Advance Sustainable Science, Engineering and Technology (ASSET)
Vol. 7, No.3, July 2025, pp. 02503024-01 ~ 02503024-12
ISSN: 2715-4211 DOI: https://doi.org/10.26877/asset.v7i3.1952

Enhancing Biology Students' Mastery of Animal Anatomy with a Web-Based Electronic Atlas: Toward Sustainable Digital Learning Tools

Sulistiyawati[1,2*], Farida Hanum[1], Tien Aminatun[3], Cecilia Yanuarief[4]

[1]Departement of Educational Science, Postgraduate School, Universitas Negeri Yogyakarta, Indonesia

[2]Departement of Biology Education, Faculty of Tarbia and Teaching Science, UIN Sunan Kalijaga Yogyakarta, Indonesia

[3]Departement of Biology, Faculty of Mathematics and Natural Science, Universitas Negeri Yogyakarta, Indonesia

[4]Departement of Physics, Faculty of Science and Technology, UIN Sunan Kalijag Yogyakarta, Indonesia

sulistiyawati@uin-suka.ac.id

Abstract. Learning animal anatomy in higher education often suffers from limitations in terms of visual media and practical time. Technology-based solutions such as web-based electronic atlases (e-atlases) can improve conceptual understanding and support digital continuous learning. This study aims to evaluate the effectiveness of web-based e-atlas in improving biology students' animal anatomy learning outcomes through a flipped classroom approach. This study used the ADDIE development model and a quasi-experimental design with a pretest-posttest control group approach. A total of 130 third semester students from three universities in Yogyakarta were divided into control (n=64) and experimental (n=66) classes. Instruments in the form of objective tests were validated by experts, and data were tested using Gain Score, N-gain, and t-test with parametric assumptions. The experimental class using e-atlas showed a significant increase in learning outcomes (N-gain=0.75; high category) compared to the control class (N-gain=0.29; low category), with significant differences based on t-test ($p<0.001$). These results support that e-atlas integration is effective in improving students' anatomical literacy. The use of web-based e-atlas in flipped classroom learning is effective, efficient, and has the potential to support the sustainability of biology learning. The findings recommend continued development of digital media to expand access and reduce reliance on physical animal dissection.

Keywords: e-atlas, flipped classroom, N-gain, web-based learning, sustainable education, anatomy learning.

(Received 2025-05-06, Revised 2025-06-27, Accepted 2025-07-02, Available Online by 2025-07-18)

1. Introduction

Students' understanding of animal body structure is an important part of biology education at the tertiary level. Animal Anatomy courses not only provide a foundation of organ function and physiological adaptation, but also form the basis for advanced studies in ecology and evolution. However, the anatomy learning process still faces various obstacles, such as limited time for laboratory practice, the availability of specimens for dissection, and the lack of accurate and accessible visual media [1,2].

In response to these challenges, digital technologies such as electronic atlases (e-atlases) are a potential solution. E-atlases present clearer and more detailed photos of observed objects with dynamically adjustable displays [3,4]. E-atlas can be used as a confirmation medium when performing the identification process of the observed object, helping the learning process when the original object cannot be found in the surrounding environment and can be used as a learning medium that helps the development of student knowledge to be more in-depth [5,6]. The development of e-atlas for learning animal anatomy begins with the process of animal dissection. This process produces real photos of the internal organs. Besides contributing to learning effectiveness, e-atlas also supports the principle of sustainable education by minimizing the use of biological resources and laboratory waste.

To maximize the benefits of digital media such as e-atlas, the flipped classroom pedagogical approach is an appropriate strategy. The flipped classroom model is a learning model that 'flips' the traditional model, where in the traditional learning model, learning activities are carried out together with the lecturer [7,8]. In the flipped classroom learning model, learning activities are carried out independently before the discussion session with the lecturer. During the independent learning session, factual knowledge provided through learning media must be studied first as a basis before the discussion session with the lecturer [9,10]. Furthermore, the discussion session with the lecturer is used to assimilate and implement the knowledge obtained from the independent learning session [11]. Therefore, it is necessary to develop a learning medium that is used to support the flipped classroom learning model in learning animal anatomy [12].

