

Effect of the STAD Model Assisted by Wordwall on Junior High School Students' Biotechnology Learning Outcomes

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Abstract: The low learning outcomes of students in biotechnology indicate the need for innovative, collaborative, and technology-integrated learning strategies that are aligned with the characteristics of learners in the digital era. This study aimed to analyze the effect of the Student Teams Achievement Division (STAD) cooperative learning model, assisted by Wordwall media, on students' learning outcomes in biotechnology at SMP Negeri 23 Medan. This study employed a quasi-experimental design with a nonequivalent control group. The sample consisted of 62 students, including 31 students in the experimental class and 31 students in the control class, selected through purposive sampling. The research instrument was a 20-item multiple-choice cognitive achievement test that had been validated and shown to be reliable. Data were analyzed using descriptive and inferential statistics, including the Shapiro-Wilk normality test, Levene's homogeneity test, and the Independent Samples t-test at a 5% significance level. The results showed that the experimental class's mean posttest score (75.48) was higher than the control class's (59.84). Hypothesis testing revealed a Sig. (2-tailed) value < 0.001 , indicating that the STAD learning model, assisted by Wordwall, had a significant effect on students' learning outcomes. These findings demonstrate that integrating cooperative learning with interactive digital media can increase student engagement, strengthen conceptual understanding, and serve as an innovative instructional strategy for teaching conceptual and abstract science topics.

Keywords: Biotechnology; Cooperative Learning; STAD; Student Learning Outcomes; Wordwall.

Introduction

Education plays a fundamental role in developing high-quality human resources and is widely recognized as one of the main determinants of national progress [1]. In the 21st century, science education is expected not only to deliver factual knowledge but also to cultivate critical thinking, creativity, collaboration, and problem-solving skills that are essential for students to respond to scientific and technological developments [2]. Science learning is inherently inquiry-based, emphasizing observation, experimentation, and data analysis to help students construct knowledge systematically and logically [3]. The successful implementation of science learning therefore depends on teachers' ability to design instructional experiences that are interactive, innovative, and relevant to students' needs in the digital era [4].

Despite these expectations, science learning outcomes in Indonesia remain relatively low. According to the Programme for International Student Assessment (PISA) 2022 results, Indonesian students ranked 67th among 81 participating countries in science, indicating that students' scientific literacy and reasoning skills still require substantial improvement [5]. This finding reflects a broader challenge in science education, where students often memorize concepts without fully understanding their meaning or application in real-life contexts [6]. As a result, many students struggle to

connect scientific concepts to authentic problems, which ultimately affects their academic achievement [7].

This issue was also identified at SMP Negeri 23 Medan, where this study was conducted. Interviews with the Grade IX science teacher revealed that classroom instruction was still dominated by conventional discussion and question-and-answer methods, resulting in low student participation and reduced concentration during lessons. Formative assessment data showed that 42 of 62 students (67.7%) scored below the Minimum Learning Mastery Criteria (KKTP), with the lowest score reaching 30. The problem is particularly prominent in biotechnology, a topic characterized by abstract concepts and specialized terminology such as fermentation, genetic engineering, and tissue culture. These concepts require students to visualize processes that cannot be directly observed, making conceptual understanding more difficult when instruction relies solely on verbal explanations [8]. Student questionnaire responses further indicated that science lessons were perceived as monotonous and lacked sufficient variation, especially when addressing conceptually complex material.

To overcome these challenges, teachers need instructional strategies that actively engage students, promote collaboration, and provide meaningful conceptual reinforcement. One promising approach is the Student Teams Achievement Division (STAD) cooperative learning model. STAD organizes students into heterogeneous groups

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and emphasizes positive interdependence, individual accountability, and group rewards [9]. Previous studies have shown that STAD improves students' science learning outcomes [10]. STAD has also been reported to increase student participation, motivation, and conceptual understanding through peer tutoring and collaborative discussion [11].

The effectiveness of STAD can be further enhanced by integrating interactive digital media. Wordwall is a game-based learning platform that enables teachers to design engaging activities such as quizzes, matching games, and categorization tasks [12]. Research has shown that Wordwall can significantly improve students' motivation and learning outcomes in biology [13]. Other studies have reported that Wordwall strengthens conceptual understanding and increases students' achievement in science learning by providing immediate feedback and interactive reinforcement [14].

