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Development of Biotic (Biology E-Comic) Audiovisual Media to Train Metacognitive Awareness and Cognitive Learning Outcomes

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ABSTRACT 21st-century learning emphasizes a student-centered approach. Learners are expected to develop an awareness of how to manage their own learning and apply appropriate learning strategies, a concept called metacognitive awareness. Students with a high level of metacognitive awareness tend to achieve better cognitive learning outcomes. Therefore, there is a need for instructional media that can support the development of both metacognitive awareness and cognitive achievement. This study aims to develop a Biotic (Biology E-Comic) audiovisual media based on the Think Pair Share (TPS) model and integrated with the Sustainable Development Goals (SDGs) Good Health and Well-Being to train metacognitive awareness and cognitive learning outcomes on the respiratory system material for Grade 11 students (Phase F) at SMAN 1 Singosari. The research and development process adopted the Lee and Owens model, comprising five stages: assessment and analysis, design, development, implementation, and evaluation. However, the implementation stage was not carried out in this study because the research conditions did not permit it; therefore, it focused solely on the validation and practicality of the media. The final product is a Biotic audiovisual media piece based on TPS, integrated with the SDGs, consisting of illustrated comic stories with voice-over dubbing for character dialogues. Validity tests conducted by a subject-matter expert, a media expert, and a Biology education practitioner yielded an average result of 98.1%. Practicality tests based on the trial results yielded a practicality level of 90.8%. It can be concluded that Biotic audiovisual media are valid and practical to use.

Keywords: Audiovisual, Cognitive learning outcomes, E-Comic, Metacognitive awareness, Respiratory system

1. INTRODUCTION

Rapid technological breakthroughs in the twenty-first century have fundamentally changed the educational landscape. The traditional teacher-centered approach is no longer practical, and the current learning paradigm requires a shift toward student-centered learning. (Tang, 2023). This approach positions students as active participants in the educational process. Students are required to engage collaboratively and independently to construct and investigate their understanding of the learning material. (Afriani, Soegiarto, Suyuti, Amarullah, & Aristanto, 2024). In response to these demands, individuals must develop the capacity for autonomous learning to develop their knowledge and understanding. (Paethrangsi, Teekasap, Khiewpan, & Jandaboue, 2024). Hence, students must be aware of how to manage their learning and adopt effective learning strategies.

A person's success in learning depends on their ability to track learning progress, plan strategies, and assess learning outcomes; this ability is known as metacognitive awareness (Sholihah & Sofiyana, 2021). Metacognitive awareness refers to one's conscious understanding of one's thinking processes during cognitive activities (Negi, Rajkumari, & Rana, 2022; Schraw & Dennison, 1994). Metacognitive awareness can be further defined as what we

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know and how we can apply these processes to enhance our learning. Abdullah & Soemantri (2018) outlined five leading indicators of metacognitive awareness: cognitive preparation, cognitive management, cognitive monitoring, cognitive strategy, and cognitive evaluation. These five aspects form a crucial foundation for students to learn independently and reflectively, ultimately contributing to improved cognitive learning outcomes. Metacognitive awareness enables students to organize, allocate, and assess their learning processes, thereby enhancing academic achievement (Stanton, Sebesta, & Dunlosky, 2021). Previous research has demonstrated that increased metacognitive awareness leads to improved learning outcomes in Biology, as students become better able to regulate their learning behaviors (Asaidah, Mustofa, & Chaidir, 2022; Khairinaa, Wahyuningsih, & Khasanah, 2023). Consistent with the importance of metacognitive awareness, cognitive learning outcomes are also a primary benchmark for evaluating learning effectiveness.

Cognitive learning objectives are behavioral shifts that reflect mastery of knowledge, understanding, and logical thinking skills obtained through learning experiences. (Sudjana, 2009). These cognitive learning outcomes relate to thinking, intelligence, and mental abilities. (Hui & Mahmud, 2023). Referring to Anderson et al. (2001)Cognitive learning outcomes include six hierarchical thinking domains: remembering, understanding, applying, analyzing, evaluating, and creating. Each level reflects the depth of students' thinking processes towards the material they are studying. Therefore, learning outcomes can serve as indicators or benchmarks of student and teacher success in the learning process. (Choiriyah & Hidayah, 2023). Cognitive learning outcomes are influenced by complex interactions among students' internal conditions, the teaching methods employed, and the learning media used (Asysyura, Adnan, & Faisal, 2023; Li & Xue, 2023). Preliminary research using a needs analysis questionnaire administered to students at SMAN 1 Singosari indicated that both their metacognitive awareness and cognitive learning outcomes remain relatively low, especially in Biology. This condition underscores the importance of developing a learning approach that encourages students to think independently and comprehend the subject matter of Biology.

One branch of science is Biology, which studies living things and their environments. Biology encompasses a wide range of ideas and concepts, enabling a profound understanding of living things, from tiny organisms to more complex creatures, such as humans. (Forniawan et al., 2024). Preliminary research using a needs analysis questionnaire from SMAN 1 Singosari showed that over 50% of students experience difficulties in learning the respiratory system, particularly concepts such as respiratory volume and respiratory rate. Preliminary research also revealed that students struggled to comprehend the material, as explanations were often lacking due to the reliance on textbooks alone. Biology is often considered difficult because students feel bored by the amount of material to be learned and because teachers present it in less engaging and varied ways. (Husna, Nerita, & Safitri, 2023). Additionally, static images and text in textbooks are insufficient to help students visualize the biological processes of the respiratory system. (Paramitha, Fadllah, & Sari, 2023).

An engaging and appropriate learning medium is necessary to train metacognitive awareness, cognitive learning outcomes, and understanding of respiratory system material. Learning media serves as a means of delivering educational messages and improving student understanding. (Ulya, Suhailah, Putri, & Revita, 2025). Learning media comes in many forms, including audiovisual media. Audiovisual media is a form of media that can display image and sound elements simultaneously when conveying information or a message. (Dhitya & Setiyowati, 2024). Audiovisual media integrate auditory and visual stimuli, catering to different learning styles and improving memory retention. (Agada & Sam-Kayode, 2022; Surjono, 2022). With advances in technology, audiovisual media can now be transformed into interactive digital formats, such as comics.

