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Analysis of Critical Thinking and Communication Skills of High School Students with the Application of Blended Discovery Learning

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Abstract. Critical thinking skills (CTS) and communication skills (CS) in students still need to be improved. This study aims to analyze CTS and CS through the experimental implementation of blended discovery learning (BDL). The research method used is a quasi-experimental design with a pretest-posttest control group design. The study subjects consisted of high school students who were divided into experimental and control groups. The experimental group received learning with the BDL model, while the control group used conventional methods. The research instruments were observation sheets for critical thinking and communication skills, as well as CTS tests. The data analysis results showed a significant increase in CTS and communication skills after the implementation of BDL compared to the control group. This increase can be seen from the results of statistical tests that showed a significant difference in pretest and posttest scores in the experimental group. Thus, the implementation of BDL has proven effective in improving CTS and CS, so that it can be an alternative for innovative and interactive learning.
Keywords: Blended discovery learning, critical thinking skill, communication skill.

Introduction

Critical thinking skills (CTS) and communication skills (CS) are two essential competencies that students must have in facing challenges in the industrial revolution 4.0 and Society 5.0 eras. Current education is aimed at transferring knowledge and developing high-level thinking skills that enable students to analyze, evaluate, and solve problems independently (Facione, 2011). In addition, effective communication skills are important in collaboration (Maryuningsih et al., 2024) and in conveying ideas clearly, especially in science learning that requires evidence-based argumentation (Roviati & Widodo, 2019). However, research shows that many students still have difficulty developing critical thinking and communication skills in biology learning, including the concept of the immune system (Etobro & Fabinu, 2017). The immune system concept is one of the most complex materials in biology and requires a deep understanding of the human body's defense mechanisms against pathogens (Goh et al., 2023). Difficulty in understanding this concept is often caused by its abstract and multi-level nature, requiring students to have good analytical skills (Goh et al., 2023). In addition, scientific communication is also a challenge because students must be able to explain immunological mechanisms coherently and logically in scientific discussions and arguments. Therefore, a learning approach is needed

that can help students build a deeper concept of the immune system and improve their CTS and CS (Maryuningsih et al., 2024).

One innovative approach that can be used is BDL, which combines the discovery learning model with digital-based learning methods. Discovery learning encourages students to discover concepts independently through exploration and problem-solving, which is effective in improving CTS (Aji et al., 2024; Nusantari et al, 2018; Indah, 2020; Chusni et al, 2021; Ristanto et al., 2022). Meanwhile, digital-based learning in BDL provides flexibility for students to access various learning resources, discuss in online forums, and conduct virtual experiments that support a deeper understanding of the concept of the immune system (Aji et al., 2024; Druckman & Ebner, 2018; Harper et al., 2024; Sukirman et al., 2022). With this combination, it is hoped that students can develop CTS through interpretation, analysis, inference, evaluation, and explanation, as well as improve their CS in scientific discussions. Although previous studies have discussed the benefits of discovery learning and digital-based learning separately, studies that specifically analyze the effectiveness of BDL on CTS and CS in biology learning are still limited. Several studies have shown that blended learning can improve students' learning outcomes and CS (Hur et al., 2020; Newell & Bain, 2020; Terblanché, 2015), but not many have explored how this approach can develop critical thinking in the context of immune system learning. Therefore, this study presents novelty by specifically analyzing the impact of BDL on students' CTS and CS in the concept of the immune system.

In addition, this study also contributes to filling the research gap related to the effectiveness of the combination of discovery learning and digital learning in improving CTS and CS. By empirically analyzing how the implementation of BDL affects these two skills, this study is expected to provide new insights for educators in designing more effective learning strategies. Thus, the results of this study not only have implications for the development of science education theory but also for more innovative learning practices that are demanded by the demands of 21st-century education. Overall, this study is relevant and important because it offers a learning approach that can overcome challenges in understanding the concept of the immune system and improve CTS and CT. By integrating independent exploration through discovery learning and the use of digital technology in learning, it is hoped that students can be more active in building concepts independently, developing sharper critical thinking, and improving their scientific CS. The purpose of this paper is to determine the effectiveness of implementing BDL in improving CTS and CS. Therefore, this research not only contributes to the development of innovative learning models but also creates a generation that is more prepared to face global challenges with strong CTS and CS.

