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Design Thinking in Action: *How Pre-Service Biology Teachers Represent Abstract Concepts Through Learning Media*

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Abstract

Background: *The development of biology learning media requires pedagogical skills, conceptual understanding, and representation skills. However, research examining how pre-service teachers integrate these three elements in the design thinking process to develop learning media is still very limited. This study aims to identify the types of biological concepts chosen by pre-service biology teachers in the development of learning media, investigate how they represent abstract biological concepts, and analyze their thinking process in designing learning media.* **Methodology:** *The study employed a concurrent mixed-methods design to examine pre-service biology teachers' design thinking through analysis of blueprints and photos of learning media developed by seven groups; data were coded for concept types, representation types, and design thinking processes, with only concept types analyzed quantitatively using percentage calculations across groups.* **Findings:** *The results showed that the types of biological concepts selected were structure, system, and process. The consistency of all groups in using visual representations, symbols, and narratives for all types of concepts demonstrates the pedagogical awareness of pre-service biology teachers regarding the importance of integrating multiple representations to support meaningful concept understanding. From a design thinking perspective, students went through the stages of empathy, defining problems, generating ideas, and selecting the media to be developed.* **Contributions:** *This study shows that pre-service biology teachers have developed representational competence, but they still tend to prioritize visual appeal over conceptual support. These findings recommend strengthening pre-service biology teachers' skills in designing learning media that promote deep conceptual understanding, not merely visual appeal.*

Keywords: *Concept Representation; Learning Media; Design Thinking; Biology; Pre-Service Teacher*

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INTRODUCTION

Biology learning at the senior high school level frequently presents significant challenges for students due to the abstract and complex nature of its concepts. Many biological objects are too small or too large to be observed directly and are sometimes interrelated across concepts (Gilissen et al., 2021), abstract in nature and not directly accessible to sensory experience (McDaniel et al., 2022), and even involve multiple levels of life organization, which increases their complexity (Christensen & Lombardi, 2024; Narguizian, 2025). As a result, these characteristics often hinder students' conceptual understanding and lead to persistent conceptual difficulties in biology learning.

To bridge abstract concepts that are beyond the reach of the eye and present easily understandable relationships, a medium is needed. This medium is learning media (Lubis et al., 2023; Saputri et al., 2025). The representation of something abstract in a symbol (Thyberg et al., 2024), visual appearance (Uminski et al., 2025; Thyberg et al., 2024), and analogies will influence the way students construct their understanding of a biological concept (Torkar, 2017). There needs to be a medium that is conceptually appropriate and easy for students to use. An inappropriate medium will actually be detrimental to students, causing misconceptions and simplifying information or concepts incorrectly (Maduratna & Jayanti, 2022). Therefore, learning media should be created by people who are competent in pedagogy and related scientific fields, such as teachers. This is the basis for the importance of pre-service teachers having the ability to design and develop learning media.

Pre-service biology teachers need to have open-mindedness, breadth of thinking, and creativity in developing learning media. Many media developed focus only on their aesthetic appearance (Çeken & Taşkın, 2022). Many media are also developed by imitating existing media examples. Not a few learning media developments are not based on the characteristics of the concept and the characteristics of students (Martin & Bolliger, 2022; Tao & Tao, 2024). In fact, the principles of media development include coherence and signaling, which aim to reduce cognitive load and make it easier for students to understand, not just to attract them (Mayer, 2017). The process of developing learning media actually requires a process of thinking. The thinking process of an educator in this case involves an accurate understanding of biological concepts, pedagogical abilities, and the skills to represent concepts.

The thought process of pre-service teachers in designing these media is rarely explored in depth. Most research on learning media development still focuses on the final product, namely the validity, practicality, and effectiveness of the learning media developed. This is demonstrated in a systematic literature review of 28 articles on media development, which shows that media is developed through a series of research and development, some of which use the ADDIE model (Khowim, 2024). A bibliometric analysis of 43 Scopus articles specifically examining publications on the development of biology learning media still predominantly discusses the product and effectiveness of media in terms of learning outcomes (Kusmahardhika et al., 2024). The approach in these studies has not explored teachers' mindsets in analyzing the underlying reasons for media development and how media is designed in terms of

content characteristics and student characteristics. The cognitive and pedagogical processes of educators in developing media have not been revealed.