Comics have distinctive characteristics that set them apart from other forms of media. As a learning medium, comics combine visual and textual elements through storytelling to foster understanding, making them an engaging learning tool. (Golding & Verrier, 2021; Pange, 2023). The advantages of comics lie in their visually appealing content and simple language, both of which enhance students' motivation and interest in reading. (Dewi, Jampel, & Wibawa, 2023). Comics can also visualize concepts or structures that students cannot directly observe, facilitating better comprehension. (Amalia, Indrowati, & Oetomo, 2022). Its digital form, namely e-comics, further enhances learning effectiveness by leveraging interactive technology that encourages students' independent learning. (Berger, Michael, & Christoph, 2023). Therefore, comics, especially in digital and audiovisual forms, are a promising medium for development. Audiovisual e-comics are not only visual formats that present sound and images, but also support educational narratives, making them easier to grasp and more captivating. (Cotiangco et al., 2024).

However, audiovisual e-comics alone may not be sufficient. Their effectiveness increases when embedded in an active learning strategy. This can be achieved by integrating audiovisual e-comics with the appropriate learning strategy, specifically the Think-Pair-Share (TPS) model. TPS, which involves three phases — think, pair, and share — is a cooperative learning model. According to Arends (2012), TPS encourages students to think independently, discuss their opinions with a partner, and

present their findings to the class. Studies confirm that TPS fosters metacognitive processes by encouraging students to articulate, evaluate, and refine their thinking (Hetharia, Corebima, & Gofur, 2024). In addition, this approach improves cognitive learning outcomes by actively engaging students in processing information, facilitating peer interaction, and enhancing their understanding (Nurlaika, Sahade, & Rijal, 2024).

Furthermore, aligned with global educational goals, integrating Sustainable Development Goals (SDGs) into classroom instruction is essential. The United Nations' SDGs provide a worldwide framework for advancing the sustainability of life on Earth. (Sorooshian, 2024). The ability to meet current demands without compromising the capacity of future generations to meet their own is known as sustainability. (Nurmala, Nurlambang, Sukada, & Ayu, 2023). One of the 17 SDGS is Goal 3, Good Health and Well-Being. This goal ensures well-being and advanced welfare for individuals of every generation. (Bappenas, 2014). Based on a preliminary study, 91.7% of students were unaware of the SDGs, and teachers had not yet incorporated them into their teaching. Education is essential for promoting critical thinking and fostering attitudes that support the preservation of human health and a more sustainable future. (Baena-Morales & Fröberg, 2023). This highlights the strong connection between education and health. Moreover, introducing the SDGs to students raises awareness about global social issues and encourages responsible citizenship.

Previous studies have also shown valid and practical results on the development of comics on metacognitive awareness. (Choiriyah & Hidayah, 2023; Sunarto, Hidayah, Hidayah, & Sumuba, 2024). Studies by Dewahrani, Apriani, & Kurniati, (2023) and Indriyani, Ningsih, & Yuniarti (2024) Also, research has shown that comics can improve cognitive learning outcomes because they are easier to understand. However, few have integrated comic elements, audiovisual materials, metacognitive awareness, cognitive learning outcomes, the TPS learning model, and global context, especially in teaching respiratory system topics in high schools. Therefore, this study aims to develop Biotic (Biology E-Comic) audiovisual media based on the TPS model, integrated with the SDG Good Health and Well-Being, to train metacognitive awareness and cognitive learning outcomes in respiratory system material for Phase F senior high school students, in a manner that is valid and practical. Based on the stated objectives, the following research questions are proposed:

1 How valid is the Biotic audiovisual media in terms of material, media, and biology learning?
2 How practical is the Biotic audiovisual media when applied in a trial?

2. METHOD

This study employed a Research and Development (R&D) methodology. Lee & Owens (2004) Development model. The Lee and Owens model was chosen for its systematic, easy-to-follow steps. Additionally, the model is well-suited to the media being developed in this study, as it was specifically designed for creating interactive multimedia products. (Aka, 2019). Lee & Owens (2004) Consists of five stages: (1) assessment and analysis, (2) design, (3) development, (4) implementation, and (5) evaluation (Figure 1).

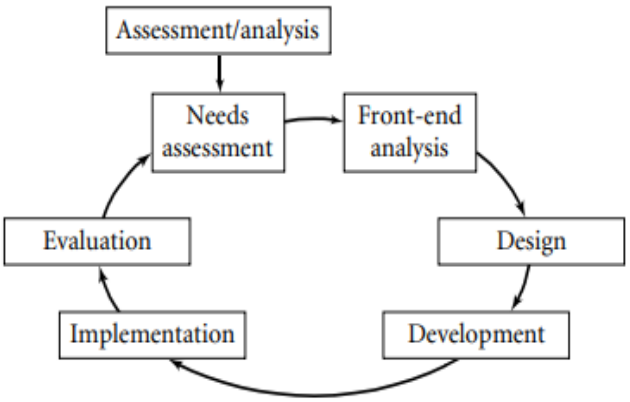


Figure 1 The Lee and Owens development model stages (Lee & Owens, 2004)

The needs assessment and analysis phase is conducted to specify objectives, identify gaps between the current and ideal conditions, and establish priorities. After the analysis phase, the next step is the planning or design phase for creating Biotic audiovisual media. The third phase, development, includes three principles: pre-production, production, and post-production. The storyboard is developed in the pre-production phase, followed by prototype development in the production phase. In the post-production phase, the product is evaluated for its quality through validation and practicality tests. A subject matter expert, a media expert, and a Biology education practitioner assess the product's validity. The next step is a practical test, which is conducted in three stages based on Branch (2009): (1) one-to-one trial, (2) small group trial, and (3) field trial. This study did not proceed to the fourth stage, namely implementation, due to situational constraints that made it unfeasible to conduct the research in the school setting. Furthermore, the final stage carried out was evaluation, which aimed to assess the feasibility of the Biotic audiovisual media. As a result, this study was limited to the validation and trial phases, focusing on measuring the media's quality in terms of validity and practicality, without examining its effectiveness in actual classroom implementation.

