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Article

BIOMECHPAS: Integrated Science Media Based on Pascal's Law and Simple Machines for Simulating the Human Arm Movement System

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ABSTRACT

This study aims to develop learning media in the form of a teaching aid representing the human arm movement system. This medium is designed to be used in physics lessons on pressure (Pascal's Law) and biology lessons on the human movement system. The integration of these two subjects is expected to help students better understand the relationship between the concept of pressure and the mechanism of arm movement in humans. In addition, this medium also introduces the concept of simple machines involved in the arm movement system. This type of research is classified as Research and Development (R&D) using a 3D development model, which includes the following stages: (1) defining the requirements, (2) designing the media, and (3) developing and testing the media. Data were collected through validation questionnaires administered to a team of five media and material experts. The obtained data were analyzed using a quantitative descriptive method. The validation test results showed an average score of 4.06, which falls within the "good" category (3.41–4.20). Therefore, it can be concluded that the learning media on the human arm movement system developed in this study is suitable for use as a teaching aid in junior high school science education.

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INTRODUCTION

Science education at the junior high school level requires students to understand concepts holistically and integrate branches of science, such as physics and biology. However, in practice, the learning process often faces obstacles due to the limited availability of learning media that can link these concepts in a concrete and contextual manner. Observations at the school where the internship was conducted showed that the science laboratory was not being used optimally. Some laboratory rooms

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had even been converted into classrooms, while some of the teaching aids were no longer suitable for use. This situation led to a reduction in practical activities, making it difficult for students to understand scientific concepts in a real and in-depth manner (Qosyim & Priyonggo, 2017).

Laboratories play an important role in science learning in junior high schools. They serve as a means to develop scientific process skills, foster curiosity, and build conceptual understanding through direct experience. Through practical activities, students not only learn to understand theory but also observe natural phenomena empirically and relate them to the scientific concepts they have learned (Ramlawati, 2017). In addition, laboratory-based learning can also increase learning motivation and foster scientific attitudes such as thoroughness, critical thinking, and objectivity (Rahmawati & Suyono, 2020). Therefore, optimizing the function of laboratories is an important aspect in realizing meaningful and contextual science learning at the junior high school level.

One of the subjects that requires concrete learning media support is fluid pressure, especially in the application of Pascal's Law in everyday life. This subject is often conveyed only through text or two-dimensional images, making it difficult for students to imagine how pressure works and moves in fluids. The limitations of visual media and practical activities result in students' understanding of the relationship between pressure, force, and surface area being less than thorough (Soeharto, 2021). The use of technology-based media and interactive experiments can help students visualize the concept of pressure more realistically, thereby supporting the formation of a stronger conceptual understanding (Sahida et al., 2020). In the context of integrated learning, the material on fluid pressure can be linked to simple machines, such as the use of hydraulic jacks that apply Pascal's Law to multiply force. The integration of these two materials allows students to understand the relationship between abstract physics concepts and their application in the working mechanisms of simple tools in everyday life.

To overcome these problems, innovative learning media are needed that not only display the working process of the human musculoskeletal system, but also integrate relevant physics concepts. One concept that can be applied is Pascal's Law, which states that pressure applied to a fluid in a closed space will be transmitted equally in all directions. This principle can be used to mimic the mechanism of muscle action using a simple hydraulic system (Andri et al., 2016). This approach not only shows the relationship between physics and biology concepts but also fosters an understanding that natural phenomena are interrelated and can be explained scientifically through integrative models.

Based on this idea, the BIOMECHPAS (Biomechanical Pascal System) learning media was developed, which is an integrated science media based on Pascal's Law and the principles of simple machines used to simulate the human arm movement system. This media is designed to show the mechanism of contraction and relaxation of the biceps and triceps muscles in real life through a fluid pressure system using a syringe filled with water. In addition, this media also introduces the concept of a lever-type simple machine that works similarly to the movement of the human arm. Thus, students can see how fluid pressure and mechanical principles work together in the human body system (Sahida et al., 2020).