The cognitive and pedagogical processes involved in designing and developing learning media demonstrate an educator's design thinking. Design thinking is a systematic process for solving problems in an innovative and user-centered manner (Eamcharoen, 2024). Educators need to have design thinking as a lens of analysis for the media they will develop (Albay & Eisma, 2025; Novak & Mulvey, 2021). Design thinking is more relevant than instructional design models because it emphasizes the cognitive and pedagogical thinking processes of pre-service teachers in understanding students' characteristics, biological concepts, and appropriate representations when designing learning media (Panke, 2019). While others models mainly guide educators through structured procedural steps (Baran & Alzoubi, 2023), design thinking functions as an analytical lens that reveals the pedagogical and conceptual depth needed by pre-service teachers to plan and implement meaningful and engaging learning.

The development of effective learning media in biology requires educators to possess a clear understanding of students' characteristics, the conceptual nature of biological content, and appropriate strategies for representing abstract biological ideas through instructional media. For pre-service teachers, these competencies are closely related to their design thinking abilities, which reflect how they integrate pedagogical considerations with conceptual understanding during the media development process. Investigating the design thinking of pre-service biology teachers is therefore important to reveal the depth of their pedagogical and conceptual reasoning as future educators who will be responsible for planning and implementing meaningful learning experiences. Accordingly, this study aims to examine the types of biological concepts selected by pre-service teachers when developing instructional media, to analyze how abstract biological concepts are represented through learning media in ways that facilitate student understanding, and to explore the cognitive processes underlying pre-service teachers' decisions when designing such media. Understanding these aspects is expected to provide insights into the development of pre-service teachers' pedagogical content knowledge and their conceptual understanding of biology, which ultimately reflects their readiness to perform professional roles as biology educators.

METHOD

Research Design

The design thinking of pre-service biology teachers was examined through artifact analysis using a concurrent mixed-methods approach (qualitative and quantitative) (Mertens, 2009). Quantitative and qualitative data were collected to answer each research objective (Table 1). Design thinking consists of five stages, which are empathize, define, ideate, prototype, and test (Kelley & Brown, 2018). In this study, design thinking was used as a framework for analyzing artifacts. The artifacts referred to are learning media blueprints and media products.

Table 1. Quantitative and Qualitative Data Components of the Study

Research Focus	Data Type	Unit of Analysis	Data Collected
Types of biological concepts selected in learning media development	Quantitative	Learning media topic	Frequency of biological concepts categorized as process, system, and structure
	Qualitative	Description of learning content	Characteristics of abstraction in each biological concept
Representation of abstract biological concepts in learning media	Qualitative	Visual and textual elements of media	Types of representations (visuals, analogies, symbols, narratives, diagrams)
Thinking process of pre-service teachers in designing learning media	Qualitative	Design decisions and rationale	Evidence of empathize, define, ideate, and prototype stages

The analysis was conducted starting from the mindset of pre-service biology teachers in determining the basis for media development (empathy), defining the problem (define), developing media ideas (idea), to selecting media (prototype). In this study, the framework was limited to the prototype stage, that is, how students determine or select the media products they develop.

Research Subject and Context

The subjects of this study were 48 pre-service biology teachers (divided into 7 groups) who took the biology learning media course at Universitas Negeri Yogyakarta in 2025. In order to uphold ethical considerations, researchers have obtained consent from participants for their media designs to be published and guarantee not to mention their names in the research (anonymous). The subjects were selected using convenience sampling, based on accessibility and the availability of data during the implementation of the course. The selected class implemented a learning process that involved the development of learning media from blueprint preparation to final media production, enabling comprehensive data collection for the purposes of this study. Their task was to design and produce biology learning media appropriate for the needs of students and the material requirements of biology learning implemented under the Merdeka Curriculum.

