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Article

BATIK (Batang Interaktif Kapilaritas): Educational Media for Learning Concepts of Structure and Mechanisms of Water Transport in Plants

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ABSTRACT

Science education at the junior high school level is often abstract, making it difficult for students to understand the structure and function of plant tissues and the process of water transport. BATIK (Batang Interaktif Kapilaritas) is a new innovation that integrates biology and physics concepts through the visualization of the capillary process in plants. This study aims to develop an innovative three-dimensional learning medium called BATIK (Interactive Capillary Stem) to help students understand the relationship between the structure of leaves, stems, and roots in the water absorption process, and to relate it to the principles of capillarity, adhesion, and cohesion in a concrete and interactive manner. The uniqueness of this media lies in the presence of water-absorbing sponge elements and simple measuring tools that allow students to directly observe the water absorption process. This research uses the Research and Development (R&D) method with a 3D model (Define, Design, Develop). The validation results show a media feasibility level of 91.2% (very feasible category). This media is considered to help teachers explain the concept of capillarity in a concrete manner, attract students' interest in learning, and train scientific process skills. Thus, BATIK media is suitable for application in junior high school/MTs science learning as an innovative tool for understanding the mechanism of water transport in plants.

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INTRODUCTION

21st century learning requires the world of education to produce human resources (HR) who are not only excellent in terms of knowledge, but also have a balance between attitude and skills (Lukman & Firmansyah, 2022). In line with these demands, the education system in Indonesia continues to strive to develop various innovative learning media so that the learning process becomes more meaningful and able to foster critical and creative thinking skills in students. One subject that plays an important role in shaping scientific thinking skills is Natural Sciences (IPA), especially at the junior high school (SMP) level. However, in practice, IPA learning in schools still tends to be theoretical and teacher-centered, so that students often have difficulty understanding abstract concepts.

One of the topics that often causes difficulties is the structure and function of plant tissues, especially the mechanism of water transport from the roots to the leaves. Concepts such as

capillarity, adhesion, and cohesion are difficult to understand if they are only explained verbally without the aid of concrete media. As a result, students' understanding of concepts and scientific process skills become low. The use of real media can help teachers increase student participation and improve their understanding of the material (Nursofiza et al., 2024).

The main problem in science education lies in the lack of interactive learning media that can bridge abstract concepts to real and meaningful learning experiences. In fact, learning media serves as a tool to clarify material, deepen understanding, and train students' thinking skills (Rafika Putri, 2022). This condition is exacerbated by the minimal use of learning media in schools, which is one of the obstacles in the teaching and learning process. Rahma et al. (2024) state that low student learning outcomes are caused by the lack of effective learning media, making it difficult for students to understand complex concepts, especially those that are difficult to visualize. Zalnika and Rochintaniawati (2023) emphasize that teachers' ability to manage and utilize learning media has a significant impact on the effectiveness of the learning process. Similarly, Maharani et al. (2022) mention that the use of learning media is an important strategy to increase student engagement and present material in an interesting and easy-to-understand manner. Miranda et al. (2022) also prove that the appropriate use of learning media can significantly improve student learning outcomes. Although various studies show the effectiveness of innovative media, most of the media used in schools are still limited to two-dimensional visualizations such as images or digital animations, which do not provide an immersive experience.

As a solution to this problem, this study developed the BATIK (Batang Interaktif Kapilaritas) learning media. This media is designed in three dimensions, combining the concepts of biology and physics to explain the mechanism of water absorption in plants through the process of capillarity. BATIK media uses artificial stems equipped with water-absorbing sponge elements and simple measuring devices so that students can directly observe the rate of water absorption. Through this simulation, students can understand the relationship between the structure of roots, stems, and leaves in the water transport process more concretely. In addition, the application of experimental methods in the use of this media provides space for the development of critical thinking skills, creativity, and collaboration among students, important components in 21st-century scientific learning (Widiya & Radia, 2023).

The main innovation of this research lies in the development of BATIK media that is concrete, interactive, and easy to use by both teachers and students. This media not only presents a realistic visualization of the capillarity process, but also integrates a hands-on learning approach to strengthen students' understanding of scientific concepts and hone their scientific thinking skills.

