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Development of 3D mock-up media for respiratory system learning in elementary schools

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Abstract. Students often struggle to understand scientific concepts due to their abstract nature and the limited use of interactive learning media. This study aims to develop 3D mock-up media for learning about the respiratory system in elementary schools. The research adopts an R&D approach using the ADDIE development model. The study participants included one teacher and 25 fifth-grade students from SDN 3 Ngeling. Data collection methods encompassed observation, interviews, questionnaires, as well as pre-test and post-test. Data were analyzed qualitatively and quantitatively to assess the feasibility of the product. The results of the validity test from the media validator obtained a score of 98.6% and 97.3% with a very valid category. In comparison, the material's validity test achieved a 97.75% result, placing it in a very valid category. This shows that this media is valid for use in research. In addition, the results of the student and teacher questionnaires also showed positive results, respectively 95% and 96% with a very good category, thus indicating that this media is feasible and effective for use in learning the respiratory system. The results of the paired sample T-test, with N-Gain values of 0.000 and 0.662, indicate differences and improvements in student learning outcomes. As a follow-up, it is expected that 3D mock-up media can be combined with digital technology to improve students' learning experiences.

Introduction

One of the core subjects in elementary school is Natural and Social Sciences (IPAS). This subject explores various aspects of the universe and its contents, providing a deeper understanding of the world around humans (Istimewa et al., 2021). However, learning IPAS often encounters challenges, especially in learning that requires abstract and complex understanding, such as the human respiratory system (Sinaga et al., 2023). One way to strengthen students' understanding of the material is to utilize innovative and interactive learning media (Marwiyah et al., 2023).

Learning media plays an important role in improving student understanding. Media can be used as a means to convey information from a source to students (Fadilah et al., 2023). In addition, media can also create a conducive learning environment (Himawati et al., 2023). The presence of media makes it easier for students to learn difficult material, and can foster their interest and motivation to learn (Elfiana et al., 2022). In addition, the use of appropriate facilities can support them in improving their learning outcomes better (Zumrotun et al., 2020). Based on these various

explanations, it can be concluded that the media makes a significant contribution to increasing student interest, motivation, and learning outcomes. The use of media also supports students in understanding the material better; concepts that are difficult to visualize become easier to understand, interestingly and interactively (Wahyuni et al., 2024; Purnadewi & Widana, 2023).

The results of observations, interviews, and documentation conducted at SDN 3 Ngeling revealed several problems in the human respiratory system material for grade V. Specifically, teachers struggle to facilitate learning on conceptual materials, such as human respiratory system materials, due to the lack of available learning media. Based on interviews with teachers, limited space and time with dense materials are one of the factors that result in less than optimal learning. Some students also appear less active in learning and have difficulty responding to questions asked by the teacher. As a result, student learning outcomes are less than optimal. The results of daily tests show that around 64% of the total students scored below the Learning Objective Achievement Criteria, with a minimum completion criterion of 70. There are nine students, or 36% of all students, who scored exceptionally well and have exceeded the standard, with the highest score of 79, the lowest score of 55, and an average score of 69.

Based on the results of interviews with students, it was stated that science is a complicated subject, especially in material that explains biological processes that cannot be observed directly by students, and requires students to imagine them. This challenge makes science less popular and is often considered boring (Ratna & Sitepu, 2022; Widana et al., 2021). To overcome this problem, teachers need to create innovations to motivate students and make it easier for students to understand the material (Susilo, 2020; Suhardita et al., 2024). One approach that can be applied is to utilize technology or interactive teaching aids, enabling students to understand abstract concepts more easily. Thus, 3D mock-up media can be an effective solution to overcome this problem.

Mock-ups can be used as supporting media during the learning process. Mock-ups are 3-dimensional media that are made to resemble their original form (Fazilla, 2023). Mock-ups have several advantages, including (1) having a 3-dimensional form that is similar to the original form, (2) a realistic color display, making it interesting to observe, and (3) providing direct experience to its users (Saputri et al., 2024). In addition, 3D mock-ups can also increase student interest in the material being studied (Sahir & Ernawati, 2020), and can eliminate student boredom when the teacher delivers the lesson material (Adventyana et al., 2023). Thus, the development of this 3D mock-up media is expected to be used as an effective means of learning the human respiratory system.