Data Sources and Data Collection Techniques

The first data source analyzed was the learning media blueprint designed by pre-service biology teachers as a reference in media development. This media blueprint is a preliminary design created before the media is developed. The learning media blueprint consisted of several minimum components, included: (1) media title; (2) subject and learning material; (3) learning outcomes; (4) learning objectives;

(5) type of media; (6) function of the media within the learning syntax; (7) analysis of learning needs and problems; (8) detailed explanation of media content, which could be presented in the form of images, tables, or descriptive text; (9) mode of use (classical or individual); (10) supporting learning devices, such as lesson plans, student worksheets, or other relevant materials; (11) technical requirements, including tools, materials, and technology; and (12) validation plan. The blueprint contains information about pre-service biology teachers thinking that underlies media development and media design selection. The blueprint is a source of data to answer all research questions. The second data source is media products documented in the form of photographs. This media provides information about the realization of the blueprint.

The triangulation was conducted by comparing data from the learning media blueprint and the resulting media products to see the compatibility between the preliminary design and the development results. In addition, peer debriefing was conducted through discussions between researchers. The first and third researchers were biology education lecturers who were experienced in teaching learning media courses and played a role in analyzing pedagogical compatibility and the representation of biological concepts in the media. The second researcher is an expert in the field of biological research who is tasked with examining the accuracy of concepts and the depth of biological content raised in the media. The fourth researcher is an expert in the field of learning innovation who plays a role in assessing the novelty, feasibility, and potential for student engagement in the developed media.

Data Analysis Techniques

Data analysis was conducted according to the type of data in each research question. The first question about the type of biological concepts chosen by pre-service biology teachers was answered by identifying biological concepts in the blueprint and then categorizing them. This categorization is based on research by Chatzikyriakidou et al., (2021), who classified five core concepts of biology, which are structure and function, systems, biological processes, transformation of matter and energy, and evolution. The data for the first research question was described quantitatively and qualitatively. The frequency of occurrence of each concept group selected by pre-service biology teachers was calculated. Next, qualitative data was obtained by reducing the data, selecting important data by coding it, then collecting and analyzing the codes according to the research questions (Belotto, 2018). The characteristics of abstraction in each biological concept are investigated by assigning a code to the type of characteristics for each topic. Coding was carried out by the first author to maintain code consistency. The coding results were then discussed with the other authors for review to obtain inter-rater reliability, based on the researchers' agreement.

The second question about how to represent abstract concepts was answered by analyzing the visual elements in the media, the explanatory text used in the media, and the flow that appeared in the media. The data for the second research question was analyzed using coding developed based on multiple representation theory with coding categories including visual, symbolic, narrative, analogy, and diagram

representation types. One topic can be represented in more than one type of representation. This is based on the multiple representation theory proposed by Shaaron Ainsworth (Ainsworth, 1999; Cromley, 2020). Ainsworth (1999) explains the three main functions of multiple representations, namely complementary (each representation provides complementary information or processes), constraining (one representation reinforces another representation that is still abstract), and constructing deeper understanding (the integration of several representations encourages deeper understanding). Data was described qualitatively.

The third question regarding the stages of the thinking process of pre-service biology teachers was analyzed using design thinking. The indicators of each stage of design thinking in this study are demonstrated through the abilities exhibited by pre-service teachers. The empathize stage is reflected in their sensitivity to user needs and material characteristics; define stage in their ability to identify the root causes of difficulties underlying media development; ideate stage in their ability to propose media construction ideas; prototype stage in the realization of ideas into concrete designs; and test stage in their efforts to test the effectiveness of media.

