Journal of Technology and Computer (JOTECHCOM)
Vol. 2, No. 4, November 2025, pp. 231~243
ISSN: 3048-0477 (Media Online)

Transformation of 2D Animated Botany Learning to Recognise Types of Roots and Leaves in Plants

Antonius Christian Pakpahan[1]
[1]Department of Informatic Engineering, Faculty of Computer and Engineering, University of Harapan Medan, Medan, Indonesia
[1]antoniuschristian19@gmail.com

Article Info

Article history:

Received October 25, 2025
Revised November 15, 2025
Accepted November 26, 2025

Keywords:

2D animation
Botany
Digital transformation
Learning media
Types of leaves
Types of roots

ABSTRACT

Digital transformation has opened opportunities for innovation in the world of education, including in the field of botany. This study aims to develop and test the effectiveness of a 2D animation-based learning media to help students learn about the types of roots and leaves in plants. This material is often considered abstract and boring when delivered only through conventional methods such as textbooks or static images. The research method used is Research and Development (R&D) with the Multimedia Development Life Cycle (MDLC) model, which consists of six stages: Concept, Design, Material Collecting, Assembly, Testing, and Distribution. In the concept stage, an analysis of student needs and learning difficulties was conducted. The design stage involved the creation of storyboards and scripts. The assembly stage was the process of producing 2D animations using Adobe Animate software. The final product was then implemented among elementary school students and evaluated. The results of validation from material and media experts stated that the 2D animation media was highly feasible. Testing on students showed a significant increase in post-test scores compared to pre-test scores, indicating that this media is effective in improving students' understanding and recognition of root and leaf types. The conclusion of this research is that 2D animation is a transformative medium that is not only engaging and interactive but has also been proven to facilitate a better understanding of plant morphology concepts. It is recommended that educators utilize similar media in biology instruction.

Corresponding Author:

Antonius Christian Pakpahan
University of Harapan Medan
Email: antoniuschristian19@gmail.com

1. INTRODUCTION

Biology is a branch of science that requires strong conceptual and visual understanding. One of the subjects taught at the elementary and secondary education levels is the types of roots and leaves in plants. This material is often abstract because it requires direct observation of real objects that are sometimes difficult to obtain in the learning environment. The limitations of learning media that rely solely on static images in textbooks make it difficult for students to distinguish the characteristics of each type of root and leaf in detail. This results in low conceptual understanding and interest in learning this material among students.

The use of technology-based learning media, especially animation, is one solution to overcome these obstacles. Animated media has the ability to dynamically display objects, visualise processes that are not directly observable, and enhance the interest and interactivity of learning [1],[2],[3]. Research conducted by Erviana [4] shows that the use of animated media in biology learning can increase the average learning

outcomes of students to 76.48%, higher than the conventional learning method of 74.93%. These findings prove that animated media can help students understand concepts better.

In addition, research by Ardianti et al. revealed that the use of animated media had a significant effect on increasing student learning activities in science subjects [5]. The results of this study showed an effect size of 0.69, which is classified as moderate, indicating that animation plays a positive role in encouraging student engagement during the learning process. Meanwhile, Melisa, in her research at SMP Negeri 1 Peukan Bada, found that the use of animation in biology learning increased student learning completeness classically to 86.80% compared to the control class of 68.18%. This data proves that animation not only has an impact on concept understanding but also on overall learning achievement [6].

Although various studies have shown the effectiveness of animation media in biology learning [7][8], studies that specifically develop interactive 2D animation on root and leaf types are still rare. In fact, interactive 2D animation has great potential to visualise the shape and structure of roots (e.g., taproots, fibrous roots) and types of leaves (e.g., simple leaves, compound leaves) more clearly and attractively. With interactivity, students can explore independently, such as enlarging objects, rotating views, or comparing types directly on the screen.

Based on the above description, research is needed to develop and test the effectiveness of interactive 2D animation media as a learning aid for root and leaf types, with the title "Transformation of Botany Learning Based on 2D Animation to Understand Root and Leaf Types in Plants." This research is expected to contribute to improving the quality of biology learning, particularly in terms of conceptual understanding, learning interest, and active student engagement.

2. METHOD

2.1. Hardware and Software Requirements Analysis

This research requires devices that must support the system requirements and learning application design. In order for the application to run properly, it must be supported by several components, namely.

