



Development of a Three-Dimensional (3D) Video-Based Human Skeletal System E-Atlas to Improve High School Students Understanding of the Human Movement System Material

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Abstract

This study aims to analyze the characteristics, validity, feasibility, and effectiveness of the E-Atlas of the human skeletal system as a support for practical activities to improve student understanding. The design of this study uses Research and Development (R&D) with the ADDIE method. The subjects of this study were students of class XI SMA N 1 Belik, with 15 students in the small-scale trial and 35 students in the large-scale trial. The data collection method was a questionnaire and a test consisting of 25 multiple-choice questions. The results of the study showed that the developed E-Atlas has the characteristics of facilitating teachers and students with 3D video facilities. The average validity of material experts and media experts was 94.95% in the very valid category, feasibility with indicators of practicality and readability and responses from teachers and students was 87% in the very feasible category, and an increase in understanding of learning outcomes by 0.92 in the high category. This study can conclude that the E-Atlas of the human skeletal system has characteristics according to the design, valid, feasible, and effective to be used as a support for practical activities.

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INTRODUCTION

According to the National Education System Law Number 20 of 2003, education is a conscious, planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have spiritual, religious strength, self-control, personality, intelligence, noble morals, and the skills needed by themselves, society, nation, and state (Angga et al., 2022). According to the Republic of Indonesia Law Number 20 of 2003 concerning the National Education System, Chapter I, Article 1, paragraph 20, states that learning is a process of interaction between students and educators and learning resources in a learning environment (Siregar & Rohani, 2024). Learning resources appropriately used by teachers in learning significantly affect the activeness and achievement of students because learning resources are indicators in determining the achievement of learning objectives themselves in addition to indicators of teacher professionalism (Far & Pattiasina, 2021). Media is part of the educational scheme, media plays a very important role in the learning process, such as providing the same stimulus, creating the same perception, and equalizing students' learning experiences (Komari et al., 2022). The results of the study showed that students found it challenging to learn the material on systems, cell division, and genetics categorized as complex biology topics (Fauzi et al., 2021). Students are required to understand essential concepts in biology material through reasoning, understanding related concepts, and forming relationships between concepts in order to apply them in problem solving (Novallyan et al., 2023). The material on the motor system is more abstract and sometimes causes misunderstandings, making it difficult for students to understand (Karim et al., 2023).

Based on interviews with biology teachers at SMA N 1 Belik, information was obtained that teaching materials in the form of books prepared by the school and modules prepared by the teacher were used in delivering the material on the movement system. According to the biology teacher, students prefer learning media that contain pictures so that students are more interested in understanding the material. The biology laboratory carries out practical activities using the torso bone media. However, learning seems less effective because no guide makes it easier for students to recognize the parts of the bones. With this method, teachers have difficulty providing all the material due to time constraints, so they only convey the essentials. To overcome this problem, a practical guide is needed with comparative images explaining the movement system's parts and functions. This study guide can be realized as an E-Atlas, which is expected to make it easier for teachers and students to learn the torso and be more efficient in managing practical time. Atlas is a teaching material that presents various images, accompanied by brief and detailed descriptions (Wulansari in Putri et al., 2021). In addition, the information provided can be accessed anytime and anywhere as long as there is an internet network (Kamaliya et al., 2022). The advantage of atlas media presented electronically (E-Atlas) is that it can be directly accessed via mobile phone using the internet, making it practical to use, providing an interesting learning atmosphere and making it easier for students to understand the material. In addition to images, videos are presented in three-dimensional form, so that students can observe the skeletal system from all sides.

Based on the description above, it is necessary to conduct research into the development of a three-dimensional (3D) video-based E-Atlas of the human skeletal system as a supporting medium for practical work, so that it can help achieve learning objectives through alternative learning resources so that students understand the concepts of the material being taught.

RESEARCH METHODS

This research was conducted at SMA N 1 Belik on November 11-15, 2024 in the odd semester of the 2024/2025 academic year. This research was designed using the Research method. and Development (R&D) using the ADDIE model approach. The subjects of this trial used a purposive sampling technique. One biology teacher and 15 students of class XI.5 of high school conducted small-

scale trials. Meanwhile, large-scale trial subjects were conducted by class XI.1 of high school, totaling 35 students, to determine the effectiveness of the E-Atlas of the human skeletal system in improving learning outcomes. Data collection methods were carried out using questionnaires and tests. The implementation used a Pre-experimental research design with the One Group Pretest-Posttest Design model to determine student learning outcomes. Data analysis included analysis of the validity of the atlas, feasibility, and learning outcomes using descriptive methods and improving student learning outcomes with non-parametric and N-gain tests.