However, this study limits its analysis to the decision stage, which is the ability of pre-service teachers to choose the final media design based on clear pedagogical considerations as an interpretation of the prototype stage. The steps taken were that the researcher read the blueprint and then determined whether the pre-service biology teachers had empathy for the students who would learn using the media. Next, the blueprint was compared with the resulting media to see whether the results were in accordance with the design and whether there were any changes during the development process that indicated a realistic thinking process during the media development process. The data for the third research question was described qualitatively.

RESULT AND DISCUSSION

Learning media serves to bridge and shape interactions between students and biological objects that have certain characteristics. These characteristics include being invisible because they are too large or too small, abstract, and even boring. In this study, pre-service biology teachers developed learning media to bridge these characteristics of objects. They developed non-digital learning media using simple materials that they might encounter in their daily lives. The creation of this non-digital media can be a means for pre-service biology teachers to practice creating enjoyable learning experiences with the tools and materials available around them.

During the development process, pre-service biology teachers worked in groups to analyze needs by studying the characteristics of the material and problems encountered in schools. They developed media designs in the form of operational blueprints. In addition to developing blueprints, students also developed lesson plans that outlined the learning process so that they could demonstrate the position of media in the learning process. Based on the blueprint and the media products developed, the results of the artifact analysis can be presented to answer the research questions regarding: 1) the type of biology concepts chosen by students, 2) how students

represent biology concepts, and 3) the thinking process of pre-service biology teachers in developing media.

Types of Biological Concepts Chosen By Pre-Service Biology Teachers In Developing Learning Media

An analysis of the types of biological concepts chosen by pre-service biology teachers for developing media was conducted based on the blueprint. From the seven groups, topics chosen by students were identified and categorized based on the types of concepts represented (Table 2).

Table 2. Types of Concepts Represented

Concept	Topic	Amount of media	Characteristics of abstraction
Biology process	Photosynthesis	1 (14.29%)	Processes within cells that cannot be observed directly, occur within a certain period of time, and involve energy transformation.
System	Excretory system Digestive system	2 (28.57%)	Interactions occur between components within the system, mechanisms occur within the body, and cause-and-effect relationships cannot be understood as a single entity.
Structure and function	Prokaryotic cell structure, eukaryotic cell structure, DNA structure, human body organs	4 (57.14%)	Cannot be seen directly because they are very small or located inside the body.

The results of the blueprint analysis show that pre-service biology teachers chose the concepts of process, system, and microscopic. The most frequently chosen concept was structure. The dominance of structure-based concepts (57.14%) indicates that pre-service teachers are aware that the main difficulty for students lies in the unique nature of biological objects. As stated by Treagust et al. (2003), the difficulty in learning biology is because biological entities cannot be observed with the senses or "invisible entities problem." For example, cells, both prokaryotic and eukaryotic cells, are very small and can only be seen with the help of a microscope or cannot be observed directly with the naked eye. Similarly, high school students cannot participate in dissection practices to see the anatomy and morphology of human organs. The use of media helps to visually represent the original form of these structures. This visual representation can serve to supplement information that cannot be conveyed verbally, clarify an object, and help build a deeper understanding (Ainsworth, 2006).

The second most popular concept was systems. Preservice biology teachers chose the excretory system and the digestive system. In a system, biological

phenomena are understood as interactions between interdependent components that form a functional working system. So, the abstraction in this system concept discusses structure, namely how it is formed, discusses the processes that occur, and how everything works together. The existence of media will make it easier for students to imagine the processes that occur, the organs involved, and the effects if one of the components in the system is disrupted. The selection of this system concept is in line with the deep learning policy implemented in the Indonesian education system. One of the characteristics of deep learning is meaningful learning (Feriyanto & Anjariyah, 2024). This means that by learning about systems in biology, students will not only learn about organs but also their complexity, including their connection to symptoms and phenomena in life, so that learning will have real meaning for students.