Table 1. Hardware Requirements

Device	Description
Processor	Minimum Intel Core i3 or equivalent
Memory	4GB RAM
Storage	Minimum 500 GB HDD / SSD
Graphics Processing Unit	1 GB VRAM to support 2D animation
Monitor	Minimum resolution of 1366x768 pixels

Next, software requirements include applications and operating systems used in the design. The following are details of the software used in the design.

Table 2. Software Requirements

Software	Description
Operating System	Windows 10
Animation Design Application	Adobe Animate
Image Editing Application	Adobe Photoshop

2.2. Problem Analysis

The problems found in conventional botany learning can be seen from several aspects. First, the delivery of material still mostly uses print media or static images that seem less interesting to students. Second, the interactivity between students and the material being studied is relatively low, so that students are less actively involved in the learning process. Third, students' understanding of the shape and function of roots and leaves is still limited and superficial due to the limitations of the available visual aids. Fourth, the monotonous presentation of material also leads to low student motivation to learn.

2.3. Analysis of Problem Solving Using the MDLC Method

Concept

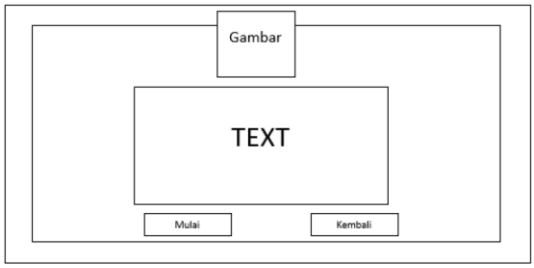
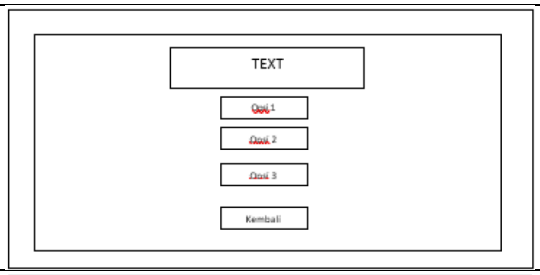
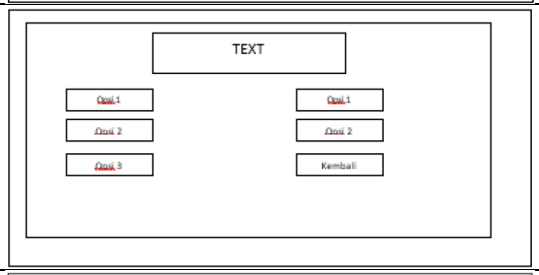
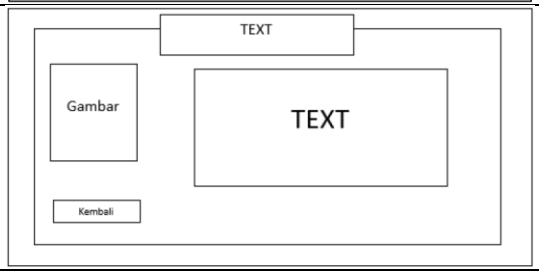
This stage aims to define the objectives, targets, and needs of the learning media. Based on observations, botany lessons in schools still use verbal explanations and static images, so students are less interested and have difficulty understanding the material on roots and leaves. To overcome this, interactive 2D animation media was developed to display moving visualizations of roots and leaves, so that differences in shape, structure, and function can be understood more clearly. The target users are third-grade elementary school students, with the aim of improving their understanding of the types of roots (taproot, fibrous, aerial,

hanging) and leaves (pinnate, palmate, parallel). The main requirements include: botanical material content, 2D animation with narration and text, a computer/Android platform, and a final product in the form of learning media that supports teachers and independent learning for students.

Design

This stage includes the creation of storyboards, animation flow, interface, and voice narration with an educational cartoon visual style. This design is expected to produce interactive, interesting, and understanding-enhancing 2D animation-based botanical learning media.