RESULTS AND DISCUSSION

Characteristics of the E-Atlas of the Human Skeletal System

The Human Skeletal System E-Atlas that has been developed can be seen from several components contained in this atlas, including:

Table 1 Product characteristics

No.	Product Characteristics	Criteria Met
1.	The product developed is an electronic atlas of the human skeletal system to support the practicum of grade XI students in the odd semester.	✓
2.	E-Atlas is displayed electronically with the help of an application called Flip Builder. Flip PDF Professional is easily accessible to teachers and students and has additional facilities in the form of links that lead to specific videos/information sources.	✓
3.	The images in the E-Atlas are presented in color with proportional image captions. There are 3D videos with explanations that cover the human skeleton from the head, thorax, upper and lower extremities, and joints.	✓
4.	E-Atlas is made in A4 format and designed using the Canva application. The structure of E-Atlas consists of a cover, foreword, instructions for using E-Atlas, table of contents, contents, student worksheets, quizzes, bibliography, and developer profiles. On some pages, there will be important information and unique facts about the bone parts of the skeletal system.	✓
5.	At the end, there is a worksheet that students can work on during learning activities, and there is a quiz as enrichment after carrying out learning activities.	✓
6.	E-Atlas is developed and accessed in link format using a mobile device or computer connected to the internet.	✓

The characteristics of the developed E-Atlas of the human skeletal system can be seen in the composition of the atlas, including the cover, foreword, instructions for use, table of contents, contents, student worksheets, quizzes, bibliography, and author profiles. The components on the cover consist of the university logo, the atlas title, class targets, the year the atlas was developed, and the author's name. In addition to functioning as a protector of the content, the book cover also acts as an element that attracts the attention of potential readers. Learning media with an attractive visual design will make it easier for teachers to convey material and make students interested in learning in a pleasant classroom atmosphere (Katona et al., 2023). The foreword page contains the purpose of developing the atlas, the purpose of the atlas, gratitude, and expectations. In addition, there is also an explanation of learning outcomes, the primary sources used in making the atlas, and the month and year the atlas was developed. The instructions for use page functions provide guidance on how to use the features in the E-Atlas. The instructions for use are designed in the form of a scheme to make it easy to understand because one of the characteristics of good media is that instructions are written in simple language using short sentences and vocabulary that is appropriate to the age and abilities of the user (Astuti, 2021). The table of contents page is arranged on one page to make it easier for readers to find

the contents of the atlas as a whole. In addition, the table of contents is placed in the form of a hyperlink so that by simply pressing the word you want to go to, the page will automatically go directly to that page. The atlas contents page contains human skeletal system material to support the practicum of grade XI students in the odd semester. On the top of the contents page, there are chapter and sub-chapter titles. Under the title is an introductory narrative about the bone parts so that students are motivated to read. Furthermore, there are pictures, short descriptions, 3D videos, and explanations with captions below them. The contents of the material in the E-Atlas are presented starting from the skull, thorax, upper extremities, lower extremities, and joints. The following section contains a red box containing unique facts or important information to increase students' insight. There are also difficult words with hyperlinks that lead to sources of information on the meaning of the word. At the bottom left of the page, there is a back sign that will lead to the table of contents. Bibliography page, the bibliography contains reference sources that support the validity of the contents of the E-Atlas. The bibliography shows data referring to reliable sources and avoids plagiarism. The author's profile page contains a description of the compiler of the E-Atlas. 3D animation can provide realistic and engaging visualizations, making it easier for students to understand abstract and complex concepts in science. Several studies have shown that 3D animation can enhance learning effectiveness in various fields, including mathematics, science, and language (Putri, 2024).

Validity of the Human Skeletal System E-Atlas

The validity of the E-Atlas Human Skeletal System product that has been developed is the average validation value by media experts and material experts. The following is a presentation of the validity assessment by material experts in Table 2.