Methods

This study used a pre-post test control group design. The research method used was a quasi-experimental design, with two classes, namely one class as an experimental class that applies the BDL model and a control class that does not apply the BDL model in biology learning. The population of this study was grade XI high school students at one of the high schools in Cirebon Regency. Sampling was carried out by purposive random sampling. The research instrument was an observation sheet of BDL implementation in student learning activities and observation of CS during the learning process. Learning outcomes were in the form of pre-tests and post-tests using essay tests with critical thinking ability indicators.

Table 1. Student activities with the application of BDL and CTS indicators

No	BDL syntax	Student Activities	CTS indicators	Characteristic
1	Stimulation	Students prepare for learning	Interpretation	Offline
2	Problem identification	Students identify, define, and interpret problems.	Interpretation	Offline

3	Data collection	Students collect data from reliable sources to solve problems.	Analysis	Online (online-offline)
4	Data processing		Inference	
5	Verification	Students display data in an appropriate and correct format	Evaluation	(online-offline)
6	Generalization	Students communicate their learning outcomes in a class discussion forum.	Explanation	(offline)

The assessment includes CTS and CS. CTS is assessed from student learning activities with observation sheets and learning outcome tests.

Table 2. Communication skills indicators

No	Communication skills indicators
1	Communicating in discussion forums
2	Interacting and communicating positively with other students.
3	Collaborating with other students in a team
4	Responding to the opinions of other students on different teams

This study hypothesizes that students' CTS increases with the implementation of BDL and can develop CS in students. Data analysis was carried out qualitatively and quantitatively. Qualitative data include student learning activities using student learning observation instruments with the BDL model and observation of student CS. Quantitative analysis was obtained from the value of learning outcomes with CTS assessment, then tested using the n-gain test and the Mann-Whitney non-parametric test because the data was not normally distributed and homogeneous.

Results and Discussion

Student learning activities in applying the BDL model to the immune system material based on BDL syntax can be described in figure 1.

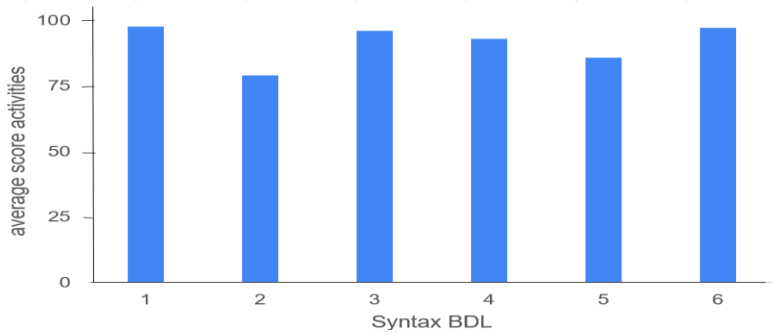

Figure 1. Average score of activities implementing the BDL model

Description:
1: stimulation (offline)
2: problem identification (offline)
3: data collection (online)
4: data processing (online-offline)
5: verification (online/offline)
6: generalization (offline)

The next stage is data collection (online), where students search for information from various digital sources, such as journals, articles, or educational videos. After the data is collected, they process the data (online-offline) by analyzing, classifying, and organizing the information logically. This process not only hones CTS but also requires students to communicate their findings systematically, both in online discussions and in-class meetings. The verification stage (online/offline) is carried out by comparing the results of the analysis with trusted sources or discussing with teachers and peers. After obtaining valid conclusions, students enter the generalization stage (offline), where they formulate concepts or principles that can be applied in other situations. With this approach,

students not only learn to understand material in depth but also develop communication skills in conveying their findings effectively. The average results of CTS scores from observations of the learning process between the experimental class and the control class can be described in Figure 2.

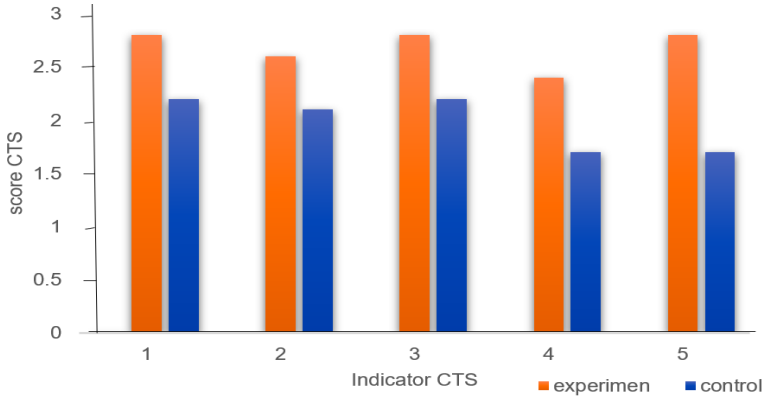

Figure 2. The average score of CTS
Description:
1 : interpretation. 2 : analysis. 3 : inference. 4 : evaluation. 5 : explanation