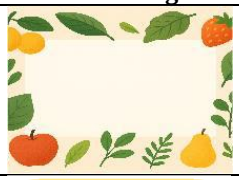
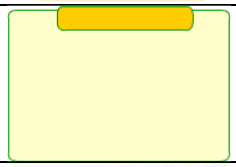
Table 3. Application Storyboard

Scenario	Display	Description
Scenario 1		The menu display on the application is as follows. 1. Start to move to the information options page. 2. Exit button to exit the application. 3. Text containing the application name. 4. Image containing the university logo as the application development identity.
Scenario 2		On the material selection screen, which contains options for the material to be viewed, there are three main material options, followed by a back button to return to the main menu.
Scenario 3		Then, on the next screen, there are more sub-topic options that discuss the types of material presented, with 5 material options. Then there is a back button to return to the main menu.
Scenario 4		The information display will explain the selected object or image, containing text that describes the object. Then, press the back button to return to the main menu.

Material Collecting

The material collecting stage is the process of gathering all the materials needed to support the development of learning media, including images, illustrations of roots and leaves, narrator's voice, and background music that supports learning. In this study, material collection was carried out to ensure that the content displayed in the 2D animation was in line with the needs of botany learning, especially on the subject of plant roots and leaves.

Table 4. Asset Collection

Asset Name	Asset Image	Usage
Visual Assets		These assets are used as the background of the application.
Visual Assets		These assets will be the location of the application buttons.
Visual Assets		This asset is where text information and images are placed in the application.
Visual Assets		This asset is one of the objects displayed in the application.
Font Assets	Kembali	The font used in the application is called MV Boli, which is used as the main font for both information content and buttons.

Assembly (Creation/Production)

This stage integrates images, text, sound, and animation into 2D animated learning media using software such as Adobe Animate. The process begins with a storyboard and flowchart as a guide for the material flow, then an interactive 2D animation is created that displays the types of roots and leaves in motion. Explanatory text and voice narration are added to clarify the information, as well as navigation buttons to facilitate interaction. The final product is rendered and compiled in a format that can be accessed on a computer/laptop.

Testing

Trials are conducted on small groups of students to assess the ease of understanding, appeal, and technical stability of the animated media.

Distribution/Implementation

The completed media is distributed via computers, laptops, or online platforms so that teachers and students can use it in learning.

3. RESULTS AND DISCUSSION

3.1. Implementation

The implementation stage is a part of the process carried out to run the developed application. Its purpose is to evaluate the extent to which the learning materials are presented through the developed learning application. After the implementation is completed, testing is conducted by performing trials on the menus available in the learning application. This step aims to observe how well each menu functions and how appropriate its responses are when selected by the user.

3.2. Evaluation and Testing

At this stage, the author performs testing on the developed learning application. This process begins by running the application.

3.2.1.Main Page Implementation

The initial display of the learning application on roots and leaves in plants, which is based on 2D animation, can be seen in Figure 1 below.

Figure 1. Main Page

This application is the result of a botany learning transformation project designed by students of the Informatics Engineering Study Program, Faculty of Engineering and Computer Science, Universitas Harapan Medan. Adopting the concept of interactive learning based on 2D animation, this application aims to help students or users understand and recognize various types of roots and leaves in plants in a more visual and engaging way.

The application features a user-friendly interface with nature- and plant-themed graphic elements to attract learning interest. On the main page, users are presented with two buttons: Start to begin the learning session and Exit to close the application. At the top of the display, there is the logo of Universitas Harapan Medan, serving as the institutional identity of the application's developer.

The implementation of this application focuses on digital-based learning media that can be utilized in educational settings, particularly at the elementary and secondary school levels. By leveraging 2D animation technology, users are encouraged to explore various forms of roots and leaves through informative and enjoyable animations. This approach is expected to enhance students' understanding of basic botanical concepts more effectively compared to conventional learning methods.

The functions of the Start button and other components mentioned above are as follows:

```
btn_start.addEventListener(MouseEvent.CLICK, fl_ClickToGoToAndStopAtFrame);
function fl_ClickToGoToAndStopAtFrame(event:MouseEvent):void {
        gotoAndStop(2);
}
```

3.2.2.Implementation of the Root and Leaf Learning Menu

The learning menu page can be seen in the figure below.

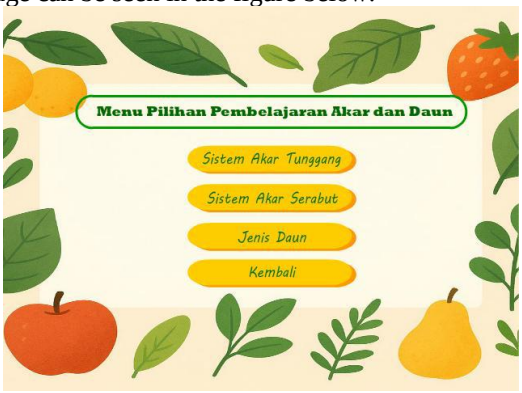


Figure 2. Learning Menu Page

The image above shows the main learning menu of the 2D animation-based application themed around the introduction of root and leaf types in plants. Testing was carried out to ensure that all buttons in this menu function properly and direct users to the appropriate learning materials.