Previous research shows that e-atlases are able to improve understanding of organ structures and support independent learning. The study of Wang et al [13] examined the effectiveness of Virtual Reality (VR)-based anatomy learning in nursing students. The results show that the VR-based cooperative learning group achieved significantly higher scores in their gross anatomy laboratory courses compared to their counterparts learning through traditional methods. Another study by Gianotto et al[14] Examined the use of photogrammetry-based video e-atlas in anatomy education. This study shows that digital visualization that resembles real objects can help learning without direct dissection.

[15] Examined the integration of flipped classroom and multimodal digital resources (including e-atlas). The results showed an increase in learning outcomes and student learning experience. Furthermore, the study of Akram & Yassir Akram & Yassir (2024) showed that medical students who used mobile learning tools in learning plant anatomy scored higher on formative assessments, especially when the content could be accessed flexibly online. [17] Naing et al also conducted a Meta-analysis on flipped classroom in health professions education found that flipped learning resulted in better academic outcomes than traditional learning, but not all studies examined the effect of specific media.

While there are a number of international studies that demonstrate the effectiveness of digital technologies in anatomy learning, there is still a research gap in the multi-campus context in Southeast Asia, especially those that examine the effectiveness of e-atlas in the flipped classroom model and its sustainability in terms of reuse of digital resources.

Based on the description above, this study aims to test the following hypotheses:

a. Is there an increase in students' learning outcomes using the e-atlas for animal anatomy?
b. Are students' learning outcomes influenced by the use of the e-atlas for animal anatomy?
c. Is there a difference in students' learning outcomes between those who use manual learning media based on the traditional model and those who use the e-atlas for animal anatomy?

2. Methods

2.1. Research Design

This research is part of the Research and Development (R&D) uses the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) development model [5,18]. The procedure with the ADDIE model, along with an outline of research activities at each stage, has been shown in Figure 1.

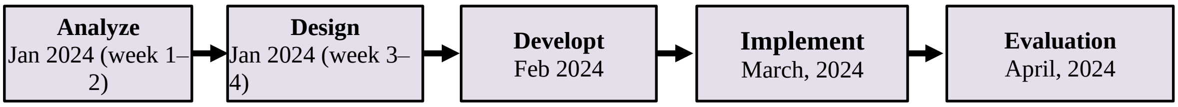

Figure 1. The Procedure with ADDIE Model

Figure 1 illustrates the procedural flow of e-atlas development using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Each phase includes the following activities:

1. Analysis - A needs analysis is conducted on the Animal Anatomy course, student characteristics, and available media.
2. Design - Initial design of the e-atlas, including display structure, navigation, and mapping of material based on organ systems.
3. Development - Creation of e-atlas content in the form of white rat anatomy documentation, as well as validity testing by experts and practicality testing by students.
4. Implementation - The e-atlas was applied in the experimental class with a flipped classroom approach, while the control class used conventional methods.
5. Evaluation - The effectiveness of the e-atlas is evaluated based on the improvement of learning outcomes through pretest and posttest analysis.

This figure shows the linear relationship between phases that are interconnected to ensure the media is developed systematically and as needed.