Table 2 Validity recapitulation by material experts

No.	Assessment items	Number of items	Total score	Score obtained	P (%)
1.	Aspects of validity of material content	10	40	36	90
2.	Aspects of language validity	8	32	27	84
3.	Contextual validity aspects	1	4	4	100
	Total	19	76	67	91.3
	Criteria	Very valid			

Material experts assessed the validity of the Human Skeletal System E-Atlas based on 3 aspects with a total of 67 scores with a percentage of 91.3% from the content aspect 36 scores with a percentage of 90%, the language aspect 27 scores with a percentage of 84%, and the contextuality aspect 4 scores with a percentage of 100%. So, the E-Atlas criteria are "very valid".

The aspect of content of the material and suitability of the learning outcomes are shown in the presentation of the material in the form of images, captions, and others in the E-Atlas according to the learning outcomes. The accuracy of the material is shown by the images, captions, and descriptions presented, which can visualize the framework structure according to accurate facts and data to improve student understanding. The up-to-dateness of the material is shown by the material presented being able to implement concepts broadly and stimulate student knowledge. Digital media can increase the attractiveness of the learning process for students because incorporating digital components into learning can diversify learning patterns and increase student involvement to achieve goals and achieve optimal results (Purnama et al., 2024).

Language aspects, straightforward, are shown by the use of sentences that represent the content of the message to be conveyed. Communicative and interactive indicators show that the message conveyed in E-Atlas uses common language in written Indonesian communication and the delivery of messages between one chapter and another shows the sequence and interconnectedness of the

content and language that creates a sense of pleasure when students read. Using the term symbol has illustrated a concept consistently in each chapter in E-Atlas. Delivering the correct information is very important because it determines the realization of effective communication in learning which influences the success or failure of the learning process in the classroom which can be seen from the achievement of learning objectives (Rombean et al., 2021).

The contextuality aspect encourages students to relate their knowledge to its application in everyday life related to the material of the human skeletal system. In biology learning, students are not only required to understand the material but also required to acquire skills in activating resources so that students can associate biological concepts with phenomena that exist in everyday life. (Novallyan et al., 2023). Learning by connecting something learned with real life is suitable for learning biology because biology learning must be environmental (Saraswati et al., 2022). The validity assessment by media experts is shown in Table 3 below.

Table 3 Recapitulation of validity results by media experts

No.	Assessment items	Number of items	Total score	Score obtained	P (%)
1.	Validity aspects of the presentation	4	16	16	100
2.	Graphic validity aspects	18	72	70	97.2
	Total	22	88	86	98.6
	Criteria	Very valid			

Media experts assess the validity of the E-Atlas of the Human Skeletal System based on 2 aspects with a total of 86 scores with a percentage of 98.6% from the presentation aspect with 16 scores with a percentage of 100%, and the graphic aspect with 70 scores with a percentage of 97.2%. So, the E-Atlas criteria are "very valid". The percentage of the average value of material experts and media experts is 94.95% with very valid criteria.

In the presentation aspect, the title is positioned at the right center of view so that it becomes the initial attraction of the E-Atlas. The contents of the E-Atlas include images and captions appropriately. The foreword page contains the purpose of writing the E Atlas, for whom the E-Atlas was compiled, and expressions of gratitude and the bibliography page is written according to applicable rules including the completeness of the components of writing a bibliography. The media must follow the established systematics. The beginning consists of a foreword and table of contents, the contents section consists of chapters containing text and images, and the end consists of a bibliography (Setiawan et al., 2021).

Graphical aspects: E-Atlas have been adjusted to ISO (International Organization for Standardization) standards. for Standardization) is A4 (210mmx297mm), the selection of this size is adjusted to the material's content because it affects the layout of the E-Atlas content section. The cover design indicator displays a layout that is consistent with both the front and back covers. The color display clarifies the delivery of the topic of the material; the color selection is not striking, and the background and the writing can be distinguished. The illustrations provided an understanding of the material and can visually display the type of illustration according to the E-Atlas material. The illustrations on the cover have considered the accuracy of the size, namely not covering the identity and paying attention to the aspects of shape, size, and proportional illustration objects so as not to cause misinterpretation for students. The title uses letters with proportional fonts and colors to quickly convey information about the contents of the E-Atlas. The E-Atlas content design indicator displays a consistent layout between (title, subtitle, foreword, table of contents, illustrations, etc.). The arrangement of images and sub-chapters is spaced, the placement of elements of the illustration/image layout and image captions is proportional by displaying the unity of the caption with the illustration on one page so as not to interfere with the clarity and delivery of information that can hinder student

understanding. The images presented clarify the presentation of the material both in proportional size and attractive colors and image captions are placed close to the image. The typography of the E-Atlas content is straightforward, and the presentation of symbols/icons is consistent, so it does not use various types of letters without disturbing students when absorbing information. The layout design in the book plays a role in supporting the message to be conveyed. A book functions as a messenger. The message to be conveyed through the book is through its writing and design (Asthararianty & Lesmana, 2018).

