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Fostering Critical Thinking in Biology Education Through a TGT-Based Digital Interactive Module

Neska Fadillah✉, **Miza Nina Adlini**

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Universitas Islam Negeri Sumatera Utara, Indonesia

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Abstract

The advancement of 21st century education demands learning media that not only deliver subject content but also develop students' critical thinking skills through interactive and collaborative experiences. This study aims to develop a digital interactive module based on the Team Games Tournament (TGT) model for the excretory system topic to enhance students' critical thinking. The research employed the 4D development model, which includes the stages of Define, Design, Develop, and Disseminate. The Define stage involved a needs analysis through interviews, questionnaires, and curriculum reviews. In the Design stage, the module was created by integrating interactive elements such as videos, animations, quizzes, and problem-solving tasks based on the TGT framework. The Develop stage included expert validations and limited trials with 30 tenth-grade students, using instruments such as validation sheets, response questionnaires, and critical thinking tests based on Facione's indicators. Validation results showed that the module was highly valid, with scores of 98.67% from media experts and 99% from subject experts. The practicality score was also high, with 97.23% from teachers and 90.67% from students. The module's effectiveness was demonstrated by a significant increase in students' critical thinking, with an average N-Gain score of 0.83 (high category). These findings indicate that the TGT-based digital interactive module is valid, practical, and effective, and it can serve as an innovative learning resource for improving students' critical thinking in biology education.

How to Cite

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✉ Correspondence Author:
E-mail: neskafadillah@uinsu.ac.id

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INTRODUCTION

Critical thinking skills are foundational competencies essential in 21st century education. In a globalized world with unprecedented information flow, students must discern relevant and reliable knowledge across diverse real life contexts. The Programme for International Student Assessment (PISA) highlights that Indonesian students struggle with complex problem solving and in depth analysis (Organisation for Economic Co-operation and Development, 2022). This indicates an urgent need to prioritize critical thinking in education, equipping learners to navigate professional and societal challenges. Beyond academic settings, critical thinking empowers individuals in daily decision making by enabling data analysis, multi perspective evaluation, and evidence based conclusions (Wahyudi et al., 2020). It also supports logical reasoning in managing data driven inquiries and complex problems (Anfa et al., 2023; Kustiani et al., 2020).

In biology education, critical thinking is vital due to the abstract and interconnected nature of biological systems. The human excretory system exemplifies this complexity, requiring students to analyze organ functions and waste processing through higher order thinking (Damayanti et al., 2022; Yuliani et al., 2021). Thus, there is a pressing need for instructional media that deliver content while fostering critical thinking through interactive, problem based learning.

To improve conceptual understanding, especially in biology, innovative learning tools are crucial (Mardiani et al., 2020). Digital and interactive media offer alternative pedagogical strategies and align with learners' needs in the digital era (Pratiwi & Wiarta, 2021). Conventional methods often fail to make abstract concepts tangible, whereas digital tools such as animations and simulations enhance engagement and comprehension (Ridzal et al., 2023; Sari & Adlini, 2024). However, many digital media still lack features that promote collaboration, a key element in 21st century science education (Rusni et al., 2023). Collaborative learning fosters cognitive, interpersonal, and social development, especially in project based environments (Rahmasari et al., 2023). Therefore, developing digital tools that facilitate cooperation is essential to maximize their educational impact.

In this context, digital modules have emerged as significant innovations that bridge technology and pedagogy in modern classrooms. These modules are instrumental in facilitating teachers' efforts to create more dynamic, accessible, and visually enriched learning experiences (Bakri, 2021). One instructional method that has demonstrated potential in enhancing student engagement and critical thinking is the Team Games Tournament (TGT). TGT promotes collaborative learning through team-based competition and knowledge sharing, which has been shown to enhance motivation, social interaction, and deeper understanding of academic content (Istiqomah & Sukmawati, 2023). The synergy between interactive digital modules and the TGT model presents a promising strategy to establish a learning environment that is engaging, collaborative, and conducive to critical thinking development (Salam et al., 2015; Ulfani et al., 2024).

Teaching the excretory system poses challenges due to its abstract processes and microscopic mechanisms. Students often have difficulty understanding internal organ functions, further complicated by traditional media's limitations in illustrating these processes (Miharja & Juniawan, 2020; Rahayu et al., 2024). Interactive digital modules incorporating TGT methodology offer immersive experiences that allow students to visualize complex content and interact meaningfully, thereby enhancing understanding and critical thinking (Muttaqien et al., 2021).