The final concept chosen by pre-service biology teachers was the concept of process. The concept of process was chosen for the topic of photosynthesis because this process is difficult to visualize. Photosynthesis is a process that occurs within cells, involving parts of plant cells that are invisible, involving invisible energy flows, processing and producing substances that are not visible, and occurring in specific stages over time. This series of processes cannot be observed with the naked eye. Therefore, media in the form of diagrams or charts that represent a process concept are needed (Jackson et al., 2025; Sheredos & Bechtel, 2017). With this media, students can have an idea of the flow that occurs, the parts involved, and the products produced. The three concepts chosen by students to develop their media show that media functions as a connecting bridge that forms an interaction between the learning subject, namely students, and the learning object, namely all phenomena in living things.

How Pre-Service Biology Teachers Represent Abstract Biological Concepts Into Something Understandable Through Learning Media

The analysis of pre-service biology teachers' representations of biological concepts was analyzed through blueprints and developed media. The focus of the analysis was on the type of representation and its suitability to the characteristics of concept abstraction, the results of which are presented in Table 2. As per Shaaron Ainsworth's theory of multiple representations (Ainsworth, 1999), a single concept can be represented in more than one way. All concepts are represented in more than one type (several examples of the media are shown in Figure 1). Process concepts, such as those in photosynthesis material, are represented in the form of diagrams (as the main representation) supplemented with other representations, such as visuals, symbols, and narratives that support the process in the flowchart. This is in line with Ye et al., (2025), who state that a process concept will be clear and easy to understand if it is presented in the form of a flowchart as a sequence of the process.

Table 2. Matrix of Representation Methods For Each Learning Medium

No.	Name of media	Topic	Type of representation				
			Visual	**Analogy**	**Symbol**	**Narrative**	**Diagram**
1	Photosynthesis Card	Photosynthesis process	Illustration of leaves, chloroplasts	-	ATP, NADPH, CO2, O2	Description of light and dark reactions and the components involved	Flowchart of light and dark reaction stages
2	Smart box of the excretory system	Excretory system	Image of the organs of the excretory system	Water	Filtration, reabsorption, augmentation	Explanation of the function of each organ	The process of urine formation
3	Felt board of the journey of food	Digestive system	Image of the digestive organs	felt fruit model (watermelon), modeling clay	Digestive enzymes	Explanation of the function of each organ	The flow of food through the system
4	3D model of a bacterial cell	Structure of a prokaryotic cell	Shape of bacterial cell organelles	-	Names of organs	Explanation of organ function	-
5	3D model of an animal cell	Structure of an animal cell	Shape of animal cell organelles	-	Names of organs	Explanation of organ function	-
6	DNA double helix	DNA structure	Shape of nitrogen base bonds in DNA		Nitrogen bases (ATGC)	Explanation of DNA double helix structure	
7	Monopoly of body organs	All human body organs	Images of human body organs	-	Names of organs	Explanation of organ functions	-

Concepts such as the excretory and digestive systems are represented visually, through analogies, symbols, narratives, and diagrams. In a concept system, the media displays the structure of the organs in the system visually, the names of the organs are represented symbolically, their functions are explained narratively, and the processes within the system are presented in diagrams. In systems that show processes of change, analogies need to be used (Chen et al., 2024; Forbus et al., 2018; Lankers et al., 2023). Pre-service biology teachers analogized water as blood undergoing a process in the kidneys to produce urine. In addition, they also analogized a watermelon slice-shaped model as food entering the mouth and soft clay as an analogy of feces coming out of the anus. These analogies help make it easier for someone to understand a complex system concept more concretely (Forbus et al., 2018).

In the concept of structure, the representations chosen by students are visual, symbolic, and narrative. Structure is closely related to forms that can be observed visually. Presenting colorful, large, 3D forms with complete parts makes it easier for students to imagine the original form of a structure. In this form, it will certainly be clearer if each visible part is named, with the names presented in the form of symbols. In addition, structure is closely related to function, where the function is conveyed in the form of a narrative. Narratives give meaning to the visual forms and symbols displayed in the media. Without narratives, visual displays and symbols cannot be studied, including what components they are and the relationships between the forms and descriptions (Fernández-Fontecha et al., 2019; Reyes & Villanueva, 2024). This structure is the simplest concept, so the type of representation used is the least compared to other types of concepts.