Feasibility of the Human Skeletal System E-Atlas

The Human Skeletal System E-Atlas is assessed based on the practicality and readability aspects of teacher and student responses. The results of the practicality and readability assessment of the E-Atlas of the Human Skeletal System by the teacher are in Table 4 below.

Table 4 Recapitulation of the results of the teacher's practicality and readability assessment

No.	Assessment Items	Number of items	Total Score	Score obtained	P(%)
1.	Practical aspects	8	32	32	100
2.	Readability aspects	8	32	32	100
	Total	16	64	64	100
	Criteria	Very practical			

Biology teachers value practicality and readability E-Atlas of the Human Skeletal System based on 2 aspects with a total of 64 scores with a percentage of 100% from the practicality aspect 32 scores with a percentage of 100% and the readability aspect 32 scores with a percentage of 100%. So, the E-Atlas criteria are "perfect".

Next is the assessment of practicality and readability. E-Atlas of the Human Skeletal System by students. The results of the practicality and readability assessment of the E-Atlas of the Human Skeletal System by students are in Table 5 below.

Table 5 Recapitulation of the results of the student's practicality and readability assessment

No.	Criteria	Number of students
1	Very good	12
2	Good	23
3	Pretty good	0
4	Not good	0
5	Not good	0
Total number of students		35
Classical percentage (%)		80
Criteria		Good

Of the 35 students, it is known that 12 students gave responses with perfect criteria, 23 students gave responses with good criteria with a classical percentage of 80%. This percentage shows that the E-Atlas of the Human Skeletal System have practicality and readability with good criteria.

Practicality aspect, E-Atlas learning activities are considered to facilitate in-depth study of the material because the images presented can visualize the human skeletal system concretely and contain all the human body parts that add cognitive knowledge. The ease of use indicator shows the ease of E-Atlas, which can be accessed anywhere if there is a cellphone and internet network. All tools in the media can be used properly. Instructions for use are presented in the form of a scheme that can make it easier for students to understand how the media works. Videos and explanations can be played well and the sound is clear. Students want media that is interesting, not boring, easy to understand, has

supporting images that are closely related to everyday life, easy to implement and able to make them understand the concept of the material given (Mahartika et al., 2023).

Regarding readability, language presentation assesses that the material presented uses simple language and is based on EYD rules to make it easy to understand. The images, captions, and descriptions help students understand the material. In addition, sentences with instructions for using the media can convey the information in clear language and interactive sentences and invite students to communicate. The format for writing material sentences in E-Atlas uses a consistent font type. The writing in E-Atlas pays attention to aspects of size, color, and proportional clarity of images, making them easy to read and understand. The more senses used to receive and process information, the greater the likelihood that the information can be understood and retained in memory. Thus, students are expected to be able to receive and absorb easily and well the messages in the material presented (Sapriyah, 2019).

Next is the assessment of the feasibility of teacher and student responses. The results of the evaluation of teacher and student responses E-Atlas of the Human Skeletal System by the teacher are in Table 6 below.

Table 6 Recapitulation of teacher response assessment results

No.	Assessment Items	Number of items	Total Score	Score obtained	P(%)
1.	Media Design Aspects	4	16	13	81.25
2.	Media Usage Aspects	7	28	28	100
Total		11	44	41	90.6
Criteria		Good			

Biology teachers respond to developments E-Atlas of the Human Skeletal System based on 2 aspects with a total of 41 scores with a percentage of 90.6% from the media design aspect 13 scores with a percentage of 81.2% and the media usage aspect 28 scores with a percentage of 100%. So, the E-Atlas criteria are "perfect".

Next is the response assessment E-Atlas of the Human Skeletal System by students. The results of the response assessment E-Atlas of the Human Skeletal System by students are in Table 7 below.

Table 7 Recapitulation of student response assessment results

No.	Criteria	Number of students
1.	Very good	10
2.	Good	23
3.	Pretty good	2
4.	Not good	
5.	Not good	
Total number of students		35
Classical percentage (%)		77
Criteria		Good

Of the 35 students, it is known that 10 students gave responses with perfect criteria, 23 students gave responses with good criteria, and 2 students gave responses with quite good criteria with a classical percentage of 77%. This percentage shows that E-Atlas has good criteria. The percentage of practicality and readability by teachers is 100% and students are 80% and teacher responses are 90.6% and students are 77% so an average value of 87% is obtained with very decent criteria.

