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Implementation of *Constructivist Teaching Sequence*-Based Teaching Modules Assisted by *Augmented Reality* to Improve Biology Learning Outcomes

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Abstract

Background: *The main problem in this study is the low achievement of student learning outcomes which is influenced by the suboptimal use of interactive and innovative teaching materials in the learning process. This study aims to determine the improvement in student learning outcomes after the implementation of a Constructivist Teaching Sequence (CTS)-based teaching module assisted by Augmented Reality (AR) on the circulatory system material.* **Methodology:** *This study uses a quantitative approach with a pre-experimental type and a one-group pretest–posttest design. The study was conducted at SMA Negeri 1 Tapa Senior High School with a sample of 61 students obtained using cluster random sampling techniques at the class level. The instrument used was an essay test based on Higher Order Thinking Skills (HOTS). Data analysis techniques used the N-gain test and paired sample t-test.* **Findings:** *The research findings show that the average pretest score is in the low category, while the posttest score experienced a significant increase with an N-gain value of 0.76 which is included in the high category. The paired sample t-test yielded a significance value of 0.000 < 0.05, indicating a significant difference between the pretest and posttest results.* **Contributions:** *This study provides empirical evidence that integrating CTS-based teaching modules with Augmented Reality can enhance students' learning outcomes in biology, particularly on the circulatory system.*

Keywords: *Augmented Reality; Circulatory System; Constructivist Teaching Sequence; HOTS; Learning Outcomes*

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INTRODUCTION

Learning in the 21st century demands a meaningful learning process, one that focuses not only on mastering factual information but also on developing higher-order thinking skills such as analysis, synthesis, and evaluation. According to Ngatminiati et al., (2024), critical thinking skills are becoming increasingly important in 21st-century education, particularly in developing student competencies. Meaningful learning occurs when students are able to connect new knowledge with existing experiences and apply it to solving contextual problems. According to Kharisma et al., (2025), in education, is considered successful if it can integrate cognitive, affective, and psychomotor aspects in a balanced manner. Therefore, learning media and models are needed that can encourage active student involvement in building a deeper understanding of concepts (Khasanah et al., 2025).

The development of Higher Order Thinking Skills (HOTS) has become one of the primary objectives of 21st-century science education. However, international assessments continue to indicate that Indonesian students experience difficulties in solving analytical and problem-solving tasks. The Programme for International Student Assessment Primahesa et al., (2022) reported that Indonesian students' science performance remains below the OECD average, particularly in competencies involving scientific reasoning, interpretation of evidence, and problem-solving. These findings indicate that biology learning requires instructional approaches capable of promoting conceptual understanding alongside higher-order thinking skills.

Teachers play a crucial role in creating meaningful learning through structured and interactive learning tools. In 21st-century education, teachers act not only as information providers but also as facilitators and agents of change, helping students face global challenges (Lestari et al., 2025). One learning tool that can support active learning is a learning module. Through systematic preparation, a teaching module can guide a more structured and interactive learning process, while fostering critical and reflective thinking skills. Its development needs to be aligned with learning models that encourage active student engagement, such as the *Constructivist Teaching Sequence* (CTS)-based learning model (Mulyani & Insani, 2023).

The C*onstructivist Teaching Sequence* (CTS) learning model is an approach rooted in constructivist principles that emphasizes active student involvement in constructing knowledge. The constructivist approach emphasizes students' active role in constructing understanding based on learning materials and experiences gained. In this approach, students' direct experiences are considered a primary factor in the learning process (Pratami, 2024). Through structured learning phases, including introduction, exploration, reconstruction of previous concepts, application of concepts, and evaluation. This process encourages students to actively engage in learning and independently develop conceptual understanding (Bustomi et al., 2024).

The implementation of CTS-based teaching modules can be supported by learning media such as *Augmented Reality* (AR), which is interactive and contextual, because digital media in 21st-century learning functions as a means to present learning experiences through visual representations that can be accessed and processed digitally (Wicaksono et al., 2022). AR technology combines real-world objects with threedimensional displays, helping students understand concepts more concretely,

particularly in the topic of the circulatory system, through visualization of organ structures, blood flow, and substance transport processes, thereby enhancing conceptual understanding and learning engagement (Sylvia et al., 2020).

