

## CTML-BASED INTERACTIVE LEARNING MEDIA FOR ECOSYSTEM LEARNING: FEASIBILITY AND PRACTICALITY

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### ABSTRACT

This study developed interactive learning media for ecosystem topics using the Cognitive Theory of Multimedia Learning (CTML) as an instructional design framework and examined its expert-assessed feasibility and student-perceived practicality. A research and development approach was employed using the analysis, design, and development phases of ADDIE. Four validators, comprising one subject-matter expert, one media expert, and two learning experts, assessed product feasibility. A formative trial involving 35 Grade X students was used to assess practicality through a four-point questionnaire. Descriptive percentage analysis indicated an overall expert-feasibility score of 97.5% and an overall student-practicality score of 86%. Among CTML-related ratings, coherence received the highest score (89%), whereas signaling received the lowest (80%); the interactivity principle was rated at 85%. These findings indicate that the product was judged feasible by experts and practical by the participating students. However, CTML-informed design was not tested through direct measures of cognitive processing, cognitive load, or learning outcomes. Further implementation and controlled evaluation are required to determine its effects on ecosystem understanding.

**Keywords:** cognitive theory of multimedia learning; ecosystem; interactive learning media

### INTRODUCTION

Education in the 21st century focuses on learning that is centered around the student and helps them build important skills like thinking critically, analyzing situations, and solving problems that are needed in today's world (Griffin et al., 2012; OECD, 2019; Voogt & Roblin, 2012). The Independent Curriculum is designed to encourage flexible and meaningful learning, allowing students to take an active part in their education and helping them build scientific thinking skills to better understand complicated biological concepts (Chi, 2009; Hmelo-Silver, 2004; Mayer, 2014; OECD, 2019).

Learning media helps present information in a way that fits how students learn, making it easier for them to pay attention and create clear ideas about what they are learning (Hadi & Agustina, 2020;

Mayer, 2021; Moreno & Mayer, 2010, 2007; Suryanti et al., 2025). In biology education, this role is important because the topics are closely connected in meaning and need good visual representations to understand properly (Ainsworth, 2006; Gilbert, 2008; Treagust & Tsui, 2014). Studies from around the world suggest that using interactive multimedia tools can help students better understand science concepts and stay more interested in their learning (Abdulrahman, Faruk, Oloyede, Surajudeen-Bakinde, Olawoyin, & Mejabi, 2020; Kalyuga, 2021; Zhu, 2020).

Ecosystem matter is a complicated type of biological material because it involves the way living and non-living parts interact in a constantly changing system (Hafzah, 2020; Odum & Barrett,

2005; Urry, 2020). This complexity often makes it hard for students to understand certain ideas, especially since many processes can't be seen directly and require knowing how different parts connect together (Mayer, 2021; N. Nurhidayah, 2020; Treagust, 2008)

any high school students still have wrong ideas about ecosystem materials, especially when it comes to how energy moves through an ecosystem and how different organisms relate to each other (Duit, 2012; Nurfadilah, 2021; Özkan, 2004) . This means that for students to learn effectively, the information presented needs to help them create clear and correct mental images of what they are learning (Abdulrahman, Faruk, Oloyede, Surajudeen-Bakinde, Olawoyin, & Mejabi, 2020; Fiorella & Mayer, 2015; Mayer, 2021). Studies from around the world have found that using multimedia visuals can help clear up misunderstandings about complicated science topics (Kalyuga, 2021; Moreno & Mayer, 2007; van Merriënboer & Sweller, 2010)

These challenges are also connected to how the mind processes information (Mayer, 2021; Paas & van Merriënboer, 2020; Sweller et al., 2011). The limited capacity of working memory can make it harder for students to handle complex information, which may increase their mental effort (Mayer, 2021; Paas & van Merriënboer, 2020; Sweller, Ayres, et al., 2019). Irrelevant cognitive load happens when information is presented in a messy or too much way, making it harder to understand (Kalyuga, 2021; Leppink, 2013; Mayer, 2021).

In multimedia learning, information should be presented in a well-planned way to lower extra mental effort and make learning more effective (Abdulrahman,

Faruk, Oloyede, Surajudeen-Bakinde, Olawoyin, & Mejabi, 2020; Mayer, 2009, 2021). This shows that creating learning materials isn't just about how they look, but also about how well they match how students think and learn (Fiorella & Mayer, 2015; Kalyuga, 2021; Putri et al., 2025; Sweller, Ayres, et al., 2019)

In line with this, the Cognitive Theory of Multimedia Learning (CTML) says that people process information through both visual and audio channels, which have a limited ability to handle information. This theory also talks about how people choose, arrange, and combine information together (Fiorella & Mayer, 2015; Mayer, 2014, 2021; Sweller, Ayres, et al., 2019). Using CTML principles helps present information in a more focused way, which can help students understand better (Abdulrahman, Faruk, Oloyede, Surajudeen-Bakinde, Olawoyin, & Mejabi, 2020; Kalyuga, 2021; Mayer, 2021).

