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Development of a Constructivist Teaching Sequence-Based Teaching Module Assisted by Augmented Reality to Train Digital Literacy Skills and Improve Learning Outcomes

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Abstract

Background: *The rapid development of digital technology requires students to possess digital literacy skills. However, previous studies indicate the integration of Augmented Reality (AR) in biology learning, particularly on virus material, remains limited and has not extensively examined its impact on students' digital literacy. Virus concepts are often considered difficult to understand because they are microscopic, abstract, and cannot be directly observed. Therefore, this study aimed to develop a Constructivist Teaching Sequence (CTS)-based teaching module assisted by Augmented Reality (AR) to improve students' digital literacy and learning outcomes on virus material.* **Methodology:** *This study employed a Research and Development (R&D) approach using the ADDIE model, limited to the implementation stage. The participants consisted of 34 tenth-grade. Data were collected using module validation sheets, implementation observation sheets, teacher and student response questionnaires, digital literacy tests, and learning outcome tests. Data were analyzed descriptively using validity, practicality, reliability, and N-gain analyses.* **Findings:** *The developed module achieved a validity score of 96% from media experts and 93% from material experts, both categorized as very valid. The practicality evaluation showed excellent results, indicated by an average implementation score of 96%, teacher responses of 100%, and student responses of 88%. Students' digital literacy improved significantly, as reflected by the increase in average scores from 58% in the pretest to 80% in the posttest. The research test instrument meets the validity and reliability criteria, with a reliability coefficient of 0.63 (moderate reliability).Learning outcomes also increased, with an N-gain value of 0.69 in the moderate category. The integration of CTS and AR facilitated students in visualizing virus structures and replication processes, thereby reducing the abstractness of the material and supporting more meaningful learning experiences.* **Contribution:** *This study contributes empirical evidence that CTS-based modules assisted by AR can effectively enhance students' digital literacy and learning outcomes while providing an innovative learning resource for teaching abstract biological concepts such as viruses.*

Keywords: *Augmented Reality; Constructivist Teaching Sequence; Digital Literacy; Learning Outcomes; Virus.*

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INTRODUCTION

Education in Indonesia is undergoing substantial evolution in response to the rapid advancement of digital technology (Judijanto, 2024). The phenomenon of digitalization has transformed conventional instructional paradigms into a more dynamic, accessible, and adaptable system that meets the essential demands of a generation growing up in the digital age (Subroto et al., 2023). Thus, digital literacy is no longer viewed as a complementary option but as an inherent competency absolutely necessary for every individual.

Digital literacy is a crucial competency for students facing the challenges of the 21st century and the era of Society 5.0 (Islamia & Arif, 2024). This concept of digital literacy goes beyond mere technical mastery of technological devices and also encompasses fundamental aspects such as the ability to acquire, critically evaluate, and responsibly apply information (Kusumaningrum & Hafida, 2021).

Constructivism theory states that students actively construct knowledge through experience and social interaction (Piaget; Vygotsky). Consequently, the Independent Curriculum (Kurikulum Merdeka) is a form of educational transformation in Indonesia that promotes smooth learning and focuses on students, supporting student development according to their needs and learning context (Rizki & Fahkrunisa, 2022).

Digital literacy can improve the quality of learning because it encourages students to be more active and independent in the learning process, as well as developing excellent thinking skills (Akhyar et al., 2024). Digital literacy competencies, which include internet searching, hypertextual navigation, content evaluation, and knowledge assembly, are essential aspects to support the 21st-century learning process.

Several studies have reported that Augmented Reality (AR) can improve students' motivation, conceptual understanding, and engagement in biology learning. However, most previous studies focused primarily on learning motivation and conceptual understanding, while limited attention has been given to the integration of AR with Constructivist Teaching Sequence (CTS) to enhance students' digital literacy skills. Furthermore, studies that simultaneously examine the validity, practicality, and effectiveness of CTS-based teaching modules assisted by AR on virus material remain limited.

Virus material is considered difficult because viruses cannot be directly observed with the naked eye and involve abstract concepts such as structure, replication mechanisms, and interactions with host cells (Ruron et al., 2020; Wahyuni et al., 2022; Firmanshah et al., 2020; Warouw et al., 2025). These characteristics often lead students to experience misconceptions and difficulties in understanding the concepts.