The viability of Biotic audiovisual media is evaluated by measurement validation and practicality tests. The

Instruments used in this study include validation sheets and student response questionnaires. The development of these instruments was guided by relevant literature on the evaluation of instructional media. Three types of validation sheets were prepared: (1) a material validation sheet to assess the content suitability and accuracy with the Biology material, (2) a media validation sheet to assess the aspects such as quality media, as well as media relevance with metacognitive awareness and cognitive learning outcomes' aspects, and (3) a Biology education practitioner validation sheet to collect feedback from experience Biology educators. Validators were selected using purposive sampling from three categories of experts: (1) a subject matter expert, a Biology lecturer with over five years of teaching experience, (2) a media expert, a media development lecturer with more than five years of teaching experience, and (3) a Biology education practitioner, a high school teachers with over ten years of experience in teaching.

The practicality of the media was measured by students using student response questionnaires. The questionnaire focused on engagement and ease of understanding. This research was conducted at SMA Negeri 1 Singosari, with 48 students from Class XII IPA D and XII IPA E as subjects. The trial was conducted with students who had previously studied the related material to ensure that their evaluation of the media focused on its practicality and clarity rather than on unfamiliarity with the content. The subject selection was carried out using a purposive sampling technique. Purposive sampling was employed to ensure that participants had specific experiences and knowledge relevant to the study's topic. (Arikunto, 2013).

The data obtained from the validity and practicality tests are used to determine the results. The data collected is quantitative, obtained from validation scores completed by experts and a practitioner, as well as questionnaires completed by students. Validity and practicality were assessed using a 5-point Likert scale ranging from "strongly agree" to "strongly disagree". The validity and practicality are evaluated using the formula based on Akbar (2013).

$$\text{Result (x)} = \frac{\text{Total score achieved}}{\text{Total expected score}} \times 100\%$$

The evaluated data are then used to determine the criteria. The criteria are used to assess product validity and practicality based on a series of values. Table 1 presents the criteria for the product's validity and practicality.

Table 1 Criteria for the validity and practicality

Percentage	Criteria	Statement
x = 100	Very Valid/Practical	Can be used without revisions
80≤x<100	Valid/Practical	Can be used with minor revisions
60≤x<80	Less Valid/Practical	Moderate revision, not recommended for use
40≤x<60	Invalid/Impractical	Major revisions, not recommended for use
20≤x<40	Very Invalid/Impractical	Total revision, not to use

Source: Aka, Akbar, & Sahertian (2018)

3. RESULTS AND DISCUSSION

3.1 Analysis

Need Assessment

The needs analysis phase was conducted to identify the research and development objectives, the gap between the actual and ideal conditions, and to set priorities (Lee & Owens, 2004). The needs analysis was conducted through a preliminary survey distributed to teachers and 36 students at SMA Negeri 1 Singosari. The needs assessment survey results indicated that the learning media at SMA Negeri 1 Singosari were not varied. The media most frequently used by teachers during lessons were PowerPoint (PPT) presentations. Lecture and assignment methods were also still commonly used during learning, which often led to student passivity and, consequently, disengagement. (Liu, Wang, & Izadpanah, 2023). The limited variation in instructional media negatively affected students' interest and motivation to learn. (Firdaus, Zubaidah, & Munzil, 2024). The preliminary research results also showed that audiovisual comic media had never been used in Biology lessons.

Further needs analysis was conducted using a metacognitive awareness test, a questionnaire adapted from Abdullah & Soemantri (2018), comprising five indicators: cognitive preparation, cognitive management, cognitive monitoring, cognitive strategy, and cognitive evaluation. The findings with the metacognitive awareness questionnaire showed that 47.2% of students did not know about metacognitive awareness, with an average metacognitive awareness score of 48.4, which falls within the very low category according to the criteria for achieving learning objectives at SMAN 1 Singosari. These results indicate that students struggle to apply metacognitive awareness in everyday life. The low metacognitive awareness occurred because metacognitive indicators were never practiced during lessons, resulting in low learning outcomes (Goren & Kaya, 2023). Cognitive learning outcomes, as reflected in daily test scores, remain low at 54.8 and are classified as low according to the criteria for achieving learning objectives at SMAN 1 Singosari. According to Zarestky, Bigler, Brazile, Lopes, and Bangerth (2022), training students to write reflections and notes continuously can increase metacognitive awareness and students' interest in and comprehension of the subject matter. Therefore, media is needed that can help train metacognitive awareness and cognitive learning outcomes.

Front-End Analysis

The front-end analysis phases aim to determine the methods to address the discrepancies observed in the previous analysis. (Lee & Owens, 2004). The front-end analysis phases are divided into several analyses. The audience analysis focuses on students from grade XI at SMA Negeri 1 Singosari. The technology analysis reveals that students can use a variety of devices, including laptops, computers, and other devices. The task analysis involves selecting the respiratory system material. The critical incident analysis involves determining the essential material and learning objectives for phase F. The situation analysis focuses on ensuring a conducive environment that supports access to technology-based learning media. The objective of the analysis is to develop valid and practical learning media. The media analysis focuses on developing the Biotic audiovisual media that can enhance metacognitive awareness and cognitive learning outcomes. The extant data analysis includes identifying modules, teaching materials, and references related to the content. The cost-benefit analysis is conducted to determine the costs associated with developing and utilizing the media.

3.2 Design

In this phase, five steps are carried out: (1) project schedule, (2) project team, (3) media specifications, (4) lesson structure, and (5) control configuration and review. (Lee & Owens, 2004). The research and development schedule runs from August 2024 to January 2025, with a project team comprising supervising lecturers and a research student. The developed media specifications include graphic specifications such as theme, colors, font styles, editing symbols, as well as content specifications covering the components and materials to be developed. The learning structure in the Biotic audiovisual media will refer to and integrate with SDG 3, Good Health and Well-Being, and will be based on the TPS learning model. The control configuration and review are detailed across several stages, including the format type, format selection, and formatting application. The format used is Hypertext Markup Language (HTML). HTML is chosen to make it easy to distribute and accessible to students (Puriasih & Trisna, 2022). Biotic audiovisual media were developed using the website Heyzine. The applications used for formatting include Microsoft Word, IbisPaintX, Canva, and Music Audio Editor.