Interactive learning media combines text, images, audio, animations, and interactive activities all in one place to help students stay interested and motivated (Abdulrahman et al., 2020; Mayer, 2021; Sipayung et al., 2026; Wulandari et al., 2019). So, interactive media can help solve problems when people struggle to understand complicated topics like ecosystems.

The first observation results showed that the media use indicators scored 79%, learning difficulties scored 63%, information processing scored 78%, media needs scored 77%, and media availability scored 70%. All of these were in the high category. The high levels of media use and need showed that students really needed media as part of their learning, while the indicators of learning challenges and how information was processed showed that

there were problems in understanding the material.

The results match up with studies that show students have a high need for Biology learning materials, especially ones that are visual and interactive (Abdulrahaman et al., 2020; Putri et al., 2026; C. C. Sipayung et al., 2026; Wulandari et al., 2019) This shows that there is still a big need for interactive learning materials in studying Biology.

However, the use of text, images, audio, animation, and interactive features does not by itself indicate that multimedia has been designed according to CTML. Empirical and theoretical evidence in multimedia learning shows that learning depends not only on the availability of multiple media elements but also on how verbal and visual information is selected, organized, and presented in accordance with cognitive processing principles (Abdulrahaman et al., 2020; Kalyuga, 2021; Mayer, 2021).

Digital multimedia has been developed and examined for a range of science topics, including ecology and ecosystems. In *Eduproxima*, (Agustin et al., 2025) evaluated Android-based interactive multimedia for ecology and biodiversity learning, while (Yarnas & Sari, 2026) developed Scratch-based media for ecosystem topics and reported feasibility, learner responses, and pretest–posttest results. (Purnama et al., 2025) identified the need for interactive digital resources addressing ecosystem learning, and (Zahrah et al., 2026) developed educational games focused on interactions among ecosystem components. In another science context, (Ihsan et al., 2024) reported expert judgments of Android-based interactive multimedia oriented toward higher-order thinking skills.

Collectively, these studies establish the educational relevance of interactive multimedia; however, they differ in educational level, product type, evaluation design, and learning outcomes. Their findings should not be treated as evidence that CTML-informed designs outperform conventional interactive multimedia. An unresolved design and evaluation issue is how specific multimedia features are explicitly mapped to cognitive principles rather than simply combined in a digital product. CTML offers a theory-informed framework for organizing visual and verbal representations through principles such as coherence, signaling, contiguity, segmenting, and pre-training (Mayer, 2021). The present study therefore focuses on traceable connections between selected CTML principles, media features, expert feasibility judgments, and student-perceived practicality within Grade X ecosystem learning. This is a design-oriented contribution, not a comparative test of CTML-based versus conventional multimedia.

The novelty of this study lies in the development of interactive learning media that systematically integrates CTML principles, including coherence, contiguity, signaling, segmenting, pre-training, multimedia, personalization, and interactivity, into the design and presentation of ecosystem material. In this study, CTML serves as a theoretical framework for designing the media rather than as an empirically tested model of students' cognitive processing. Therefore, the study focuses on the feasibility of the developed media and students' perceptions of its practicality, without directly measuring cognitive processing, cognitive load, conceptual understanding, or learning outcomes.

Therefore, this study aims to develop interactive learning media based on CTML for ecosystem material and to evaluate its feasibility and practicality.

## **RESEARCH METHODS**

### **Research Approach**

This study is a research and development project that focuses on creating interactive learning materials based on CTML ecosystem content. The model used for development is ADDIE, which has five steps: Analysis, Design, Development, Implementation, and Evaluation. In this study, the focus is on the development stage because the research is mainly about creating and first checking if the learning media is possible and useful.

### **Research Participants**

The product feasibility test was reviewed by four experts, including one who specializes in materials, one who focuses on media, and two who are experts in learning. The experts evaluated media feasibility in terms of content, presentation, and learning suitability.

The experts' qualifications are described without naming them, but the information given is clear and helpful. The subject matter expert is a permanent lecturer in the Biology Education program at a university and holds a S2 education qualification. They have expertise in the field of ecosystem materials. The media expert is a full-time lecturer in the Biology Education program and specializes in educational technology and creating digital learning materials. Meanwhile, the learning expert is made up of two people: one is a Biology Education lecturer with a S3 qualification, and the other is a High School Biology teacher who is currently

teaching. This helps them better understand the students' characteristics and how learning happens in the classroom.

The practicality test involved 35 students from one Grade X class consisting of 41 students. The participants were students who were present and completed the practicality questionnaire at the time of data collection, while six students did not participate because they were absent or had permission to be away from school. Thus, the 35 participants represented the available students in the selected class rather than a statistically representative sample of the wider Grade X population. Therefore, the practicality results describe the responses of the participating students within this specific classroom context and should not be generalized to a broader student population.

This practicality assessment was conducted as a formative trial in one selected Grade X class using a non-probabilistic classroom sample.

### **Research Instruments**

The research data was gathered by observing at the beginning, talking to teachers, asking students about their needs through questionnaires, getting validation from experts, and also checking what students think about the media. The needs analysis questionnaire was used to get a general idea of how people use media, the challenges they face in learning, how they process information, what media they need, and what facilities are available. The first observation results showed that the media use indicators scored 79%, learning difficulties scored 63%, information processing scored 78%, media needs scored 77%, and media availability scored 70%, and all of these were in the high range.