2.2. Research Stage

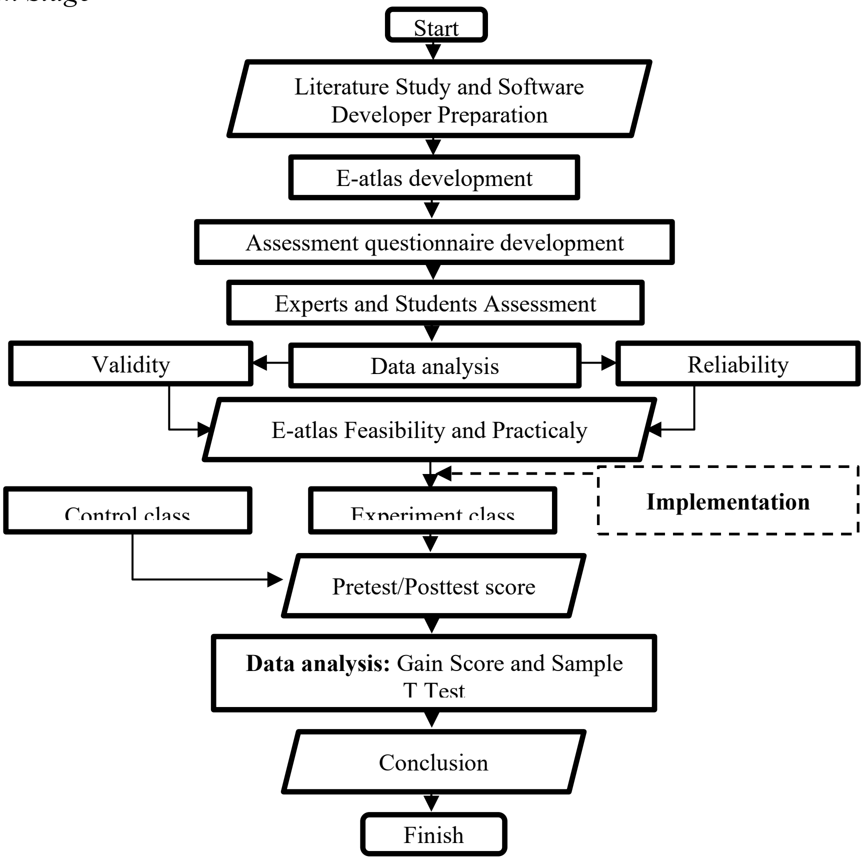

Figure 2. The Research Flow Chart

Figure 2 presents a flowchart of the entire research process from start to finish. The flowchart consists of:

1. Preliminary Preparation: Literature study, software development, and preparation of evaluation instruments.
2. E-atlas Development: Technical process of making e-atlas and feasibility testing (expert validation, practicality test by students).
3. Field Implementation: Implementation of learning in experimental and control classes, followed by pretest and posttest data collection.
4. Data Analysis: Data processing using Gain Score, N-gain, and statistical test (t-test).
5. Conclusion: Drawing conclusions about the effectiveness of the media.

At the analysis, design, and development stage, the e-atlas for animal anatomy based on the flipped classroom model was first developed until it was declared feasible by experts and practical by students through expert validation testing and students' practicality testing processes. After the e-atlas for animal anatomy based on the flipped classroom model was declared feasible and practical, it can be used for the implementation stage in animal anatomy learning in universities. The examples of the appearance of e-atlas for animal anatomy based on the flipped classroom model that was declared feasible and practical are shown in Figure 3.

Figure 3. Examples of The Appearance of The E-Atlas For Animal Anatomy Based on The Flipped Classroom Model Were Declared Feasible and Practical

The white rat species *(Rattus norvegicus)* was chosen as the object of anatomical dissection due to its high availability, complete representation of the mammalian organ system, and conformity with the curriculum of the Animal Anatomy course at the three participating universities. In addition, the use of a single species allows visual and content similarity of the e-atlas to avoid the bias of structural differences between species.

At the Implementation stage, trials were conducted on e-atlas for animal anatomy based on the flipped classroom model that has been developed by researchers at the university to improve learning outcomes. After that, an evaluation was carried out to obtain conclusions regarding the effectiveness of using e-atlas for animal anatomy based on the flipped classroom model in learning animal anatomy, based on pretest/posttest scores.

2.3. Research Ethics

This research has received ethical approval from the Research Ethics Committee of Yogyakarta State University with decision letter number: KEP-UNY/2024/EDU/0229. All participants gave their consent consciously through an informed consent form before participating in the research activities.

2.4. Participant

The population in this study were all students of Biology Education Study Program in three universities in Yogyakarta Special Region Province. Sampling was conducted using purposive sampling technique with the criteria that the participants were 3rd semester students, because in that semester they were taking courses containing Animal Anatomy material. The selection of students was not done randomly or based on the highest academic achievement, but rather considered proportional representation of population characteristics. The composition of the control class and experimental class was attempted to be equal, including students with above-average, average, and below-average abilities. This ability equalization technique was carried out through pretest score ranking, where all students' initial scores were sorted, then divided into two groups with equal ability distribution. The number of students involved as test subjects in this study is presented in Table 1.

Table 1. The number of students used as test subjects

University	Control Class	Experimental Class
UIN Sunan Kalijaga Yogyakarta (UINSK)	29	30
Universitas Negeri Yogyakarta (UNY)	21	21
Universitas Sanata Dharma (USD)	14	15
Total	64	66

The power analysis was conducted using G*Power 3.1 software with the parameters: effect size = 0.6 (medium-high category based on the results of previous studies), $\alpha = 0.05$, and power $(1-\beta) = 0.80$. The results showed that the minimum sample size required was 45 students per group. The actual number (control = 64; experimental = 66) exceeded the minimum limit, making the data suitable for inferential analysis.