Previous studies have proven that mock-ups are effective in learning. One of them is a study conducted by Ngainin (2024), which obtained a practicality test result of 92.72% with a very good category, proving that the use of mock-ups can foster student learning motivation. In addition, Prasetya et al. (2022) showed that visual and tactical mock-up representations can provide concrete learning experiences for students. Thus helping them with various learning styles (audio, visual, and kinesthetic). This study obtained a feasibility test of 86.66%, falling within a very feasible category. This media provides students with the opportunity to learn actively through direct observation or by holding the media directly. so that, with the advantages of this media, it can encourage student involvement in learning and create a more enjoyable learning process. With this, it can be concluded that 3D mock-up media has been proven to help students understand the material more easily.

Teaching aids are a means that teachers can use to facilitate the learning process. Another study also shows the effectiveness of teaching aids in learning the human respiratory system (Salsabila et al., 2023). The study examined the use of simple teaching aids to help teachers explain the

material on the human respiratory system. The teaching aids are made from simple materials such as used bottles, balloons, rubber, and straws. As a result, the use of teaching aids succeeded in reducing student boredom and created a more lively classroom atmosphere, as evidenced by the increase in the average student creativity score to 79. Another study conducted by (Fazilla, 2023) also showed that 3D mock-up media had a positive impact on making it easier for students to understand concepts in science subjects as evidenced by the average pretest score in the control class reaching 41.957 while in the experimental class it was 48.261, the average post-test score in the control class increased to 78.043 while in the experimental class it reached 86.304.

This research has several new features compared to previous research; these differences can be seen in the following table:

Table 1. Differences in media novelty with previous research

Aspect	Previous research	This research
Media Forms	Simple lung model	3D model of a complete human body, including chest and head
Media making materials	Made from used bottles and balloons	Made of wood, equipped with balloons and lights
Component	A simple balloon lung model with a trachea and a simple diaphragm.	Complete: nose, pharynx, larynx, trachea, bronchi, bronchioles, alveoli
Process Visualization	Demonstrates the breathing process (expanding/ contracting)	Clearly shows the airways and the processes of inspiration and expiration.
Educational Label	Sticky paper	Equipped with interactive labels and light switches
Interactivity	Interaction is limited to when the balloon is pressed.	Interactive air pump + organ button

The development of 3D mock-up media for learning the respiratory system in elementary schools has several urgencies, including that this media can address the challenges of learning abstract concepts that are difficult for students to understand. This is related to the results of national studies such as PISA (Programme for International Students Assessment) 2018, which shows that the scientific literacy skills of Indonesian students are still low, with an average score of 396, far below the OECD average of 489. The lack of use of interactive media is one of the factors in the lack of students' scientific literacy skills. Thus, 3D mock-up media plays an important role as a visual aid that can bridge the abstraction of material to make it more real and easier to understand. The development of this media not only supports the learning process to be more meaningful and engaging, but can also be a solution to the limitations of teaching aids in elementary schools, especially in areas that have limited access to digital technology, so it is expected to be a solution to improve the scientific literacy skills of Indonesian students.

Based on the various descriptions, the formulation of the problem in this study is (1) how is the process of analyzing needs in developing 3D mock-up media? (2) how is the process of developing 3D mock-up media? (3) how is the validity and feasibility of 3D mock-up media in learning the respiratory system? (4) how is the effectiveness of 3D mock-up media in learning the respiratory system? Meanwhile, the objectives of this study are (1) to analyze needs in the process of developing 3D mock-ups (2) to develop 3D mock-up media in learning the respiratory system (3) to find out the validity and feasibility of 3D mock-up media in learning the respiratory system, and (4) to find out the effectiveness of 3D mock-up media in learning the respiratory system.