Textbook analysis in Indonesian schools reveals significant limitations in fostering critical thinking. These materials largely present factual content, lacking analytical tasks or real world applications. Topics such as excretory processes beyond the kidneys and their relevance to health technology are rarely covered. Consequently, instruction emphasizes memorization over higher order thinking. Interviews with teachers and a needs analysis confirm that textbooks do not adequately support active learning. Additionally, limited interactive resources and continued reliance on conventional methods reduce student engagement and meaningful learning. As a result, instruction on the excretory system often fails to develop the critical thinking skills emphasized in the curriculum.

To address these gaps, researchers have developed digital modules targeting learning outcomes in the human excretory system. Miharja & Juniawan (2020) created a TGT based digital module integrating visuals and interactivity to enhance analytical skills. Their findings showed a positive impact on students' abilities to understand complex content. Wulansari et al. (2018) further emphasized that digital modules offer features such as self-instructional, self-contained, stand-alone, adaptive, and user-friendly designs, which increase their pedagogical value. These

modules also integrate attractive illustrations, structured content, and clear presentation of information, making them superior to traditional printed materials (Dede & Setiawan, 2020). Another study by Rahayu et al. (2024) developed a flipbook-style module for high school students that helped demonstrate the functions and biological mechanisms within the excretory system. This interactive approach resulted in improved student comprehension and academic performance. Similarly, Setyoningtyas et al. (2022) produced a deductively structured e-module that systematically guided students from basic concepts to complex applications, demonstrating how structured instructional design can enhance academic outcomes.

Despite evidence supporting the benefits of digital modules and the TGT model independently, limited research has explored their integration. Digital modules are often designed to improve cognitive mastery, while TGT primarily addresses social and motivational aspects of learning (Adiatma & Thana, 2022; Hariyani et al., 2019). As Muthi'ah & Sukmawati (2023) observed, although the development of digital modules is widespread, few studies combine them with TGT to foster both conceptual understanding and collaborative learning. A rare example is provided by Thahira & Jayanti (2024), who developed a TGT-based module for respiratory system instruction; however, similar efforts focusing on the excretory system remain scarce. Moreover, many existing modules do not intentionally incorporate structured critical thinking tasks, as noted by Rodiawati & Komarudin (2018), limiting their ability to holistically support students' higher-order thinking development.

This study seeks to fill these gaps by developing a digital interactive module based on the Team Games Tournament approach for excretory system instruction. The module focuses on three main aspects: validity, practicality, and effectiveness in enhancing high school biology learning. It also aims to cultivate students' critical thinking, a key competency in modern education. The resulting module is expected to serve as a technology based learning resource accessible to both students and teachers, aligning with the growing demand for educational tools that foster critical thinking throughout the learning process.

METHOD

Fostering students' critical thinking skills has become a central goal in 21st-century biology education. In response to this need, educators are encouraged to adopt innovative learning strategies and digital technologies that promote active engagement and deeper understanding. One such strategy is the Team Games Tournament (TGT), a cooperative learning model that stimulates student interaction, competition, and reflection. To integrate this strategy effectively into classroom practice, this study developed a digital interactive module designed to support TGT-based learning activities in biology. The module aims to provide an engaging platform that facilitates the development of critical thinking skills through structured, game-based tasks aligned with biological concepts. The approach employed in this research was a research and development methodology utilizing a 4D model. This model is comprised of four distinct phases: (1) Define, (2) Design, (3) Develop, and (4) Disseminate (Thiagarajan et al., 1974). The progression of this research and development model is illustrated in Figure 1.