1. "Taproot System" Button
   Purpose: Directs users to the animation material page about taproots. Test Result: When the button is clicked, the system successfully displays visual materials and interactive animations explaining the characteristics, examples of plants with taproots, and their functions. The button functions as expected.
2. "Fibrous Root System" Button
   Purpose: Directs users to the animation material about fibrous roots. Test Result: After clicking the button, the application displays a 2D animation explaining the structure of fibrous roots along with examples of plants that have them. The button works correctly and responsively.
3. "Leaf Types" Button
   Purpose: Opens materials explaining various types of leaves in plants. Test Result: The user is directed to a learning page featuring animations of leaf types (such as pinnate, palmate, and parallel leaves), including their functions and plant examples. The button functions well without issues.
4. "Back" Button
   Purpose: Returns the user to the main application page. Test Result: When the "Back" button is pressed, the system directs the user to the main page displaying the university logo and the "Start" and "Exit" buttons. The back button functions smoothly according to the application's navigation flow.

All buttons on the Root and Leaf Learning Menu page have been tested and function correctly according to design. This testing demonstrates that the application's navigation is intuitive and supports interactive learning goals, providing an enjoyable and easily understood learning experience, particularly for elementary and secondary students.

3.2.3.Implementation of the Root Learning Page

The root learning menu page can be seen in the following figure.

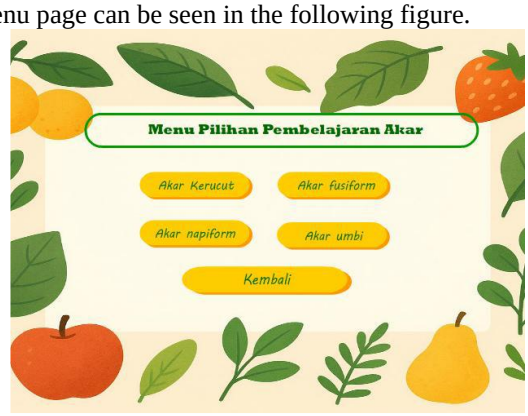


Figure 3. Taproot Learning Page

The figure above shows the main learning menu on taproots. Testing was carried out to ensure that all buttons in this menu function properly and direct users to the appropriate learning materials.

1. "Conical Root" Button
   Purpose: Directs users to the animation material page about conical roots. Test Result: When the button is pressed, the system successfully displays visual materials and interactive animations explaining the characteristics of conical roots.

Figure 4. Conical Root Learning Page

The slide presents the material in a structured manner: Title: "Conical Root" → immediately focuses on the topic. Illustration: Provides clear and easy-to-understand visual examples. Definition: Explains the general concept of conical roots. Characteristics: Emphasizes the shape and type of roots. Function: Explains the role of conical roots (food storage). Plant Examples: Helps students recognize real examples around them.

Implementation in the Learning Process: In Class: Teachers can use this media when explaining types of roots. Independent Learning: Students can study independently via computer or smartphone since the interface resembles an interactive app. Evaluation: Navigation buttons can be developed to link to quizzes or practice exercises.

Advantages of This Media: Helps students understand concepts through text, images, and interactive navigation. Makes learning more engaging and less monotonous. Connects theory (conical root explanation) with real practice (examples: carrot, radish, beet).

2. "Fusiform Root" Button

   Purpose: Directs users to the animation material about fusiform roots. Test Result: After clicking the button, the application displays 2D animations describing the structure of fusiform roots and examples of plants that have them. The button works correctly and responsively.

Figure 5. Fusiform Root

The slide presents structured content as follows: Title: "Fusiform Root". Illustration: Provides easy-to-understand visuals. Definition: General explanation of fusiform roots. Characteristics: Highlights root shape and type. Function: Explains the role (food storage). Examples: Helps students relate to real plants (e.g., radish, jicama).

Implementation and Advantages are similar to the conical root section.