Figure 1. Media Using Multiple Representations

The analysis results show that, consistently, all groups use visual representations, symbols, and narratives. This indicates that pre-service biology teachers view these three forms of representation as basic elements that must be included in learning media. Visuals include images and shapes of organs, cells and organelles, and models of the double helix DNA structure. Symbols include codes or terms involved in the processes, systems, and structures of biological objects. Narratives take the form of descriptions of organ functions and the workings of a system. The existence of these various types of representations indicates an early awareness of the importance of using multiple representations to support conceptual understanding through learning media.

The analysis results show that all media use more than one representation. This indicates that students are beginning to understand the importance of integrating multiple representations to overcome the limitations of a single type of representation in explaining complex abstract concepts. This fact shows that pre-service biology teachers are developing pedagogical content knowledge (PCK), particularly in terms of knowledge of instruction strategies for teaching biology (Waugh et al., 2025).

Pre-biology teachers realize that abstract concepts need to be conveyed using specific strategies that differ from those used for concrete concepts. They also realize that their task is not only to convey information, but also to transform biology content so that it is easier for students to understand. This shows that they realize the importance of applying appropriate learning strategies by considering the students' perspective.

The use of multiple representations in a single medium can facilitate student learning but may also pose challenges for students. Indeed, some researchers agree that multiple visual representations will influence how students reason (Thyberg et al., 2024), construct knowledge (Uminski et al., 2025), build concepts (Uminski et al., 2025), and even reason and connect biological levels of organization (Thyberg et al., 2024). However, it is important to remember that the inappropriate use of visuals, such as incorrect arrow symbols (Wright et al., 2018), inconsistent terminology, and inaccurate images, can lead to misconceptions and affect student learning outcomes (Maduratna & Jayanti, 2022). The diversity of representations also makes it difficult for students to connect between them (Torkar, 2017). Therefore, it is important for experts or senior teachers to assess or judge the media before it is used in the classroom.

Students' Thought Processes in Designing Learning Media

Students' thought processes were analyzed by tracing their thought processes and chosen designs. This tracing was carried out by following the Design Thinking stages, namely Empathize, Define, Ideate, and the resulting design decision.

Empathize

The thinking process of pre-service biology teachers in designing learning media is based on a needs analysis that includes curriculum requirements, material characteristics, and student or field learning conditions. Pre-service biology teachers strive to understand the characteristics of material that is abstract and cannot be observed directly. Some of them express that biological processes are difficult for

students to visualize. The following is an example of notes taken by pre-service biology teachers on the subject of the digestive system.

> "Digestive system material is abstract because many processes occur inside the body and are not directly visible, making it difficult for students to imagine without the aid of visual media."

This fact is also supported by the results of identification in cell material. "*The structure and function of animal cells are difficult to understand without real visualization.*" These characteristics of biological material form the basis for the development of biology learning media. In addition to analyzing the characteristics of the material, pre-service biology teachers also analyzed the learning conditions in schools. They found that students' learning styles influence their learning media needs.

> "Students have different learning styles (visual, auditory, kinesthetic), while the lecture method is only suitable for auditory learners."

This fact shows that pre-service biology teachers have empathy for students in school who experience cognitive difficulties (concept abstraction) and need concept visualization. This indicates that they have knowledge of student understanding as part of pedagogical content knowledge (PCK) (Sæleset & Friedrichsen, 2021). Pre-service biology teachers are aware that students need to have diverse sensory experiences to understand processes that cannot be observed directly. This indicates that they are sensitive to students' needs and empathetic to students' limitations.