Interviews at SMA Negeri 1 Marisa Senior High School revealed that learning had not been implemented effectively. Students tended to be passive and had difficulty understanding abstract material, particularly the concept of viruses, because the learning process still focused on conventional approaches. Furthermore, the teaching modules did not include digital technology or a constructivist approach, and only presented text and images. Furthermore, interviews indicated that students still lacked digital literacy. This was evident in their limitations in effectively searching for

information (internet searching), evaluating information sources (content evaluation), and integrating information into new knowledge (knowledge assembly). Furthermore, learning outcomes were low, with most grades in biology lessons on viruses not reaching the minimum passing grade (KKM) of 70 for grade 10. These problems were also influenced by teachers' suboptimal understanding of implementing constructivist learning models and utilizing technology in the learning process.

Therefore, this study offers a novel contribution by integrating Constructivist Teaching Sequence (CTS) and Augmented Reality (AR) into a teaching module specifically designed to train students' digital literacy skills and improve learning outcomes on virus material. Unlike previous studies, this research combines constructivist learning stages with AR visualization to address both conceptual abstraction and digital literacy development. This study aims to analyze the validity, practicality, and effectiveness of an AR-assisted CTS-based teaching module developed for virus characteristics, structure, replication, and the role of viruses in human life. Furthermore, this study also aims to determine how the AR-supported CTS-based teaching module helps students practice digital literacy skills and improves their learning outcomes on viruses. It is hoped that combining the CTS model with AR technology will enable more interactive, contextual, and learner-centered learning.

METHOD

This research will be conducted at SMA Negeri 1 Marisa Senior High School in class X (tenth-grade) with a total of 34 students, The participants were selected using purposive sampling. Class X was chosen because students had previously studied prerequisite biology concepts and had not yet received learning using AR-assisted teaching modules. located at Jl. Trans Sulawesi, Marisa District, Pohuwato Regency, Gorontalo Province. This research conducted in March 2026. This research uses the Research and Development (R&D) method with the ADDIE model which includes the stages of analysis, design, development, implementation and evaluation. This research is limited to limited scale testing until development.

Instruments

The measuring instruments used include interview sheets, expert validation sheets, teacher and student response questionnaires, learning implementation sheets, and questionnaires to assess digital literacy skills, as well as written tests in the form of 10 essay questions given at the pre-test and post-test stages as learning outcomes.

Data Collection

Data were collected from lecturers, one media expert, one material expert, one biology teacher, and 34 tenth-grade students at SMA Negeri 1 Marisa Senior High School. Validity data were obtained through media and material expert validation sheets to assess the feasibility of the developed module. Practicality data were collected through learning implementation observation sheets, teacher response questionnaires, and student response questionnaires. The teacher response questionnaire consisted of three aspects: practicality, readability, and usability, while the student response

questionnaire consisted of 20 items covering interest, material presentation, and ease of use. Effectiveness data were obtained through a digital literacy questionnaire consisting of 20 items covering internet search, hypertext navigation, content evaluation, and knowledge gathering, as well as a learning outcome test consisting of 10 essay questions given during the pretest and posttest. The limited trial involved 34 tenth-grade students selected using purposive sampling and one biology teacher.

Research Procedures

Needs analysis

The analysis of teacher and student needs, materials, and infrastructure showed that learning was still dominated by conventional teaching materials, students' digital literacy skills were moderate, and learning outcomes were low, particularly on abstract virus material. Furthermore, students were supported by resources such as smartphones and adequate internet access.

Design

The design phase involved developing a Constructivist Teaching Sequence (CTS)-based teaching module, combined with Augmented Reality (AR) technology. The module was structured according to the CTS stages: introduction, exploration, restructuring, concept application, and evaluation.

Development

The development stage in the ADDIE model focuses on validation, revision, and initial product trials. The Constructivist Teaching Sequence (CTS)-based Augmented Reality (AR)-assisted learning module was first validated by two experts, a media expert and a material expert, using a validation sheet to assess feasibility and obtain suggestions for improvement. Next, the module was revised based on the validator's input to improve the content, appearance, and presentation. The revised product was then trialed on a limited basis with 34 tenth-grade students of SMA Negeri 1 Marisa Senior High School, involving one biology teacher. The trial aimed to assess the module's practicality through teacher and student responses. The research design used was a One Group Pretest-Posttest, where students were given a pretest before treatment and a posttest after learning to determine improvements in learning outcomes. The data obtained were analyzed to determine whether learning outcomes and digital literacy improved after using the AR-assisted CTS learning module. After the trial, the module was further revised to obtain a more optimal product.

Data Analysis

Validation Analysis of Teaching Modules

The validity analysis of the teaching module was analyzed using a Likert scale reference. The Likert scale criteria are presented in Table 1. There are 10 components of the assessment aspects for constructivist teaching sequence (CTS)-based learning modules supported by augmented reality (AR), namely the aspects of (1) cover design, (2) identity, (3) time allocation, (4) Achievements and (5) learning objectives, (6)

material description, (7) learning activities, (8) video message design, (9) audio message design, (10) media/tools, materials, and supporting resources, (11) language.