2.5. Data Collection

Data collection was carried out in the control and experimental classes using test techniques to obtain pretest and posttest scores. The procedures carried out in this test technique are a) Pretest: providing a pretest before the implementation stage, b) Treatment: implementing the implementation stage of animal anatomy learning in the control class and experimental class, and c) Posttest: providing a posttest after the implementation. The difference in treatment between the control class and the experimental class is shown in Table 2.

Table 2. The Difference In Treatment Between The Control Class And The Experimental Class

Control Class (Traditional Model)	**Experimental Class (Flipped Classroom Model)**
Pretest.	Pretest.
The lecturer opens the lesson with greetings and appreciation.	The lecturer opens the lesson with greetings and appreciation.
The lecturer delivers the material using manual learning media. Students listen to the material from the lecturer and have discussions.	The lecturer provides instructions for studying the material independently using the e-Atlas for animal anatomy. Students study independently under the supervision of a lecturer to ensure that students study independently according to instructions.
The lecturer gives instructions to draw animal organs and identify them as an individual task.	The lecturer gives instructions to draw animal organs and identify them as an individual task.
	Students and the lecturer discuss the material studied and assignments completed in the previous session.
Posttest	Posttest

2.6. Atlas Development Technologies

E-atlas was developed using the following technology stack:

1. Programming languages: HTML5, JavaScript
2. Framework: Bootstrap 5
3. Database: Local JSON for image index and metadata
4. Hosting: Stored on the institution's local server and online version on GitHub Pages (during testing period)
5. Visual documentation tools: DSLR camera with standard laboratory lighting

2.7. Data Analysis

Data were analyzed using Gain Score, N-gain (Hake's category), as well as Paired Sample T-Test and Independent Sample T-Test. Normality (Kolmogorov-Smirnov) and homogeneity (Levene's Test) assumption tests were conducted prior to the t-tests. Effectiveness was compared using Cohen's d effect size.

The effect of implementing animal anatomy learning in both control and experimental classes in improving student learning outcomes is seen from the results of data analysis of student pretest and posttest scores. The test data analysis was carried out in several stages, including:

2.8. Gain Score

The gain score was carried out to answer the question of whether there was an increase in student learning outcomes using the e-atlas for animal anatomy based on the flipped classroom model. Gain score data analysis was conducted through the "One-Group Pretest-Posttest Design" scheme. The scheme is shown in Figure 4.

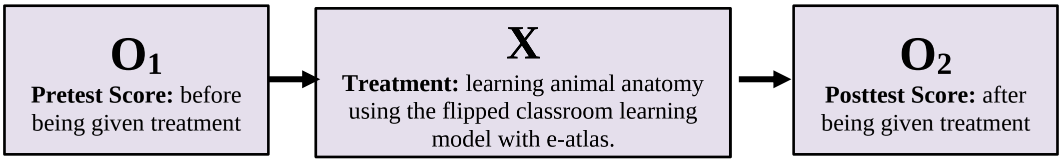

Figure 4. "One-Group Pretest-Posttest Design" Scheme

The amount of gain score can be calculated using (1).

$$gain\ score = O_2 - O_1 \qquad (1)$$

To determine whether the gain score is in the high, medium, or low category, this is done by calculating the normalized gain score (N-gain), which can be calculated using (2).

$$N - gain = \frac{O_2 - O_1}{100 - O_1} \quad (2)$$

The N-gain calculation result will be matched to the N-gain category coefficient interval based on Hake's formula. [32]. Category N-gain based on Hake's formula has been shown in Table 3.

Table 3. Category N-Gain Based On Hake's Formula

N-gain	Category
N-gain ≥ 0,7	High
0,3 ≤ N-gain < 0,7	Medium
N-gain < 0,3	Low

2.9. Asumption test

Before the t-test was conducted, the pretest and posttest data were tested: Normality test using Kolmogorov-Smirnov and Homogeneity test using Levene's Test. The results of both show normal data distribution and homogeneous variants ($p > 0.05$), so the use of parametric tests (Paired Sample T-Test and Independent Sample T-Test) can be statistically justified.