3.3 Development

The development phase is divided into pre-production, production, and post-production, with quality review. The product is created in this phase using the product strategy developed in the previous phase. The pre-production phase is the product preparation stage, during which an outline and concept map for the media to be developed are created. (Lee & Owens, 2004). A storyboard or framework is created to develop the Biotic audiovisual media in this phase.

The production phase involves creating the media. (Lee & Owens, 2004). In this phase, a prototype is developed based on the previously created storyboard. The media development activities include drawing the comic, adding supporting elements such as text and illustrations, and incorporating audio dubbing. The final result of this phase is the Biotic product, which has been uploaded to the Heyzine website. The Biotic audiovisual media on the Heyzine website is presented as a flipbook, and the audio plays automatically on the story pages. Therefore, the Biotic audiovisual media on the Heyzine website makes it easier to access, listen to, and read the comic story. According to Amiyah & Hardiana (2024)Students can learn the content more easily and practically because the Heyzine website can be accessed anytime, anywhere. The Heyzine website also allows for the presentation of audio and visual features, which align with the Biotic audiovisual media. According to Pratiwi, Hidayat, & Suherman (2023)Heyzine offers the advantage of incorporating attractive features — such as audio, video, text, and images — to avoid monotonous displays. Figure 2 shows the Biotic audiovisual media in flipbook form on the Heyzine website.

Figure 2 Biotic audiovisual media on the Heyzine Website

Figure 3 Characters in the Biotic audiovisual media

The Biotic audiovisual media is a comic that tells the adventure of oxygen in the human respiratory system. Oxygen's adventure is accompanied by the brain, which explains the respiratory system's role in humans. The characters in the Biotic audiovisual media include oxygen, the brain, carbon dioxide, and red blood cells. According to Strong, Cook, Belet, & Calarco (2023)A comic story with characters and a world that incorporates learning elements can help students understand the real world. Figure 3 shows the characters in the Biotic audiovisual media. The Biotic audiovisual media includes several elements: usage instructions, learning objectives, learning goals, metacognitive awareness rubrics, synopsis, character introductions, metacognitive learning journals, material, and practice questions. The respiratory system material includes subtopics: (1) structure and function of the respiratory system; (2) mechanics of breathing and gas exchange; (3) lung volumes and capacities, breathing frequency; (4) and respiratory system disorders (Figure 4).

All the subtopics are presented as comics, featuring images and voice dubbing by the comic characters. Comics as a learning medium are considered more engaging because they can convey stories through images, entertaining students and helping them better understand the content presented, thereby enriching the learning experience. (Berger et al., 2023).

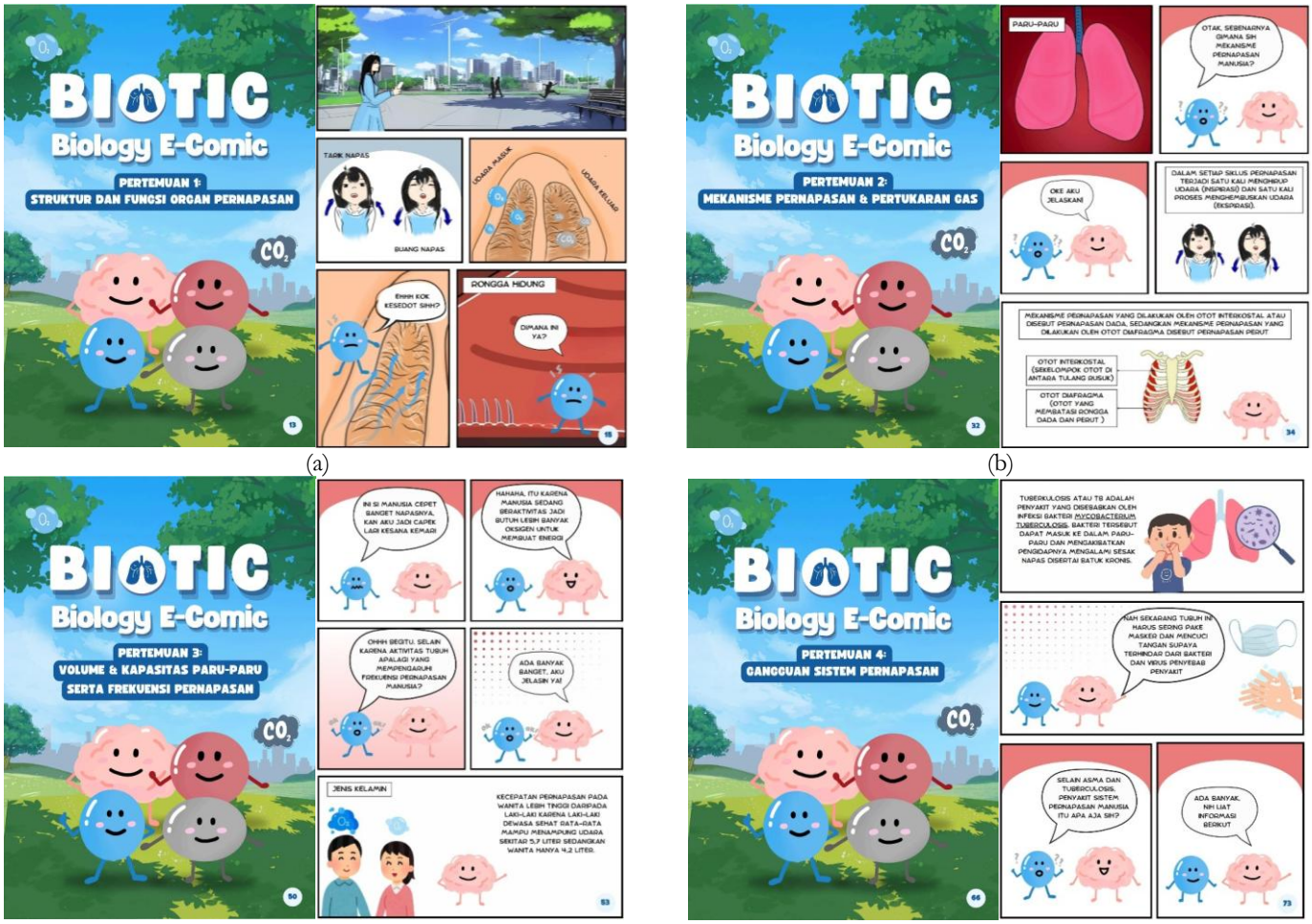


Figure 4 Material in the Biotic audiovisual media: structure and function of respiratory system organs (a), mechanics of breathing and gas exchange (b), lung volumes and capacities, as well as breathing frequency, and respiratory system disorders (d)