Preliminary classroom observations conducted at SMA Negeri 1 Tapa senior high school indicated that students experienced difficulties in understanding the circulatory system because many biological processes cannot be directly observed. Similar findings have been reported by Sylvia et al., (2020), who explained that abstract biological concepts require interactive visualization to facilitate conceptual understanding. This condition is reflected in students' low engagement during learning activities and limited opportunities to reconstruct misconceptions through interactive media.

The implementation was conducted over three learning meetings (3 × 45 minutes each). During the reconstruction stage, students used Android smartphones to scan AR markers embedded in the teaching module. The AR application displayed interactive three-dimensional visualizations of the human heart, blood vessels, and blood circulation pathways, enabling students to compare their prior conceptions with scientific concepts before applying the acquired knowledge to contextual problem-solving activities. The integration of CTS and AR creates a complementary learning mechanism. CTS provides a structured constructivist learning sequence consisting of introduction, exploration, reconstruction of preconceptions, concept application, and evaluation, whereas AR functions as a visualization tool that transforms abstract biological concepts into interactive three-dimensional representations.

During the reconstruction stage, students actively compare their initial understanding with AR visualizations, thereby facilitating conceptual change. This integration enables students not only to acquire factual knowledge but also to analyze, evaluate, and apply biological concepts, which are essential components of Higher Order Thinking Skills (HOTS). Problems in learning the circulatory system are indicated by students' low conceptual understanding and limited active engagement, which are influenced by learning processes that are still conventional and less interactive. In addition, the use of visual-based learning media, both two-dimensional and three-dimensional, is still limited, causing students to have difficulties in understanding the abstract concepts in this topic. This condition indicates the need for learning innovations that can improve learning outcomes as well as student activity through the implementation of more interactive learning models and media.

Several previous studies have shown that the use of CTS and AR has a positive impact on learning. Research by Asriani et al., (2025) revealed that AR-assisted CTS based modules have a very high level of validity, but have not yet tested their contribution to student learning outcomes. Research by Fadillah (2024) found that the CTS model is effective in improving students' visual representation abilities, but has not yet involved the use of AR technology in the learning process. Meanwhile, Malanua et al., (2025) reported that the use of AR-assisted CTS can improve the implementation of the learning process, but has not focused on improving learning outcomes and overall student engagement. Based on these research results, there is still a research gap regarding the contribution of AR-assisted CTS-based learning modules to improving student learning outcomes.

The novelty of this research lies in the implementation of a *Constructivist Teaching Sequence* (CTS)-based teaching module assisted by *Augmented Reality* (AR) which focuses on its contribution to improving students' learning outcomes on the human circulatory system. Previous research generally only focuses on module validity, learning implementation, or students' visual representation abilities, while this research emphasizes the contribution of the implementation of an AR-assisted CTS based teaching module in improving *Higher Order Thinking Skills* (HOTS)-based learning outcomes through *pretest-posttes*t analysis, *N-gain* values, and *paired sample ttest*. In addition, the research highlights the relationship between constructivist syntax in the CTS model and AR in helping students reconstruct abstract concepts concretely and meaningfully. Thus, this research not only integrates the constructivist learning model and digital technology, but also demonstrates its contribution to the development of students' higher-order thinking skills in biology learning.

METHOD

This research was conducted at SMA Negeri 1 Tapa senior high school in the odd semester of the 2025/2026 academic year, using a quantitative method with a *one-group preexperimental pretest-posttest* design approach. This design was used to determine the contribution of the implementation of a *Constructivist Teaching Sequence* (CTS)-based learning module assisted by *Augmented Reality* (AR) on student learning outcomes in the circulatory system material. The population in this study included all grade XI IPA students, while the research sample was determined using a *cluster random sampling* technique at the class level. The research instrument was 10 essay questions based on *Higher Order Thinking Skills* (HOTS) used in the *pretest* and *posttest* implementation. The research procedure included the preparation, implementation, and final stages. Data analysis was carried out descriptively quantitatively through the calculation of the average value, *N-gain*, and *paired sample t-test* using IBM SPSS Statistics at a significance level of 0.05. The research design according to Sugiyono (2016) is presented in Table 1.