2.10. Validity and Reliability

The multiple-choice question instrument (30 items) was content validated by two anatomy expert lecturers and one educational measurement expert. The reliability of the instrument was tested using Cronbach's alpha of 0.82, which indicates high reliability.

2.11. Sample T Tests

Sample T Tests: what was done in this research include: Paired-Sample T Test and Independent-Sample T Test. The Paired-Sample T Test was used to answer the question whether students learning outcomes were influenced by the use of the e-atlas for animal anatomy based on the flipped classroom model. The Paired-Sample T Test was carried out on both classes, namely: control class pretest data with control class posttest data and experimental class pretest data with experimental class posttest. While The Independent-Sample T Test was used to determine whether there was a difference in students learning outcomes between those who used manual learning media based on the traditional learning model and the experimental class which used the e-atlas for animal anatomy based on the flipped classroom model. The Independent-Sample T Test was carried out on control class posttest score data with experimental class posttest scores [19,20].

3. Results and Discussion

The results of the data analysis are displayed in the form of average pretest and posttest scores with their standard deviations from each university. The average pretest and posttest score data are then used as data to calculate the gain score and N-gain. The results of the data analysis have been shown in Table 4.

Table 4. The Results Of The Data Analysis

Class	University	Average value of Pretest (Std Dev)	Average value of Posttest (Std Dev)	Gain Score	N-gain (Category)
Control	UINSK	41,62 (8,54)	58,03 (6,64)	16,41	0,28 (Low)
	UNY	38,95 (18,47)	55,24 (9,84)	16,29	0,27 (Low)
	USD	29,36 (7,16)	52,07 (6,64)	22,71	0,32 (Medium)
	Average	36,64 (5,26)	55,11 (2,43)	18,47	0,29 (Low)
Experimental	UINSK	36,00 (8,93)	82,17 (5,79)	46,17	0,72 (High)
	UNY	42,00 (15,42)	82,38 (7,47)	40,38	0,70 (High)
	USD	31,20 (6,49)	87,93 (4,01)	56,73	0,82 (High)
	Average	36,40 (4,42)	84,16 (2,67)	47,76	0,75 (High)

Table 4 displays the average data of pretest and posttest scores along with the gain score and N-gain values of each class at each university. The calculation of the gain score and N-gain values is done analytically using (1) and (2). When viewed from the gain score value, the calculation results for all classes at each university show a positive value. This shows that there is an increase in learning outcomes after students are given treatment of learning animal anatomy material using both traditional and flipped classroom learning models. However, the experimental class are higher when compared to the control class at each university. According to research Nurhayati & Saputro [21] that traditional learning models with conventional media can also improve learning outcomes, but the increase in learning outcomes is not greater when compared to learning using digital media. The increase in learning outcomes occurred at the three universities have been shown in Figure 5.

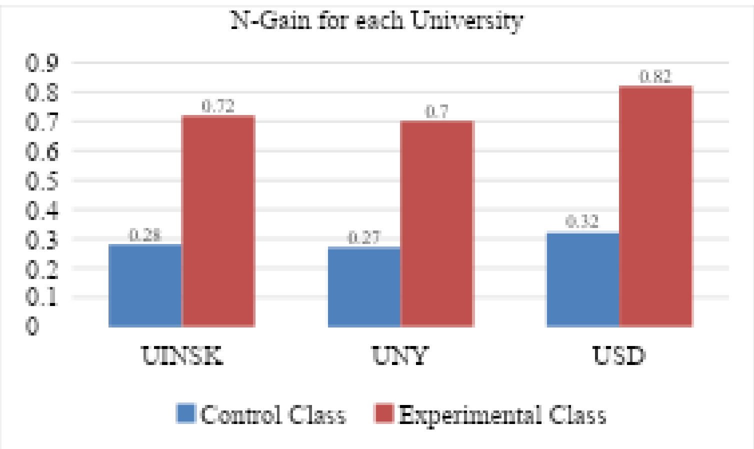

Figure 5. The Difference In Learning Outcomes Based On N-Gain Between The Control Class And The Experimental Class From Each University

Figure 5 shows that for each university, the animal anatomy learning outcomes based on the N-gain in both class increased. In particular, the greatest increase occurred in USD students because they had previously received animal dissection training in the Animal Development and animal anatomical structure course, thus providing a scientific basis or experience in learning animal anatomy [22].