### **Data Collection**

During the analysis phase, the team first looked at how students were learning, talked to biology teachers, and gave questionnaires to students. This helped find out about the learning environment, how often media was used, the challenges students faced, how they process information, what media they need, and whether there were enough supporting resources available. The findings from the needs analysis helped decide the features of the created media.

During the design phase, learning goals are created, the materials are matched to the ecosystem, the flow of media is planned, a storyboard is made, and different ways of interacting are decided. Media design is based on the CTML principle, which involves three kinds of thinking processes: extraneous processing, essential processing, and generative processing. In extraneous processing, they use three main ideas: signaling to highlight what's important, coherence to remove extra stuff that isn't needed, and contiguity to keep text and images close together and shown at the same time. In essential processing, the ideas of breaking material into smaller parts step by step and teaching basic ideas before moving on to the main topic are used. At the same time, in generative processing, the ideas of using different types of media like text, pictures, and animation, making content fit the user's needs with appropriate language, and letting students interact by navigating and participating in the media are all used.

The development stage involves turning the design into an interactive learning tool that includes text, images, animations, sounds, navigation features, and interactive elements. After the

products are made, they are checked by experts in materials, media, and learning. These experts give their opinions on whether the material is appropriate, how good the media is, how well it's presented, and if it matches the students' needs. A small test is done to see how students react to the new media that was created.

### **Data Analysis**

The data from expert validation and student perception were analyzed quantitatively descriptively using percentages. Expert validation assessments were used to determine the feasibility of the media, while the results of student perceptions were used to determine the practicality of the media. The results of the percentage of student perception were then interpreted based on practicality criteria, namely 81–100% very practical, 61–80% practical, 41–60% quite practical, 21–40% not practical, and 0–20% impractical. The student perception questionnaire uses a four-level Likert scale, namely a score of 4 (*strongly agree*), 3 (*agree*), 2 (*disagree*), and 1 (*strongly disagree*). The media is declared practical if it obtains a minimum percentage of 61%.

## **RESULTS AND DISCUSSION**

### **Results of the First Research Objectives**

The results of the development of interactive learning media on ecosystem materials are visualized in several main displays that reflect the application of CTML principles. These views are presented in Figure 1.



**Figure 1. Interactive Learning Media Display Based on the Cognitive Theory of Multimedia Learning (CTML) Principle**

Interactive learning media on ecosystem materials was developed by referring to the principles of *Cognitive Theory of Multimedia Learning (CTML)*. The application of these principles is shown in an integrated visual unit in Figure 1 which consists of six main displays. In the initial part, the principles of *signaling* and *spatial contiguity* are applied through the emphasis of important information and the placement of text and images adjacent to help students focus their attention and connect visual and verbal information. In addition, the principle of *interactivity* is also seen in the main menu which allows students to choose material independently so as to increase engagement in learning.

Furthermore, the *pre-training principle* is applied through the presentation of basic terms before the core material, while the principle of *coherence* is realized by presenting relevant information without distracting elements. In the other part, the principles of *segmentation* and *interactivity* are applied through the division of material into small parts accompanied by interactive activities. Meanwhile, the *multimedia* principle is applied through the use of learning videos that integrate visual and audio elements. Overall, the six views in Figure 1 show that the media is systematically designed by paying attention to the

interconnectedness between CTML principles.

## Results of the Second Research Objectives

The results of the feasibility assessment of interactive learning media by experts are presented in the form of a graph to facilitate interpretation and comparison between aspects of assessment. The graph provides a clearer picture of the distribution of scores from each expert so that it facilitates the analysis of the overall results. Visualization of the results of the feasibility assessment of the learning media is presented in Figure 2.

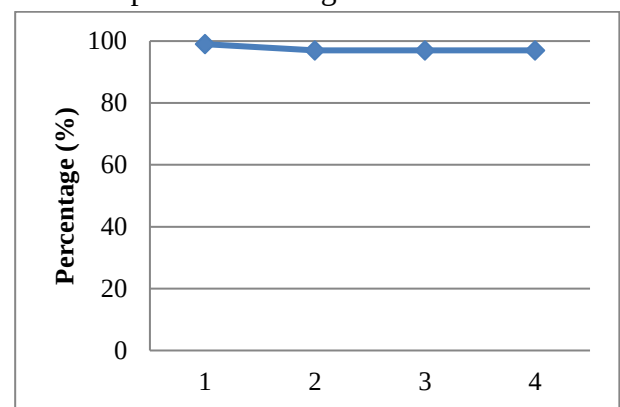


**Figure 2. Results of Media Eligibility Assessment by Members**

**Description: 1 = Media Expert; 2 = Material Expert; 3 = Learning Expert 1; 4 = Learning Expert 2.**

Based on the graph of the results of the media feasibility assessment by experts, it was obtained that the learning media developed had an average percentage of 97.5% with a very feasible category. The highest score was obtained from media experts at 99%, while material experts and two learning experts were each at 97%.