Define

After identifying the characteristics of the material and the students' conditions, pre-service biology teachers formulated the main problems that caused students' limitations in concretizing abstract concepts. At this stage, they identified the difficulties or problems that led to the importance of developing learning media. Several groups explained that the complexity of the concepts made them difficult to understand. For example, in their notes, they wrote:

> "The material on the structure and function of animal cells is difficult to understand without real visualization. Organelles such as mitochondria, endoplasmic reticulum, lysosomes, and nuclei need to be displayed in 3D form... Students' difficulties: imagining the 3D shape and position of organelles."

The complexity in this case is that the material not only discusses the names and functions of organelles, but also how they are specifically arranged in terms of shape and layout. This supports the idea that animal cell organelles are not easily understood by students if only presented in 2D images.

One group wrote that "*Many students have difficulty identifying cell parts and understanding the differences between prokaryotic and eukaryotic cells.*" Supporting this finding, in the photosynthesis material, pre-service biology teachers mentioned that

"*Students tend to memorize without understanding the logical sequence*." This supports the previous finding that visualization difficulties are one of the concepts that require media.

These identified problems also underlie the selection of appropriate media based on the characteristics of the material. It is important to find weaknesses in the presentation of material so that ways to overcome them can be considered (Castro-Alonso et al., 2021). The results of the analysis show that pre-service biology teachers are sensitive in identifying problems in each material they determine.

Ideate

This ideate stage demonstrates the creativity of pre-service biology teachers in choosing various forms of media based on the problems identified. An example of an idea that emerged was 3D visuals. According to the analysis of pre-service biology teachers, 3D models are interactive models that can be touched, rotated, and observed from various angles. Another idea that emerged was media that combines various aspects so that it involves more of the students' senses. An example is a model of a bacterial cell.

> "This medium combines visual, kinesthetic, and experiential aspects, allowing students to see, touch, and understand cell structure in greater depth."

In addition to developing ideas from a visual perspective, pre-service biology teachers also develop ideas in terms of their use in creating enjoyable emotional interactions. An example of this is game-based ideas. "*Monopoly games have been proven to be effective in increasing students' interest and understanding of biology material.*" By paying attention to this entertaining aspect, it shows that pre-service biology teachers not only view media as an appropriate and easy-to-use bridge, but also as something that should be enjoyable. This is in line with the analysis of current in-depth learning requirements that seek to create enjoyable learning or "joyful learning." Enjoyable learning can increase students' motivation, engagement, and interest in learning (Hasanah & Jumini, 2025; Nadeem et al., 2023).

Decision

The media design decisions made by pre-service biology teachers show a tendency for them to choose media that emphasize visuals. This means that they think more about media that must be attractive, touchable, and movable. Pre-service biology teachers interpret media design as something that is concrete, touchable, and makes learning more enjoyable, so that abstract or sometimes boring biology concepts will be easier and more interesting to learn. However, media should not only be prioritized for its visual aspects, but its function should also be considered, namely to help students gain a deeper understanding, think critically, and think holistically (Hasanah & Jumini, 2025; Hidayati et al., 2024) so that learning can be meaningful and mindful (Mystakidis et al., 2021).

CONCLUSION

Based on the analysis of design thinking among pre-service biology teachers in developing biology learning media, information can be obtained regarding the types of biological concepts they choose, how they represent abstract biological concepts, and their thinking patterns in designing learning media. They tend to choose biological process concepts that cannot be observed directly. The nature of biological objects that are difficult to access underlies the design of learning media. Pre-biology teachers represent biological concepts in visual, analogical, symbolic, narrative, and diagrammatic forms. They tend to use multiple representations in developing media. From a design thinking perspective, they have gone through the stages of empathy, defining problems, generating ideas, and selecting the media to be developed. Therefore, this study shows that the representational competence of pre-service biology teachers has developed, but they still tend to emphasize the visual aspects and attractiveness of the media. The implication of this finding is that it is important for pre-service biology teachers to learn how to develop media that is not only creative and attractive, but also oriented towards forming students' deep conceptual understanding. The results of this study are limited to only one study program, therefore it becomes an opportunity for further research to investigate the design thinking of pre-service biology teachers at other universities so that the information obtained is more comprehensive.

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