Recent studies have demonstrated that combining cooperative learning with digital game-based media can create a more meaningful and student-centered learning experience. A previous study reported that the use of STAD assisted by Wordwall resulted in higher posttest scores than conventional instruction [15]. Another study emphasized that the integration of digital technology in collaborative learning enhances students' cognitive engagement and supports deeper conceptual understanding [16].

Although numerous studies have investigated STAD and Wordwall separately, and several have integrated both approaches into general science topics, research on their combined implementation in junior high school biotechnology learning remains very limited. This constitutes an important research gap because biotechnology contains abstract concepts that require both collaborative explanation and interactive visualization to facilitate meaningful understanding.

Therefore, the novelty of this study lies in examining the effect of the STAD cooperative learning model assisted by Wordwall media, specifically on students' biotechnology learning outcomes in junior high school. This study aims to analyze the effect of the STAD cooperative learning model assisted by Wordwall media on students' learning outcomes in biotechnology at SMP Negeri 23 Medan. The findings are expected to contribute theoretically to the development of innovative science instruction and provide practical guidance for teachers in selecting effective strategies to improve students' conceptual understanding and academic achievement.

Research Methods

This study employed a quasi-experimental design with a nonequivalent control group, as the research subjects were situated in naturally formed classrooms, rendering random assignment of students unfeasible. The independent variable was the cooperative learning model of the Student Teams Achievement Division (STAD) type assisted by Wordwall media, while the dependent variable was students' learning outcomes in biotechnology, measured through a cognitive multiple-choice test.

The population comprised all ninth-grade students at SMP Negeri 23 Medan in the 2025/2026 academic year, totalling 11 classes. The sample was selected using

purposive sampling based on equivalence of initial academic ability, equal class size (31 students per class), and recommendations from the science teacher, resulting in class IX-I as the experimental group (n = 31) and class IX-J as the control group (n = 31).

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O ₁	X (STAD + Wordwall)	O ₂
Control	O ₃	Y (Project-Based Learning)	O ₄

Notes:

O₁ = Pretest of the experimental group

O₂ = Posttest of the experimental group

O₃ = Pretest of the control group

O₄ = Posttest of the control group

X = STAD learning model assisted by Wordwall

Y = Project-Based Learning (PjBL) model

In the experimental class, the STAD model, assisted by Wordwall, was implemented across three meetings totalling 8 lesson hours, following a systematic syntax. The steps were: (1) conveying learning objectives and motivating students through videos and real examples of biotechnology products; (2) teacher presentation of material on the definition, types, and impacts of biotechnology using PowerPoint slides and images; (3) organizing students into heterogeneous groups of 4–5 members with diverse academic abilities; (4) guiding groups in discussions to complete Student Worksheets (LKPD) containing analytical questions, while the teacher circulated to provide guidance and observe each member's participation; (5) evaluating learning through interactive quizzes using the Wordwall platform, both in groups and individually, with activities such as multiple-choice quizzes, match-up, and group sort, which students accessed via their mobile phones; (6) providing rewards to groups with the highest quiz scores and the best collaboration. Wordwall was integrated at the end of each meeting as a tool to reinforce concepts and conduct formative assessment, making the review process more engaging and less monotonous.

Meanwhile, the control class was treated with the Project-Based Learning (PjBL) model without the integration of Wordwall media. The choice of PjBL as the control treatment was based on interviews with the science teacher, who stated that PjBL is the most frequently used regular learning model in the school for science instruction, particularly for contextual topics such as biotechnology. Thus, the application of PjBL in the control class reflected everyday teaching practices (business as usual), making it a valid control group for comparing the effectiveness of the STAD model assisted by Wordwall, while also avoiding potential bias because both models are student-centered. The fundamental difference between the two treatments is as follows: in the experimental class, the learning process emphasized structured group cooperation with individual responsibility and group rewards, along with repeated concept reinforcement through interactive Wordwall media; where as in the control class, learning focused on completing simple biotechnology product projects (such as tape cassava, yogurt, or pickled vegetables) without the integration of

interactive digital media, so students spent more time on practical activities and project report writing.

The research instrument consisted of a cognitive learning outcomes test in the form of multiple-choice questions, developed based on the learning achievement indicators of biotechnology material in accordance with the teaching modules and curriculum implemented at the school. The test blueprint was constructed based on the revised Bloom's taxonomy by Anderson and Krathwohl, covering cognitive levels C1-C6 [17]. The instrument was validated by experts to assess content validity, construct validity, and language clarity. Subsequently, the instrument was piloted on a group of 31 students to determine its validity, reliability, discrimination index, and difficulty level. The summary of the instrument try-out results is presented in Table 2.