The results of the practical test of interactive learning media by students

based on assessment indicators are presented in table 1.

**Table 1. Results of the Practical Test of Learning Media by Students Based on Media Assessment Indicators**

| Indicator              | Statement          | Quantity | Percentage (%) | Average (%) |
|------------------------|--------------------|----------|----------------|-------------|
| <b>Display</b>         | Interesting        | 119      | 88             | 85          |
|                        | Clear              | 118      | 87             |             |
|                        | Proportional       | 118      | 87             |             |
| <b>Language</b>        | Consistent         | 110      | 81             | 88          |
|                        | Simple             | 121      | 89             |             |
|                        | Communicative      | 122      | 90             |             |
|                        | Easy to understand | 118      | 87             |             |
|                        | Effective          | 117      | 86             |             |
| <b>Material</b>        | Conform            | 114      | 84             | 86          |
|                        | Accurate           | 118      | 87             |             |
|                        | Systematic         | 120      | 88             |             |
|                        | Relevant           | 117      | 86             |             |
|                        | Interactive        | 116      | 85             |             |
| <b>Interactivity</b>   | Responsive         | 107      | 79             | 83          |
|                        | Participatory      | 113      | 83             |             |
|                        | Engaging           | 117      | 86             |             |
| <b>Benefits</b>        | Help               | 121      | 89             | 87          |
|                        | Simplify           | 115      | 85             |             |
|                        | Improve            | 114      | 84             |             |
|                        | Helpful            | 124      | 91             |             |
| <b>Overall average</b> |                    |          |                | 86          |

Based on Table 1, the results of the practical test of interactive learning media by students show that all indicators are in the category of practical to very practical.

The results of the assessment of the practicality of the media based on the indicators are also visualized in the form of a graph to clarify the comparison between the indicators, as presented in Figure 3.

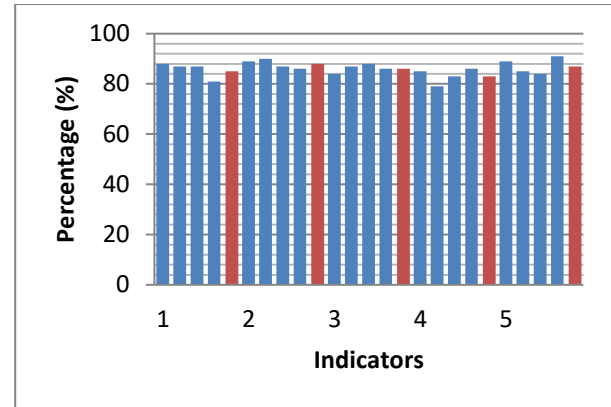


**Figure 3. Graph of the results of the media practicality test by students**

**Description: 1 = Appearance; 2 = Language; 3 = Material; 4 = Interactivity; 5 = Benefits.**

Based on Figure 3, all indicators show relatively high values.

The results of the assessment on each principle are presented in Table 2.

**Table 2. Media Practicality Test Results Based on CTML Principles**

| Types of Cognitive Processes | Principle              | Average (%) |
|------------------------------|------------------------|-------------|
| <b>Extraneous Processing</b> | <i>contiguity</i>      | 87          |
|                              | <i>coherence</i>       | 89          |
|                              | <i>signaling</i>       | 80          |
| <b>Essential Processing</b>  | <i>segmenting</i>      | 86          |
|                              | <i>pre-training</i>    | 87          |
|                              | <i>multimedia</i>      | 87          |
| <b>Generative Processing</b> | <i>personalization</i> | 87          |
|                              | <i>interactivity</i>   | 85          |
| <b>Overall Average</b>       |                        | 86          |

Based on Table 2, an overall average of 86% was obtained, which shows that the application of CTML principles in learning media received a positive response from students.

To clarify the comparison of assessment results on each CTML principle, the data is also presented in the form of a graph in Figure 4.

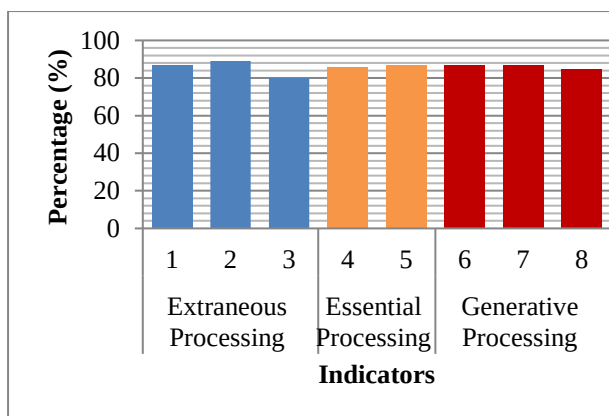


**Figure 4. Media Practicality Test Results Based on CTML Principles**

**Description:** 1 = Contiguity; 2 = Coherence; 3 = Signaling; 4 = Segmenting; 5 = Pre-training; 6 = Multimedia; 7 = Personalization; 8 = Interactivity.