Table 1. Validation criteria for teaching modules, Refers to Patmaniar et al., (2024)

Assessment	Score %
Very valid	81-100
Valid	61-80
Fairly valid	40-60
Less valid	20-40
Not valid	0-20

The criteria score is determined using the following formula as referenced by Kaya (2025),

$$\text{Validation of teaching module} = \frac{\sum Total\ Score\ of\ Each\ Aspect}{\sum highest\ score} \text{ X } 100\% \quad \text{.....(1)}$$

Practicality Analysis of Teaching Modules

This analysis aims to assess the level of conformity between teacher learning implementation and established standards or criteria. Table 2 presents the assessment categories used to measure learning implementation.

Table 2. Implementation of learning, Refers to Handoko (2023)

Category score	Score %
Very poor	0-20
Poor	21-40
Suficient	41-60
Good	61-80
Very good	81-100

Data processing in this analysis uses calculations using the following formula as referenced by Handoko (2023).

$$\text{Learning implementation} = \frac{Score\ for\ each\ aspect}{Maximum\ score} \text{ X } 100\% \quad \text{.....(2)}$$

The assessment of learning implementation is said to be good if the teacher's class management is in the good or very good criteria. The teacher response questionnaire was given after the learning process was completed. The results of the percentage calculation were interpreted into the following criteria.

Table 3. Teacher Response Questionnaire Score, Refers to Rantung et al., (2023)

Criteria	Presentation
Very Practical	81 - 100%
Practical	61 - 80%
Quite practical	41 - 60%
Less practical	21 - 40%
Very less practical	0 - 20%

Data processing in this analysis uses calculations using the following

formula as referenced by Rantung et al., (2023). The student response questionnaire was administered after the learning process. The results of the percentage calculation of the student response questionnaire in the limited-scale trial are presented in Table 4.

$$\text{Assessment criteria} = \frac{Score\ of\ Each\ Aspect}{Maximum\ score} \text{ X } 100\ \% \quad \text{.....(3)}$$

Table 4. Interpretation of Student Response Questionnaire Scores, Refers to Putri & Soeparno (2024)

Criteria	Score %
Very Eligible	86-100
Eligible	71-85
Quite Eligible	56-70
Less Eligible	41-55
Not Eligible	<40

To calculate the percentage of each answer, use the following formula as referenced by Putri & Soeparno (2024),

$$\frac{Student\ answer\ score}{Maximum\ Score}\ X\ 100\% \quad \text{..... (4)}$$

Digital Literacy Skills Analysis

Analysis was performed on each component based on questionnaire assessment scores using a Likert scale of 1–4, with assessment categories including Very Aware (ST), Know (T), Don't Know (TT), and Very Unaware (STT). The following formula, as referenced by Suherlan & Halida (2024). The digital literacy range categories established as referenced by Suherlan & Halida (2024), which found in Table 5.

$$\text{Score} = \frac{Total\ Student\ Score}{Maximum\ Score} \text{x } 100\% \quad \text{..... (5)}$$

Table 5. Digital Literacy Range Category, Refers to Suherlan & Halida (2024)

Score %	Categori
67 - 100	High
34 - 66	Medium
0 - 33	Low

Analysis of Learning Results

According to Anshari et al., (2024) the management and analysis stages are as follows. Calculating the correlation between the score of each item and the total score using the Pearson product moment formula.

$$rxy = \frac{n\ (\Sigma xy) - (\Sigma x).(\Sigma y)}{\sqrt{\{n.\Sigma x^2 - (\Sigma x)^2\}.\{n.\Sigma y^2 - (\Sigma y)^2\}}} \quad \text{.....(6)}$$

Description:
rxy: calculated correlation coefficient
N: number of test participants
X: score on variable X (item score)
Y: score on variable Y (total score)

The test was conducted at a significance level of α=0.05 with degrees of freedom (dk=n - 2). The basis for decision-making in the validity test is as follows, If the calculated r value > r_table, then the item is declared valid. If the calculated r value < r_table, then the item is declared invalid.

Reliability

The procedure for determining instrument reliability is described as referenced by Ghozali (2018),

$$r_{11} = \left[\frac{k}{(k-1)}\right]\ \left[1 - \frac{\Sigma Si}{St}\right] \quad \text{.....(7)}$$

Description:
r_{11}: instrument reliability coefficient
k: number of test items
ΣSi: total variance per item
St: total variance of test items

The criteria for decision-making in reliability testing are as follows: A test instrument is deemed reliable if the Cronbach's Alpha value > 0.60. Conversely, a test instrument is considered unreliable if the Cronbach's Alpha value is < 0.60. The testing criteria employing the Cronbach's Alpha formula are detailed in Table 6.

