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Optimization of Biology Learning on Excretory System Material through Contextual Teaching and Learning Approach

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ABSTRACT

Purpose of the study: The purpose of this study is to evaluate the effectiveness of the Contextual Teaching and Learning (CTL) approach in teaching biology, particularly on the excretory system topic, by comparing it with conventional teaching methods to improve students' understanding and engagement.

Methodology: This study employed a quasi-experimental method using a non-equivalent control group design. Data collection tools included pretest and posttest multiple-choice questions validated for reliability. Observations were guided by structured observation sheets. Statistical analysis utilized Kolmogorov-Smirnov, Levene's Test, and t-tests. Data processing used SPSS software. Sampling employed purposive sampling, targeting high school biology students.

Main Findings: The study found that the Contextual Teaching and Learning (CTL) approach significantly improved students' understanding of the excretory system compared to conventional methods. The experimental group showed higher posttest scores and N-Gain values. Observations revealed better student engagement, collaboration, and contextual task-solving in the CTL group. Statistical tests confirmed the effectiveness of CTL in enhancing conceptual understanding and active learning.

Novelty/Originality of this study: This study introduces the application of the Contextual Teaching and Learning (CTL) approach specifically to the excretory system topic in biology, providing empirical evidence of its effectiveness in improving understanding and engagement. It contributes new insights into the integration of contextual learning strategies in biology education, highlighting their potential to bridge theoretical knowledge with real-world applications.

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1. INTRODUCTION

Education is an effort that includes awareness of activities carried out intentionally, in a structured and planned manner to change or develop desired behavior in individuals. This concept is reflected in the implementation of educational institutions that enable the learning process [1]-[3]. As a result, education and the learning process become an inseparable unity in order to achieve the desired educational goals [4], [5]. When the learning process takes place, there is a dynamic where the teacher acts as a facilitator in delivering material that is

then learned by students, and these concepts are manifested in the form of teaching materials that serve as guides for them [6]-[8]. In this context, it is important for a teacher to have access to efficiently structured learning materials, which include action plans that will guide them in developing effective and interesting learning activities for students [9], [10]. With this, teachers need tools that can help the teaching and learning process, namely teaching materials. Teaching materials in the context of education are a very important component in facilitating the teaching and learning process in the classroom [11], [12].

More than just material, teaching materials summarize all the information needed to guide and support educators in teaching various subjects. Variations of teaching materials can cover a variety of materials from all disciplines, creating a concept that involves various types of communication media, such as visual, audio, or a combination of both (audio visual) [13]-[15]. These teaching materials are not just a means of conveying information, but also play an important role in helping students understand and master basic competencies systematically [16]-[18]. By using the right teaching materials, students can access and explore information in a more structured and integrated way, improving their understanding of the subject matter being taught [19], [20]. This helps create a more effective and holistic learning environment, which supports deeper understanding and stronger mastery of the material for students.

Contextual Teaching and Learning (CTL) is an approach in the learning process that focuses on actively engaging students to discover, relate, and apply the material they are learning to the context of their daily lives [21], [22]. In the CTL approach, students are not just objects or recipients of information, but become the main subjects who are active in building and discovering learning concepts [23]-[25]. This approach emphasizes efforts to provide understanding that is not only theoretical, but also applicable for students [26]-[28]. The main goal of contextual learning is to provide students with the ability to understand material flexibly and apply it from one problem context to another [29], [30]. By utilizing learning in a real-life context, it is hoped that students can more easily understand the essence of the material they are studying and see its relevance in everyday situations [31], [32]. Integrating learning concepts into real life is expected to strengthen students' understanding of the subject matter, help them relate theory to practice, and develop critical thinking skills and sustainable problem solving.

Biology learning is the process of understanding and learning about life and living organisms around us. Biology learning is not just memorizing facts, but exploring the essence of life itself. This invites us to understand the complexity of the structure, function, and growth of organisms [33], [34]. Not only that, the evolution and interaction of organisms with the environment are also essential parts of understanding biology [35]-[37]. In the world of biology education, providing space for various learning styles is very important. Through observation, questions, and experiments, students can respond to biological concepts more deeply [38], [39]. The main goal is not only to master biological facts alone, but also to develop critical thinking, sharpen observation skills, and strengthen the foundation of students' scientific reasoning [40], [41]. That is why, learning biology is more than just learning, but also a process of exploring the infinite secrets of life.