The development of learning media such as BIOMECHPAS plays a strategic role in supporting contextual and hands-on science learning. Media that allow students to interact with real scientific phenomena can increase motivation and engagement in learning, as they are directly involved in the process of observation and scientific reasoning. This is in line with the results of a study (Rahmawati et al., 2022), which shows that the use of contextual phenomenon-based experimental media can increase scientific activity and understanding of fluid pressure concepts in junior high school students. Furthermore, Susanti et al. (2023) emphasize that the integration of physics and biology concepts in a single learning medium effectively improves analytical thinking skills and cross-disciplinary concept understanding, which are important characteristics in integrated science learning.

The BIOMECHPAS media is expected to create a more interactive, interesting, and meaningful learning process. Through this approach, students not only learn theory but also directly observe the application of fluid pressure concepts and mechanical principles in a biological context. Teachers are also assisted in explaining the relationship between physics and biology in an integrated manner, in line with the characteristics of integrated science learning at the junior high school level (Soeharto, 2021). Thus, the development of BIOMECHPAS media not only serves as a means of visualization but also as a conceptual and pedagogical tool that helps students understand the interrelationships between scientific concepts. This media is expected to address learning issues that are still predominantly theory-oriented, as well as provide a solution to the limitations of laboratory facilities in schools. Through the

application of integrative and applicable media, the science learning process can become more meaningful, active, and encourage students' scientific thinking skills in line with the demands of the 21st-century curriculum.

METHOD

This study uses the Research and Development (R&D) method with a 3D model consisting of the Define, Design, and Develop stages. This method was used to develop and test the feasibility of a product that will later be applied in the world of education. The 3D model-based R&D method was chosen because this approach allows researchers to refine the developed product to suit the needs of science learning (Waruwu, 2024).

The selection of R&D methods was based on the need to create innovative, tested learning media that were in line with the characteristics of science learning in schools. Through this approach, researchers could conduct repeated evaluations at each stage so that the resulting products truly fulfilled functional, educational, and visual aspects. The 3D development model also provides flexibility for researchers to make revisions based on expert validation results and limited field trials.

The stages in the 3D development model are described as follows:

a) Define Stage

This stage focuses on identifying needs and gathering information relevant to the media development objectives. Researchers analyze the conditions of science learning in schools, including the availability of teaching aids, laboratory facilities, and student characteristics. The results of the analysis are used to determine the important aspects that need to be accommodated in the BIOMECHPAS media design, such as liquid pressure material, the application of Pascal's Law, and the human arm movement system.

b) Design Stage

At this stage, researchers design the form and structure of BIOMECHPAS learning media by considering functional, aesthetic, and usability aspects. The design process includes material selection, size determination, and the combination of components that represent the human arm movement system. In addition, educational and safety aspects are also important considerations so that the media can be used effectively by teachers and students in teaching and learning activities.

c) Development Stage

This stage is the process of refining the media and testing its feasibility through expert validation. Validation is carried out by five experts, consisting of media experts and subject matter experts (science teachers). Each validator assesses the suitability of the content, appearance, mechanical function, and accuracy of the concepts in the developed media.

The assessment is carried out using a validation test instrument compiled in the form of a Likert scale with a value range of 1–5. The validation data is then analyzed using a calculation formula to determine the product's feasibility level (Madiyantoro, 2021). The formula used to calculate the average value of the validity test results is as follows:

Average Rating per Validator

$$Final\ score = \frac{\Sigma\ Score\ Obtained}{\Sigma\ skor\ item}$$

Final Validation Test Score

$$Final\ value\ of\ validator\ test = \frac{\Sigma\ validator\ vinal\ score}{\Sigma\ final\ validator\ item\ score}$$

The eligibility criteria for media instruments are as follows:

Table 1. Media instrument feasibility criteria

Score Interval	Description
4,21 - 5,00	Very Good
3,41 - 4,20	Good
2,61 - 3,40	Enough
1,81 - 2,60	Less
1,00 - 1,80	Very Poor

RESULT AND DISCUSSION

Development Of Bimechpas Learning Media

The development of BIOMECHPAS learning media was carried out using the 3D model (Define, Design, Develop), with each stage carried out systematically to produce media that is valid, effective, and suitable for use in junior high school science learning. The define stage began with observations of science learning conditions at the junior high school level, which showed limitations in laboratory facilities and suboptimal teaching aids. As a result, practical activities were rarely carried out, so that the learning process tended to focus on theoretical explanations and minimal direct experience. This condition had an impact on students' difficulty in understanding abstract and multidisciplinary science concepts, especially in the material on the human motion system, which required the integration of biology and physics concepts. These findings are in line with research (Anjiana et al., 2023), which explains that the management of science laboratories in many schools is still ineffective, both in terms of the availability of tools and materials and the utilization of space, so that the learning process is not yet fully contextual and scientific.

To address this issue, Pascal's Law was established as the main concept in the development of learning media, because its principles are very relevant to demonstrate the relationship between fluid pressure and mechanical force. Pascal's Law states that pressure applied to a fluid in a closed space will be transmitted equally in all directions ($P = F/A$). The application of this principle in simple media is illustrated by two syringes connected by a tube filled with water so that students can directly observe how fluid pressure is transmitted and produces mechanical motion. The results of the study (Sulistyawati, 2021) show that media based on a simple hydraulic system is effective in improving students' understanding of the concept of fluid pressure because it provides concrete experiences that foster scientific understanding through manipulative activities.

In addition, the concept of a simple lever-type aircraft was also integrated because it is directly relevant to the mechanism of human arm movement. The human arm mechanically functions as a third-class lever, where the fulcrum is at the elbow, the force is generated by muscle contraction, and the load is at the hand. By combining the principles of Pascal's Law and simple machines, the developed media is expected to be able to show the functional relationship between fluid pressure and the biological movements of the human body in a tangible way.

The design stage is a continuation of the needs analysis in the define stage, where the design focuses on producing learning media that can integrate the concepts of fluid pressure (Pascal's Law), simple lever-type machines, and the human arm movement system in a concrete and contextual manner. The media design was carried out based on the principles of simplicity, efficiency, and relevance to the characteristics of junior high school students who need experiential learning.