Table 6. Interpretation of Instrument Reliability, Refers to Ghozali (2018)

Cronbach's Alpha Score	Description
< 0.50	Low Reliability
< 0.70	Reliabilitas Sedang
> 0.70	Reliabilitas Mencukupi

A research instrument is considered reliable if the Cronbach's alpha value is greater than 0.60. Therefore, the basis for decision-making in reliability testing is that if the Cronbach's alpha value is > 0.60, the questionnaire items are considered reliable. Conversely, if the Cronbach's alpha value is ≤ 0.60, the questionnaire items are considered unreliable (Forester et al., 2024).

N-gain Analysis

Earning outcome analysis is obtained by determining the student's learning achievement, which can be calculated using the following formula as referenced by Muthmainnah et al., (2023),

$$\text{Learning Outcomes} = \frac{\text{Total Score Obtained by the Participant}}{\text{Total Maximum Score}} \text{X } 100 \quad \text{.....(8)}$$

Student learning outcomes were measured using the developed learning modules through pretest and posttest data collection. The data was then analyzed using the N-Gain test. The N-Gain level categories are presented in Table 7. The N-Gain formula as referenced by Muthmainnah et al., (2023) is as follows:

$$N\text{-}Gain = \frac{Score\ Pos\ tes - Pretest}{100 - Pretest\ Score} \quad \text{..... (9)}$$

Description:
S post = final test score
S pre = initial test score
S maks = maximum score

Table 7. Level Category N-Gain, Refers to Muthmainnah et al., (2023)

Limits	Category
g > 0,7	High
0,3 ≤ g ≤ 0,7	Moderate
g < 0,3	Low

RESULTS AND DISCUSSION

This research resulted in a constructivist teaching sequence (CTS)-based teaching module with augmented reality (AR) support on viruses. The development process was conducted using the ADDIE model up to the development stage, with limited trials.

Validation of teaching modules

The purpose of validation in this study was to assess the feasibility of the developed learning module so that it can be used in the learning process. According to Kaya et al., (2025) assessing the feasibility of a learning module through expert validators is crucial to ensure the appropriateness of the material presented and the effectiveness of its presentation format in learning. Therefore, the learning module developed in this study was validated by two expert lecturers: a material expert and a media expert, to obtain a comprehensive assessment of the content and presentation of the learning media. The results of the media expert validation of the AR-assisted CTS-based virus learning module are shown in Figure 1.

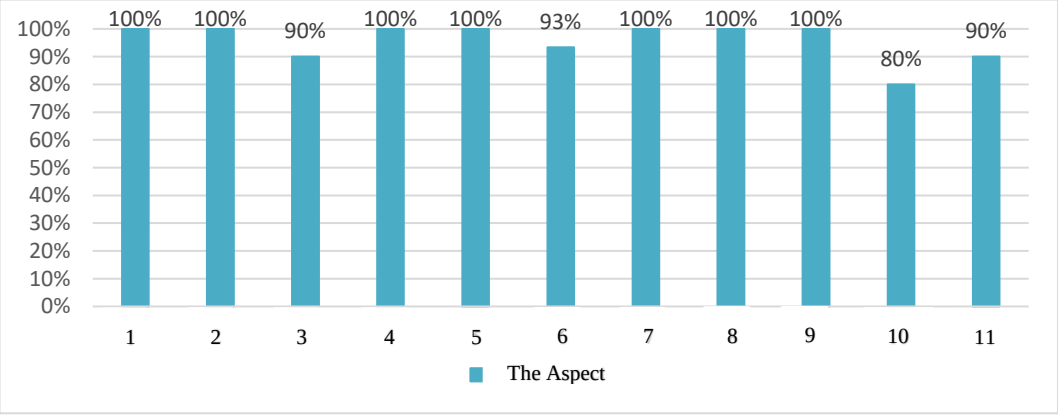

Figure 1. Media expert validation results graph

Based on the assessment of media experts, the constructivist teaching sequence (CTS)-based teaching module assisted by augmented reality (AR) obtained a very valid category in almost all components, aspects of (1) cover design, (2) identity, (4) achievements and (5) learning objectives, (7) learning activities, (8) video and audio message design, and (9) assessment with a score of 100% (Very valid). In addition, (3) time allocation and (11) language obtained a score of 90%, (6) material description 93%, and aspects (10) media/tools, materials and supporting sources 80% with a valid category. This is because the learning resources used are not yet diverse enough.