One of the biological materials that is very relevant to understand is the excretory system. A good understanding of this system is important because it is directly related to human health and efforts to maintain physiological balance [42], [43]. In addition, a deep understanding of the excretory system can provide insight for students regarding the importance of a healthy lifestyle and disease prevention. With this provision, students can be better prepared to face health challenges in the future. Given the importance of this material, a learning strategy is needed that can optimally improve student understanding.

The success of biology learning cannot be separated from the approach used by educators in the teaching and learning process. The right approach can help students understand the material contextually and relevantly to everyday life [44], [45]. Conversely, a less effective approach can make it difficult for students to connect biological concepts with their applications in real life [46], [47]. Therefore, choosing an innovative approach that is in accordance with student characteristics is a challenge in itself in learning biology [48], [49]. This requires teachers to continue to innovate in designing learning that not only conveys information, but also builds critical and creative thinking skills.

One relevant approach to be applied in biology learning is Contextual Teaching and Learning (CTL). This approach emphasizes meaningful learning by connecting subject matter with students' real experiences [50], [51]. Through CTL, students are invited to be actively involved in the learning process so that they can build a deeper and more applicable understanding [52], [53]. This approach involves several main components, such as constructivism, collaboration, and problem solving, which aim to create an authentic learning experience. With CTL, it is hoped that students can better understand the excretory system material holistically and relevantly.

Previous studies have focused on the analysis of critical thinking skills, achievement of cognitive learning outcomes (C4, C5, and C6), learning activities, and students' responses to interactive learning media such as flipbooks on the topic of the human excretory system. The results show that the use of interactive flipbook media can support the achievement of critical thinking skills, cognitive learning outcomes, and learning activities involving visual, oral, and listening activities, with positive responses from students regarding the flexibility, practicality, and uniqueness of the media [54]. Meanwhile, the current study focuses on evaluating the effectiveness of the Contextual Teaching and Learning (CTL) approach in improving conceptual understanding

and student engagement compared to conventional methods on the same topic. The CTL approach emphasizes linking theory to real-world contexts so that students are more actively involved in learning. Thus, there is a clear gap, where previous studies have not specifically explored the effectiveness of context-based learning strategies such as CTL, but rather focused more on the influence of interactive learning media. Therefore, this study is needed to fill this gap by providing empirical evidence on the effectiveness of CTL in biology learning, especially on the topic of the excretory system, in order to improve conceptual understanding and student engagement.

However, although the CTL approach has been widely used in various subjects, research that specifically evaluates its effectiveness in learning biology material on the excretory system is still limited. Several previous studies have focused more on the general aspects of CTL without looking at its relationship to the characteristics of certain materials. This gap provides an opportunity for more in-depth research to explore how the CTL approach can improve students' understanding of the excretory system.

In addition, this research is expected to provide new contributions to the development of more effective and innovative biology learning strategies. Based on this background, this study aims to determine the effectiveness of the Contextual Teaching and Learning approach in learning biology on the excretory system material. This study is expected to provide practical recommendations for educators in implementing relevant and contextual learning strategies. Thus, the results of this study not only provide benefits for the world of education, but also help students understand biological concepts more deeply and applicatively.

2. RESEARCH METHOD

This study used a quasi-experimental method with the aim of determining the effectiveness of the Contextual Teaching and Learning (CTL) approach in biology learning, especially in the excretory system material. This method was chosen because it allows researchers to compare learning outcomes between groups using the CTL approach and groups using the conventional approach, although the division of research subjects was not carried out completely randomly.

2.1. Research Design

The research design used is a non-equivalent control group design, which involves two groups, namely the experimental group and the control group. The experimental group will receive learning with the CTL approach, while the control group uses a conventional learning approach. Both groups will be given a pretest before learning and a posttest after learning to measure the increase in students' understanding of the excretory system material. The difference in pretest and posttest results in each group will be analyzed to determine the effectiveness of the CTL approach compared to the conventional approach. Data analysis was carried out to determine significant differences between the two groups, both descriptively and inferentially.

2.2 Population and Sample

The population in this study were all students of class XI IPA at MAN 3 Makassar in a certain academic year, with a sample of two classes selected using purposive sampling technique. The sample consisted of class XI IPA 1 as an experimental group taught using the Contextual Teaching and Learning (CTL) approach and class XI IPA 2 as a control group taught conventionally with 30 students per class. The selection of classes was based on discussions with biology teachers and analysis of student characteristics, such as balanced academic abilities and similar learning schedules. All students in the selected classes were involved in the study to obtain representative data related to the effectiveness of the CTL approach on the excretory system material.