Table 2. Summary of Instrument Try-Out Results

Parameter	Value	Criteria
Item Validity	22 valid items out of 50	Valid
Reliability	0.89	Very High
Difficulty Level	5 difficult, 12 moderate, 3 easy	Good
Discrimination Index	4 very good, 10 good, 6 fair	Good

Table 2 shows that of the 50 items tested, 22 were deemed valid and used as the research instrument. The instrument's reliability was calculated using the KR-20 formula, yielding a coefficient of 0.89, which falls in the "very high" range. The item difficulty levels varied: 5 difficult, 12 moderate, and 3 easy. Meanwhile, the discrimination index indicated that 4 items were categorized as very good, 10 items as good, and 6 items as fair. Data collection was conducted by administering a pretest before instruction and a posttest after instruction. Both tests used the same set of questions; however, the order of items was rearranged to minimize the possibility of students recalling the sequence. The collected data were analyzed using descriptive statistics to determine the mean, highest score, lowest score, and standard deviation. Prior to hypothesis testing, prerequisite tests were conducted: a normality test using the Shapiro–Wilk test because the sample size was ≤ 80 [18], and a homogeneity test using Levene's Test [19]. Hypothesis testing was then performed using the Independent Samples t-test at a significance level of $\alpha = 0.05$ with the assistance of SPSS version 27 [20].

Results and Discussion

Students' learning outcomes in this study were assessed through pretests and posttests administered in both the experimental and control classes. The experimental class was treated using the cooperative learning model of the Student Teams Achievement Division (STAD) assisted by Wordwall media, while the control class was taught using the Project-Based Learning (PjBL) model without the use of Wordwall.

The pretest was administered before the learning process to determine students' initial abilities in both classes. After the learning process was completed, a posttest was administered to measure students' learning outcomes. The

comparison of students' learning outcomes in the experimental and control classes is presented in Table 3.

Table 3. Students' Learning Outcomes in the Experimental and Control Classes

Class	Mean Pretest	Mean Posttest	N
Experimental	42.90	75.48	31
Control	40.48	59.84	31

Based on Table 3, the mean pretest score in the experimental class was 42.90, while in the control class it was 40.48. These results indicate that students' initial abilities in both classes were relatively similar. After the learning process, the mean posttest score in the experimental class increased to 75.48, while in the control class it increased to 59.84. This shows that both classes improved in learning outcomes; however, the increase in the experimental class was greater than that in the control class. This comparison is illustrated in Figure 1.

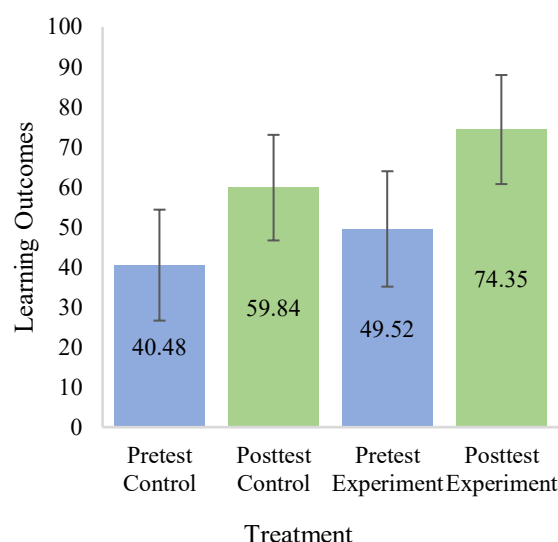


Figure 1. Comparison of Pretest and Posttest Scores of the Experimental and Control Classes

Based on the figure, both classes showed an increase in mean scores after the learning process. The experimental class improved from 42.90 (pretest) to 75.48 (posttest), while the control class improved from 40.48 (pretest) to 59.84 (posttest). The letter notations on the graph (AA and AB) indicate that the posttest score of the experimental class differed significantly from the pretest scores of both classes and the posttest score of the control class. This suggests that the STAD model, when supported by Wordwall, had a greater effect on students' learning outcomes.

Normality Test

Before conducting hypothesis testing, prerequisite analysis was performed, including a normality test. The purpose of the normality test was to determine whether the data were normally distributed. In this study, the Shapiro–Wilk test was used. Based on Table 4, all significance values are greater than 0.05. Therefore, the data are normally distributed. Thus, the data meet the requirements for further statistical analysis.