Table 1. One Group Pretest-Posttest Research Design, Adapted from Sugiyono (2016)

Pretest	***Treatment***	***Posttest***
O1	X	O2

Description,
O_1 = Pretest of student abilities
X = Implementation of a *Constructivist Teaching Sequence* (CTS)-based teaching module
O_2 = Posttest of student abilities

Sample or Participant

The population in this study included all eleventh-grade science students at SMA Negeri 1 Tapa senior high school, consisting of six classes, each with a total of 25 – 31 students. All students were selected as part of the population because they had taken Biology. The research sample was determined using a *cluster random sampling*

technique, which involves random sampling based on classes within the population. This technique was chosen because the population consists of several relatively homogeneous classes, making randomization more effective at the class level and more efficient in conducting the researchSix classes were available in the population. A lottery was conducted using the *Spin* application, resulting in the selection of classes XI-3 and XI-4 as the research samples, comprising a total of 61 students. The selection was carried out randomly without differentiating between superior and regular classes, so that each class had an equal chance of being selected. Thus, this technique was used to ensure that the obtained sample was representative and objective.

Instrument

The instrument used in this study consisted of ten Higher Order Thinking Skills (HOTS)-based essay questions designed to measure students' cognitive learning outcomes on the human circulatory system. The instrument was developed based on the Biology Learning Outcomes in the Merdeka Curriculum and referred to the revised Bloom's Taxonomy, covering the cognitive levels of analyzing (C4), evaluating (C5), and creating (C6). A table of specifications (blueprint) was prepared by aligning learning objectives, learning indicators, cognitive levels, and question items to ensure content representativeness. Before being administered, the instrument underwent content validation by two experts in biology education to evaluate the relevance of the items to the learning objectives, the clarity of the language, the appropriateness of the scientific concepts, and the suitability of the HOTS indicators. Suggestions provided by the validators were used to revise several items before empirical testing. The revised instrument was then subjected to empirical validity testing using the Pearson Product–Moment correlation coefficient. An item was considered valid when the calculated correlation coefficient (rcount) exceeded the critical value of rtable at a significance level of 0.05. The results indicated that all ten essay items met the validity criteria. Instrument reliability was subsequently determined using *Cronbach's Alpha* coefficient

Data collection

The research instrument consisted of ten Higher Order Thinking Skills (HOTS)-based essay questions designed to assess students' cognitive learning outcomes on the human circulatory system. The instrument was developed based on the Biology Learning Outcomes in the Merdeka Curriculum and referred to the revised Bloom's Taxonomy, covering the cognitive levels of analyzing (C4), evaluating (C5), and creating (C6). A table of specifications (blueprint) was prepared by aligning learning outcomes, learning indicators, cognitive levels, and question items to ensure content representativeness.

Before being administered, the instrument underwent content validation by two experts in biology education to evaluate the relevance of the items, the accuracy of the scientific content, the clarity of the language, and the suitability of the HOTS indicators. The revised instrument was then empirically tested using the Pearson Product–Moment correlation coefficient, in which an item was considered valid when the calculated correlation coefficient (*r*count) exceeded the critical value of *r*table at a significance level of 0.05. Instrument reliability was determined using Cronbach's

Alpha coefficient, yielding a reliability value of 0.76, indicating good internal consistency (Nunnally & Bernstein, 1994).

Data collection was carried out using the validated essay test through pretest and posttest administered before and after the instructional treatment. The treatment was implemented over three meetings (3 × 45 minutes each) using a Constructivist Teaching Sequence (CTS)-based teaching module integrated with Augmented Reality (AR). During the reconstruction of preconceptions stage, students used Android smartphones to scan AR markers embedded in the teaching module. The AR application displayed interactive three-dimensional visualizations of the human heart, blood vessels, and blood circulation pathways, enabling students to observe biological structures and processes that cannot be directly seen. Students explored these visualizations individually and in groups, followed by discussions and worksheet activities to compare their initial conceptions with scientific explanations. The pretest and posttest scores were subsequently used to measure improvements in students' HOTS-based learning outcomes after the implementation of the AR-assisted CTS learning module.