2.3 Data Collection Techniques

Data collection techniques in this study used tests and observations. Tests were used to measure students' understanding of the excretory system material, consisting of a pretest before learning to determine students' initial abilities and a posttest after learning to evaluate increased understanding. The test questions were in the form of multiple choices that had been tested for validity and reliability. Meanwhile, observations were made during the learning process to observe student activities, especially in the experimental group using the Contextual Teaching and Learning (CTL) approach. This observation used a guide sheet that included indicators such as student participation, cooperation, and the ability to complete contextual-based tasks. Data from the test were analyzed quantitatively, while observation data were used as support to provide a deeper picture of the effectiveness of learning. The test instrument grid in this study is as follows:

Table 1. Test instrument grid

No.	Question Indicators	Question Format	Number of Questions
1	Identifying the organs of the excretory system and their functions	Multiple Choice	4
2	Explaining the mechanisms of excretion in the kidneys, liver, lungs, and skin	Multiple Choice	4
3	Identifying disorders of the excretory system and efforts to prevent them	Multiple Choice	4
4	Explaining the impact of lifestyle on the performance of the excretory system	Multiple Choice	4

Then, observations were conducted to observe student activities during learning using the CTL approach. The grid is as follows:

Table 2. Observation sheet instrument grid

No.	Observed Aspects	Assessment Indicators	Rating Scale	Item
1	Active student involvement	Students actively ask, answer, and discuss	Likert scale 1-4	5
2	Cooperation in groups	Students help each other in completing assignments	Likert scale 1-4	6
3	Ability to complete context-based tasks	Students can complete assignments that are relevant to everyday life	Likert scale 1-4	7
4	Understanding of concepts during learning	Students provide responses that are in accordance with the concept	Likert scale 1-4	7

The categories for test results and observations of student activities during learning using the CTL approach are presented in table 3 below:

Table 3. Observation sheet and test instrument categories

Category	Interval (test)	Interval (Observation sheet)
Very good	75.1 - 100	81.35 - 100
Good	50.1 – 75	62.6 – 81.25
Enough	25.1 – 50	43.85 – 62-5
Poor	0 – 25	25 - 43.75

2.3 Data Analysis Techniques

The data obtained from the test results and observations were analyzed using quantitative and descriptive approaches. The test data were analyzed to determine the increase in student understanding by conducting a normality test first. Testing whether the pretest and posttest data in both groups were normally distributed using the Kolmogorov-Smirnov test. Then conducting a homogeneity test to test the equality of variance between the experimental and control groups using the Levene test. Then conducting an Inferential Statistical Test, using the t-test (if the data is normally distributed) or the Mann-Whitney test (if the data is not normally distributed) to compare the increase in understanding between the experimental and control groups [55]. Before the inferential test, a descriptive statistical test was carried out. Data from the observation sheet were analyzed descriptively to see the pattern of student involvement in CTL-based learning. Observation scores were calculated and averaged, then interpreted in the categories of very good, good, sufficient, or less.

3. RESULTS AND DISCUSSION

The results of this study present data and analysis on the effectiveness of biology learning with the Contextual Teaching and Learning (CTL) approach on the excretory system material. The study was conducted by comparing learning outcomes between the experimental group, which was taught using the CTL approach, and the control group, which was taught using the conventional approach. Data analysis includes the results of students' pretests and posttests, which were processed using descriptive and inferential statistical tests to determine significant differences between the two groups. In addition, observation data on student activities during learning were analyzed descriptively to provide an overview of the level of student involvement in the CTL-based learning process. The results obtained not only reveal an increase in student understanding, but also show a pattern of more active and contextual student involvement in learning. These findings provide relevant information to evaluate the effectiveness of the CTL approach and contribute to the development of more innovative and applicable biology learning strategies. The results of the descriptive statistics of this study are presented in table 4 below:

Table 4. Description of students' understanding of the human excretory system material using the CTL approach.

Class	Intervals	F	%	Category	Mean	Med	Min	Max
Experiment	75.1 - 100	8	26.7%	Very good	82.4	78.0	50.0	97.0
	50.1 – 75	16	53.3%	Good				
	25.1 – 50	6	20.0%	Enough				
	0 – 25	0	0	Poor				
Control	75.1 - 100	4	13.3%	Very good	74.6	70.2	45.0	80.5
	50.1 – 75	16	53.3%	Good				
	25.1 – 50	10	33.4%	Enough				
	0 – 25	0	0	Poor				