METHOD

This study used a research and development method with a 3D model (Define, Design, Develop) adapted from Thiagarajan, Semmel, and Semmel (1974). This method was chosen because it was suitable for producing simple, valid, practical, and feasible experiment-based learning media for junior high school science education. In the define stage, the researcher identified learning needs by analyzing the junior high school science curriculum, particularly the basic competencies regarding the mechanism of water transport in plants. An analysis of student characteristics was also conducted to determine the initial level of understanding and difficulties experienced by students in understanding the concept of capillarity. In addition, a literature review was conducted to obtain theoretical basis and examples of similar media development. The design stage was carried out by designing BATIK (Batang Tiruan Kapilaritas) media in the form of a transparent rod model equipped with a sponge as an artificial root and food coloring as an indicator of water movement. At this stage, a validation instrument was also developed in the form of a 1–5 Likert scale questionnaire covering six aspects, namely

material suitability, durability, accuracy, efficiency, aesthetics, and student safety. The development stage included the creation of a media prototype, which was then validated by four expert validators who were junior high school science teachers. The validators provided quantitative assessments and suggestions for media improvements. Revisions were made based on the input to ensure that the media met the eligibility criteria. The validation data were analyzed using the average and feasibility percentage formulas according to the theories of Arikunto (2005) and Usman & Akbar (2008). Quantitative analysis was carried out systematically through the stages of calculating the average score and feasibility percentage to determine the feasibility level of the developed media.

The validated data were analyzed using simple qualitative and quantitative descriptive methods. Quantitative analysis was performed by assigning scores to each indicator according to the assessment scale. The average value for each criterion was calculated using the following formula:

$$X = \frac{\sum x}{N}$$

Description:

X = Average value

$\sum x$ = Total score obtained

N = Number of validators

Table 1. Media Quality Criteria

No	Score Interval	Category
1.	4,21-5,00	Very Good
2.	3,41 – 4,20	Good
3.	2,61 – 3,40	Enough
4.	1,81 – 2,60	Less
5.	1,00 – 1,80	Very Poor

Then the average score is converted into a percentage of eligibility using the formula:

$$P = \frac{\text{Total score obtained}}{\text{Criteria score total}} \times 100\%$$

Table 2. Media Eligibility Percentage Criteria

No	Percentage	Category
1.	81% – 100%	Highly recommended
2.	61% – 80%	Worthy
3.	41% – 60%	Quite Adequate
4.	21% – 40%	Unsuitable
5.	0% – 20%	Not suitable

RESULT AND DISCUSSION

This study produced BATIK (Batang Interaktif Kapilaritas) learning media designed to help students understand the concepts of plant tissue structure and water capillarity mechanisms in concrete terms. The development of this media was carried out through three stages of the 3D model (Define, Design, Develop) with a research and development approach. The results of the study show that the developed media obtained a very high feasibility score and had a positive impact on students' understanding of science learning at the junior high school level.

The BATIK medium is a three-dimensional model resembling a plant stem. The bottom part is equipped with a sponge as an artificial root that absorbs water from the container, while the stem is made of a transparent tube so that the process of water rising through capillary action can be observed directly. The water used is colored so that its movement is more clearly visible, while a simple measuring scale is attached to the tube to measure the rate of water movement. This design allows students to make real observations of the concepts of adhesion, cohesion, and surface tension, which have been difficult to understand abstractly.

The validation results by four validators, consisting of science teachers, showed that BATIK media obtained an average score of 91.2% with a category of very feasible. The

assessment was based on six aspects: material suitability, durability, accuracy, efficiency, aesthetics, and safety. The validation results data can be seen in the following table.

Table 3. Validation Result

No	Validator Name	School of Origin	Percentage (%)	Category
1	Suroso, S.Pd.	SMPN 3 Karangjati	90,5	Highly Recommended
2	Fery Prahara Mukti, S.Pd.	SMPN 1 Karangjati	92,0	Highly Recommended
3	Ulfatin Prya Yufian, S.Pd.	SMPN 3 Karangjati	89,3	Highly Recommended
4	Adilah Endah, S.Pd.	SMP Muhammadiyah 2 Ponorogo	93,0	Highly Recommended
Average			91,2	Highly Recommended

Based on this assessment, it can be concluded that BATIK media meets all eligibility criteria with consistent results in all aspects. The results of the analysis per aspect are shown in the following bar chart.