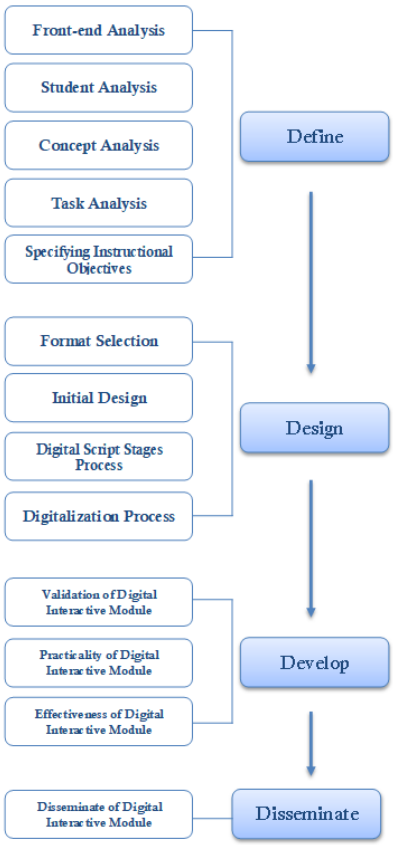


Figure 1. 4-D Model Design

This study involved 30 eleventh-grade students from Madrasah Aliyah Laboratorium UIN Sumatera Utara. Data were collected using teacher interview guidelines and a needs analysis questionnaire to explore the teaching materials in use

and students' learning outcomes. The validation process employed a media expert validation sheet and a material expert validation sheet, both of which were used to obtain feedback on the developed interactive digital module. The practicality of the module was assessed using teacher and student response questionnaires that evaluated the module's usability, the relevance of its content to learning needs, and the clarity and accessibility of the material. The effectiveness of the module was measured by its impact on students' critical thinking skills, assessed through six essay questions based on Facione (2015). All instruments, including the validation sheets and student response indicators, were measured using a Likert scale ranging from one to four.

The development of the educational module followed the four stages of the 4D model, namely define, design, develop, and disseminate. In the define phase, a series of needs analyses was conducted to ensure that the module aligned with the learning requirements. These analyses included a front-end analysis, which served to identify the main problems guiding the development process, a student analysis to understand the characteristics, needs, and comprehension levels of the learners, a concept analysis to delineate the scope of the material, a task analysis to identify learning activities relevant to the topic, and a learning objective analysis to ensure alignment with the intended competencies. These components are in line with the framework proposed by Mahendri et al. (2023). In the design phase, the focus shifted to developing the storyboard, compiling instructional content, constructing assessment instruments, and selecting appropriate learning strategies. This phase followed the model suggested by Zubaidillah et al. (2016). The develop phase involved transforming the module draft into a tangible product and evaluating it for validity, practicality, and effectiveness as described by Syaiful et al. (2023). The final stage, dissemination, focuses on sharing the outcomes of the developed product with a broader audience (Adlini et al., 2024).

The data collection process integrated both qualitative and quantitative methods. Qualitative data consisted of teacher interviews and written suggestions from validators, while quantitative data included validator assessment scores, responses from teacher and student questionnaires, and student scores on the critical thinking test. All data were analyzed using descriptive techniques, encompassing both qualitative interpretation and quantitative calculations. The validity of the Team Games Tournament-based digital interactive module was determined from the ratings given by two expert validators. The module's practicality was assessed through teacher and student feedback. The quantitative data analysis was conducted using Formula 1, and the results related to the validity and practicality of the module were interpreted based on the criteria established in Table 1 and Table 2.

Furthermore, to assess the development of students' critical thinking skills, the research employed indicators proposed by Facione, which include interpretation, analysis, evaluation, inference, explanation, and self-regulation. These indicators were systematically embedded in the critical thinking test and served as a framework for measuring the module's effectiveness in promoting higher-order thinking skills within the context of biology learning.

$$\text{Percentage } (100\%) = (Score\ obtained)/(Maximum\ score) \times 100\% \quad (1)$$

Table 1. Criteria for Validating Test Results

Percentage (%)	Evaluation Criteria
80.00-100.00	Highly Valid
60.00-79.99	Valid
50.00-59.99	Sufficiently Valid
00.00-49.99	Not Valid

(Riduwan & Akdon, 2010)

Table 1 presents the criteria for interpreting test validity percentages as outlined by Riduwan & Akdon (2010). Scores ranging from 80.00% to 100.00% indicate a highly valid test, while those between 60.00% and 79.99% are considered valid. A percentage between 50.00% and 59.99% reflects sufficient validity, whereas scores below 50.00% are categorized as not valid.