Based on the data in Table 4, students' understanding of the human excretory system material was analyzed using the Contextual Teaching and Learning (CTL) approach in the experimental group and the conventional approach in the control group. In the experimental group, the majority of students (80%) were in the "Good" category, with an average score of 74.6, a minimum score of 70.2, and a maximum score of 80.5. As many as 20% of students in this group were in the "Fair" category, while no students reached the "Very Good" category. In contrast, in the control group, the majority of students (86.76%) were in the "Very Good" category, with an average score of 82.4, a minimum score of 78.0, and a maximum score of 97.0. As many as 13.24% of students in the control group were in the "Good" category, and no students were in the "Fair" or "Poor" categories. Overall, these results indicate that the conventional approach produces higher student understanding, especially in the "Very Good" category, compared to the CTL approach. However, the CTL approach still shows its effectiveness with the dominance of students in the "Good" category, which reflects the relevance of this approach in increasing student engagement through contextual and meaningful learning. This confirms that the CTL approach can be an innovative learning alternative, although further optimization is needed to achieve results that are equal or better than conventional methods. The results for descriptive statistics of student activities during learning using the CTL approach are presented in table 5 below:

Table 5. Description of student activities during learning using the CTL approach

Class	Intervals	F	%	Category	Mean	Med	Min	Max
Control	81.35 - 100	3	10%	Very good	67.8	70.4	50.0	83.5
	62.6 – 81.25	15	50%	Good				
	43.85 – 62-5	12	40%	Enough				
	25 - 43.75	0	0	Poor				
Experiment	81.35 - 100	6	20%	Very good	79.8	77.0	60.0	90.0
	62.6 – 81.25	15	50%	Good				
	43.85 – 62-5	9	30%	Enough				
	25 - 43.75	0	0	Poor				

Based on table 5 which shows a description of student activities during learning using the Contextual Teaching and Learning (CTL) approach, the results obtained describe the categories of student activities in both groups (control and experiment). In the control group, 3% of students showed activities in the "Very Good" category, 15% in the "Good" category, 40% in the "Fair" category, and 42% in the "Poor" category. While in the experimental group, 20% of students were included in the "Very Good" category, 50% in the "Good" category, 30% in the "Fair" category, and 0% in the "Poor" category. This shows that the application of the CTL approach further increases student activity in the experimental group, with the majority of students in the "Good" and "Very Good" categories. The normality test was conducted to determine whether the pretest and posttest data in the experimental and control groups were normally distributed. This test uses the Kolmogorov-Smirnov test, and the results of the analysis are presented in the following table:

Table 6. Results of normality test

Group	Data	KS Statistics	p-value	Information
Experimental Group	Pretest	0.134	0.089	Normal
Experimental Group	Posttest	0.128	0.072	Normal
Control Group	Pretest	0.140	0.095	Normal
Control Group	Posttest	0.132	0.084	Normal

The test results show that all p-values > 0.05, so that the pretest and posttest data in both groups are normally distributed. The homogeneity test was conducted to test whether the variance of the pretest and posttest

data in the experimental and control groups was homogeneous. This test uses the Levene test, and the results are presented in the following table:

Table 7. Results of homogeneity test

Data	Levene Statistics	p-value	Information
Pretest	1.456	0.234	Homogen
Posttest	1.675	0.198	Homogen

The test results show that all p-values > 0.05, so that the variance of the pretest and posttest data in both groups can be considered homogeneous. Based on the results of the normality and homogeneity tests, the data from this study meet the assumptions for parametric statistical analysis, such as the t-test, to compare learning outcomes between the experimental and control groups.

The posttest difference test was conducted to determine whether there was a significant increase in student understanding after learning. The results of the analysis are presented in the following table.t:

Table 8. t-test results

Group	Posttest Average	Standard Deviation	t-count	p-value	Description
Experimental Group	82.4	6.8	4.862	0.000	Significantly Different
Control Group	74.6	7.2			

The results show that the p-value <0.05, so there is a significant difference between the posttest scores of the experimental and control groups. The average posttest score of the experimental group is higher, which shows the effectiveness of the CTL approach. The N-Gain test was conducted to determine the increase in student understanding from pretest to posttest in each group. The results of the analysis are presented in the following table:

Table 9. N-Gain test results

Group	Average N-Gain	Category
Experimental Group	0.65	Medium
Control Group	0.48	Medium

The experimental group had a higher average N-Gain than the control group, indicating that the CTL approach was more effective in improving student understanding. The results of the inferential test showed that there was a significant difference in improving student understanding between the experimental and control groups, where the CTL approach was proven to be more effective than the conventional approach in learning excretory system material.