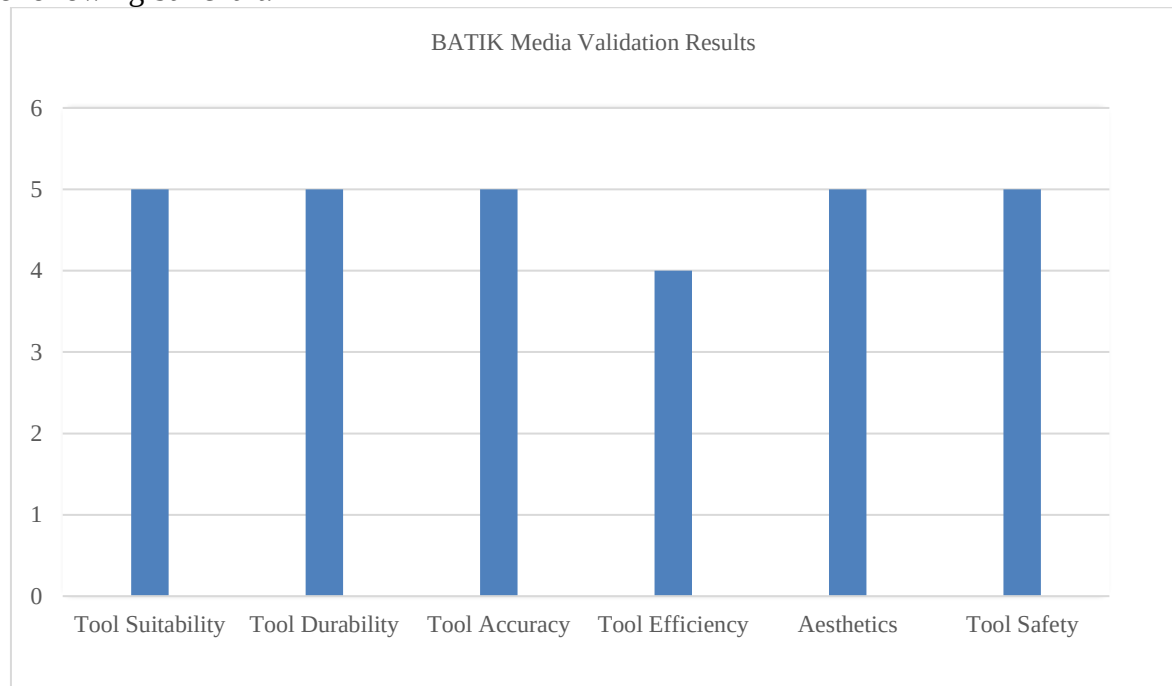


Figure 1. Diagram of BATIK Media Validation Results

Diagram 1. BATIK media validation results based on assessment aspects (showing the highest scores for material suitability and accuracy, while the lowest score was for efficiency because it still requires drying time after use).