Table 2. Criteria for Practicality Test Assessment Results

Percentage (%)	Assessment Criteria
81-100	Very Practical
61-80	Practical
41-60	Fairly Practical
21-40	Not Practical

(Riduwan & Akdon, 2010)

Table 2 presents the criteria for assessing the practicality of a module, adapted from Riduwan and Akdon (2010). The percentage score obtained from the practicality test is categorized into four levels: a score of 81–100% indicates that the module is very practical, 61–80% signifies practical, 41–60% reflects fairly practical, and 21–40% means not practical. According to these

standards, a module must achieve at least 61% to be considered practically usable. In the context of interactive learning modules, this minimum threshold also implies that the module should offer ease of use, user engagement, and efficient navigation to support meaningful learning experiences.

The effectiveness of TGT-based learning modules is obtained using the N-Gain calculation in Formula 2.

$$\text{N} - \text{Gain} = ((Post - test\ score) - (Pre - test\ score))/((Maximum\ score) - (Pre - test\ score)) \times 100\% \quad (2)$$

The interpretation of the N-Gain calculation results refers to Table 3.

Table 3. N-Gain Criteria

N-Gain	Evaluation Criteria
g > 0.7	High
0.3 < g < 0.7	Moderate
g < 0.3	Low

(Nasution & Rasyidah, 2022)

Table 3 describes the N-Gain criteria used to evaluate the effectiveness of learning interventions. An N-Gain value greater than 0.7 indicates a high level of effectiveness, values between 0.3 and 0.7 represent a moderate level, while values below 0.3 are considered low. According to these criteria, an interactive module is regarded as effective if it achieves at least a moderate category, with an N-Gain value above 0.3 (Nasution & Rasyidah, 2022).

RESULT AND DISCUSSION

This research produced an interactive digital module that applies the Team Games Tournament (TGT) model, focusing on the human excretory system. The module can be accessed via smartphones and computers, providing flexible use in both classroom and remote learning settings. It is designed to improve students' critical thinking skills through structured, collaborative, and interactive learning experiences. The development process followed the four stages of the 4D model, namely Define, Design, Develop, and Disseminate, to ensure its pedagogical relevance and technical feasibility.

The integration of the Team Games Tournament model into the digital module offers a strong instructional approach to developing critical thinking in science education. TGT is a cooperative learning strategy that involves students in group discussions and academic competitions. These activities require learners to interpret information, evaluate the ideas of others, construct logical arguments, and draw conclusions. These are essential elements of critical thinking as defined by Facione (2015). In the context of the excretory system, the use of TGT encourages students to engage in reflective and analytical thinking while solving real world biological problems in a team setting. In addition, the balance between competition and cooperation within TGT fosters active participation and responsibility among students. Through the inclusion of TGT based tasks in the module, students are supported not only in mastering biological concepts but also in critically exploring, questioning, and applying what they have learned. This alignment between learning strategies and cognitive development goals makes the module a valuable tool for enhancing students' ability to think critically.

This section presents a comprehensive analysis of the development and effectiveness of the Team Games Tournament (TGT)-based Digital Interactive Module in fostering students' critical thinking skills. The discussion begins with a detailed description of each component of the module and its alignment with Facione's critical thinking indicators, including interpretation, analysis, evaluation, inference, explanation, and self-regulation. The integration of TGT strategies is designed to create collaborative and engaging learning experiences that challenge students to think critically through interactive tasks and structured game-based learning (Darmuki et al., 2023). Furthermore, the effectiveness of the module is examined using the N-gain test results, which compare students' pre-test and post-test scores to determine the degree of learning improvement (Hake, 1998). These findings serve as the foundation for the subsequent discussion of each development stage, beginning with the Define phase.

1. Define

The definition phase of this development research seeks to systematically identify and articulate learning challenges as a foundation for creating an interactive digital module based on Team Games Tournament (TGT). This phase is vital, as the design of effective instructional materials must stem from a thorough comprehension of the learning requirements in the field. Consequently, a detailed analysis was performed across five key dimensions: front-end analysis, learner analysis, concept analysis, task analysis, and learning objective analysis. Each of these analyses offers both a theoretical and empirical basis for designing modules that are not only pertinent to

student characteristics and the curriculum but also capable of meeting the challenges of 21st century learning, particularly in enhancing students' critical thinking skills. The following is a summary of the analysis outcomes from the define phase in this research.