However, these aspects still meet the requirements that allow them to be used in learning. According to Setiawan (2022) which states that a variety of learning resources is very important to support the learning process because it can improve students' understanding and increase their desire to learn. Overall, the module obtained an average score of 96% and was included in the very valid category, which means that it is suitable for use in learning. Other research Taib et al., (2025) which found that teaching modules with a validity of 80% to 100% fall into the valid category, meaning they are highly valid and suitable for use in learning. According to Khatimah et al., (2023), these criteria indicate that the teaching modules developed are in accordance with the Independent Curriculum and meet students' needs. Furthermore, teaching modules must meet established requirements, particularly regarding minimal compliance with the applicable curriculum. The results of the media expert validation on the AR-assisted CTS-based virus material teaching module can be seen in Figure 2.

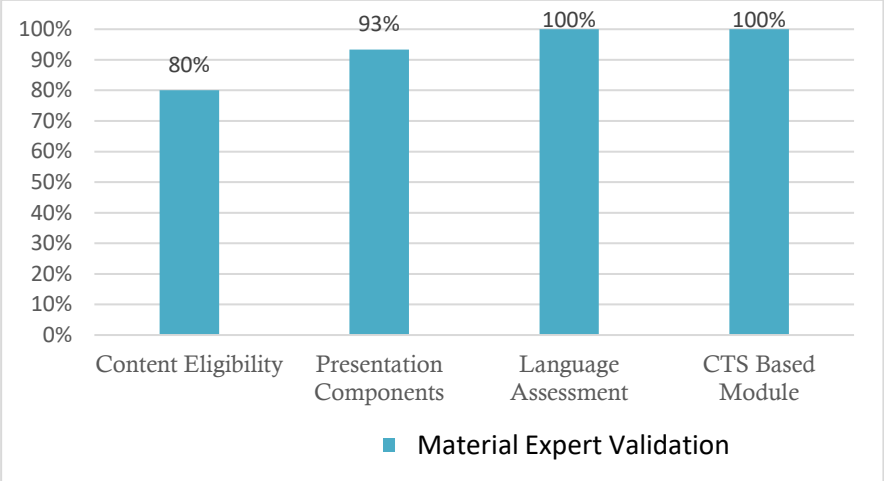

Figure 2. Graphic of material expert validation results

Based on the results of the material expert assessment, the linguistic aspects and conformity with the constructivist teaching sequence (CTS) model received the highest score of 100% (very valid), indicating that the module uses clear language and conforms to CTS syntax. The presentation aspect received a score of 93% (very valid) because the material is presented coherently and interestingly. Meanwhile, the content aspect received a score of 80% (valid) because there are still several parts of the virus material that need to be improved, such as the explanation of the structure, virus replication, and the use of scientific terms. According to Afriliska & Zulyusri (2021)

conceptual accuracy, completeness of material, and the use of appropriate scientific terms are very important in teaching materials to avoid misconceptions among students. Therefore, improvements in the content aspect are needed so that the module can provide a deeper understanding of concepts and comply with scientific principles.

Overall, the module achieved an average score of 93%, categorized as highly valid, and is therefore deemed suitable for use in the learning process. According to Latjompoh (2018) A learning device is said to have a good level of validity if all its components are relevant to the scientific substance and support each other in achieving learning objectives.

Practicality of Teaching Modules

In this study, three main elements were reviewed to assess the practicality of the teaching module: learning implementation, teacher response, and student response. In a 1999 journal on learning devices, Yakop et al., (2024) stated that learning devices are considered practical if they are easy to use by both teachers and students during the learning process. The practicality of the developed learning devices can be determined through user responses, both teachers and students, obtained from the results of completing the response questionnaire. Furthermore Rahayu et al., (2019) stated that the practicality of learning tools is determined by clarity of use, appropriate time allocation, and their benefits for teachers and students. The results of the implementation of learning in the AR-assisted CTS-based virus teaching module can be seen in Figure 3.