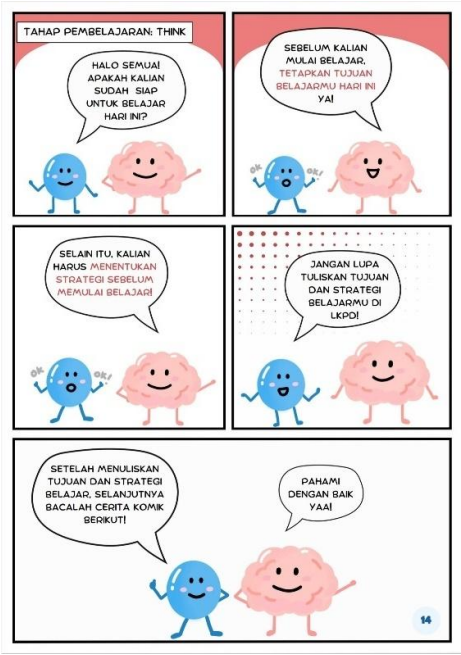


Figure 5 Learning journal in Biotic audiovisual media

Figure 6 Practice questions in Biotic audiovisual media

The learning journal in the Biotic audiovisual media contains questions related to metacognitive awareness indicators (Figure 5). The metacognitive awareness indicators refer to Abdullah & Soemantri (2018) Moreover, include five indicators: (1) cognitive preparation, (2) cognitive management, (3) cognitive monitoring, (4) cognitive strategies, and (5) cognitive evaluation. The learning journal is filled out before and after each lesson to monitor students' metacognitive awareness. The initial learning journal helps students prepare for the lesson by enabling them to understand the material they will study. In contrast, the end-of-lesson journal is used to evaluate their learning. (Chinpakdee, 2022; Lang, 2018). According to Nurmi, Susilo, Ibrohim, & Suhadi (2024)Written learning journals can help students understand their learning strategies, thereby increasing self-awareness and the quality of learning.

The practice questions in the Biotic audiovisual media contain questions related to the material learned from the media (Figure 6). The questions refer to the cognitive learning outcome indicators by Anderson et al. (2001), which include six indicators: (1) remembering, (2) understanding, (3) applying, (4) analyzing, (5) evaluating, and (6) creating. The practice questions are provided once students have read the material. Research by Taira, Agustin, & Rochintaniawati (2024) Indicates that comics serve as an effective learning medium, making it easier for students to understand, and their use can enhance students' learning outcomes.

The Biotic audiovisual media is integrated with the SDG Good Health and Well-Being in the subtopic of respiratory system disorders. This subtopic discusses respiratory disorders, including asthma and tuberculosis (TB). This is related to the SDG Good Health and Well-Being because it aims to combat infectious diseases such as TB and reduce diseases caused by chemicals and pollution, such as asthma. (Bappenas, 2014). The integration of SDGs Good Health and Well-Being issues also strengthens the relevance of Biology learning materials in real life. This global context helps students understand the relationship between the human respiratory system and broader health issues. Students are encouraged to understand issues at the local, national, and global levels that align with their educational level, so they can develop creative, innovative solutions that positively impact sustainable development. (Lestari et al., 2024). Figure 7 shows the integration of the

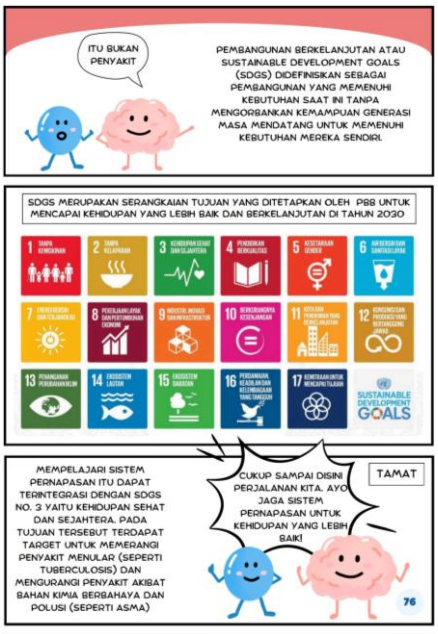
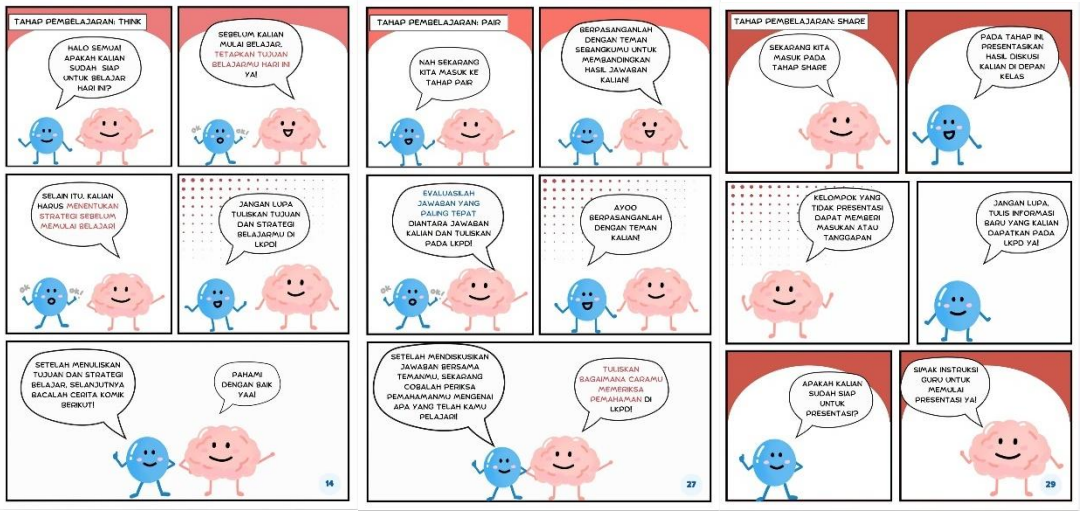


Figure 7 Integration of the respiratory system material with SDG Good Health and Well-Being



(a) (b) (c)

Figure 8 TPS learning phase on Biotic audiovisual media: think (a), pair (b), and share (c)

respiratory system material with SDG Good Health and Well-Being.