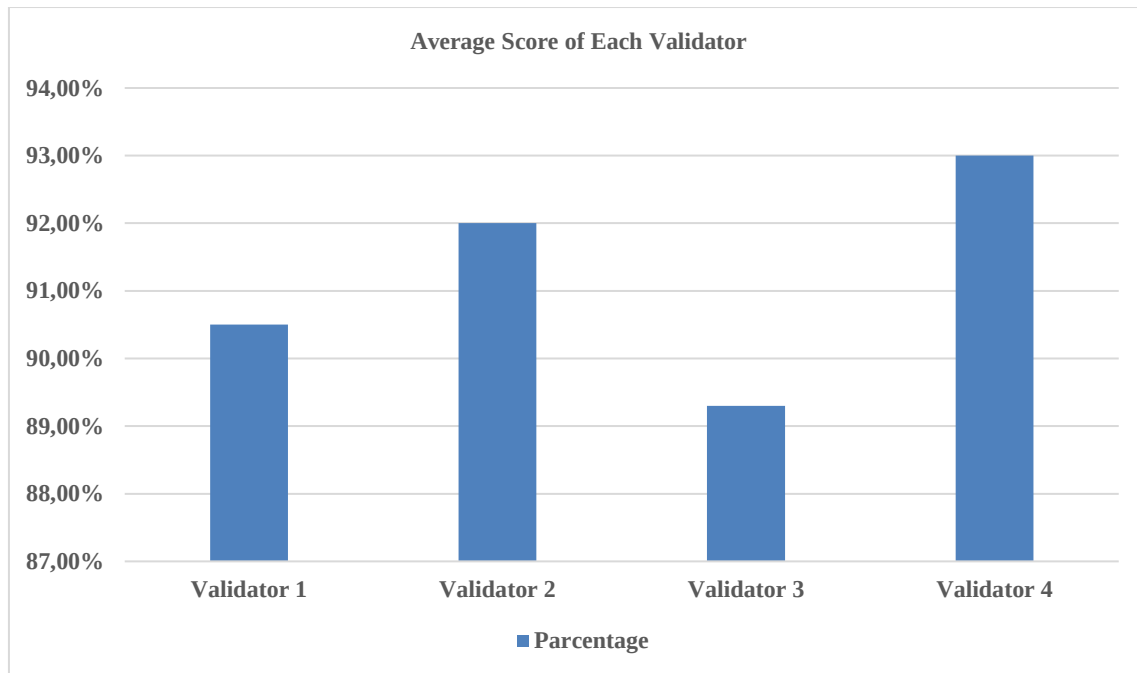


Figure 2. Diagram of BATIK Media Validation Average Score

Diagram 2. BATIK media validation results based on the average score of each validator (showing that all validators gave scores above 89%, with the highest score of 93% given by the fourth validator from SMP Muhammadiyah 2 Ponorogo).

In general, the validation results show that BATIK media has met the principles of content validity, practicality, and aesthetics. The high score in the aspect of material suitability indicates that this media has succeeded in representing the scientific concept of capillarity accurately and in accordance with basic science competencies. In addition, the aspects of accuracy and safety are also received high scores because the media is easy to use and does not pose a risk to students. The efficiency score was slightly lower than other aspects because the media requires drying time before it can be reused, but this does not reduce its overall suitability. Furthermore, the research results were analyzed based on three stages in the 3D model, namely *Define*, *Design*, dan *Develop*.

Stage Define.

The define stage is a process of analyzing needs and identifying learning problems that form the basis for designing BATIK media. At this stage, an analysis of the curriculum, student characteristics, and science material related to plant tissue structure and water transport mechanisms is carried out. The results of the analysis show that the concepts of capillarity, cohesion, and adhesion are abstract and difficult to understand if only explained theoretically. The process of water movement from the roots to the leaves cannot be observed directly, so students need media that can visualize this phenomenon in a concrete form. This condition is in line with Arsyad's (2017) opinion, which emphasizes that learning media is needed to help students understand material that cannot be observed directly in real life.

In addition, science learning at the junior high school level still mostly uses two-dimensional media such as pictures and videos. Although helpful in the initial stages of visualization, these media do not fully provide an exploratory learning experience. Sanjaya (2020) states that learning that relies solely on static visual media tends to make students passive recipients of information rather than active learners. This finding is supported by Zatnika & Rochintaniawati (2023), who identified that the limitations of simple experimental media in schools are one of the factors contributing to the low opportunity for students to conduct scientific activities directly.

Based on this analysis, it can be concluded that there is a need to develop three-dimensional media that allows students to observe the phenomenon of capillarity in real life through a visual-experiential learning approach. This approach is in line with the recommendations of Maharani et al. (2022), who state that simple practical-based media can improve students' observation skills, curiosity, and understanding of science concepts. Therefore, the define stage is the main foundation in formulating the specifications and design of BATIK media so that it is relevant to the needs of science learning at the junior high school level.

Stage Design.

This stage includes designing the media structure, selecting materials, and developing assessment instruments. Materials are selected based on their function, availability, and similarity to natural conditions. The materials used include styrofoam, sponges, and dyes to create a natural simulation of water absorption. In addition, to emphasize students' understanding of the concept of capillarity, a small hose connected to a syringe filled with yellow water is added. This tube allows water to rise through the capillary mechanism, enabling students to directly observe how water can move against gravity through a narrow channel. Thus, this media not only provides a visual representation but also an experiential learning experience that reinforces the physical and biological concepts of water absorption in plants.



Figure 3. BATIK Learning Media front view



Figure 4. BATIK Learning Media side view

At this stage, a validation rubric is also developed, covering six aspects of assessment to ensure that the media evaluation process is objective. The BATIK media design is simple but representative of the scientific processes that occur in plants. The principle of hands-on learning is applied so that students can interact directly with the media during learning.

Stage Develop

This stage included prototype development, expert validation, and limited classroom testing. After validation, the validators provided several suggestions for improvement, such as strengthening the tube connections to make them more durable and clarifying the measurement scale on the transparent rod. After revision, the media was tested on a small group of students. The results showed an increase in participation and understanding of the concept. Students were more enthusiastic and able to explain the water absorption process in their own words, demonstrating that this media is effective in converting abstract concepts into meaningful learning experiences.