Based on Figure 4, all principles show relatively high values and there are no striking differences between the principles.

### Discussion of the First Research Objectives

The application of these principles shows that learning media is not only designed to attract visual attention, but also considers the process of processing students' information. CTML explained that learning will be more effective if information is presented through visual and verbal channels that are integrated and managed according to working memory capacity (Fiorella & Mayer, 2015; Mayer, 2021). The integration between proper text and images, as well as the reduction of irrelevant information, can help students build more structured mental representations (Kalyuga, 2021; Moreno & Mayer, 2020).

These findings are also supported by recent research that shows that the use of interactive multimedia in science learning can improve students' understanding of concepts and engagement (Leppink &

Duvivier, 2016; Schindler et al., 2017; Zhu et al., 2020). In addition, the application of the principle *Segmenting* and *Consistency* proven to reduce cognitive load so that the learning process becomes more effective (Mayer, 2021; Sweller, van Merriënboer, et al., 2019). Thus, in this study, the integration of CTML principles indicates that the developed media was designed in accordance with CTML-based multimedia design principles; however, its effects on students' cognitive processing or conceptual understanding were not directly measured.

### Discussion of the Second Research Objectives

The results of expert validation show that the learning media developed has met the feasibility aspects which include content, display, and use. From the material aspect, the media is assessed in accordance with learning competencies and has good conceptual clarity. From the media aspect, an attractive appearance and easy-to-use navigation are the main advantages, while the learning aspect indicated suitability for classroom use.

The high feasibility score indicates suitability for ecosystem learning, but does not establish effectiveness or improved conceptual understanding. These results are in line with the opinion (Akbar, 2013) which states that a good learning medium must meet the aspects of content, display, and usage validity. In addition, these results are also supported by the CTML theory which emphasizes that proper visual and verbal integration can improve students' understanding (Fiorella & Mayer, 2015; Mayer, 2021). Other research has also shown that interactive and structured multimedia design improves the quality of learning and student engagement

(Abdulrahaman, Faruk, Oloyede, Surajudeen-Bakinde, Olawoyin, Mejabi, et al., 2020; Kalyuga, 2021; Mayer, 2021). Thus, the findings support the feasibility of the developed media and its practical potential for use in ecosystem learning, without establishing learning effectiveness or improved conceptual understanding.

The results of the practicality test showed that the interactive learning media developed was in the category of practical to very practical with an average of 86%. The display indicator obtained a score of 85%, language 88%, material 86%, interactivity 83%, and benefits of 87%. These results indicate that students perceived the media positively in terms of its design, language, material presentation, interactivity, and benefits.

Overall, the practicality score reflects positive student perceptions of media usability, not direct evidence of improved learning effectiveness. The findings indicate that students perceived the developed media positively in terms of usability and interactivity. Its usability allows students to access and use the media during the learning process (Al-Fraihat et al., 2020; ). Interactivity in media can provide opportunities for active participation in learning (Costley & Lange, 2021).

The results of the practicality test showed the positive response of students to the use of the developed media. The findings can be reviewed based on the CTML foundation used in media design. CTML explains that learning involves active processing through the process of selecting, organizing, and integrating information received through visual and verbal channels with limited capacity (Mayer, 2021). This framework is based on three main assumptions, namely *dual*

*channels, limited capacity, and active processing* (Mayer, 2021; Fiorella & Mayer, 2015). The application of the principles of *signaling, segmenting, and coherence* in multimedia design is aimed at optimizing the presentation of information to match the cognitive processing characteristics of students (Kalyuga, 2021; Mayer & Fiorella, 2021). Other research also shows that the use of interactive multimedia can improve cognitive engagement and the quality of student learning (Abdulrahaman et al., 2020). Thus, the high practicality score indicates positive student perceptions of the usability and CTML-based design of the media, rather than direct evidence of reduced cognitive load or improved understanding.

The practicality of media based on CTML principles was assessed through student perceptions of eight design principles grouped theoretically into extraneous, essential, and generative processing categories, namely *extraneous processing, essential processing, and generative processing*, which include eight principles, namely *contiguity, coherence, signaling, segmenting, pre-training, multimedia, personalization, and interactivity*.

All principles are in the practical category, with the highest score on the *principle of coherence* at 89%, followed by *contiguity* at 87% and *multimedia, personalization, and pre-training* at 87%. The principle of *interactivity* received a score of 85%, while *segmentation* was 86%. The principle of *signaling* received a score of 80% and remained in the practical category.

On types of cognitive processes *extraneous processing*, principle *coherence* obtained the highest score of

89%, followed by *contiguity* by 87% and *signaling* by 80%. The scores reflect positive student perceptions of relevant information (*coherence*), adjacent text–image placement (*contiguity*), and emphasis on important information (*signaling*). In CTML, the principle *coherence*, *signaling*, and *contiguity* Role in managing *extraneous processing* so as not to overload the cognitive capacity of students (Fiorella & Mayer, 2021).

The application of *the principle of coherence* in interactive learning media can be seen more concretely in the media display presented in Figure 5.