a. Front-end Analysis

A front-end analysis was conducted to identify the main problems occurring in the biology learning process at school. At this stage, observations were made regarding the learning process carried out in biology lessons at the Madrasah Aliyah Laboratory of the State Islamic University of North Sumatra. Based on the results of a review of the Biology textbooks used in teaching, it was found that there are several aspects that need to be improved to maximize the effectiveness of teaching and learning, particularly in developing students' critical thinking skills. The textbooks available are generally descriptive and concept-oriented, without providing space for students to analyze, evaluate, or reflect on the concepts they have learned. In addition, the learning process still uses the 2013 curriculum and the learning approach used is mostly conventional, so it is not yet able to facilitate optimal student participation. This problem shows a gap between the ideal conditions for biology learning that develops 21st-century skills and the actual conditions that are still limited to textual delivery of material.

b. Student Analysis

Student analysis was conducted to understand the characteristics and learning needs of the students who were the subjects of the module development. The results of interviews with teachers and a needs analysis questionnaire showed that most students had difficulty understanding abstract biology concepts, especially in the material on the excretory system. They tended to be passive in the learning process because they were not directly involved in activities that challenged their higher-order thinking skills. This has led to low ability among students to connect concepts with real-life phenomena and a lack of confidence in expressing opinions or solutions to problems related to the subject matter. Therefore, there is a need for learning media that can stimulate students' interest in learning and encourage them to actively engage in critical thinking processes. Students also support the development of interactive digital media required for ongoing learning activities.

c. Concept Analysis

Concept analysis was conducted to identify, define, and organize the material to be developed in the interactive digital biology learning module systematically, namely the material on the human excretory system. Based on a review of the curriculum and textbooks used in schools, it was found that the presentation of material on the excretory system is still limited to the functions and structure of the kidneys, while other excretory organs such as the lungs, liver, and skin have not been explained comprehensively. Additionally, the relationship between the excretory system and current health technologies, such as hemodialysis and early detection of kidney disorders, has not been integrated into the learning process. Therefore, the development of this digital module will expand the scope of the material by incorporating more contextual and applicable concepts to support a deeper understanding.

This analysis is to develop learning objectives and important parts to be studied and to compile relevant material based on basic competencies. The human excretory system material for grade XI that will be developed is found in KD (Basic Competency) 3.9, which is to analyze the relationship between the tissue structures that make up the organs in the excretory system in relation to bioprocesses and functional disorders that can occur in the human excretory system. The Competency Achievement Indicators (IPK) based on the Basic Competencies are: (1) Explain the relationship between the tissue structures of the organs in the excretory system and the biological processes that occur in the body. (2) Identify functional disorders that can occur in the human excretory system based on an analysis of its structure and function.

d. Task Analysis

Task analysis aims to identify the types of activities or competencies that students must engage in to achieve the learning objectives. Based on observations and input from teachers, students are not yet accustomed to tasks that encourage them to analyze data, draw conclusions, or solve real-life case-based problems in the context of the excretory system. Activities previously provided were generally simple, such as answering multiple-choice questions or memorizing biological terms, without encouraging critical and reflective thinking. Therefore, the development of the module will include Team Games Tournament (TGT)-based activities designed to promote group collaboration, logical argumentation, and the development of higher-order thinking skills.
This analysis involves identifying tasks that align with Basic Competency (KD) 4.9, which is presenting analysis results on the influence of lifestyle on disorders in the structure and function of organs that lead to excretory system problems and

their relation to technology. The tasks assigned to students are conducted in groups. The learning activities are aligned with the indicators of competency achievement (IPK), which include: (1) Analyzing the impact of lifestyle on disorders occurring in the human excretory system; (2) Compiling analysis results regarding excretory system disorders and their connection to the application of health-related technology.

e. Specifying Instructional Objectives

The analysis of instructional objectives is conducted to formulate learning goals that align with students' needs and curriculum demands. Based on task and concept analyses, the instructional objectives formulated serve as the foundation for developing this module. These objectives not only guide students to understand the theoretical concepts of the excretory system but also encourage them to apply these concepts in daily life and enhance their critical thinking skills. The formulated objectives also serve as a basis for designing the module content and creating appropriate assessment instruments. Furthermore, the instructional objectives are aligned with the Pancasila Student Profile and 21st century competency demands, emphasizing the importance of critical thinking. This interactive digital module based on the Team Games Tournament (TGT) approach is developed as an innovative solution to achieve these goals through meaningful and engaging learning experiences.