Procedure

The research procedure began with a pretest given to students to determine their initial abilities in the circulatory system material before the learning process was carried out. Next, the learning process was carried out using a *Constructivist Teaching Sequence* (CTS)-based teaching module assisted by *Augmented Reality* (AR) which was carried out over three meetings according to the learning syntax, namely introduction, exploration, reconstruction of preconceptions, application of concepts, and evaluation. After the entire learning process was completed, students were given a *posttest* to measure improvements in learning outcomes and conceptual understanding after the treatment. *Pretest* and *posttest* data were then used as a basis for analyzing improvements in student learning outcomes in the cognitive domain.

Data analysis

The data analysis technique used in this study was quantitative descriptive statistics. Student learning outcome data was obtained from *pretest* and *posttest* scores, which were then analyzed to determine learning achievement levels. Individual learning completion analysis was conducted using the following percentage formula refers to Rosdiana et al., (2015):

$$Student\ Score = \frac{Score\ obtained\ by\ student}{Maximum\ score} \times 100\ \% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Analysis of the achievement of learning outcomes classically is reviewed from the average class value calculated using the formula Rosdiana et al., (2015):

$$\bar{X} = \frac{X_1 + X_2 + \ldots\ldots + X_n}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

The significance of the improvement in learning outcomes was analyzed using a paired sample t-test to determine differences in learning outcomes between the pretest and posttest stages. A summary of the hypothesis test results can be seen in Table 3.

$$g = \frac{X_{Posttest} - X_{Pretest}}{X_{Maximum} - X_{Pretest}} \quad \text{..... (3)}$$

The results of the N-gain calculation are then grouped into high > 0,70, medium < 0,70, and low < 0,50 categories based on the predetermined value range. Hypothesis testing is then carried out using the T test (paired sample t-test) with the help of SPSS version 27 at a significance level of 0.05. The test results show that H_0 is rejected and H_1 is accepted if the Sig. (2-tailed) value is <0.05, while H_0 is accepted if the Sig. (2-tailed) value is >0.05 (Muthmainnah et al., 2023).

RESULT AND DISCUSSION

The results of the study showed an increase in student learning outcomes after implementing a *Constructivist Teaching Sequence* (CTS)-based teaching module with *Augmented Reality* (AR) on the circulatory system. This improvement was analyzed by comparing pretest and posttest scores, which were then calculated using N-gain. The results of this analysis are presented in Table 2.

Table 2. Results of *Pretest, Posttest*, and *N-gain* of Students

Respondent Average	*Pretest*	Category	Average *Posttest*	*N-gain*	Category
61 PD	35.29	Low	84.88	0.76	High

PD: learners (Muthmainnah et al., 2023).

The N-gain value of 0.76, which is included in the high category, indicates that the AR-assisted CTS-based learning module on the circulatory system material contributes to improving student learning outcomes. This improvement occurs because the CTS stages help students connect prior knowledge with the concepts being learned. Lamante et al., (2025) stated that CTS-based learning integrated with AR can support improved learning outcomes through clearer visual presentations. while AR presents more concrete visualizations of the circulatory system so that abstract concepts become easier to understand. Sudharsono et al., (2024) stated that augmented reality-based media can increase student learning motivation through interesting and interactive learning experiences. The use of interactive media is also able to attract attention and encourage active participation of students in the learning process.