The learning activities follow the Think-Pair-Share (TPS) phase. The first phase is thinking; the teacher gives each student time to think (think time) and consider their answers to the questions (Arends, 2012). During this phase, students learn independently by reading the Biotic audiovisual media. In this phase, metacognitive awareness indicators, such as cognitive preparation and cognitive management, are applied through the completion of the learning journal. The cognitive learning outcome indicators (remembering, understanding, applying, analyzing, and creating) are applied by answering the questions in the Biotic audiovisual media. The think phase helps develop metacognitive awareness and cognitive learning outcomes by allowing students to plan their understanding during the think time (Kesuma, Sutarsyah, & Nurweni, 2024; Wiwit et al., 2024).

The second phase is a pair. In the pair phase, the teacher requires students to discuss questions or issues with their peers. Students interact by sharing and responding to each other's answers or solutions. (Arends, 2012). Students discuss the questions in pairs during this phase. After the discussion, students fill out the learning journal. In this phase, metacognitive awareness indicators, such as cognitive monitoring, are applied by completing the learning journal for the Biotic audiovisual media, and cognitive learning outcomes are evaluated by determining the correct answers to the questions. The pairing phase helps develop metacognitive awareness and cognitive learning outcomes because learning becomes more meaningful when students collaborate to monitor their learning and construct knowledge. (Çini, Järvelä, Dindar, & Malmberg, 2023; Wiwit et al., 2024).

The final phase is share. In the share phase, students are asked to share their discussion results with their pair. All students benefit from hearing different opinions about the same question during the sharing activity. (Arends, 2012). The learning continues with filling out the learning journal, which contains metacognitive awareness indicators such as cognitive strategies and cognitive evaluation. The share phase helps develop metacognitive awareness by giving students time to evaluate their learning. (Rimun & Yumarnamto, 2024). Figure 8 shows the TPS phase in Biotic audiovisual media.

The next phase is post-production and quality review of the Biotic audiovisual media. In the post-production phase, a review of the Biotic audiovisual media is conducted to determine whether it is functioning well in line with the intended goals. (Lee & Owens, 2004). The evaluation includes validity testing and practicality testing. Validity testing aims to ensure the appropriateness of the media and to gather expert validation to improve the quality of the Biotic audiovisual media. A subject-matter expert, a media expert, and a Biology education practitioner conduct the validation.

3.4 Evaluation

Validity Test

The purpose of the validity test is to ensure alignment with the media and to gather feedback and suggestions from expert validators to enhance the quality of the Biotic audiovisual media product. (Lee & Owens, 2004). After validation, revisions are made to improve the developed product based on the validation results. Validation was conducted by experts in the subject matter and media, as well as a Biology education practitioner.

The subject matter expert validation aimed to evaluate the content of the Biotic audiovisual media. It was conducted by a lecturer from the Department of Biology at the State University of Malang with over five years of teaching experience. Content validity was assessed using a validation sheet for subject matter experts in two stages.

Table 2 Results of validation by subject matter expert

No.	Aspects Evaluated	Score Obtained	Maximum Score	Percentage	Criteria
1	Content Suitability	80	80	100.0%	Very Valid
2	Presentation	30	30	100.0%	Very Valid
3	Language	30	30	100.0%	Very Valid
Total		**140**	**140**	**100.0%**	**Very Valid**

Table 3 Results of validation by media expert

No.	Aspects Evaluated	Score Obtained	Maximum Score	Percentage	Criteria
1	Media Quality	45	45	100.0%	Very Valid
2	Media's Ability to Train Metacognitive Awareness	25	25	100.0%	Very Valid
3	Media's Ability to Train Cognitive Learning Outcomes	30	30	100.0%	Very Valid
4	Display	83	85	97.6%	Valid
5	Visual Communication	35	35	100.0%	Very Valid
Total		**218**	**220**	**99.1%**	**Valid**

The results of the subject matter expert validation are shown in Table 2.

Based on the data in Table 2, it is evident that the content of the Biotic audiovisual media encompasses three evaluation aspects: content suitability, presentation, and language. All three aspects received a 100% score, indicating they are "very valid." This indicates that the content of the Biotic audiovisual media is suitable for use. The subject-matter expert's validation must yield valid results and provide accurate or reliable information to avoid misunderstandings among learners when interpreting it. (Wati, 2016; Wisdayana, Achyani, Aththibby, & Pratiwi, 2025)

According to the subject-matter expert, the content in the Biotic audiovisual media aligns with the learning objectives, and the material concepts are very accurate. Content suitability received a 100% score, indicating that the content aligns with the educational goals and learning outcomes and meets the academic standards expected of the media. (Daryanes et al., 2023). The presentation aspect received a 100% score, indicating that the material was presented appropriately, with engaging colors and images, as the subject matter expert suggested. According to Golding & Verrier (2021) and Maharani et al. (2022)In comic media, content is presented in panel features with structured images and text, which can facilitate understanding of the material and enhance the comic's usefulness for learning. The language aspect also received a 100% score, indicating adherence to Indonesian language rules. The validator further stated that the media uses proper grammar and only requires minor revisions to achieve more transparent and communicative sentences. The language used in the media must be clear and compelling to explain concepts, thereby improving communication and learning. (Firdaus et al., 2024). Overall, the subject matter expert's validation results indicate that the Biotic audiovisual media's content is of excellent quality and ready to use in the learning process.