Method

This study used the Research and Development (R&D) method based on the ADDIE model. The ADDIE model, as described by Branch 2009 consisted of five stages, namely Analyzing, Designing, Developing, Implementing, and Evaluating. These stages aimed to develop and evaluate learning media (Putri Weldami & Yogica, 2023). The following is a picture of the stages of the ADDIE development model:

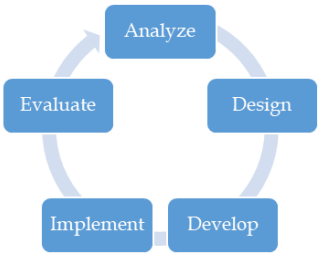

Image 1. Stages of the ADDIE Development Model

The image above illustrates the stages of the ADDIE development model. The first stage of analysis included needs analysis, content, and curriculum analysis, which were conducted with teachers and students through observation, interviews, and questionnaires. Furthermore, at the design stage, the product design was developed, validity instruments were prepared, and student and teacher response questionnaires were created. In the development stage, material and media validity tests were carried out, followed by product trials in the context of respiratory system learning. These trials were then evaluated through analysis of the pre-test and post-test results. The final stage, evaluate, aimed to assess the effectiveness of the product and to make improvements based on observation and analysis of the student and teacher response questionnaires.

This research was conducted at SDN 3 Ngeling from December 2024 to March 2025 with 25 fifth-grade students (9 males and 16 females) as subjects. It involved one fifth-grade teacher, one material expert validator, and two media expert validators. Data collection techniques in this study were obtained through observation, interviews, and questionnaires to measure the perception and effectiveness of the media developed. Data analysis was carried out descriptively and quantitatively. Qualitative data were analyzed based on comments, suggestions, and expert validators obtained from questionnaire respondents. Quantitative data were then analyzed using a Likert scale. This scale is used to assess perception by measuring the level of agreement or disagreement with a particular subject or object (Sugiyono, 2020). Meanwhile, to determine the feasibility of the media, the following percentage formula can be used:

$P = f/N \times 100\%$

Description:
P : Percentage value
$\sum x$: Score obtained
N : Maximum score

The calculation of the validity test result data can be calculated using the formula above, so that quantitative data will be obtained, which is then accumulated into the form (%). To find out the validity of the product that has been developed, it can be seen in the following criteria table:

Table 2. Validity Criteria for Materials and Media

Value	Criteria	Percentage
A	Very valid	80% ≤ x ≤ 100%
B	Valid	60% ≤ x < 80%
C	Quite valid	40% ≤ x < 60%
D	Less valid	20% ≤ x < 40%
E	Not valid	0% ≤ x < 20%

(Ulinuha, 2020)

To find out the feasibility of the product that has been developed, you can see the following criteria table:

Table 3. Media Eligibility Criteria

Percentage (%)	Validity Criteria	Test Decision
80% - 100%	Very Eligible	No Revision Required
60% - 80%	Eligible	No Revision Required
40% - 60%	Quite Eligible	No Revision Required
20% - 40 %	Less Eligible	Required Revision
0% ≤ x ≤ 20%	Not Eligible	Required Revision

(Biologi & Balitar, 2024)

To find out the responses of students and teachers to the use of the product, this data was collected through a questionnaire. The questionnaire analysis criteria can be seen in the following table:

Table 4. Interpretation Category Criteria

Percentage	Interpretation
≤ 20%	Very Less
21 % – 40%	Less
41 % – 60%	Enough
61 % - 80 %	Good
81% - 100%	Very Good

(Purba et al., 2022)

The data analysis technique used to test the effectiveness of the development of this 3D mock-up media uses quantitative descriptive methods, including normality tests, homogeneity tests, paired sample T-tests, and N-Gain tests. The interpretation categories of values in the N-gain test can be seen in the following table:

Table 5. Interpretation of N-Gain Index

N-Gain Index	Interpretation
N-Gain ≥ 0,7	High
0,3 ≤ N-Gain < 0,7	Medium
N-Gain < 0,3	Low

(Hake, 1999)

Results and Discussion

Analysis of needs in developing 3D mock-up media for respiratory system learning

The results of this study are presented in the form of 3D mock-up media, which can serve as an aid in the learning process of the respiratory system at the elementary school level. This media is an imitation of the organs of the human respiratory system that teachers can use to explain the

material in learning (Riani, 2023). The process of developing 3D mock-up media in learning the respiratory system uses the ADDIE model, which has five steps, including: Analyze, Design, Develop, Implement, and Evaluate.