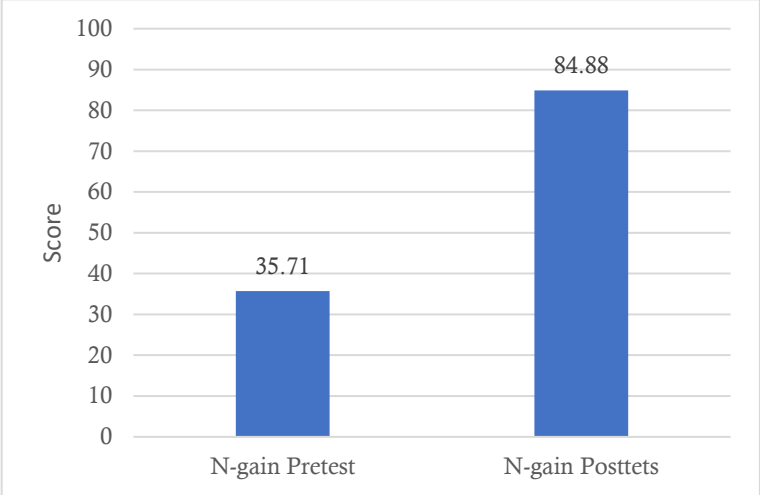

Figure 1. Average Pretest and Posttest Scores of Students

To determine the significance of this improvement, a paired sample t-test was conducted to examine differences in learning outcomes before and after treatment. The results of the hypothesis test are presented in Table 3.

Table 3. Paired Sample *T-Test Pretest* and *Posttest* Results

Variable	*Mean Difference*	t	df	*Sig. (2-tailed)*	Description
Pretest – Posttest	-49.213	-45.161	60	0.000	Significant

The paired sample *t*-test yielded a *t* value of -45.161 with a significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between students' pretest and posttest scores. The relatively large *t* statistic was influenced by the substantial mean difference between the two measurements (49.213 points) accompanied by a relatively small standard deviation of the paired differences (SD= 8.511). These findings indicate that the improvement in learning outcomes was consistent across participants following the implementation of the AR-assisted CTS-based teaching module.

These results are in line with Ausubel's theory of meaningful learning, which explains that new knowledge is easier to understand when it is linked to the cognitive structures that students already have (Khasanah et al., 2025). Based on the *paired sample t-test*, a significance value of $0.000 < 0.05$ was obtained, indicating a significant difference between the *pretest* and *posttest* scores. Thus, H_1 is accepted. This finding aligns with research by Jannah & Oktaviani (2022), which explains that the use of AR can aid conceptual understanding while simultaneously encouraging improved student learning outcomes. Furthermore, Darti et al., (2025) suggested that the implementation of the CTS module integrated with AR can provide a more active and meaningful learning process for students. The high *t* value obtained in this study reflects not only the magnitude of the increase in students' learning outcomes but also the consistency of the improvement among participants. Because most students experienced comparable gains after the instructional treatment, the variability of the paired

differences remained relatively small, resulting in a large *t* statistic. Therefore, the statistical result indicates a strong treatment effect rather than an analytical error.

Improved learning outcomes are also inseparable from the application of CTS syntax during learning activities. In the introductory stage, students are directed to identify prior knowledge through discussions and video observations related to the circulatory system. This activity helps students build connections between existing concepts and the material being studied, thus making learning more meaningful. This is in line with Bustomi et al., (2024), who stated that the introductory stage in constructivism provides concrete examples related to everyday life and considers students' prior knowledge before moving on to the next stage. The constructivist approach also emphasizes collaboration. According to Norma et al., (2022), 21stcentury education requires students to have critical thinking, communication, creativity, and collaboration skills to face global competition. Active learning, experiential learning, and comprehensive assessment play a role in supporting the development of cognitive abilities and higher-order thinking skills (HOTS), such as critical and creative thinking. This is in line with constructivist theory, which emphasizes that knowledge is built through active student involvement in the learning process (Wahab & Rosnawati, 2021).

Exploration activities provide students with opportunities to independently acquire information through group discussions, summarizing, and completing student worksheets (LKPD). The concept of exploration in learning assessment emphasizes the process of discovery, experimentation, and in-depth understanding of the material. Through this approach, students are actively engaged in learning and have the opportunity to explore ideas, concepts, and applications of the material more freely and meaningfully (Hastika et al., 2024). This process helps students understand the material through active involvement in the learning process while also practicing their thinking skills in processing the information they receive. This activity demonstrates the development of thinking skills, from remembering to understanding, in accordance with Bloom's Taxonomy theory. Kusmaryono & Wijayanti (2021) also emphasizes that social interaction and reflective learning experiences can strengthen the internalization of knowledge.