Figure 5. Application of *the Principle of Coherence* in Interactive Learning Media



Figure 5. Application of *the Principle of Coherence* in Interactive Learning Media

The image shows the presentation of material that focuses on relevant information by reducing unnecessary visual elements, reflecting the coherence principle in CTML. This design is theoretically intended to minimize extraneous processing, although students' cognitive processing was not directly measured in this study.

In the essential processing category, the pre-training principle obtained a score of 87%, while segmenting obtained 86%. These scores indicate positive student perceptions of the presentation of basic concepts before the main material and the

gradual division of material into smaller sections. Theoretically, pre-training and segmenting are intended to help learners manage complex information and avoid over-processing (Fiorella & Mayer, 2021; Sweller, Ayres, et al., 2019); however, these cognitive effects were not directly measured in this study.

On types of cognitive processes *generative processing*, principle *multimedia* and *personalization* each obtained a score of 87%, while *interactivity* obtained a score of 85%. These scores reflect positive perceptions of multimedia, personalization, and interactivity, but do not directly measure generative cognitive processing. Research shows that the use of various forms of representation needs to be accompanied by appropriate instructional design in order to support the learning process optimally (Abdulrahman, Faruk, Oloyede, Surajudeen-Bakinde, Olawoyin, Mejabi, et al., 2020; Costley et al., 2021).

The interactivity score of 85% was slightly lower than coherence (89%) and the 87% scores for contiguity, pre-training, multimedia, and personalization, although it remained within the practical category and was higher than signaling (80%). This gap suggests that students responded more strongly to the organization and presentation of information than to the interactive features of the media. Therefore, interactivity should not be interpreted only as ease of navigation or the availability of clickable features, but also as the extent to which these features provide opportunities for students to actively select, explore, and respond to learning content. However, because this study measured students' perceptions of practicality rather than their cognitive processes directly, the interactivity score

cannot be used as evidence that the media increased generative cognitive engagement. The result instead indicates a need to strengthen interactive activities that require meaningful responses to ecosystem concepts and to examine their relationship with cognitive engagement through direct measures in future research.

Overall, the average practicality based on the CTML principle is 86% indicates that the developed interactive learning media has obtained a positive response from students. Highest score on principle *coherence* 89% is one of the main strengths of the media, because it shows that the information is presented in a relevant and not exaggerated manner. This condition is important considering that irrelevant information can interfere with students' cognitive processing processes. Kajian (Skulmowski & Xu, 2022) asserts that the reduction *extraneous cognitive load* It is necessary for cognitive resources to be used for the more important learning process, while research (Fiorella & Mayer, 2021) Placing *coherence*, *signaling*, and *contiguity* as an important principle in reducing unnecessary processing. Thus, the practicality results indicate that students responded positively to media features designed according to CTML principles, but they should not be interpreted as direct evidence of students' cognitive processing or learning effectiveness.

The findings related to CTML principles should therefore be interpreted within the scope of this study. The percentages obtained represent students' perceptions of the practicality of media designed according to CTML principles, not direct measurements of the cognitive processes proposed by CTML. This study did not directly assess cognitive load,

selecting, organizing, or integrating processes, conceptual understanding, or learning outcomes. Consequently, the findings provide evidence of the feasibility and perceived practicality of the CTML-based media design, but do not establish its cognitive or instructional effectiveness. Further research using direct measures of cognitive processing and learning outcomes is needed to examine these effects.

## CONCLUSION

Based on the results and discussion, the CTML-based interactive learning media developed for ecosystem material met the feasibility and practicality criteria. Expert assessment placed the media in the very feasible category, while student responses indicated practical to very practical use. The CTML principles integrated into the media also received positive student responses, with coherence obtaining the highest score. These findings indicate that CTML principles can be systematically incorporated into feasible and practical interactive learning media for ecosystem material. However, this study did not directly measure students' cognitive processes, conceptual understanding, or learning outcomes; therefore, the findings should not be interpreted as evidence of cognitive or instructional effectiveness. Further research is needed to examine these outcomes directly. In addition, this study was limited to the analysis, design, and development stages of the ADDIE model and did not include comprehensive implementation and evaluation stages. Therefore, the findings are limited to the feasibility and practicality of the developed media within the context of this study and cannot yet be used as a basis for

concluding the success of the media in broader learning contexts. Further research should include full implementation and evaluation to examine the media across wider classroom settings.

The formative assessments conducted during the development stage should not be interpreted as the full Evaluation stage of the ADDIE model.