Table 4. Results of the Normality Test

Class	Data	Sig.	Conclusion
Experimental	Pretest	0.86	Normal
Experimental	Posttest	0.17	Normal
Control	Pretest	0.46	Normal
Control	Posttest	0.83	Normal

Homogeneity Test

In addition to the normality test, a homogeneity test was conducted to determine whether the variances of the two sample groups were equal. Based on Table 5, the significance values are greater than 0.05, indicating that the variances of the two groups are homogeneous. This means that both classes have equal variances, allowing the analysis to proceed to hypothesis testing.

Table 5. Results of the Homogeneity Test

Data Type	Sig.	α	Conclusion
Pretest (Experimental & Control)	0.67	0.05	Homogeneous
Posttest (Experimental & Control)	0.41	0.05	Homogeneous

Hypothesis Testing

After completing the prerequisite tests, the Independent Samples t-test was used to determine whether there was a significant difference in learning outcomes between the experimental and control classes. First, hypothesis testing was conducted on the pretest data to determine whether there was a difference in initial abilities between the two classes. The results are presented in Table 6.

Table 6. Results of Hypothesis Testing for Pretest Data

Class	N	Mean	Std. Deviation	Sig. (2-tailed)	Conclusion
Control	31	40.48	13.866	0.503	H ₀ accepted
Experimental	31	42.90	14.421		

The significance value (2-tailed) was $0.503 > 0.05$, so H₀ was accepted. This indicates that there was no significant difference in initial abilities between the experimental and control classes. Next, hypothesis testing was conducted on the posttest data to assess the treatment effect. The results are presented in Table 7.

Table 7. Results of Hypothesis Testing for Posttest Data

Class	N	Mean	Std. Deviation	Sig. (2-tailed)
Control	31	59,84	15.20	<0.001
Experimental	31	75.48	13.45	

Based on the results presented in Table 7, the significance value (Sig. 2-tailed) is less than 0.05. This indicates that H₀ is rejected and H_a is accepted. Therefore, it can be concluded that the STAD cooperative learning model, assisted by Wordwall media, has a significant effect on students' learning outcomes in biotechnology.

Biotechnology Learning Outcome

Discussion The results of this study indicate that the application of the Student Teams Achievement Division (STAD) cooperative learning model assisted by Wordwall media has a significant effect on students' learning outcomes in biotechnology, with the mean posttest score of the experimental class (75.48) being significantly higher than that of the control class taught using the Project Based Learning (PjBL) model without Wordwall (59.84).

The difference in effectiveness between the two models requires in-depth analysis. First, the STAD model is grounded in social interdependence theory [21], which states that positive interdependence among group members encourages them to help one another, share knowledge, and work collaboratively toward common goals. In the experimental class, students were divided into heterogeneous groups (4–5 members) with diverse academic abilities.

Each member was responsible not only for understanding the material themselves but also for assisting group members who experienced difficulties, thereby creating a peer-tutoring process that strengthened conceptual understanding [22]. In contrast, in the control class using the PjBL model, the main focus was on completing projects (for example, making tape, yoghurt, or pickled vegetables). Students spent considerable time on procedural activities such as preparing tools and materials, conducting fermentations, making observations, and writing reports, so that the deepening of theoretical biotechnology concepts, such as enzyme mechanisms, the role of microorganisms, and the principles of genetic engineering, became less effective. This was evident in the low ability of control-class students to answer questions requiring analysis (C4) and evaluation (C5).

Second, the reward system in STAD provides structured motivation. Individual development scores were calculated as improvements from baseline and then aggregated into group scores. The group with the highest score received an award. This system aligns with self-determination theory, which states that students' intrinsic motivation increases when they feel competent, valued, and have positive social relationships [23]. In the experimental class, group rewards created a healthy competitive atmosphere and encouraged each student to study seriously. In the control class, there was no structured reward system, so student motivation relied more on individual factors. Third, the integration of Wordwall media provides unique features not present in PjBL Wordwall is a game-based learning platform that allows teachers to create various interactive activities.