Applying the BDL model in learning encourages students to develop CTS through various stages of learning. In the interpretation stage, students observe the given phenomena or problems and relate them to the concepts learned. Furthermore, they analyze by sorting relevant information from various sources, both online and offline, to understand patterns or relationships between variables. Based on the results of the analysis, students make inferences by formulating temporary conclusions that can be tested for truth through experiments or further discussions. In the evaluation stage, students assess the accuracy of the information and consider whether the data obtained is strong enough to support the conclusions made. Finally, students convey logical and systematic explanations or explanations regarding their learning outcomes, either through written reports or class discussions, so that their CTS and CS continue to develop. The results of the CTS gain test between the control class and the experimental class are in Table 3.

Table 3. Percentage of achievement n gain

Category n gain	Experiment class	Control class
High	48%	28 %
Medium	50%	60%
Low	2%	12%
Average	70.02	55.8
Standard Deviation	5.89	18.89

Based on the N-gain data, the experimental class showed a higher increase in understanding compared to the control class. The percentage of high increase in the experimental class reached 48%, while in the control class, it was only 28%. Most students in the experimental class were in the medium category (50%), slightly lower than the control class (60%). However, the experimental class had a smaller percentage of the low category (2%) than the control class (12%), indicating better intervention effectiveness. Overall, the average N-gain of the experimental class (70.02) was higher than the control class (55.8), with a smaller standard deviation (5.89 versus 18.89), indicating more consistent learning outcomes in the experimental class. The results of the hypothesis test using the Mann-Whitney U test are in Table 4.

Table 4. Results of the Mann-Whitney U N-gain test on CTS

Data	Mann-Whitney U N-gain
Sig 2-tailed	0.02
α	0.05
Conclusion	0.02<0.05 There is a difference in improvement

The results of the Mann-Whitney U test on the N-gain of CTS showed a significance value (Sig 2-tailed) of 0.02, which is smaller than the α value (0.05). This suggests a significant difference in improvement between the experimental and control classes. Thus, the method or treatment given to the experimental class is proven to be more effective in improving learning outcomes compared to the control class. Meanwhile, the results of observations of students' CS in the experimental and control classes can be described in Figure 3.

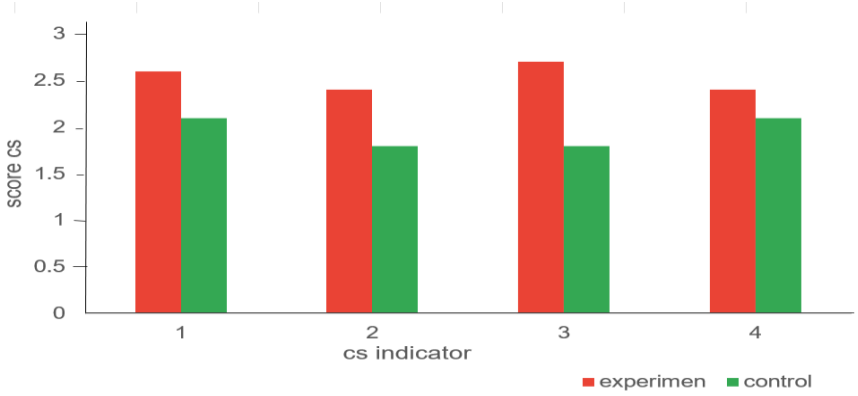

Figure 3. The average score of CS

Description:

1: communicating in a discussion forum

2: interacting and communicating positively with other students.

3: cooperating with other students in a team

4: responding to the opinions of other students on different teams

BDL can facilitate the development of students' CS through various indicators. First, BDL allows students to communicate in an online forum, where they can discuss and share ideas actively. Second, in an interactive digital environment, students are encouraged to interact and communicate positively with classmates, thereby building better relationships. Third, BDL-based learning also encourages teamwork, where students can collaborate in completing assignments or projects together. Finally, through group discussions, students can learn to respond to opinions from other teams in a constructive manner, thereby improving their CTS and argumentation skills. The results of the N-gain test of the average CS are in Table 5.

Table 5. Results of the Mann-Whitney U N-gain test on CS

Data	Mann-Whitney U test
Sig 2-tailed	0.00
α	0.05
Conclusion	0.00<0.05 There is a difference in improvement

The results of the Mann-Whitney U test on CS showed a significance value (Sig 2-tailed) of 0.00, which is smaller than the α value (0.05). This shows that there is a significant difference in improving CS between the group that uses BDL and the group that does not. Thus, BDL is proven to be more effective in improving students' CS, such as communicating in online forums, interacting positively, working together in teams, and responding to opinions from other groups.