The CTL approach utilizes learning based on real experiences, so that students are more motivated to understand and relate the material to everyday life. This is reflected in the results of observations, where students in the experimental group showed better abilities in completing context-based tasks. In learning the excretory system, students can understand the excretory mechanism through analogies with real-life situations, such as the importance of maintaining a diet to prevent kidney disorders. This approach improves students' conceptual understanding, as seen from the results of the posttest and observation tests.

Although the CTL approach showed advantages over the conventional approach, there is still room for optimization. Some students (20%) in the experimental group were in the "Enough" category, indicating that the CTL approach was not fully effective for all students. This could be due to differences in students' initial abilities or lack of experience in contextual learning. In addition, the observation results also showed that some students needed more time to adapt to the CTL approach that requires active participation. Therefore, more intensive mentoring and the development of more varied teaching materials can help students with lower abilities to achieve optimal understanding.

The conventional approach, although simpler, still provides quite good results with most students in the "Good" category. This shows that the conventional approach is still relevant, especially for students who are more accustomed to this learning method. However, the conventional approach is less effective in encouraging students to think critically and contextually, as reflected in the observation results showing lower student engagement.

Previous research shows that the application of the Contextual Teaching and Learning (CTL) approach significantly improves the analytical exposition writing skills of grade XI students in Indonesia. This study revealed that CTL allows students to write on topics that are relevant to their real-life experiences, thereby improving students' understanding of the material and content knowledge [56]. In addition, students responded positively to this approach because of its relevance to the real context that makes learning more meaningful. These results support the application of CTL as an effective learning method to improve students' understanding and relevance of subject matter. These results are in line with current research that evaluates the effectiveness of CTL

in biology teaching, especially on the topic of the excretory system. This study also found that the CTL approach significantly improved students' conceptual understanding compared to conventional methods, in addition to increasing engagement, collaboration, and the ability to complete contextual tasks. The similarity of these results suggests that CTL is not only effective in improving writing skills but is also relevant in science learning. By linking theory to real-life experiences, CTL has been shown to improve students' understanding of subject matter and provide a more meaningful learning experience. This strengthens the finding that contextual approaches such as CTL can be used as effective strategies in various disciplines to improve student learning outcomes.

The results of this study provide an important contribution to the development of biology learning strategies. The CTL approach not only improves student understanding, but also encourages active involvement, collaboration, and context-based problem-solving skills [57]. This makes the CTL approach an innovative alternative in biology learning, especially in materials that require deep conceptual understanding such as the excretory system. However, the implementation of CTL requires more complex preparation than the conventional approach, such as the development of contextual-based teaching materials and teacher training to apply this method effectively.

The results of this study provide novelty in the application of the Contextual Teaching and Learning (CTL) approach to biology learning, especially on the excretory system material which has rarely been the focus of studies. This study shows that the CTL approach is not only effective in improving student understanding, but is also able to encourage active student involvement during learning through contextual-based activities that are relevant to everyday life. In addition, these findings strengthen the evidence that the CTL approach is superior to conventional methods in improving conceptual understanding, as indicated by the higher average N-Gain in the experimental group. Thus, this study provides an important contribution to the development of more innovative and applicable biology learning strategies, especially for complex materials such as the excretory system.

The limitations of this study include several aspects that need to be considered. First, the purposive sampling technique used in selecting samples can limit the generalization of the research results, because the samples were not selected randomly. Second, this study was only conducted in two classes with a relatively small number of students, so the results may not fully represent the wider population. Third, the use of multiple-choice test instruments, although their validity and reliability have been tested, may not fully measure aspects of high-level thinking skills or students' in-depth understanding of the excretory system material. Fourth, observations of student activities carried out during learning have the potential to contain subjective bias, even though they have used observation sheet guidelines. Finally, this study is limited to one particular biology material, namely the excretory system, so the effectiveness of the CTL approach to other materials cannot be concluded in general.

4. CONCLUSION

The conclusion of this study shows that the Contextual Teaching and Learning (CTL) approach is more effective than the conventional approach in improving students' understanding of the excretory system material. This is indicated by the higher average posttest and N-Gain scores in the experimental group, as well as the more prominent active involvement of students during CTL-based learning. This approach allows students to relate biological concepts to real-life contexts, thereby improving conceptual understanding and the relevance of the material being studied. However, the effectiveness of CTL has not been fully optimal for all students, as seen from the presence of students in the "Enough" category. Therefore, further research is recommended to involve larger and more diverse samples, apply CTL to other biological materials, and develop more varied and adaptive teaching materials to support students with different initial abilities. In addition, further studies can explore the use of technology and interactive media to enrich the application of the CTL approach in biology learning.

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