The instructional objectives targeted in this TGT-based digital interactive module are: (1) Students can explain the relationship between the structure of tissues composing the excretory organs and the bioprocesses occurring in the body; (2) Students can identify functional disorders that may occur in the human excretory system based on structural and functional analyses; (3) Students can analyze the influence of lifestyle on disorders in the human excretory system; (4) Students can compile the results of analyses on excretory system disorders and relate them to technological applications in the health sector.

2. Design

The design stage includes a systematic plan for developing the structure of the interactive digital module. The module is designed using the Team Games Tournament (TGT) approach, integrated with interactive elements such as videos, animations, quizzes, and digital worksheets. Its development is based on needs analysis and student characteristics. The module is constructed in stages and follows the principles of self-instruction, stand-alone, self-contained, user-friendly, and adaptive. The design also involves the creation of validation instruments, response questionnaires, and critical thinking tests based on Facione (2015) indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation. These are prepared to assess the validity, practicality, and effectiveness of the module.

This stage aims to compile teaching materials consisting of several components, including the cover page, foreword, table of contents, module description, user instructions, introduction (including Core and Basic Competencies), concept map, learning activities with objectives, material, exercises, TGT-based games, answer keys, bibliography, glossary, and author biography. Following this, the design of research instruments includes expert validation sheets for assessing the feasibility of the module, teacher and student response questionnaires to evaluate practicality, and pre-test and post-test blueprints to assess effectiveness.

This stage also involves the design of the module's visual layout, including color gradients, image and video placement, engaging information, and title frames using the Canva application. The next step is to embed hyperlinks in each designated element or command button. Once finalized, the Canva link is shared in display mode, allowing the TGT-based digital interactive module to be accessed and used online by students via smartphones.

3. Develop

After the interactive digital module based on the Team Games Tournament (TGT) model was completed in the design phase, the next step was the development stage. This phase aims to evaluate the quality of the product through validation and limited trials. It is a crucial part of the development process, as the results form the basis for determining the feasibility and effectiveness of the module before it is implemented on a broader scale. Activities at this stage include validation by experts—namely media and content experts—and module trials involving students to assess its impact on critical thinking skills. Data obtained from the validation and trial results are used to assess aspects such as completeness, content quality, language, presentation, as well as graphical and technical elements of the module.

The development stage of the TGT-based interactive digital module began with conducting a validation process. This validation aimed to determine the validity of the module developed by the researchers. The results of the validation by media and content experts are presented in Table

4 and Table 5. The media expert validation received an average score of 39.33 out of a maximum score of 40.33, resulting in a validity percentage of 98.67%, which is categorized as highly valid.

Table 4. Media Expert Validation Results

No	Evaluated Aspect	Total Score	Max Score	(%)	Criteria
1.	Completeness of Digital Interactive Module Components	13	13	100	Very Valid
2.	Module Quality	65	68	96	Very Valid
3.	Module Presentation and Graphics	40	40	100	Very Valid
Average		**39.33**	**40.33**	**98.67**	**Very Valid**

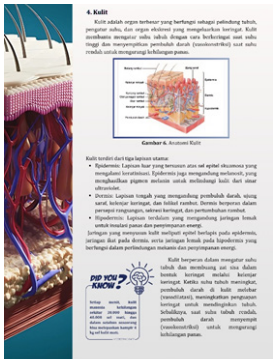
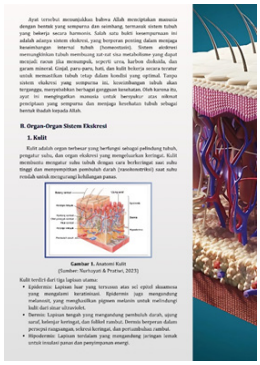
Similarly, the content expert validation yielded an average score of 30.33 out of a maximum of 30.67, with a validity percentage of 99%, also categorized as highly valid.