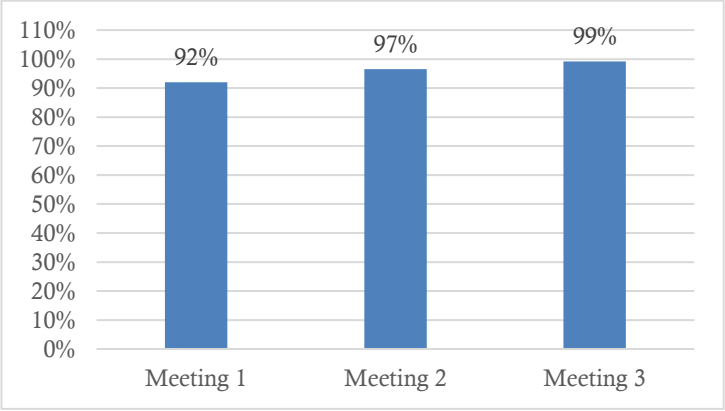

Figure 3. Learning implementation graph

Learning implementation is an indicator that shows the suitability between planning and implementation of learning in the classroom. Based on the observation results, the percentage of learning implementation showed an increase in each meeting, namely 92% in the first meeting, then increasing to 97% in the second meeting, and reaching 99% in the third meeting, with an overall average of 96% which is included in the very good category. This high implementation value indicates that the AR-assisted CTS-based teaching module can be implemented very well in accordance with the designed learning syntax. According Hakim et al., (2021) the percentage of learning processes at each meeting that falls into the good to excellent

category indicates that learning has been carried out optimally. The learning process itself is a form of interaction between teachers and students, as well as between students, in an effort to achieve learning objectives. The results of teachers' responses to the AR-assisted CTS-based virus material teaching module can be seen in Figure 4.

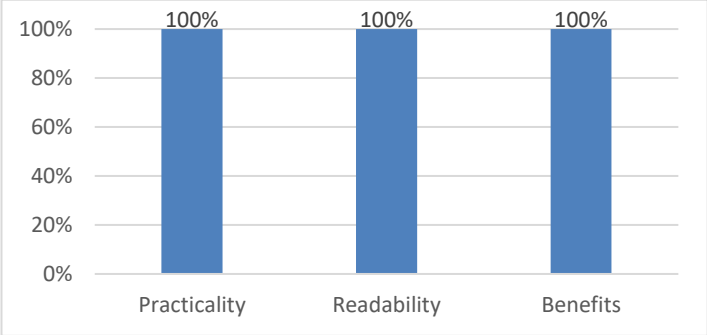

Figure 4. Teacher response graph

Teacher responses to the teaching module achieved a 100% rating, categorized as very practical. This high rating indicates that the module has been systematically designed, making it easier for teachers to implement learning, from understanding the flow of activities, using AR media, to implementing the constructivist teaching sequence (CTS) model. Furthermore, the teachers' experience and competence in managing learning contributed to this high rating. In line with Anas et al., (2025) opinion, the results of the practicality test by teachers, which received a very practical category, indicate that the material, construction, and language aspects met the eligibility criteria as a learning instrument. Teachers also assessed that the module's instructions were clearly structured, the language used was easy to understand, and the module could be implemented effectively without requiring revision. The results of student responses to the AR-assisted CTS-based virus teaching module can be found in Figure 5.

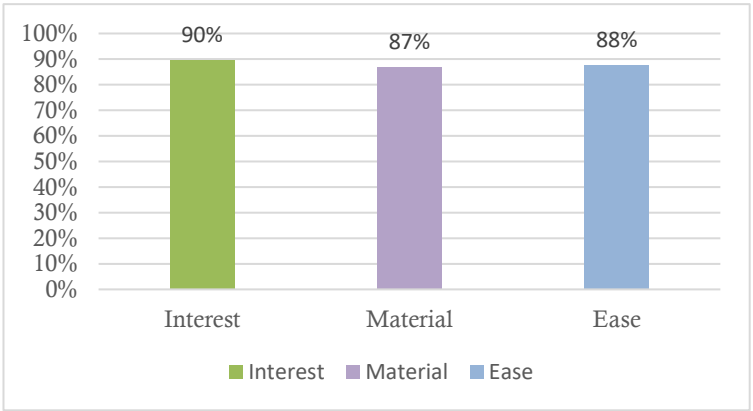

Figure 5. Graph of student responses

The results of the student response questionnaire assessment involving 34 respondents regarding the developed teaching module showed that in the interest aspect, the percentage was 90% (very appropriate), the material aspect was 87% (very appropriate), and the ease aspect was 88% (very appropriate). Obtaining an average

percentage of 88% with a very appropriate category. The percentage illustrates that the teaching module has met the criteria of practicality. According to Wahfiudin et al. (2023) a learning tool can be declared practical if it obtains a positive response from students during the process of using it in learning.