Figure 2 shows an example of a Wordwall activity used in this study, namely a multiple-choice quiz. The uniqueness of Wordwall lies in three aspects: (a) immediate feedback (students immediately know correct or incorrect answers along with their scores); (b) enjoyable repetition (students can repeat quizzes without boredom because they are packaged in a game format); and (c) activity variety (available features include quizzes, match up, group sort, open the box, etc., which can be adapted to learning indicators). The findings indicate that Wordwall can increase motivation to learn and active student participation [24]. With Wordwall, experimental class students not only

listened to the teacher's explanation but also actively answered questions, solved problems, and participated in healthy competition. The process of concept reinforcement through individually administered interactive quizzes conducted after group discussions allowed students to identify their misconceptions and immediately correct them based on the feedback they received.



Figure 2. Wordwall quiz display on the biotechnology material

Fourth, biotechnology materials have abstract characteristics and are rich in technical terms (fermentation, genetic engineering, tissue culture, cloning, recombinant DNA). Based on student questionnaire results at the research site, most students experienced difficulties in visualizing these processes. Learning with STAD and Wordwall addressed this problem through two mechanisms. First, group discussions allowed students to explain concepts to one another in their own language, fostering the social construction of knowledge. Second, Wordwall quizzes reinforced concepts through repetition in varied formats. This aligns with cognitive load theory [25], which holds that presenting information through different but integrated activities helps reduce extraneous cognitive load and facilitates the formation of more robust cognitive schemas.

A comparison with previous studies shows consistency in the findings. Increase in mastery of learning from 20% to 88.57% after implementing STAD [12]. STAD assisted by Wordwall, effectively improved student learning outcomes in a heat material [15]. The positive effect of Wordwall on motivation and learning outcomes in biology [14]. This study offers novelty by applying STAD and Wordwall specifically to biotechnology material at the junior high school level and explicitly comparing their effectiveness with the PjBL model. The STAD cooperative learning strategy can balance conceptual understanding, collaboration, and active student engagement [26].

The limitations of this study need to be acknowledged. First, the sample was limited to two classes (62 students) in one school, so generalization of the findings should be done cautiously. Second, the treatment duration was relatively short (3 meetings, 8 lesson hours). Research with a longer duration is needed to measure long-term retention. Third, this study measured only the cognitive domain (C1–C6), while the affective and psychomotor domains were not. Fourth, the purposive sampling technique may introduce selection bias. Future research with random assignment and larger samples is highly recommended.

Based on the findings of this study, several recommendations are presented. First, for teachers and education practitioners, the STAD cooperative learning model, supported by Wordwall, is recommended for broader

application in science subjects, particularly in abstract and conceptual topics such as biotechnology. Teachers should systematically plan the formation of heterogeneous groups, allocate sufficient time for each stage of the STAD syntax, and ensure that devices and internet access are available for Wordwall. Second, for schools, the results of this study can serve as a policy basis for integrating digital technology into learning, for example, by providing projector facilities, Wi-Fi access, and teacher training in developing interactive learning media. Third, for future researchers, it is recommended to conduct studies with stricter experimental designs, larger sample sizes, longer treatment durations, and to measure affective and psychomotor domains. Further research can also apply the STAD model assisted by Wordwall to other science topics or at different educational levels to test the generalizability of the findings. Fourth, this study still has limitations in its purposive sampling, so future research is advised to use random sampling to obtain more representative results. Thus, the contribution of this study is not only to demonstrate the model's effectiveness but also to provide guidance for the development of learning practices and future research.

Overall, the combination of the STAD model and Wordwall media has proven capable of creating a more active, interactive, and enjoyable learning process, and can therefore be recommended as an innovative strategy in science learning, particularly for conceptual topics such as biotechnology.

Conclusion

Based on the results of this study, it can be concluded that the Student Teams Achievement Division (STAD) cooperative learning model, supported by Wordwall, had a significant effect on students' learning outcomes in biotechnology at SMP Negeri 23 Medan. This was indicated by the higher posttest mean score of the experimental class compared to the control class, as well as the Independent Samples t-test result showing a Sig. (2-tailed) value of < 0.001 . These findings indicate that integrating cooperative learning with interactive digital media can enhance student engagement and strengthen conceptual understanding. The STAD learning model, supported by Wordwall, can be used as an innovative instructional strategy for abstract, conceptual science topics. However, this study was limited to two classes at one school and measured only cognitive learning outcomes. Therefore, future studies are recommended to apply this model to other topics and educational levels and to examine additional variables such as learning motivation and critical thinking skills.

Author's Contribution

F.A. Ujung : contributed to the research design, data collection, data analysis, and manuscript writing. Idramsa: provided supervision, guidance, and manuscript revision. All authors have read and approved the final version of this article.

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