3. "Napiform Root" Button

   Purpose: Opens material explaining napiform roots. Test Result: Directs the user to the napiform root learning page.

Figure 4.6 Napiform Root Learning Page

4. “Tuberous Root” Button
   Purpose: Opens material explaining tuberous roots. Test Result: When clicked, the display moves to the tuberous root learning page.

Figure 7. Tuberous Root Learning Page

All buttons in the Root and Leaf Learning Menu have been tested and function properly according to design. Testing shows that navigation is intuitive and supports interactive learning goals, providing enjoyable and understandable experiences for users, particularly students.

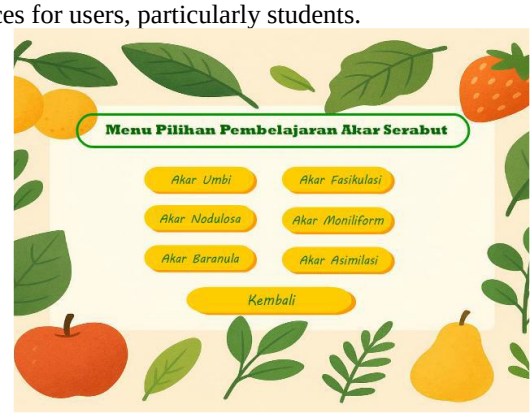


Figure 8. Fibrous Root Learning Page

The figure above shows the fibrous root learning page. Testing was carried out to ensure all buttons function properly and direct users to the correct materials.

5. “Tuberous Root” Button
   Purpose: Opens materials about tuberous roots. Test Result: When clicked, it leads to the tuberous root learning page.

Figure 9. Fibrous Root Learning Page

6. “Fasciculated Root” Button
   Purpose: Directs users to animation materials about fasciculated roots. Test Result: After clicking, the app displays a 2D animation describing the structure of fasciculated roots and examples of relevant plants. The button functions properly.

Figure 10. Fasciculated Root Learning Page

7. “Nodulose Root” Button
   Purpose: Opens material about nodulose roots. Test Result: Directs users to the nodulose root learning page.

Figure 11. Nodulose Root Learning Page

8. “Moniliform Root” Button
   Purpose: Opens material explaining moniliform roots. Test Result: When clicked, directs to the moniliform root learning page.

Figure 12. Nodulose Root Learning Page

9. “Baranula Root” Button
   Purpose: Opens material about baranula roots. Test Result: When clicked, directs to the baranula root learning page.

Figure 13. Baranula Root Learning Page

All buttons in the Root and Leaf Learning Menu have been tested and function properly according to design. This testing shows intuitive navigation and supports interactive learning, giving users—especially students—an engaging and easily understandable learning experience.

3.3. Implementation of the Leaf Learning Page

The leaf learning page can be seen in the figure below.

Figure 14. Leaf Learning Page

The figure above shows the main learning menu for fibrous roots. Testing ensures all buttons function properly and direct users to the right materials.

1. “Palmate Leaf” Button
   Purpose: Opens material explaining palmate leaves. Test Result: When clicked, the display moves to the palmate leaf learning page.

Figure 15. Palmate Leaf Learning Page

This stage defines the objectives of media creation: Purpose: Helps students understand compound leaf types—especially palmate leaves—through engaging interactive media. Target Users: Elementary and secondary students studying Science/Biology. Material: Definition, characteristics, and examples of palmate leaves.

Media Design: Visuals: Use palmate leaf illustrations as the main visual. Content Structure: Title → “Palmate Leaf”, Definition → clear and concise, Characteristics → key points for comprehension, Examples → connect learning to real life. Navigation: A “Back” button to move between material pages.

Material Sources: Texts from elementary science textbooks. Illustrations (examples: cassava, papaya, cotton, breadfruit). Supporting graphic elements (icons, backgrounds, etc.).

2. “Pinnate Leaf” Button
   Purpose: Directs users to animation materials about pinnate leaves. Test Result: Displays 2D animation explaining structure and plant examples. The button works correctly and responsively.

Figure 16. Pinnate Leaf Learning Page

3. “Curved Leaf” Button
   Purpose: Opens materials about curved leaves. Test Result: Directs users to the curved leaf learning page.

Figure 17. Curved Leaf Learning Page

4. "Parallel Leaf" Button
   Purpose: Opens materials about parallel leaves. Test Result: When clicked, the display moves to the parallel leaf learning page.