Table 5. The results of Group Statistics

University	Class	N	Mean	Std. Deviation	Std. Error Mean
UINSK	Posttest of Control	29	58.03	6.641	1.233
	Posttest of Experimental	30	82.17	5.796	1.058
UNY	Posttest of Control	21	55.24	9.838	2.147
	Posttest of Experimental	21	82.38	7.473	1.631
USD	Posttest of Control	14	52.07	6.639	1.774
	Posttest of Experimental	15	87.93	4.008	1.035

Based on the results of the Paired-Sample T Test on the scores of pretest and posttest data of the control class and the experimental class at the three Universities, the Pair 2 output of the scores of pretest and posttest data was obtained with a Sig. (2-tailed) value of 0.000 <0.05. If the Sig. (2-tailed) value is 0.000 <0.05, then the null hypothesis (H_0) which states that: "students learning outcomes are not influenced by the use of the e-atlas for animal anatomy based on the flipped classroom model", is rejected [23]. Therefore, it can be concluded that: “Students learning outcomes are influenced by the use of the e-atlas for animal anatomy based on the flipped classroom model”. Then based on the results of the Independent-Sample T Test on the score of posttest data of the control class with the score of posttest data of the experimental class at the three Universities, the Significance value of Sig. (2-tailed) equal variances assumed of 0.000 < 0.05. If the Significance value of Sig. (2-tailed) equal variances assumed of 0.000 < 0.05, then the null hypothesis (H_0) which states that: "There is no difference in the students learning outcomes between the control class and the experimental class", is rejected [23]. Therefore, it can be concluded that: “There is a difference in the students learning outcomes between who uses manual learning media based on the traditional model and who uses the e-atlas for animal anatomy based on the flipped classroom model”.

These findings continue the 3rd statement that learning animal anatomy using the e-atlas for animal anatomy based on the flipped classroom model proved to be more effective than using manual learning media based on the traditional learning model. The results of the effectiveness test produce statements that answers the researcher's basic question in the introduction above, namely:

1. There is an increase in students learning outcomes using the e-atlas for animal anatomy,
2. Students learning outcomes are influenced by the use of the e-atlas for animal anatomy,
3. There is a difference in students learning outcomes between who uses manual learning media based on the traditional model and who uses the e-atlas for animal anatomy.

The effectiveness of learning animal anatomy using the e-atlas for animal anatomy based on the flipped classroom model is supported by the learning process through stages that are in accordance with the needs of the course. Animal anatomy material is delivered using the flipped classroom model which is implemented with stages that are guided by the scientific learning approach [24,25]. During the learning process, students gain learning experiences with various procedures including: observing through observation of internal organs during the surgical process, asking questions through discussions with lecturers, collecting information through animal anatomy e-atlas media based on the flipped classroom model, associating through independent assignment work and communicating through group discussions. According to research by Demirçalı & Selvi [26] which states that the aspects of science process skills, namely observing, predicting, classifying, identifying variables, associating, interpreting data and communicating can improve science process skills in general biology courses. In addition to the learning approach used, the effectiveness of learning is also supported by the use of technology that is tailored to the needs of students. Animal anatomy material is delivered using the animal anatomy e-atlas learning media. The animal anatomy e-atlas is a learning media packaged in a website-based digital media format so that it is portable and easily accessible to students anywhere and anytime. According to research Xiao & Adnan [15] that anatomy learning with a flipped classroom model that integrates a multimodal digital approach has a positive impact on students learning experiences and shows an increase in learning performance.

Additionally, The findings in this study display significantly different results compared to the Virtual Reality (VR) based study as reported by Wang et al [13]. In that study, VR was shown to be effective in increasing students' engagement and spatial understanding of anatomical structures. However, the approach requires specialized hardware, high development costs, as well as uneven access to technology, which poses a major challenge for implementation in educational institutions with limited resources.

In contrast, this study shows that the use of a web-based e-atlas provides comparable effectiveness and even greater impact on student learning outcomes. Cohen's d = 1.92 indicates a very large effect in improving anatomical understanding, despite being conducted without advanced technology such as VR. The main contribution of this study is to show that low-cost and portable technological solutions, such as web-based e-atlas, can be a practical and sustainable alternative in anatomy learning.