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## REFERENCES

- Abdulrahman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N., Olawoyin, L. A., Mejabi, O. V., Imam-Fulani, Y. O., Fahm, A. O., & Azeez, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon*, 6(11).
- Agustin, H., Fitriani, H. Y., & Dwiningsih, K. (2025). Penerapan Multimedia Interaktif Berbasis Android untuk Meningkatkan Hasil Belajar Siswa Materi Ekologi dan Keanekaragaman Hayati Indonesia. *EDUPROXIMA: Jurnal Ilmiah Pendidikan IPA*, 7(1), 172–181.
- Ainsworth, S. (2006). DeFT framework for multiple representations. *Learning and Instruction*, 16(3), 183–198. <https://doi.org/10.1016/j.learninstruc.2006.03.001>
- Akbar, S. (2013). *Instrumen perangkat pembelajaran*. Remaja Rosdakarya.
- Al-Fraihat, D., Joy, M., Masa'deh, R., & Sinclair, J. (2020). Evaluating E-learning Systems Success: An Empirical Study. *Computers in Human Behavior*, 102, 67–86. <https://doi.org/10.1016/j.chb.2019.08.004>
- Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science*. <https://doi.org/10.1111/j.1756-8765.2008.01005.x>
- Costley, J., Fanguy, M., Lange, C., & Baldwin, M. (2021). The effects of video lecture viewing strategies on cognitive load. *Journal of Computing in Higher Education*, 33, 19–38. <https://doi.org/10.1007/s12528-020-09254-y>
- Duit, R. (2012). *Conceptual Change*. <https://doi.org/10.1007/978-94-007-2457-0>
- Fiorella, L., & Mayer, R. E. (2015). *Learning as a Generative Activity*. Cambridge University Press.
- Fiorella, L., & Mayer, R. E. (2021). Principles for Reducing Extraneous Processing in Multimedia Learning: Coherence, Signaling, Redundancy, Spatial Contiguity, and Temporal Contiguity Principles. In R. E. Mayer & L. Fiorella (Eds.), *The Cambridge Handbook of Multimedia Learning* (3rd ed., pp. 185–198). Cambridge University Press.

- <https://doi.org/10.1017/9781108894333.019>
- Gilbert, J. K. (2008). *Visualization in science education*. <https://doi.org/10.1007/978-1-4020-5267-5>
- Griffin, P., McGaw, B., & Care, E. (2012). *Assessment and Teaching of 21st Century Skills*. <https://doi.org/10.1007/978-94-007-2324-5>
- Hadi, S., & Agustina, D. (2020). Pengembangan media pembelajaran interaktif berbasis multimedia. *Jurnal Pendidikan IPA Indonesia*, 9(3). <https://doi.org/10.15294/jpii.v9i3.23820>
- Hafzah, N. (2020). Analisis kesulitan belajar siswa pada materi ekosistem. *Jurnal Pendidikan Biologi Indonesia*. <https://doi.org/10.22219/jpbi.v6i2.11967>
- Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Ihsan, M. F. N., Supriatin, A., Yuliani, H., & Annovasho, J. (2024). Pengembangan Multimedia Interaktif Berbasis Android Berorientasi HOTS pada Pokok Bahasan Fluida Dinamis. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 6(2), 585–594. <https://doi.org/10.29100/.v6i2.4468>
- Kalyuga, S. (2021). Cognitive load theory and multimedia learning. *Educational Psychology Review*, 33, 1345–1368. <https://doi.org/10.1007/s10648-021-09602-4>
- Leppink, J. (2013). Cognitive load measurement. *Medical Education*. <https://doi.org/10.1111/medu.12261>
- Leppink, J., & Duvivier, R. (2016). Twelve Tips for Medical Curriculum Design from a Cognitive Load Theory Perspective. *Medical Teacher*, 38(7), 669–674. <https://doi.org/10.3109/0142159X.2015.1132829>
- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press. <https://doi.org/10.1017/CBO9780511811678>
- Mayer, R. E. (2014). *Cognitive Theory of Multimedia Learning*. <https://doi.org/10.1017/CBO9781139547369.005>
- Mayer, R. E. (2021). *Multimedia Learning (3rd Edition)*. Cambridge University Press.
- Mayer, R. E., & Fiorella, L. (2021). *The Cambridge Handbook of Multimedia Learning* (3rd ed.). Cambridge University Press. <https://doi.org/10.1017/9781108894333>
- Moreno, R., & Mayer, R. (2010). Interactive multimedia learning. *Learning and Instruction*. <https://doi.org/10.1016/j.learninstruc.2009.02.008>
- Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review*, 19(3), 309–326. <https://doi.org/10.1007/s10648-007-9047-2>
- Moreno, R., & Mayer, R. E. (2020). Verbal redundancy in multimedia learning. *Journal of Educational Psychology*, 112(3), 684–694. <https://doi.org/10.1037/edu0000409>
- Nurfadilah, Z. (2021). Miskonsepsi siswa pada materi ekosistem. *Jurnal Pendidikan IPA Indonesia*. <https://doi.org/10.15294/jpii.v10i2.27852>
- Nurhidayah, N. (2020). Analisis kesulitan