A media expert and lecturer with more than 5 years of teaching experience also validated the Biotic audiovisual media. The validity of the media was measured using a media expert validation sheet. The validation results for the media are shown in Table 3.

Based on the data in Table 3, the aspects validated by the media expert include media quality, the ability of the media to enhance metacognitive awareness, its ability to improve cognitive learning outcomes, display, and visual communication. Table 3 presents the media expert validation findings, which indicate that the Biotic audiovisual media achieved an overall score of 99.1% and a validity category of "valid." This indicates that the Biotic audiovisual media is highly appropriate for use in the educational process. Developed media should be validated before widespread use to avoid deficiencies or errors. (Arsyad, 2019; Wisdayana, Achyani, Aththibby, & Pratiwi, 2025).

The media received a 100% score, indicating it meets the quality standards typical of comics. According to the media expert, Biotic audiovisual media generally align with learners' characteristics. Educational media, such as e-comics, must be developed to match learners' cognitive levels. (Abrori, Lavicza, & Cahyono, 2025). The Biotic audiovisual media is equipped with a learning journal accompanied by metacognitive awareness indicators, so its ability to train metacognitive awareness receives a 100% score in a very valid category. This demonstrates that the media can be utilized to train metacognitive awareness. A learning journal is an effective strategy for encouraging learners to monitor their learning process, thereby increasing metacognitive awareness. (Alt & Raichel, 2020; Makiaway, Raganas, Serbo, & Acuña, 2024). The media also yielded very valid results, scoring 100% in its ability to train cognitive learning outcomes, as it includes practice questions that students can work on. This demonstrates that the media can be utilized to train cognitive learning outcomes. Learners who engage in practice exercises or problems achieve higher learning outcomes than those who just reread the material. (Carvalho, McLaughlin, & Koedinger, 2022).

Table 4 Results of validation by Biology education practitioner

No.	Aspects Evaluated	Score Obtained	Maximum Score	Percentage	Criteria
1	Content	43	45	95.5%	Valid
2	Media Display	43	45	95.5%	Valid
3	Language	24	25	96.0%	Valid
4	Media Applicability	52	55	94.5%	Valid
Total		**162**	**170**	**95.3%**	Valid

The display aspect of the media received a score of 97.6%, categorized as valid, indicating that the Biotic audiovisual media has an appropriate display. Revisions were made in response to the media expert recommendations, particularly regarding the font size, to ensure legibility and prevent distractions in the media display. The media expert also noted that the Biotic audiovisual media is systematically organized, with appealing animations and an engaging presentation. Referring to cognitive load theory, multimedia-based learning media with interactive displays and attractive elements can reduce learners' cognitive load (Haryana, Warsono, Achjari, & Nahartyo, 2022; Sweller, 2020). Visual communication in Biotic audiovisual media received a 100% score, indicating that the effective use of images, colors, typography, symbols, and audio is achieved. The audiovisual elements in the media help convey the message more clearly and understandably, particularly for complex biological concepts. (Agada & Sam-Kayode, 2022). In conclusion, the media expert validation suggests that the Biotic audiovisual media effectively fosters metacognitive awareness and improves cognitive learning outcomes. It is suitable and relevant for use in educational settings.

The validation by a Biology education practitioner aims to assess and validate the developed media product. The media was validated by a Biology education practitioner with over 10 years of teaching experience. The validation results from a Biology education practitioner were measured using a validation sheet for Biology education practitioners. The results of the media validation are presented in Table 4.

Based on the data in Table 4, it is evident that the aspects validated by the Biology education practitioner include content, media quality, language, and the applicability of the media. The validation results from the Biology education practitioner show a 95.3% validity rate, categorized as "valid". This indicates that the Biotic audiovisual media are feasible and appropriate for use, particularly in Biology instruction.

The content aspect received a score of 95.5%, indicating validity. The content must receive a valid score, with information that supports and enhances students' understanding, ensuring a smooth learning process and alignment with the learning objectives (Ediyani et al., 2020; Wisdayana, Achyani, Aththibby, & Pratiwi, 2025). The media display aspect also received a score of 95.5%, indicating that the display is well-organized. The Biology education practitioner noted that the media has an attractive display with animations that can capture students' interest while reading the material. Educational media must feature an appealing design to engage students' attention and reduce their cognitive load (Surbakti, Umboh, Pong, & Dara, 2024; Sweller, 2020). The language aspect of the media achieved a score of 96%, indicating adherence to Indonesian rules. The language used in the media must be clear and communicate effectively, conveying conceptual explanations in a way that students can understand (Firdaus et al., 2024). The media applicability aspect scored 94.5%, demonstrating that the media is easy to operate. The validator noted that the media is user-friendly and modern, aligning with current technological trends. Educational media must be accessible and usable, which is an important factor in facilitating more effective and efficient learning processes (Astuti, Suranto, & Masykuri, 2020; Lubis, Febriani, Yana, Azhar, & Darajat, 2023). Overall, the validation results from the Biology education practitioners indicate that the Biotic audiovisual media is of high quality and ready to use in the learning process.

Practicality Test

This practicality test aims to test whether the developed Biotic audiovisual media product is practical and easy for users to use (Branch, 2009). During this trial stage, students interacted with the developed learning media during one learning session, conducted in a controlled setting and supervised by the researcher. After using and understanding the media and based on their experiences throughout the session, students were invited to complete a questionnaire to evaluate the media's practicality.

This practicality test consists of three stages, based on Branch (2009), which are essential to ensure the practicality of the developed media, namely: (1) one-to-one trial, (2) small group trial, and (3) field trial. For the one-to-one trial, three participants were selected, representing low, medium, and high cognitive levels. Similarly, nine students were selected for the small group trial, representing low, medium, and high cognitive levels. Trials were conducted with students with diverse abilities to ensure that the media developed was inclusive, adaptable, and effective for use across the full range of student abilities. (Lee & Owens, 2004). The field trial involved 36 students from the same class. The results of the Biotic audiovisual media product trial are shown in Figure 9.