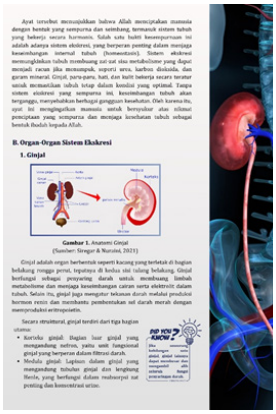
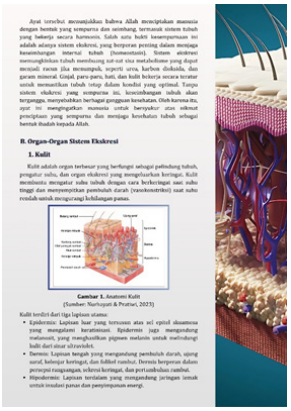
Table 5. Subject Matter Expert Validation Results

No.	Evaluated Aspect	Total Score	Max Score	(%)	Criteria
1.	Content Feasibility	28	28	100	Very Valid
2.	Language Use	31	32	97	Very Valid
3.	Presentation	32	32	100	Very Valid
Average		**30.33**	**30.67**	**99**	**Very Valid**

However, both media and content experts provided suggestions for improvement, as detailed in Table 6.

Table 6. Comments from Media and Subject Matter Validators

Suggestion	Before	After
Images in the digital interactive module must include references.	Illustrative images in the module did not include clear sources or references. 	All images in the module have been updated to include sources placed below the images in accordance with academic standards. 
The method of presenting questions in the interactive digital module needs to be reconsidered. Should the questions be answered on paper or be made fully online/interactive/digital?	The questions in the module were only presented as prompts without technical instructions for answering (e.g., in a notebook or directly in the module). 	The module now includes work instructions, and some questions are designed to be answered digitally via interactive fields or linked Google Forms. 

The order of excretory system organs should be logically arranged based on anatomical structure, e.g., from external to internal organs, or vice versa (e.g., skin → kidney or vice versa). Consistency in the order should also be reflected in the descriptions.	The presentation of excretory organs did not follow a logical or consistent anatomical order. Example: skin → kidney → lungs. 	The organ order was revised to: skin → lungs →kidneys → liver, and this sequence is applied consistently in the material description and learning activities. 
In Learning Activity 2, there are three discussion topics. It is recommended to divide the total of four topics into two topics per session.	Learning Activity 2 included three topics at once, making the material feel too dense for a single session. 	The material was restructured to present two topics per session, dividing the total of four topics into two meetings for a more balanced learning load. 

The next step was to conduct a small-scale trial by distributing questionnaires to gather responses from teachers and students.

Table 7. Results of Teacher Response Questionnaire

No.	Assessed Aspect	Total Score	Max Score	(%)	Criteria
1.	Interest	20	20	100	Very Practical
2.	Content	16	16	100	Very Practical
3.	Language	11	12	91.67	Very Practical
Average		**15.67**	**16**	**97.23**	**Very Practical**

Table 7 shows the results of the teacher response questionnaire, which obtained a total score of 47 out of a maximum of 48, with a practicality percentage of 97.23%, indicating a very high level of practicality.

Table 8. Results of Student Response Questionnaire

No.	Assessed Aspect	Total Score	Max Score	(%)	Criteria
1.	Interest	31	36	86	Very Practical
2.	Content	22	24	92	Very Practical
3.	Language	30	32	94	Very Practical
Average		**27.67**	**30.67**	**90.67**	**Very Practical**

Likewise, the student response questionnaire, conducted with 10 students and presented in Table 8, showed an average total score of 27.67 out of a maximum of 30.67, with a practicality percentage of 90.67%, also categorized as highly practical.

The developed TGT-based interactive digital module is deemed suitable for use by students in the learning process and supports students'

learning in the digital era. The high level of practicality of the module is supported by several interrelated factors. The main factor is the ease of use by both teachers and students without the need for additional training. The module is designed with an intuitive interface and clear usage instructions, making it easy to implement in the classroom. Additionally, the systematic and concise structure of the content enhances the efficiency of the learning process. The module can also be flexibly accessed through various digital devices, including laptops, tablets, and smartphones, allowing use anytime and anywhere.

Further practicality is evident from the integration of all learning components—from materials and TGT-based interactive activities to assessments—comprehensively available on a single platform. This module supports both independent and collaborative learning and has been developed in alignment with the curriculum and specified learning objectives. These aspects make the module highly practical and suitable for use in Biology classrooms. This finding aligns with research conducted by Adiatma & Thana (2022), which stated that the practicality of learning materials or media depends on how easily they can be utilized by teachers and students in the learning process.