The application of BDL in learning the immune system can improve students' CTS through various indicators, such as interpretation, analysis, inference, evaluation, and explanation. According to several studies, BDL combines face-to-face and digital learning, allowing students to access materials more flexibly and in-depth (Druckman & Ebner, 2018; Elya et al., 2018; Harper et al., 2024; Putri et al., 2020; Sefriani et al., 2021). In the context of interpretation, students can better understand the concept of the immune system through online discussions, interactive videos, and technology-based simulations that help them connect information to real experiences. In addition, students' analytical skills can improve with the use of BDL because they are allowed to review various sources of information related to the immune system independently. Learning with the BDL model that facilitates interactive discussions, students can develop the ability to distinguish facts, concepts, and theories that support the working mechanisms of the immune system. With access to a variety of digital resources and reflective activities, students can better analyze the relationship between pathogens, immune responses, and factors that influence the effectiveness of the immune system in the human body.

Students' inference skills also improved with the implementation of BDL, because they were required to draw conclusions based on scientific evidence obtained from various digital references and virtual experiments (Rahmi et al., 2024; Winarni et al., 2020). With an interactive learning model, students are more active in connecting existing information to construct scientific arguments related to the immune system. This strengthens their ability to make predictions about how the body responds to infection or vaccination based on the concepts they have learned. In terms of evaluation, BDL encourages students to assess the validity of the information they obtain, both from digital sources and from discussions with peers. According to research conducted by Haryono & Hamzah (2023), Rahmi et al. (2024), and Zahara et al. (2020), the combination of online and face-to-face learning improves students' evaluation skills because they have to compare various points of view before concluding a concept. In learning the immune system, these evaluation skills are important to help students understand scientific controversies, such as the effectiveness of vaccines or the impact of autoimmune diseases, so that they can make decisions based on critical and evidence-based thinking. In addition to critical thinking, BDL also contributes to improving students' communication skills. Students have wider opportunities to communicate in online forums, discuss with peers, and express opinions in writing and orally (Aji et al., 2024; Dina et al., 2019; Koto, 2020; Rahmi et al., 2024). In learning the immune system, effective communication is very important so that students can convey their understanding of immunological mechanisms clearly, both in group discussions and when responding to opinions from other teams. Through technology-based collaborative activities, students can also practice articulating their ideas in a more structured and logical way. Overall, BDL has a positive impact on improving students' CTS and CS in learning about the immune system. By utilizing digital technology in the learning process, students can develop better interpretation, analysis, inference, evaluation, and explanation skills. On the other hand, interaction in online forums and teamwork strengthens their CS. Thus, the implementation of BDL is an effective strategy in creating a more dynamic, interactive learning environment and encouraging better critical thinking and scientific communication. Biology learning using the BDL model has proven effective in improving various important 21st-century skills. Through a combination of online and offline learning, students are encouraged to actively explore information independently or in groups, so that their digital skills are further honed (Wisanti et al., 2024), especially in accessing, processing, and presenting biological data using technology. In addition, virtual

and face-to-face discussion activities in this model also improve digital CS (Bilici & Yilmaz, 2024; Filmi et al., 2024; González-Cespón et al., 2024; Wisanti et al., 2024) effectively and ethically. The process of working together in groups to complete discovery-based tasks also strengthens collaboration skills and builds a sense of shared responsibility. Not only that, the BDL model requires students to think creatively in formulating solutions to biological problems and to think critically in analyzing scientific phenomena based on the data and facts obtained (González-Cespón et al., 2024; Manurung & Pappachan, 2025). Thus, the BDL model becomes a holistic learning approach in preparing students to face future challenges.

Conclusion

The results of this study indicate that the implementation of BDL significantly improves students' CTS and CS in learning the concept of the immune system. BDL allows students to explore concepts independently, analyze information, and develop scientific arguments through online discussions and teamwork. This finding implies that the integration of the discovery learning model with digital learning can be an effective strategy for improving students' understanding of complex biological concepts while equipping them with CTS and CS that are relevant in the digital era. Therefore, it is recommended for educators to apply BDL in biology learning, especially in materials that require a deep analytical understanding. In addition, further research is recommended to explore the effectiveness of BDL in various other science concepts and develop more structured learning tools to maximize the benefits of this model.

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