From all stages, it can be seen that BATIK media successfully meets the learning needs of the 21st century, which demands active, contextual, and learner-centered learning

experiences. This finding is in line with the research by Rafika Putri (2022), which states that concrete media plays an important role in strengthening students' scientific understanding, as well as Rahma et al. (2024), which emphasizes that the use of effective media can significantly improve learning outcomes. Thus, BATIK media not only functions as a visual aid but also as an interactive learning tool that develops students' scientific thinking skills and exploratory attitudes.

Overall, the development of BATIK media can be considered successful because it meets the three main indicators of learning product success, namely validity, practicality, and effectiveness. Validity is demonstrated by the results of expert assessments which state that the content of the material and the representation of the capillary process in the media are in accordance with scientific concepts and learning competencies. Practicality is evident in the ease of use, simplicity of design, and availability of easily obtainable materials, enabling the application of the media in school environments with limited facilities. Meanwhile, effectiveness is reflected in the increased engagement, curiosity, and understanding of students regarding the mechanism of water transport in plants when using this media in learning activities. This means that BATIK not only helps visualize concepts but also encourages active learning through direct observation and simple experiments.

This is in line with Rafika Putri's (2022) research, which shows that concrete media can improve understanding of biological concepts through direct learning experiences. This finding is also consistent with Rahma et al. (2024), who stated that interactive demonstration media can increase student motivation and learning outcomes. Additionally, according to Miranda et al. (2022), visual experimental media are effective for explaining abstract biological processes that are difficult to observe directly.

Thus, BATIK is suitable for use as a science learning medium at the junior high school/MTs level. In the future, this medium has the potential to be further developed through the addition of digital features, such as water flow sensors or simple companion applications, to make it more adaptive to technology-based learning needs.

Citations

(Lukman & Firmansyah, 2022), (Nursofiza et al., 2024), (Rafika Putri, 2022), (Rahma et al.2024), Zatnika dan Rochintaniawati (2023), Maharani et al. (2022), Miranda et al. (2022), (Widiya & Radia, 2023), Semmel (1974).

Abbreviations and Acronyms

BATIK (Batang Interactive Capillarity), Science, Junior High School, R&D (Research and Development), 3D (Define, Design, Develop).

Equation

The analysis of the BATIK (Batang Interaktif Kapilaritas) learning media validation results was conducted using a quantitative descriptive approach to determine the media's suitability based on expert assessment. The validation was carried out by four validators who were science teachers at the junior high school level. The assessment aspects used included material suitability, durability, accuracy, efficiency, aesthetics, and safety. Each aspect was Type equation here, assessed using a 1–5 Likert scale, and the results showed that all aspects received high scores with an overall average of 4.56.

This value was calculated using the feasibility formula according to Arikunto (2005) and Usman & Akbar (2008) with the equation:

$$X = \frac{\sum x}{N}$$

Explanation :

X = average score

$\sum x$ = total score of all validators

N = number of validators

Next, the average value is converted into a percentage of eligibility using the formula:

$$P = \frac{X}{X_{max}} \times 100\%$$

Explanation:

P = percentage of eligibility

X_max = maximum score (5)

The results of the calculation are as follows:

$$P = \frac{4,56}{5} \times 100\% = 91,2\%$$

The results show that BATIK media is classified as highly feasible. This finding reinforces Sugiyono's (2019) research results, which state that a feasibility level above 81% is categorized as highly valid and can be used in learning activities. The highest scores were obtained in the aspects of material suitability and accuracy, indicating that the media is able to represent the scientific concept of capillarity appropriately and in accordance with basic competencies. Meanwhile, the efficiency score was slightly lower because the media requires drying time after use. Overall, the results show that BATIK media is suitable for use in science education. This is in line with the results of studies by Maharani et al. (2022) and Rahma et al. (2024), which state that the use of interactive concrete media can help students understand abstract concepts in a tangible way and increase the effectiveness of the learning process. Thus, BATIK media is considered valid, practical, and capable of supporting hands-on learning that strengthens students' scientific skills.