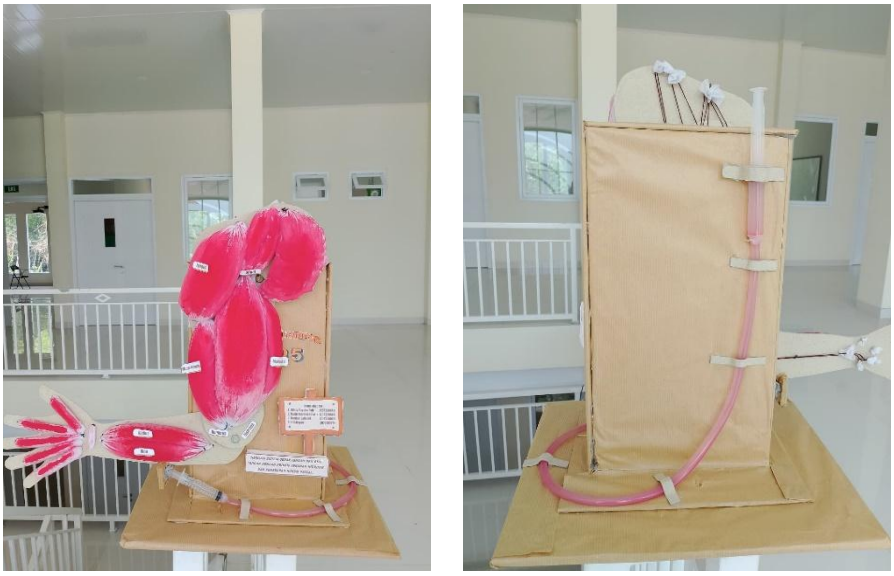

Figure 1. BIOMECHPAS Learning Media

The developed medium is named BIOMECHPAS (Biomechanical Pascal System), which works based on a simple hydraulic system as a direct application of Pascal's Law. This medium is designed using plywood as the main base to maintain the stability of the tool, thick cardboard is shaped to resemble the upper and lower arms of a human, and connected using bolts and nuts as fulcrums. This component mechanically represents a simple type III lever, where the force is between the fulcrum and the load. To demonstrate Pascal's Law, the medium is equipped with two syringes connected by a tube filled with water. When one syringe is pressed, the fluid pressure is transmitted to the other syringe and causes movement in the arm. This mechanism visually illustrates the contraction of the biceps muscle and relaxation of the triceps muscle, where fluid pressure produces a mechanical force similar to muscle work. This working principle is in line with the findings (Sulistyawati, 2021) that the application of a simple hydraulic system can clarify students' understanding of the concept of fluid pressure through manipulative experience. In developing the BIOMECHPAS media, the application of Pascal's Law needs to be designed with a commonly used mechanical form rather than directly depicting muscle motion, to avoid misconceptions that fluid pressure replaces human muscle functions. The media should focus on showing the transmission of pressure in a closed system according to Pascal's Law, which states that the pressure applied to a confined fluid is transmitted equally in all directions (Giancoli, 2005).

Moreover, the theoretical basis in the media must be strengthened to ensure conceptual and mechanical robustness. Pascal's Law must serve as the primary foundation, while the human motion system acts only as a contextual analogy. This aligns with Halliday & Resnick (2013), who emphasize that physics models must maintain conceptual validity and distinguish between biological and mechanical phenomena. Therefore, the design should employ simple systems such as third-class levers connected with hydraulic pistons, demonstrating the relationship between force (F), pressure (P), and area (A) without confusing biological interpretations. Students can directly observe the principle P = F/A, where equal pressure generates different forces depending on the surface area.

Penguatan teori yang mendasari media ini meliputi:

1. Hukum Pascal: Tekanan yang diberikan pada fluida dalam ruang tertutup akan diteruskan sama besar ke segala arah. Prinsip ini menjelaskan cara kerja sistem hidrolik dan menjadi dasar rancangan media BIOMECHPAS (Giancoli, 2005).
2. Konsep Gaya dan Luas Penampang (P = F/A): Semakin besar luas penampang penerima tekanan, semakin besar gaya yang dihasilkan (Serway & Jewett, 2018).
3. Sistem Tuas Kelas III: Digunakan untuk menjelaskan hubungan antara titik tumpu, gaya, dan beban yang secara mekanik menyerupai gerakan lengan manusia, tanpa menggambarkan proses biologis yang sebenarnya (Hibbeler, 2016).

4. Validitas Model Fisika: Model atau alat peraga dalam fisika harus menggambarkan prinsip ilmiah secara akurat dan tidak mengaburkan batas konsep lintas disiplin (Halliday & Resnick, 2013).
5. Pembelajaran IPA Terpadu: Integrasi konsep fisika dan biologi perlu dijaga agar saling menguatkan tanpa menimbulkan miskonsepsi antar bidang ilmu (Suyono & Hariyanto, 2020)

Dengan penguatan teori dan penyesuaian desain tersebut, media BIOMECHPAS tidak hanya menarik secara visual, tetapi juga memiliki dasar ilmiah yang kuat, minim miskonsepsi, dan memenuhi kriteria pembelajaran IPA terpadu berbasis konsep yang valid. Media ini berpotensi menjadi sarana efektif untuk menjembatani konsep fisika dan biologi tanpa menurunkan ketepatan ilmiahnya. After the BIOMECHPAS media have been designed, the next step in development is validation testing to ensure that the media are truly suitable for integrated science learning needs. This stage is very important because, through validation, the accuracy of the concept, clarity of presentation, and suitability of the media's functions can be objectively assessed by experts before being implemented in the classroom. This is also in line with the opinion of (Nisrina et al., 2024), that validation is an important step in development research that aims to assess the suitability of product design with user needs.