Based on the data in Figure 9, the trial results show an average of 91.4% for content, 91.1% for interest, and 90.1% for presentation. The content aspect of the learning

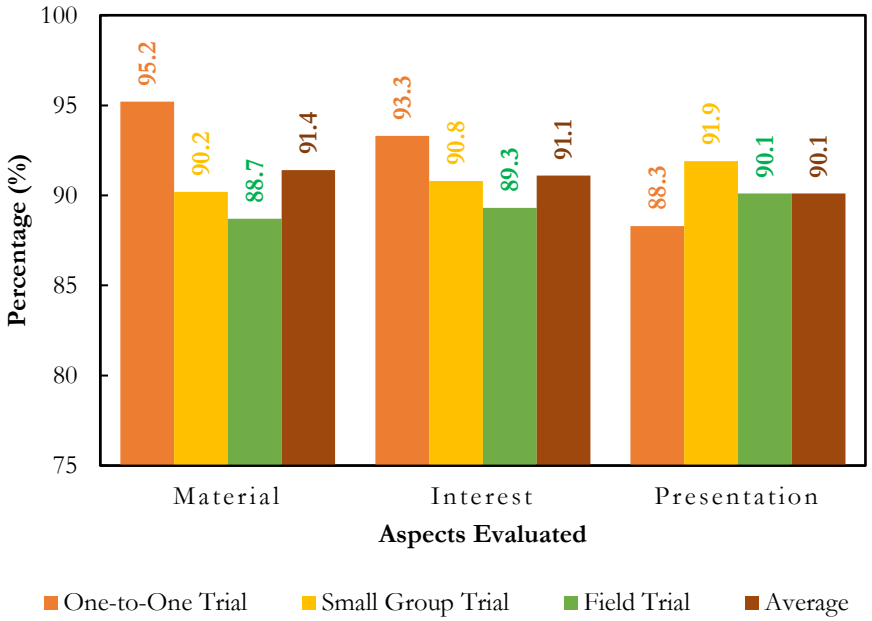


Figure 9 Diagram of practicality results

Table 5 Summary of practicality test results

No.	Type of Trial	Total Score Obtained	Maximum Score	Percentage	Criteria
1	One-to-one trial	304	330	92.1%	Practical
2	Small group trial	901	990	91.0%	Practical
3	Field trial	3,540	3,960	89.4%	Practical
Average				**90.8%**	Practical

media received a practical rating, indicating that students easily understood the content in the Biotic audiovisual media. Many students responded that the results of the three experiments were easy to understand, as presented in a comic story. Comics, as a learning medium, can convey information through their images and text. The combination of images and text into a narrative makes the material easier to understand and remember, even for an extended period. (Apostolou & Linardatos, 2023).

The interest aspect yielded a practical result, indicating that students had a high level of interest in the Biotic audiovisual media. In addition to being easy to understand, many students stated that the e-comic media was an interesting learning resource. Educational media should be attractive and interactive to increase student interest and make learning more enjoyable (Mariati, 2024). The presentation aspect achieved an average result in the practical category, indicating that the media was presented effectively. The Biotic audiovisual media is easy to operate because it includes usage instructions. Media should be easily accessible, allowing students to focus on learning and understand the material without difficulties (Nurhalimah & Azzahra, 2023). Table 5 presents a summary of the average scores from the one-to-one trial, small group trial, and field trial.

Based on the data in Table 5, the results indicate a high level of practicality across all stages, with an overall average practicality score of 90.8%, which is categorized as "practical." This indicates that the Biotic audiovisual media developed can be efficiently used across various levels of student ability. The one-to-one trial achieved 92.1% in the "practical" category. This indicates that the media can be efficiently utilized from the student's perspective. The small group trial, which simulated a more interactive experience with a small number of students, achieved 91.0% in the "practical" category. This indicates that the media were able to follow the expected learning flow in groups.

In the field trial, which involved a whole classroom with a larger number of students, the media scored 89.4% in the "practical" category. This indicates that the media remained usable even in a more complex instructional context. However, during the field trial, suggestions were made to adjust the font and table sizes for easier readability. The media's font size must be appropriate to ensure clear readability. (Hayati, Panjaitan, Tenriawaru, & Yixuan, 2025). Overall, the one-to-one, small-group, and field-trial results received positive feedback from the students. Consistent scores across trials reflect the medium's practicality anad adaptability to various classroom formats.

The validity and practicality of the Biotic audiovisual media on the respiratory system offer several advantages for students. First, the Biotic audiovisual media can enhance metacognitive awareness through the learning

journal included within the media. Using a learning journal can help students prepare for independent learning and evaluate their progress, thereby fostering metacognitive awareness. (Chinpakdee, 2022). Second, the Biotic audiovisual media can train students' cognitive learning outcomes through the comic material and practice questions included in the press. Media that provides questions after presenting the material will allow students to apply the concepts they have learned (Nurilyasari & Sundaygara, 2023). Third, in the Biotic audiovisual media, students can see how the sequence of oxygen intake processes is simulated and visualized by the comic characters. This enables students to learn more deeply through the comic's visualizations. (Boucher, Bach, Stoiber, Wang, & Aigner, 2023). In the Biotic audiovisual media. Fourth, the Biotic audiovisual media are accessible to students with varying learning styles. As an audiovisual medium, it combines the audio elements from the comic dubbing and the visual aspects of the comic story. Students with visual and auditory learning styles can benefit from this media. Audiovisual media, with engaging sound and visual features, significantly motivate students to learn. (Surjono, 2022). Therefore, Biotic audiovisual media are used to convey messages and can enhance metacognitive awareness, improve cognitive learning outcomes, and help create effective and efficient learning..

4. CONCLUSION

The research and development results indicate that the Biotic (Biology E-Comic) audiovisual media, based on the TPS model and integrated with the SDG Good Health and Well-Being, to train metacognitive awareness and cognitive learning outcomes in respiratory system material for Phase F senior high school, is valid and practical. The validity test shows valid results, with validation from a subject matter expert at 100%, a media expert at 99.1%, and a Biology education practitioner at 95.3%. The practicality test shows results: the one-to-one trial at 92.1%, the small-group trial at 91.0%, and the field trial at 89.4%. These results indicate that Biotic audiovisual media can be used in learning. Further research is needed to implement the Biotic audiovisual media and examine its effectiveness on metacognitive awareness and cognitive learning outcomes.

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