The media design aspect shows that the E-Atlas cover display is attractive. The size, font type, and image resolution in the E-Atlas media are quite straightforward to read, the color combination on the E-Atlas page is harmonious and can clarify the image, and the placement of titles, subtitles, images,

and image captions does not interfere with the clarity and delivery of information that can hinder student understanding. With variations in learning, such as diverse and attractive designs, it is hoped that students will be more active and not easily bored in the learning process (Marlena et al., 2022).

Using the media material presented in E-Atlas is easy to understand and can improve conceptual understanding of the material. The illustrations presented range from images, captions, and output displays according to the material with simple, easy-to-understand, and uncomplicated sentences. Using E-Atlas helps facilitate learning, the material and images presented in E-Atlas can stimulate students' motivation to learn and can make students interested in learning. Using technology tailored to needs will foster motivation, thereby increasing the effectiveness of student learning (Negoescu & Mitrulescu, 2023).

Effectiveness of the Human Skeletal System E-Atlas

The effectiveness of the Human Skeletal System E-Atlas is assessed based on student learning outcomes after using the E-Atlas media as a guide in learning. The results of the data normality test are in Table 8 below.

Table 8 Normality test results pretest and posttest

No.	Test	Significance	Conclusion
1.	Pretest	0.005	Data is not normally distributed
2.	Posttest	0,000	Data is not normally distributed

normality test using Shapiro Wilk at a significance level of 5%, the data is normally distributed if it meets the criteria of sig value > 0.05 conversely if the sig value < 0.05 , then the data is said to be not normally distributed. The data shows a pretest significance value of 0.005, so it can be stated that the pretest data is distributed abnormally, and the posttest significance value is 0.000, so it can be stated that the data is distributed abnormally. The results of the Wilcoxon test are in Table 9 below.

Table 9 Wilcoxon test results pretest and posttest

No.	Information	N	Mean rank	Asymp.Sig
1.	Negative ranks	0	0.00	0,000
2.	Positive ranks	35	18.00	

Wilcoxon test, a negative rank value of 0 was shown, this value indicates that there is no decrease from the pretest value to the posttest value. Students totaling 35 children experienced an increase in learning outcomes from the pretest value to the posttest value. Furthermore, the analysis results show that asymp.Sig (2-tailed) is 0.000. The value of 0.000 is smaller than 0.05, so it can be concluded that there is a difference between learning outcomes before and after using the E-Atlas media of the human skeletal system.

Next, the N-Gain test was conducted to determine the differences in student learning outcomes in the pretest and posttest. The following N-Gain test results are presented in Table 10 below.

Table 10 N-Gain pretest and posttest test result data

No.	Information	N-Gain Value	Interpretation
1.	Pretest And Posttest	0.92	Tall

Based on the N-Gain test on the pretest and posttest scores of 35 students, the scores showed an increase with a score of 0.92 which is included in the high category.

Using the E-Atlas of the human skeletal system as a learning medium has been shown to improve understanding as seen from student learning outcomes. This is shown in the cognitive values of students who took the pretest and posttest with multiple-choice questions containing cognitive indicators C2 to C4. The cognitive process produces learning outcomes. The use of appropriate learning media will have a positive impact on learning so that learning objectives can be achieved. Before using the E-Atlas, the cognitive values of 28 students did not complete and 7 students completed compared to after using the E-Atlas media, the posttest scores were 32 students completed and 3 students did not complete. The Wilcoxon test showed an asymp.sig value of 0.000 which was smaller than 0.05, and the N-Gain test revealed a value of 0.92. To ensure that learning runs well and achieves its goals, it is necessary to pay attention to various aspects related to learning. The success of learning objectives is influenced by several factors such as the delivery of material by the teacher, student learning readiness, student learning motivation, learning facilities and quality learning resources (Kaewsa, 2022).

CONCLUSION

Based on the analysis of the research results and discussion, it can be concluded that the characteristics of the E-Atlas Atlas of the Human Skeletal System developed as a biology learning media in high school are in accordance with the expected criteria, namely learning media that provide easy access for teachers and students. The E-Atlas of the Human Skeletal System is valid, feasible, and effective as a supporting media for practical activities to improve student understanding.

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