Validator	Average Score	Category
Validator 1	4,66	Good
Validator 2	3,86	Good
Validator 3	3,93	Good
Validator 4	3,93	Good
Validator 5	4,06	Good
Average	**4,08**	**Good**

Table 2. BIOMECHPAS Media Validation Test Results

The BIOMECHPAS (Biomechanical Pascal System) media validation test results were conducted by five validators, consisting of media experts and material experts. Each validator assessed the suitability of the media based on aspects of content, appearance, conceptual integration, ease of use, and mechanical accuracy. Based on the assessment results presented in Table 1, an overall average score of 4.08 was obtained, which falls into the “Good” category. In detail, the average scores given by the validators ranged from 3.86 to 4.66, all of which were in the good category. These results indicate that the BIOMECHPAS media have met the criteria for content validity and functional suitability for use in integrated science learning at the junior high school level.

The Implications Of Biomechpas Media On Students' Thinking Skills And Conceptual Understanding

The use of BIOMECHPAS (Biomechanical Pascal System) media in science education has significant implications for improving students' scientific thinking skills and conceptual understanding. Through mechanical simulations that integrate Pascal's Law principles, simple lever-type devices, and human arm motion systems, students can directly observe how fluid pressure can produce mechanical motion in biological systems. This activity encourages students to think analytically and reflectively, as they are required to reason the cause-and-effect relationship between pressure, force, and muscle movement. According to Widyaningrum et al. (2022), concrete experiment-based learning is effective in improving students' scientific reasoning because it provides opportunities for independent observation, data interpretation, and conclusion drawing.

BIOMECHPAS plays an important role in strengthening students' conceptual understanding of the interrelationships between science subjects. The integration of physics and biology concepts in a single medium enables students to construct a complete cognitive schema, so that

they do not view science as separate disciplines, but rather as a single interconnected system. This finding is in line with the results of a study (Fauziah et al., 2021), which shows that learning based on the integration of physics and biology concepts can improve middle school students' conceptual understanding and long-term retention. Thus, BIOMECHPAS not only functions as a visual aid but also as a conceptual medium that encourages the development of scientific, critical, and contextual thinking, in line with 21st-century science learning that emphasizes higher-order thinking skills.

Furthermore, the use of BIOMECHPAS media encourages a transformation from passive to active and reflective learning, as students not only observe but also run simulations that synchronize mechanical movements with scientific principles. This enables them to develop scientific reasoning through the stages of exploration, experimentation, and reflection, as found (Hanum et al., 2024) in scaffolding-based e-science modules to improve scientific reasoning in junior high school students. The use of this media can also strengthen students' conceptual understanding because they can build holistic cognitive schemas; students no longer see fluid pressure, levers, and arm motion systems as separate topics, but as a single scientific phenomenon. Mastery of science concepts greatly influences students' ability to solve physics problems. Therefore, BIOMECHPAS not only functions as a visual aid but also as a conceptual medium that facilitates scientific, critical, and contextual thinking, which is highly relevant to the demands of higher-order thinking skills in 21st-century science education (Silaban & Nainggolan, 2023).

Advantages And Limitations Of The Media

Advantages Of The Media

The BIOMECHPAS (Biomechanical Pascal System) learning media have several relevant and significant advantages in supporting the quality of science learning at the junior high school level. One of its main advantages lies in its ability to present scientific concepts in a concrete and integrated manner, thereby helping students understand the relationship between Pascal's Law, simple machines, and the human arm movement system through direct experience. The hydraulic simulation process displayed allows students to observe the relationship between fluid pressure, force, and muscle movement in real life, thereby fostering scientific thinking skills and a deeper conceptual understanding. These findings are in line with Lubis, Febriani, Fitra Yana, Azhar, and Darajat (2023), who stated that the use of manipulative and visual learning media can increase active engagement and science learning outcomes because it facilitates the process of thinking from concrete to abstract.