The first stage, Analyze, involves analyzing the needs of teachers and students. This research was conducted through interviews and surveys given to teachers and students of grade V of SDN 3 Ngeling. The results of interviews with teachers can be seen in the following table:

Table 6. Teacher interview results

Dimension	Teacher interview indicators	Percentage
Learning needs	Teachers' difficulties in delivering material without the help of interactive media	85%
Media availability	Availability of media in schools	75%
Student involvement	Student participation when teachers use media	80%
Media effectiveness	Ease of delivering material with the help of media	90%

Based on the results of the needs analysis shown in Table 6, the most dominant indicator in interviews with teachers is the ease of delivering material with the help of media. Teachers stated that they had difficulty delivering material without the help of media, especially when explaining abstract material that is difficult for students to imagine without the help of media. If teachers only use conventional media, students tend to get bored easily with understanding the material. Meanwhile, the results of the student survey can be seen in the following table:

Table 7. Student Survey Results

Dimension	Student survey indicators	Percentage
Learning needs	Students' difficulty understanding material without visualization	95%
Media availability	Availability of media used by teachers	75%
Student involvement	Students' interest and motivation in learning using media	90%
Media effectiveness	Ease of understanding the material with the help of media	90%

Based on the results of the student needs survey shown in Table 7, the most dominant indicator in the results of the student survey is the difficulty in understanding the material without visualization. Students often struggle to understand abstract concepts, such as those related to the respiratory system. They struggle to visualize the organs involved in the respiratory system, which makes it challenging for them to recall the organ's components. Thus, based on the needs analysis that has been carried out, it can be concluded that teachers need media to help in delivering the material. In contrast, students need media to help remember and understand abstract material.

The results of the needs analysis show that teachers often face obstacles in conveying abstract concepts. For example, 3D mock-up media is present as an effective solution to meet the needs of

teachers and especially students in learning the respiratory system at the elementary school level. This media can help teachers present concrete visual representations, making it easier for students to understand the organs involved in the human respiratory system. Research conducted by Eva and Prayogo (2025) states that mock-ups are designed to make it easier for students to master the material better and create a fun learning experience. In addition, the results of research conducted by Fauziyah et al. (2024) state that the use of 3D media has the potential to increase student activity in learning. Interactive visual media, such as 3D mock-ups, can provide a more meaningful learning experience, making it easier for students to understand the material (Design, 2024; Widana, 2020). Thus, 3D mock-up media in learning the respiratory system not only answers the needs of teachers in delivering material more effectively but also supports students in learning interactively and meaningfully, especially at the elementary school level.

Development of 3D mock-up media for learning the respiratory system

The next stage is design. Based on the results of the needs analysis of teachers and students, researchers know that students have difficulty understanding abstract material, so they need the help of media to visualize. Teachers also stated that it is easier to convey material with the help of interactive media. Furthermore, researchers will design a medium to aid teachers and students in the learning process, particularly with material that is difficult to visualize, such as respiratory system material. At this stage, researchers design products by determining the concept or idea of the media form. The form of the media researchers' design resembles the human body's head and chest, allowing for a precise replica of the lungs. The basic material of the media researchers' design uses wood to make it more durable. In addition, design elements are also designed in such a way that the media becomes more attractive. Researchers design interactive buttons and lights that are placed on specific parts of the organs to help students easily remember the respiratory organs. In addition to designing the product, researchers also prepare material and media validation instruments, as well as student and teacher response questionnaires regarding the use of 3D mock-up media.

At the development stage, the designed idea or design is applied to a product in the form of a 3D mock-up of the respiratory system. This product is in the form of a half-human torso model with visualization of the primary respiratory organs such as the nose, pharynx, larynx, trachea, bronchi, bronchioles, and alveoli. The respiratory organs are equipped with buttons and indicator lights. If the button is turned on, the light will turn on and show certain parts of the respiratory organs. LED lights can improve students' ability to understand organ configuration (Hapsari et al., 2024). In addition, the use of attractive colors also adds to the visual appeal of the media (Ningrum et al., 2022). This media is also equipped with a syringe, hose, and balloon. If the syringe is pulled, air will enter through the hose and go to the balloon so that it can show the inspiration and expiration process of the human respiratory system. The results of the development of 3D mock-up media can be seen in the following illustration:

