiveness of the media in various contexts and develop it for other biology topics requiring detailed visualization.

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