Figure 18. Parallel Leaf Learning Page

Testing of the parallel leaf section marks the final stage of leaf learning implementation. This demonstrates that all media functions and button features operate as intended. Users can explore and study the application according to their learning goals—whether to study root types or leaf types.

4. CONCLUSION

The author has formulated the following conclusions and suggestions based on the research conducted. These conclusions and recommendations are expected to address the research problems and objectives. Interactive 2D animation-based learning media on the topic of root and leaf types can be developed through systematic stages in accordance with the instructional media development model. The resulting media has been proven to be feasible for use based on expert evaluations and its alignment with the elementary school curriculum. The use of interactive 2D animation media can enhance students' understanding of the concepts of root and leaf types compared to conventional teaching methods. Students' responses to this learning media are very positive, as it is not only engaging but also provides a more enjoyable and easily understandable learning experience.

REFERENCES

[1] S. Pradana, S. Tinggi, and I. T. Tanggamus, "Efektivitas Penggunaan Video Animasi sebagai Media Pembelajaran Interaktif di Sekolah Dasar," *J. Transform. Pendidik. Dasar*, vol. 1, no. 1, pp. 33–39, Jan. 2025, Accessed: Oct. 01, 2025. [Online]. Available: http://synergizejournal.org/index.php/JTPD/article/view/48

[2] R. Anggara and S. Supardji, "Pengembangan Media Pembelajaran Animasi Interaktif Berbasis Adobe Animate," *J. Pendidik. Madrasah*, vol. 9, no. 2, pp. 245–250, Nov. 2024, doi: 10.14421/JPM.2024.245-250.

[3] D. A. Susanti, T. S. Cornelia, E. Eduard, W. M. Sihombing, and G. W. Sianturi, "PENGARUH PENGGUNAAN MEDIA PEMBELAJARAN VIDEO ANIMASI TERHADAP HASIL BELAJAR SISWA PADA MATA PELAJARAN PKN DI SD NEGERI 067244 MEDAN," *J. Curere*, vol. 9, no. 1,

pp. 136–143, Apr. 2025, doi: 10.36764/JC.V9I1.1547.
[4] R. Erviana, "Efektivitas Penggunaan Media Animasi terhadap Hasil Belajar Siswa pada Pembelajaran Biologi Kelas X di MAN 1 Lampung Timur," Jun. 2023, Accessed: Oct. 01, 2025. [Online]. Available: https://repository.metrouniv.ac.id/id/eprint/8414/
[5] R. K. Ardianti, D. Putra, and D. Gusfarenie, "Pengaruh Media Animasi Terhadap Peningkatan Aktivitas IPA di Sekolah Menengah Pertama," *EDU-BIO J. Pendidik. Biol.*, vol. 8, no. 1, pp. 35–46, Jan. 2025, doi: https://doi.org/10.30631/EDUBIO.V8I1.157.
[6] R. Melisa, "Efektivitas Penggunaan Media Animasi Pada Materi Sistem Pernapasan Manusia Terhadap Ketuntasan Belajar Siswa Kelas VIII SMP Negeri 1 Peukan Bada," *Pros. Biot.*, Apr. 2018, Accessed: Oct. 01, 2025. [Online]. Available: https://www.academia.edu/84179722/Efektivitas_Penggunaan_Media_Animasi_Pada_Materi_Sistem_Pernapasan_Manusia_Terhadap_Ketuntasan_Belajar_Siswa_Kelas_VIII_SMP_Negeri_1_Peukan_Bada
[7] D. Oktarini, J. Jamaluddin, and I. Bachtiar, "EFEKTIVITAS MEDIA ANIMASI TERHADAP HASIL BELAJAR BIOLOGI SISWA SMPN 2 KEDIRI," *Prism. Sains J. Pengkaj. Ilmu dan Pembelajaran Mat. dan IPA IKIP Mataram*, vol. 2, no. 1, pp. 1–7, Jun. 2014, doi: 10.33394/J-PS.V2I1.1048.
[8] R. Citra Miranda *et al.*, "Efektivitas Media Animasi terhadap Hasil Belajar Siswa Pada Materi Sistem Ekskresi Manusia," *Biosf. J. Biol. dan Pendidik. Biol.*, vol. 7, no. 2, Dec. 2022, doi: 10.23969/BIOSFER.V7I2.6396.