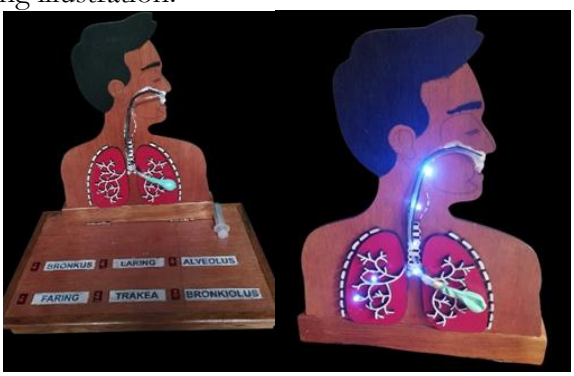

Image 2. Results of Developing 3D Mock-Up Media for the Respiratory System

Validation and feasibility of 3D mock-up media in learning the respiratory system

At the validation stage of the 3D mock-up media product, the researcher conducted a validation test on two media validators and one material validator. The first media validator gave a score of 98.6% which was included in the very valid category; the second media validator gave a score of 97.3% which was also included in the very valid category. In addition, the material validator gave a score of 97.75% with a very valid category. The results of the assessment by the media and material validators can be seen in the following table:

Table 8. Product Validation Results

Validator	Results(%)	Category
Media Expert 1	98.6% %	Very valid
Media Expert 2	97.3%	Very valid
Materials Expert	97.75%	Very valid

Based on Table 8, the 3D mock-up media developed by researchers has a very high level of validity and is very suitable for application in learning the respiratory system in elementary schools. Several studies also support the advantages of this medium. Research by Resti et al. (2024) states that 3D media has a high level of validity because it can present information visually and interactively, so that it can facilitate student understanding. Another study conducted by Harmini et al. (2024) shows that learning media using 3-dimensional displays has met the validity criteria and is very suitable for use as a learning aid. In addition, research by Irawati et al. (2024) also shows that learning media based on 3D mock-ups are not only valid but also suitable for use in various educational contexts because they can create engaging and compelling learning experiences. Thus, 3D mock-up media not only meet the validity standards in learning the respiratory system, but also contribute to creating a pleasant learning atmosphere, so this media is suitable for application in the field of education.

Effectiveness of 3D Mock-up Media in Respiratory System Learning

The next stage is Implementation. After obtaining media validation from media experts and material validation from material experts, it has been declared suitable for learning about the respiratory system. Researchers began to implement it in the learning process. However, before the media was used, a pre-test was conducted to measure students' initial understanding. Furthermore, the respiratory system material was delivered with the help of 3D mock-up media for three meetings. Furthermore, at the third meeting, researchers conducted a post-test. The next step, to measure the effectiveness of 3D mock-up media in learning, was carried out through a paired sample T-test. The results of the test analysis are presented in the table below:

Table 9. Paired Sample T-test Results

			95% Confidence Interval of the Difference				
Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
-25.320	12.348	2.470	-30.417	-20.223	-10.253	24	.000

Table 9 shows that the results of the paired sample t-test show a significance value (sig2-tailed) of 0.00, meaning (0.000 <0.05). This shows that student learning outcomes before and after using 3D mock-up media to study the respiratory system experienced significant changes (0.0000 <0.05). In addition, an N-Gain test was conducted to determine the increase in learning outcomes based on the pretest-post-test, and the results are shown as follows:

Table 10. N-Gain Results

N	Minimum	Maximum	Mean	Std. Deviation
25	-.54	1.00	.6620	.34079
25				

The N-Gain value is obtained from the difference between the post-test value and the pre-test result, then divided by the ideal score. Based on Table 10. The N-Gain result obtained is 0.662, indicating that the value falls within the moderate range. Although a minimum value of 0.54 indicates that one student experienced a decline in learning outcomes, the 3D mock-up media is generally classified as effective in improving learning outcomes.

The improvement of student learning outcomes shows that 3D mock-up media has proven effective for use in learning about the respiratory system. The ability of this media to present abstract concepts interestingly has proven to foster students' interest in learning. This can be seen from the average N-Gain value of 0.662, which is included in the moderate category. So it can be concluded that the use of 3D mock-up media contributes to improving student learning outcomes.