- siswa pada konsep ekosistem. *Biosfer: Jurnal Pendidikan Biologi*. <https://doi.org/10.21009/biosferjpb.13-2.5>
- Odum, E. P., & Barrett, G. W. (2005). *Fundamentals of Ecology*. Brooks/Cole.
- OECD. (2019). *PISA 2018 Results (Volume I): What Students Know and Can Do*. <https://doi.org/10.1787/5f07c754-en>
- Özkan, G. (2004). Students misconceptions about energy flow. *Journal of Biological Education*. <https://doi.org/10.1080/00219266.2004.9655910>
- Paas, F., & van Merriënboer, J. (2020). Cognitive load theory. *Educational Psychologist*. <https://doi.org/10.1080/00461520.2019.1589934>
- Purnama, S. P., Nusantara, T., & Mashfufah, A. (2025). Analisis Kebutuhan Media Pembelajaran Digital Berbasis Critical Thinking pada Materi Ekosistem di Kelas V. *EDUPROXIMA: Jurnal Ilmiah Pendidikan IPA*, 7(4), 1985–1993. <https://doi.org/10.29100/.v7i4.8170>
- Putri, I. I., Fauziah, N., Ferazona, S., Kalsum, U., & Hendrizal, A. (2025). Peran Artificial Intelligence (AI) dalam Mengelola Beban Kognitif Mahasiswa Biologi: Kajian Sistematis. *Biology and Education Journal*. <https://doi.org/10.25299/baej.2025.22896>
- Putri, I. I., Hidayati, N., Kalsum, U., Suryanti, S., Fauziah, N., Ferazona, S., Hendrizal, A., & Lestari, W. Y. (2026). Rasch Model dalam Evaluasi Instrumen Extraneous Cognitive Load pada Media Pembelajaran Berbantuan Artificial Intelligence. *Jurnal Kajian Pendidikan IPA*, 6(1), 37–49. <https://doi.org/10.52434/jkpi.v6i1.43181>
- Schindler, L. A., Burkholder, G. J., Morad, O. A., & Marsh, C. (2017). Computer-Based Technology and Student Engagement: A Critical Review of the Literature. *International Journal of Educational Technology in Higher Education*, 14, 25. <https://doi.org/10.1186/s41239-017-0063-0>
- Sipayung, C. C., Amanda, E., Gultom, R. A. B., Nasution, R. S. A., Arwita, W., & Mukra, R. (2026). Analisis Kebutuhan Media Pembelajaran Berbasis Multimedia Interaktif dalam Mendukung Pembelajaran Biologi di SMA Negeri 18 Medan. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, 11(1), 211–223. <https://doi.org/10.23969/jp.v11i01.44009>
- Sipayung, R., Sinaga, B., & Pasaribu, M. (2026). Innovation in Biology Learning Media. *Jurnal Inovasi Pendidikan*.
- Skulmowski, A., & Xu, K. M. (2022). Understanding Cognitive Load in Digital and Online Learning: A New Perspective on Extraneous Cognitive Load. *Educational Psychology Review*, 34(1), 171–196. <https://doi.org/10.1007/s10648-021-09624-7>
- Suryanti, Ferazona, S., Yeyendra, Darmia, & Mellisa. (2025). Profil Penerapan Kurikulum Merdeka pada Pembelajaran IPA di SMP. *Biology and Education Journal (BaEJ)*. <https://doi.org/10.25299/baej.2025.25107>
- Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. Springer. <https://doi.org/10.1007/978-1-4419-8126-4>

- Sweller, J., Ayres, P., & Kalyuga, S. (2019). Cognitive Load Theory. *Springer*.
- Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review*, 31, 261–292. <https://doi.org/10.1007/s10648-019-09465-5>
- Treagust, D. F. (2008). *Conceptual Change in Science Education*. <https://doi.org/10.1007/978-1-4020-8994-3>
- Treagust, D. F., & Tsui, C. Y. (2014). *Multiple representations in biological education*. <https://doi.org/10.1007/978-94-007-4192-8>
- Urry, L. A. (2020). *Campbell Biology*. <https://doi.org/10.1201/9780429493915>
- van Merrienboer, J. J. G., & Sweller, J. (2010). Cognitive load theory. *Educational Research Review*. <https://doi.org/10.1016/j.edurev.2010.01.003>
- Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences. *Educational Research Review*. <https://doi.org/10.1016/j.edurev.2012.04.001>
- Wulandari, T. A. J., Sibuea, A. M., & Siagian, S. (2019). Pengembangan Media Pembelajaran Berbasis Multimedia Interaktif pada Mata Pelajaran Biologi. *Jurnal Teknologi Informasi & Komunikasi Dalam Pendidikan*, 5(1), 75–86. <https://doi.org/10.24114/jtikp.v5i1.12524>
- Yarnas, S., & Sari, P. M. (2026). Pengembangan Media Interaktif Scratch pada Materi Ekosistem untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik Kelas V. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, 8(1), 495–506. <https://doi.org/10.29100/v8i1.8285>
- Zahrah, A., Nestiadi, A., & Kurniasih, S. (2026). Pengembangan Media Science Games untuk Meningkatkan Pemahaman Konsep Siswa Kelas VII pada Materi Interaksi antara Komponen Penyusun Suatu Ekosistem. *EDUPROXIMA: Jurnal Ilmiah Pendidikan IPA*, 8(1), 812–825. <https://doi.org/10.29100/v8i1.9119>
- Zhu, Y. (2020). Effects of multimedia learning on student engagement. *Computers & Education*, 144, 103708. <https://doi.org/10.1016/j.compedu.2019.103708>