As such, these findings add an important perspective to the digital anatomy education literature: that simple web-based innovations can overcome access limitations, minimize infrastructure barriers, and still have a significant impact on learning outcomes. These advantages further confirm the position of e-atlases as inclusive and relevant learning tools, especially in the context of developing countries.

4. **Conclusion**

This study shows that the use of web-based e-atlas in flipped classroom learning significantly improves student learning outcomes in animal anatomy. With high effectiveness (N-gain 0.75; Cohen's d = 1.92), this media becomes an efficient, cost-effective and accessible alternative educational technology. The main contribution of this research lies in the web-based low-cost technology approach that supports continuous learning of anatomy without relying on physical dissection laboratories or expensive VR devices. The developed e-atlas can be disseminated in an open-source manner, allowing scalability for use across different institutions with similar needs. The use of this digital medium also has the potential to reduce the use of animal specimens, supporting ethical and environmentally friendly aspects in biology education.

However, the results of this study are still limited to the geographical context and institutions in the Yogyakarta area. External validity needs to be further tested through cross-regional or national studies with a variety of species and learning conditions. As a practical recommendation, lecturers can integrate the e-atlas into an online learning system (LMS) and use it as an independent learning resource before face-to-face discussion sessions. Further development in the form of an open-access anatomical atlas platform with interactive features, as well as long-term operational cost analysis to encourage mass adoption and development of science education digitization policies are also suggested.

Acknowledgments

Gratitude is conveyed to all parties who have supported this research, to the Doctoral Study Program in Educational Science, SPs Universitas Negeri Yogyakarta and the Biology Education Study Program, FITK UIN Sunan Kalijaga.

Funding Information

No funding involved.

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

Informed Consent
We have obtained informed consent from all individuals included in this study.

Data Availability
Derived data supporting the findings of this study are available from the corresponding author [sulistiyawati] on request.

References

[1] Velásquez J, da Silva LLC, Miglino MA. Development of an Online Distance Learning Platform Combining Anatomy, Imaging, and Surgical Practice to Support Mastery Learning of the Equine Locomotor Apparatus. Journal of Veterinary Medical Education 2022;50:252–7. https://doi.org/10.3138/jvme-2022-0006.
[2] Ortadeveci A, Ermez MN, Oz S, Ozden H. A survey study on distance anatomy education: challenges unique to anatomy. Surgical and Radiologic Anatomy 2022;44:41–7. https://doi.org/10.1007/s00276-021-02772-z.
[3] Patton KT, Bell FB, Thompson T, Williamson PL. Anatomy & Physiology with Brief Atlas of the Human Body and Quick Guide to the Language of Science and Medicine-E-Book: Anatomy & Physiology with Brief Atlas of the Human Body and Quick Guide to the Language of Science and Medicine-E-Book. Elsevier Health Sciences; 2022.
[4] Martin JF, Arnold OR, Linton A, Jones JD, Garrett AC, Mango DW, et al. How virtual animal anatomy facilitated a successful transition to online instruction and supported student learning during the coronavirus pandemic. Anatomia, Histologia, Embryologia 2023;52:36–49.
[5] Oktafiyani A, Widiyaningrum P. Development of E-Atlas Anatomy of the Vertebrate Digestive System as a Teaching Material Supplement to Improve Student Learning Outcomes. Journal of Biology Education 2024;13:265–72.
[6] Priyambodo W. Electronic Atlas Morphological and Anatomical Structure of Little Egret's Cervical Bones as A Biology Learning Media. Proceeding International Conference on Religion, Science and Education, vol. 2, 2023, p. 21–3.
[7] Anjomshoaa H, Ghazizadeh Hashemi AH, Jasim Alsadaji A, Jasim Mohammed Z, Masoudi S. The effect of flipped classroom on student learning outcomes; an overview. Medical Education Bulletin 2022;3:431–40. https://doi.org/10.22034/meb.2022.332357.1052.
[8] Gopalan C, Daughrity S, Hackmann E. The past, the present, and the future of flipped teaching. Advances in Physiology Education 2022;46:331–4.
[9] Sablan JR, Prudente M. Traditional and flipped learning: Which enhances students' academic performance better. International Journal of Information and Education Technology 2022;12:54–9.
[10] Joy P, Panwar R, Azhagiri R, Krishnamurthy A, Adibatti M. Flipped classroom – A student perspective of an innovative teaching method during the times of pandemic. Educación Médica 2023;24:100790. https://doi.org/https://doi.org/10.1016/j.edumed.2022.100790.
[11] Ernawati E, Alonemarera AS, Sari TM. The critical thinking skills and independent learning analysis: The flipped classroom based on blended learning. JPBIO (Jurnal Pendidikan Biologi) 2022;7:253–63.
[12] Talbert R, Bergmann J. Flipped learning: A guide for higher education faculty. Routledge; 2023.
[13] Wang C-Y, Yin T, Ma K-H, Shyu J-F, Cheng C-P, Wang Y-C, et al. Enhancing anatomy education through cooperative learning: harnessing virtual reality for effective gross anatomy learning. J Microbiol Biol Educ 2023;24:e00100-23.
[14] Gianotto I, Coutts A, Pérez-Pachón L, Gröning F. Evaluating a Photogrammetry-Based Video for Undergraduate Anatomy Education BT - Biomedical Visualisation: Volume 16 – Digital Visualisation in Biomedical Education. In: Border S, Rea PM, Keenan ID, editors., Cham:

Springer International Publishing; 2023, p. 63–78. https://doi.org/10.1007/978-3-031-30379-1_4.
[15] Xiao J, Adnan S. Flipped anatomy classroom integrating multimodal digital resources shows positive influence upon students' experience and learning performance. Anat Sci Educ 2022;15:1086–102.
[16] Akram H, Yassir M. THE EFFECTIVENESS OF MOBILE LEARNING APPS IN PLANT ANATOMY INSTRUCTION. Journal Informatic, Education and Management (JIEM) 2024;6:82–95.
[17] Naing C, Whittaker MA, Aung HH, Chellappan DK, Riegelman A. The effects of flipped classrooms to improve learning outcomes in undergraduate health professional education: a systematic review. Campbell Systematic Reviews 2023;19:e1339.
[18] Ngitung R, Elis P, Hartono H. The Effectiveness of Adding Seaweed to Feed in Reducing Fat and Cholesterol Levels in Broiler Chickens 2022.
[19] Okoye K, Hosseini S. T-test Statistics in R: Independent Samples, Paired Sample, and One Sample T-tests BT - R Programming: Statistical Data Analysis in Research. In: Okoye K, Hosseini S, editors., Singapore: Springer Nature Singapore; 2024, p. 159–86. https://doi.org/10.1007/978-981-97-3385-9_8.
[20] Wadhwa RR, Marappa-Ganeshan R. T test. StatPearls [Internet], StatPearls Publishing; 2023.
[21] Nurhayati I, Saputro GE. Differences in Learning Outcomes Between Conventional Learning and Video Tutorial Learning in Traditional Bun Courses. Atlantis Press SARL; 2024. https://doi.org/10.2991/978-2-38476-198-2_67.
[22] Bruen C, Illing J, Daly R, Meagher F, Delany C, Offiah G, et al. Medical student experiences of Case-Based Learning (CBL) at a multicultural medical school. BMC Medical Education 2025;25:152. https://doi.org/10.1186/s12909-024-06585-7.
[23] Fiandini M, Nandiyanto ABD, Al Husaeni DF, Al Husaeni DN, Mushiban M. How to calculate statistics for significant difference test using SPSS: Understanding students comprehension on the concept of steam engines as power plant. Indonesian Journal of Science and Technology 2024;9:45–108.
[24] Chung E-K, Yun H, Nam K-I, Cho Y-S, Han E-R. The application of flipped learning to a gross anatomy dissection course. Plos One 2024;19:e0298067.
[25] Vertemati M, Zuccotti GV, Porrini M. Enhancing Anatomy Education Throu€ gh Flipped Classroom and Adaptive Learning A Pilot Project on Liver Anatomy. Journal of Medical Education and Curricular Development 2024;11:23821205241248024.
[26] Demirçalı S, Selvi M. Effects of Model-Based Science Education on Students' Academic Achievement and Scientific Process Skills. Journal of Turkish Science Education 2022;19:545–58. https://doi.org/10.36681/tused.2022.136.