4. Disseminate

After revising the components of the teaching materials, the interactive digital module based on the Team Games Tournament (TGT) model was piloted on a limited basis with students of class XI MIA 1 at the Laboratory Madrasah Aliyah of the State Islamic University of North Sumatra. This trial aimed to evaluate its effectiveness in developing critical thinking skills. The evaluation was conducted through a pre-test and post-test analysis based on the six critical thinking indicators outlined by Facione (2015): interpretation, analysis, inference, evaluation, explanation, and self-regulation. Before administering the pre-test and post-test, the test instruments were validated by experts to ensure their appropriateness. Once validated, the instruments were given to the students to test the module's effectiveness through pre- and post-testing. The results of the item validation by the experts are presented in Table 9. The expert validation yielded an average score of 6.67 out of a maximum of 6.67, resulting in a 100% score and indicating a very valid category. The results demonstrated a significant increase in all aspects, with an average N-Gain score of 0.83, placing the module's effect in the "high" category. These findings confirm that the module is not only content- and design-appropriate but also highly effective in comprehensively enhancing students' critical thinking.

For the interpretation indicator, students demonstrated the ability to accurately interpret information through team discussions and TGT-based case studies. The analysis indicator showed improvement as the tournament syntax encouraged students to analyze problems, structure arguments, and logically evaluate solutions. Inference skills also improved, as students were trained to draw conclusions from evidence in a collaborative context, consistent with findings by Ridzal et al. (2023). The evaluation indicator was fostered through post-tournament reflections that encouraged students to assess group strategies and decisions, in line with findings from Hariyani et al. (2019). Meanwhile, explanation skills developed as students were prompted to systematically present reasons during group discussions, supporting scientific arguments in accordance with Adawiyah et al. (2022). Self-regulation also improved; students became accustomed to setting goals, managing thinking processes, and reflecting on team performance, as highlighted by Bustami et al. (2022).

Table 9. Expert Validation Results of the Test Instruments

No.	Assessed Aspect	Total Score	Max Score	(%)	Criteria
1.	Clarity	8	8	100	Very Valid
2.	Core Accuracy	4	4	100	Very Valid
3.	Relevance	8	8	100	Very Valid
4.	Content Validity	4	4	100	Very Valid
5.	Absence of Bias	8	8	100	Very Valid
6.	Language Appropriateness	8	8	100	Very Valid
Average		**6.67**	**6.67**	**100**	**Very Valid**

The pre-test and post-test results also support the enhancement of critical thinking skills, with students' scores rising from 46 to 91 after using the module (Table 10).

Table 10. Pre-Test and Post-Test Results of Students' Critical Thinking Skills

Pre-Test	Post-Test	N-Gain	Percentage (%)	Category
46	91	0.829449769	82.94	High

The pre-test and post-test results also

support the enhancement of critical thinking skills, with students' scores rising from 46 to 91 after using the module (Table 10). This confirms that the TGT structure strengthens student collaboration and engagement, as reported by Lestari et al. (2022). Moreover, Mahmud et al. (2025) reported similar results with their e-Biology module on the excretory system, showing increased critical thinking (N-Gain = 0.67), while Dermawan et al. (2025) recorded high validity and critical thinking effectiveness (N-Gain > 0.7) in interactive e-modules on basic science material. Additional support comes from Damayanti et al. (2022) who found significant improvement in the Science Metacognition Model based on Cooperative Learning during ecosystem learning.

Overall, this interactive digital module based on TGT not only creates an active and enjoyable learning atmosphere but also fosters group solidarity through game-based competition. This supports findings by Salam et al. (2015) and Erviani et al. (2022) regarding improved cooperative accountability and healthy competition. However, the module still relies on external applications such as Quizalize and YouTube for certain activities, and some tasks are still conducted manually. Therefore, future development is recommended to integrate full automation within a single platform and to expand the content to cover other topics in the Grade XI Biology curriculum.

CONCLUSION

The results of this research and development demonstrate that the TGT-based interactive digital module on the excretory system is highly valid, practical, and effective in enhancing students' critical thinking skills. Expert evaluations confirmed its high validity in terms of content and media, while positive responses from teachers and students reflected its practicality. Implementation results showed a significant improvement in students' critical thinking, supported by a high N-Gain score of 0.83. However, the study was limited in terms of participant numbers and topic scope. Future research is recommended to involve broader subject groups, expand to other biological topics, and integrate adaptive and automated assessment features to enhance the module's applicability and contribution to 21st-century learning.

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