In the preconception restructuring stage, students observe their pulse and use AR media to observe visualizations of the circulatory system more realistically. The use of AR makes it easier for students to understand abstract material that is difficult to observe directly, while the CTS stage helps students refine their initial understanding through discussion, analysis, and observation. Therefore, improved learning outcomes are influenced not only by visual media but also by students' active participation in constructing concepts during the learning process. Sapulette (2023) explains that *Augmented Reality* (AR) media can support conceptual understanding, stimulate critical thinking skills, and contribute to improving student learning outcomes. These activities encourage students to reconstruct more appropriate concepts through analysis and synthesis processes. Mustaqim (2017) states that AR can support concept mastery through interactive visual displays. Karmila & Handayani (2024) also explain that synthetic skills are part of higher-order thinking that combines various information into new understandings.

In the concept application stage, students apply their previously acquired understanding to solve problems in the worksheet. This activity demonstrates that students not only understand the concept theoretically but also apply the concept in situations related to everyday life. Vygotsky's theory emphasizes scaffolding and social learning through assistance and collaboration in solving contextual problems (Suryana et al., 2022). This activity reflects thinking skills at the applying and analyzing levels because students use factual and procedural knowledge in new contexts. Karmila & Handayani (2024) state that concept application is a form of implementing higherorder thinking in real-life situations.

The evaluation stage is carried out through presentation activities and reflection on learning outcomes. These activities help students reassess their understanding while also practicing their ability to convey their thoughts systematically. This is in line with Siagian & Farabi (2024), who stated that evaluation is a continuous process carried out before, during, and after learning to gather information on students' learning progress and as a basis for improving and enhancing the quality of subsequent learning. Fadlilah (2024) stated that the CTS model is effective in improving visual representation skills, while Malanua et al., (2025) emphasized that AR-assisted CTS integration contributed to significantly improving student activity and learning outcomes.

The implementation of AR-assisted CTS creates more active learning activities and helps students understand the concept of the circulatory system more concretely. Through constructivist learning stages and digital visualization support, students are encouraged to be more active during the learning process, thus optimizing concept mastery and higher-order thinking skills. The combination of the two supports active student engagement during the learning process, enhances conceptual understanding, and helps connect theoretical material with more realistic visualizations. This can be seen from the improvement in students' abilities to understand the mechanisms of blood circulation, analyze the function of circulatory organs, and explain the human circulatory process in more depth. In the study Nurjamilah et al., (2025), the principles of constructivist theory emphasize that knowledge is actively constructed by students through learning experiences. Learning is seen as a process of building meaning, not simply memorizing information. In addition, learning needs to be connected to reallife contexts to make concepts easier to understand. Social interaction also plays a crucial role in building knowledge through discussion and collaboration. In constructivist learning, the teacher acts as a facilitator who guides students in discovering knowledge, while evaluation focuses not only on the final results but also on the learning process experienced by students. In addition Rahmah et al., (2025), The use of interactive media such as *Augmented Reality* (AR) can improve students' spatial understanding and critical thinking skills through the presentation of material that is more visual, interactive, and easy to understand.

CONCLUSION

The findings of this study indicate that the implementation of the Augmented Reality (AR)-assisted Constructivist Teaching Sequence (CTS)-based teaching module

contributed positively to improving students' learning outcomes on the human circulatory system. This improvement was evidenced by a normalized gain (N-gain) score of 0.76, which falls into the high category, and a paired sample *t*-test significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between students' pretest and posttest scores after the instructional treatment. These findings demonstrate that integrating constructivist learning stages with interactive AR visualization facilitates conceptual understanding and promotes higher-order thinking skills in biology learning. Furthermore, this study addresses the research gap identified in previous studies by providing empirical evidence that AR-assisted CTS-based teaching modules contribute significantly to improving HOTS-based biology learning outcomes, beyond merely establishing module validity or learning implementation. Therefore, the proposed instructional approach has both theoretical value in supporting constructivist learning and practical implications for biology teachers seeking innovative strategies to enhance students' learning outcomes

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