The percentage doesn't reach 100% because it's influenced by several factors. Not all students have the same digital literacy skills, so some still experience difficulties using AR technology at the beginning of the lesson. Furthermore, students need time to adjust to the learning process implemented through the CTS-based learning flow, which emphasizes active student development in independently constructing knowledge. Therefore, differences in digital literacy skills, device availability, and student readiness for CTS-based learning influence the response rate. According to the constructivist theory proposed by Piaget (1957) students actively construct knowledge through experiences and interactions during the learning process (Iskandar et al., 2023). Research by Ristiani et al., (2025) also states that the use of augmented reality technology in learning can strengthen digital literacy and increase student learning motivation. However, its implementation is greatly influenced by user readiness and students' ability to operate digital technology. Students with low digital skills tend to require more intensive guidance in the initial stages of using AR media.

Literacy Digital

The results of the digital literacy pretest and posttest on the AR-assisted CTS-based virus material teaching module can be seen in Figure 6. The indicator for internet information search ability increased from 64% (moderate) to 89% (high), indicating that students are increasingly able to access digital information in a more targeted manner. This aligns with Amri (2024) that using appropriate keywords helps students find relevant and reliable information sources, thereby increasing search efficiency.

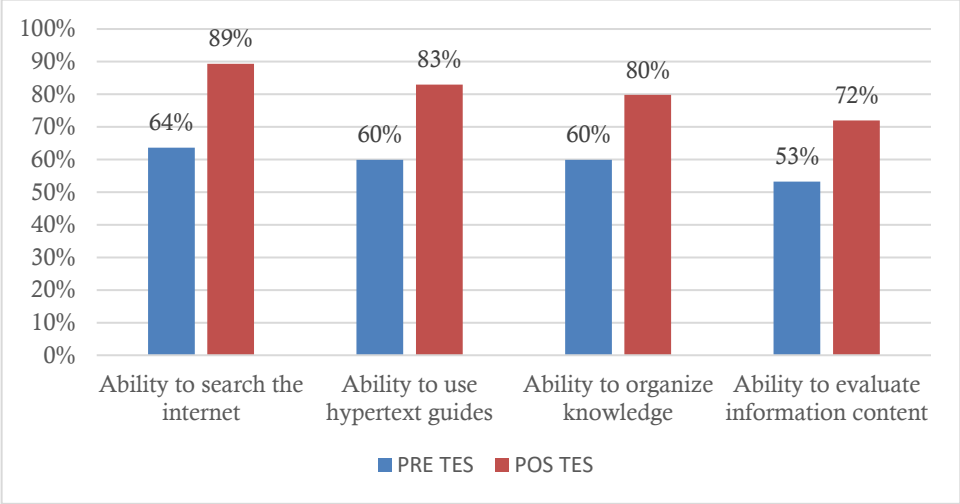

Figure 6. Graph of pretest and posttest results

The hypertext usage indicator also increased from 60% to 83%, indicating improved information navigation skills through digital links. This improvement is supported by constructivist teaching sequence (CTS)-based learning modules equipped with hyperlinks and QR codes, and aligns with Pratiwi & Indana (2022) who stated

that QR code-based e-modules can improve digital literacy through integrated link access. However, this achievement is not optimal because some students still require assistance with digital navigation.

The knowledge organization indicator increased from 60% to 80%, indicating students' ability to organize information more systematically. This aligns with constructivist theory, which emphasizes that knowledge is actively constructed through learning experiences (Rahmawati et al., 2021). Furthermore, Alfa & Asrizal (2023) also stated that AR-assisted constructivist-based learning encourages students to actively and interactively construct knowledge.

The information content evaluation indicator increased from 53% to 72%, although it remains the lowest achievement. This indicates that students' ability to compare and verify information is developing, but is not yet consistent. This finding aligns with Putri & Soeparno (2024) who stated that information evaluation is the weakest aspect of digital literacy. Digital literacy itself plays a crucial role in improving the quality of learning by strengthening critical thinking (Pratama et al., 2023).

Learning Outcomes

The validity test results indicate that all questions are valid because the calculated r value is greater than the r table at a significance level of 5% (df = 28). This indicates that each question has the ability to measure learning indicators correctly and in accordance with the virus being taught. Valid questions indicate that they have been systematically arranged and can demonstrate the abilities that students want to achieve. This is in accordance with the opinion (Lasaiba & Lasaiba, 2024) that most of the instrument components meet the validity criteria, as indicated by the calculated r value being greater than the r table at a significance level of 5%. This finding indicates that the developed has the ability to measure the constructs studied accurately and consistently. The results of the validity test can be seen in Table 8.