In addition, BIOMECHPAS is capable of creating interactive and collaborative learning, as its use encourages students to discuss, hypothesize, and evaluate their observations together. This supports the application of inquiry-based learning, which is characteristic of modern science learning. According to Sari, Rosidin, and Wahyudi (2022), simple experimental media that guide students to conduct observations and scientific reasoning can improve critical thinking skills and learning motivation. Furthermore, BIOMECHPAS also has high pedagogical value because it combines mechanical visualization, scientific process skills, and interdisciplinary concepts. This integration makes the media not only a demonstration tool, but also a conceptual tool that supports contextual learning in accordance with Higher Order Thinking Skills (HOTS) requirements.

From the teacher's perspective, BIOMECHPAS media helps overcome the limitations of laboratories and teaching aids, which are often obstacles in science learning in schools. With simple, easily obtainable, and environmentally friendly materials, this media can be an alternative to inexpensive and efficient experimental tools without reducing their scientific value. As stated by Suhendri, Handayani, and Nuraini (2023), simple tool-based media developed from local materials are highly effective in bridging science theory and practice,

especially in schools with limited laboratory facilities. Thus, BIOMECHPAS not only enriches the variety of teaching methods available to teachers but also expands students' access to authentic and applied learning experiences.

Limitations Of The Media

This media has several limitations, such as the fact that it is made of plywood covered with paper and cardboard, which is quite significant and needs to be taken into consideration in its development. One of the main weaknesses is the limited durability of the media. Plywood tends to warp and crack when exposed to changes in temperature and humidity, while the paper and cardboard layers are prone to tearing, fading, and becoming dirty due to repeated use and exposure to the environment. These conditions cause the media to deteriorate quickly and not last long, especially if it is frequently moved or used intensively by students. Cahyadi et al. (2024) also found that plywood-based learning media have weaknesses in terms of physical durability and are difficult to store for long periods of time because it is prone to deformation due to changes in room temperature.

In addition, this type of media also has limitations in terms of care and maintenance. Plywood and paper media must be kept away from water or moisture, as this will accelerate damage. This requires extra attention from teachers and students in using it, so that it sometimes becomes less practical in the daily learning process. From an aesthetic point of view, paper layers that tear and fade easily can reduce the visual appeal of the media, making it less effective in motivating students to learn. Farida et al. (2023) added that paper materials in learning media have limitations in terms of aesthetics and durability, especially if they are not coated with additional protection or lamination, as they quickly experience a decline in color and texture quality.

CONCLUSION

Based on the validation results conducted by five expert validators, the BIOMECHPAS learning media obtained an average score of 4.08, which is classified as “Good.” This indicates that the developed media is suitable for use in science learning processes at the junior high school/MTs level. BIOMECHPAS media is designed to display a hydraulic system that resembles the working mechanism of the arm muscles, while also showing the application of simple machines that work in the human arm movement system. With a design that integrates these two concepts, the media enables students to understand how force, fulcrum, and load interact in arm movement, as well as how fluid pressure in accordance with Pascal's Law is applied in biological and mechanical contexts.

The use of BIOMECHPAS media in learning can help students understand the relationship between physics concepts (pressure and Pascal's Law) and biology (the human arm movement system) in a more concrete and meaningful way. Visualization of arm movement and demonstration of simple aircraft principles allow students to directly see the relationship between the concepts of force, pressure, and human body mechanisms, making the learning process more interactive, interesting, and easy to understand. This cross-disciplinary integration also has the potential to improve students' ability to connect theory with real phenomena, facilitate conceptual understanding, and minimize misconceptions that often arise in integrated science subjects.

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