The final stage is evaluation. This stage aims to assess how well the media contributes to the achievement of learning objectives related to the respiratory system material by students. At this stage, a questionnaire was distributed to determine the responses of teachers and students to the use of 3D mock-up media, which can later be used as evaluation material in the future. The results of the teacher's responses can be seen in the following table:

Table 11. Results of teacher responses

Indicator	Score	Percentage (%)
Suitability of the curriculum and needs	10	100%
Appearance	14	93%
Benefit	24	96%
Amount	48	
Maximum amount	50	
Acquisition score	96%	

Based on Table 11. The sum of each indicator shows a score of 48 out of a maximum score of 50. Meanwhile, the average assessment of teacher responses to 3D mock-up media produces a percentage of 96%. This shows that the teacher's assessment of mock-up media is in the excellent category. Meanwhile, to find out the student's response, it can be seen in the following table:

Table 12. Results of student responses

Indicator	Score	Percentage(%)
Appearance	240	96%
Language	232	93%
Manfaat	1.100	97%
Amount	1.572	
Maximum amount	1.625	
Acquisition score	95%	

Based on Table 12. The sum of each indicator shows a score of 1,572, out of a maximum score of 1,625. Meanwhile, the average assessment of student responses to 3D mock-up media yields a 95% success rate. This shows that student assessments of 3D mock-up media are also in the excellent category.

These responses indicate that 3D mock-up media have proven effective for use in learning the respiratory system. The ability of this media to present abstract concepts interestingly has proven to foster students' interest in learning. This can be seen from the average N-Gain value of 0.662, which is included in the moderate category. So it can be concluded that the use of 3D mock-up media contributes to improving student learning outcomes. This effectiveness is further strengthened by various features that support students' understanding in learning respiratory system material.

One of the superior features that helps the learning process is the presence of indicator lights. This media is equipped with indicator lights to make it easier for students to name the various organs that play a role in the respiratory system. Research by Ngainin (2024) also states that this type of media is effective in helping students' understanding, as well as improving students' memory through meaningful learning. Delivering material using mock-up media can add an interesting impression to the learning material and can encourage students' curiosity (Sulthon Firdaus, 2019). In addition, research by Nasirudin Muhammad (2024) also shows that 3D mock-up media gets an N-gain value of 0.71, indicating that 3D mock-up media is very effective for learning the respiratory system. Thus, it can be concluded that 3D mock-up media has proven to be effective for use as a learning aid.

The various advantages of 3D mock-up media make it an effective learning medium for respiratory system material. In addition to presenting more realistic visualizations, this media also involves students' active participation. So, with 3D mock-up media, it can not only increase the effectiveness of learning on respiratory system material, but also support the creation of a pleasant learning atmosphere. In addition to the advantages, several limitations were found in the development of 3D mock-up media that need to be improved in the future, including: (1) the size of the media is quite large, and the wood material used requires a reasonably large and safe storage space from the reach of children (2) the use of this media requires active participation from students directly, so that it requires a longer learning time. Therefore, good time management skills are needed from teachers. However, 3D mock-up media has been proven to increase students' interest and motivation to learn, thereby achieving learning objectives.

Conclusion

Research related to the development of 3D mock-up media in respiratory system learning in schools was conducted using the ADDIE model, which has five steps. At the analysis stage, the process involved observation, interviews, and the distribution of questionnaires to teachers and students. The results found that students had difficulty understanding abstract material, while teachers experienced obstacles when delivering material without the help of media. At the design stage, the product's design, validation instruments, and teacher and student response questionnaire sheets were developed. Furthermore, at the development stage, the product that had been previously designed was made. At this stage, the media validity test results achieved scores of 98.6% and 97.3% in the very valid category, while the material validity test results reached 97.75% in the same category. The implementation stage involved applying 3D mock-up media to respiratory system learning in class V SDN 3 Ngeling. The implementation results, as shown by the paired sample T-test, indicate an increase in learning achievement, with an average N-Gain value falling within the moderate category. The results of the implementation indicate that the 3D mock-up media is suitable for use in learning. At the evaluation stage, it is carried out to assess how effective the media is in achieving learning objectives. Obtained. The results can be seen in the results of the teacher and student response questionnaires, which obtained scores of 96% and 95%. Thus, the 3D mock-up media is declared valid, feasible and effective for use in learning the respiratory system.

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