Table 8. Results of Question Validity Test

Questions items	Validity Test		Decision
	r_{count}	r_{table}	
1	0.405	0,361	Valid
2	0.428	0,361	Valid
3	0.473	0,361	Valid
4	0.410	0,361	Valid
5	0.387	0,361	Valid
6	0.364	0,361	Valid
7	0.482	0,361	Valid
8	0.552	0,361	Valid
9	0.693	0,361	Valid
10	0.716	0,361	Valid

The instrument, with all items declared valid, was influenced by several conditions, including the formulation of questions that clearly referred to learning indicators and the suitability of the material to the curriculum used. Furthermore, a

validation process by experts prior to the pilot test also played a role in refining the quality of each item so that it could accurately measure the intended construct. This aligns with Ariani et al., (2026) opini validator assessments were conducted to ensure the suitability of each item to the learning indicators, measurement objectives, and the materials used.

Reliability test results showed that the essay test instrument on the topic of viruses achieved a Cronbach's Alpha value of 0.63, which falls into the moderate reliability category. This value indicates that the instrument has sufficient consistency and can be used accurately to measure student understanding. Forester et al., (2024) stated that an instrument with a Cronbach's Alpha value > 0.60 can be considered reliable because it has good measurement consistency. The failure to achieve the high reliability category was influenced by variations in student abilities. This is in line with the opinion of Ary et al. In Setiyorini et al., (2022) test reliability tends to decrease if students' abilities are lower or more diverse.

Table 9. Reliability test results

Reliability Statistics	
Cronbach's Alpha	**Number of questions**
0.63	10

Student learning outcomes based on a comparison of pretest and posttest scores indicate an improvement after the learning process was implemented. This is evident from the average pretest score of 28.15, which increased to 77.44 in the posttest. The low pretest score indicates that students' initial understanding of the material is still limited. After being given the learning treatment, the posttest score increased, indicating an increase in students' understanding and mastery of the material. The N-gain calculation result of 0.69 indicates that the improvement in learning outcomes is in the moderate category. According to Muthmainnah et al., (2023) an N-gain value in the range of 0.3–0.7 is included in the moderate category, indicating that learning can significantly improve students' understanding.

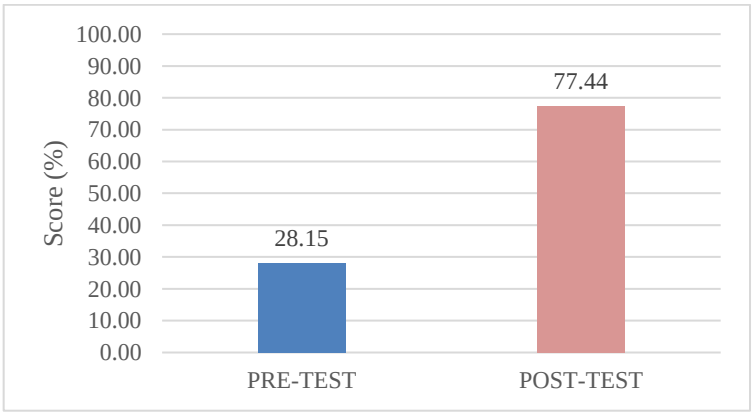

Figure 7. Comparison of the average pretest and posttest scores

The variation in students' posttest scores, ranging from a lowest of 68 to a highest of 90, with an average pretest score of 28.15 to a posttest score of 77.44, indicates a difference in the level of mastery of the material after learning. This condition is influenced by differences in initial abilities, speed of understanding the material, and student involvement during the learning process. These differences in learning outcomes can be explained through constructivism theory, which views students as constructing understanding independently based on learning experiences and prior knowledge. In line with the opinion of Handoyo & Ani (2025) knowledge is not obtained directly from the teacher, but is formed through the process of active thinking, exploration, and reflection of students. This condition is also in line with Moha et al., (2024) that students who experience learning difficulties generally have lower achievements than the class average, obtain learning outcomes that do not match the efforts made, and tend to be slow in completing assignments.

CONCLUSION

This study developed a Constructivist Teaching Sequence (CTS)-based teaching module assisted by Augmented Reality (AR) on virus material. The results showed that the module achieved a very high level of validity based on assessments from media and material experts and demonstrated a high level of practicality based on teacher and student responses. The implementation of the module also showed the potential to improve students' digital literacy skills across all measured indicators and enhance learning outcomes, as indicated by the increase in pretest and posttest scores with an N-gain value of 0.69 in the moderate category. The findings contribute theoretically to the integration of constructivist learning and digital technology in biology education. Practically, the developed module can serve as an alternative teaching resource for biology teachers in implementing the Independent Curriculum, particularly for abstract topics such as viruses. In addition, the module supports the development of students' digital literacy skills, which are essential competencies for 21st-century learning. This study was limited to the development stage and a limited-scale trial involving one class. Therefore, future studies are recommended to conduct larger-scale implementations and examine the effectiveness of similar modules on other biology topics and educational contexts.

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