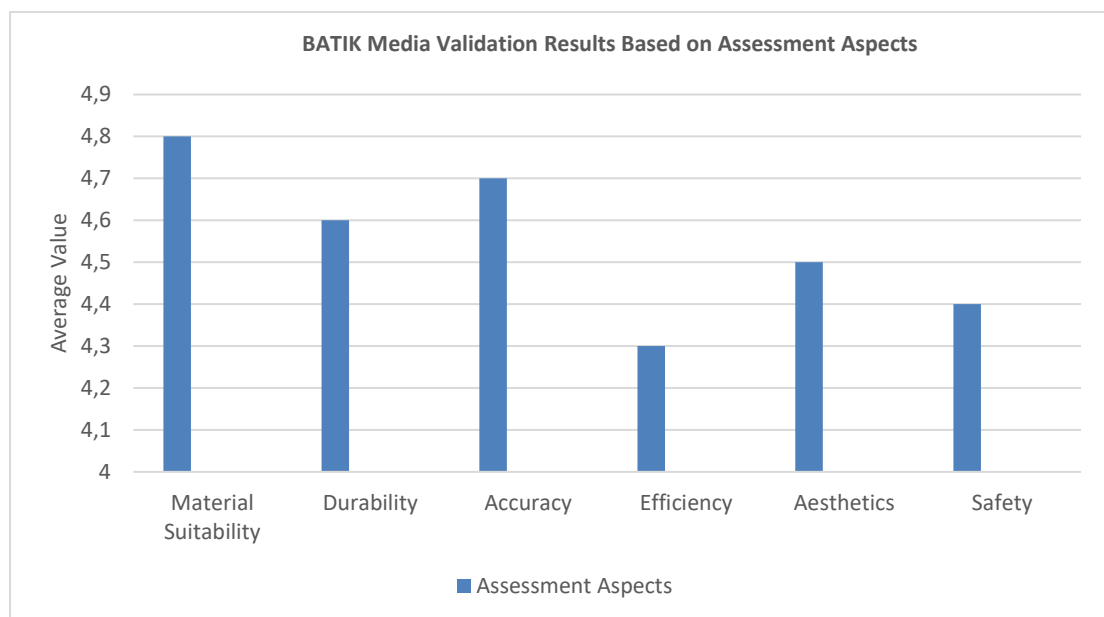


Figure 5. Diagram of BATIK Media Validation Results Based on Assessment Aspects

Miscellaneous

During the validation process, experts provided constructive feedback on improving the quality of the media so that it could be used more effectively in learning. Several key recommendations focused on improving the physical structure and clarity of the observation components. Validators suggested that the connections between the parts of the rod be strengthened to increase the durability of the media when used repeatedly. In addition, the measuring scale on the transparent tube needs to be clarified so that the observation process of the rate of water capillarity can be carried out more accurately and objectively. It is also recommended that the media be dried first after use so that the water-absorbing sponge remains durable and does not suffer damage due to excessive moisture.

The validators emphasized the importance of developing clear usage guidelines so that teachers and students can operate the media independently without direct supervision from

researchers. The guidelines are expected to include instructions for use, observation steps, and reflections on observation results that can be linked to scientific concepts. Another suggestion is to develop student observation sheets to support inquiry-based experiments, so that students not only observe but also analyze the phenomena that occur during the learning process.

The feedback obtained was used as the basis for revisions in the media development stage according to the model proposed by Thiagarajan, Semmel, and Semmel (1974), in which product refinement was carried out continuously through evaluation and feedback from validators. After the revisions were made, the BATIK media showed improvements in terms of efficiency and ease of use, which had a positive impact on student engagement during learning.

These results are in line with Rafika Putri's (2022) research, which confirms that simple experiment-based learning media can improve students' understanding of biology material in concrete terms. Miranda et al. (2022) also add that the use of interactive media in learning can foster interest in learning and strengthen students' critical thinking skills. Thus, BATIK media is not only empirically valid, but also pedagogically relevant in supporting the implementation of 21st-century science education that emphasizes creativity, collaboration, and scientific problem solving.

CONCLUSION

This research resulted in a three-dimensional learning medium, BATIK (Capillarity Interactive Rod), that aims to concretely visualize the mechanism of air transport in plants through the process of capillarity. Development was carried out through a 3D model (Define, Design, Develop) with stages of learning needs analysis, design planning, and expert validation. The validation results showed that BATIK achieved a feasibility score of 91.2%, categorized as very feasible. This medium was deemed capable of accurately representing the scientific concept of capillarity and was easily observed through a simulation of air rising in a transparent rod with sponges as artificial roots. Based on an assessment of material suitability, satisfaction, aesthetics, efficiency, durability, and safety, all validators stated that this medium can be used in science lessons at the junior high school/Islamic junior high school level.

The use of BATIK has been proven to support hands-on learning, which can enhance conceptual understanding, encourage observational activities, and foster student learning interest. Several technical improvements have been made based on expert input, such as clarifying the measurement scale and maintaining the medium for repeated use. Therefore, BATIK is recommended as an alternative science learning medium for the structure and mechanism of air transport in plants. Further research can be conducted to test its effectiveness more broadly and develop digital support features.

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