



Gen Z' Critical Thinking Skills Empowering Using E-Worksheet with Problem-Based Learning Model on Mutation Material Assisted by Bioinformatics Database

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Abstract: Life in the 21st century demands graduates who can think critically, innovate, collaborate, communicate, and face the changes that occur in the global world. The demands of 21st-century learning have implications for complex learning processes, requiring students' critical thinking skills. This research aims to determine the effect of electronic worksheets (e-worksheets) assisted by bioinformatics integrated with the problem-based learning (PBL) learning model to improve students' critical thinking skills at SMA Muhammadiyah Palembang. The type of research that will be used is Research & Development research. This research is the final stage of the 4D development model. The population of this research was Muhammadiyah High Schools 1, 5, and 6 in the city of Palembang (accreditation A), and the research sample included XII students and biology teachers. Research data analysis used the SPSS program to carry out the Kolmogorov-Smirnov, homogeneity, and Wilcoxon tests. The pretest and posttest scores were calculated using the N-Gain test. The research results showed that the overall analysis data increased students' critical thinking skills in experimental and control classes. The results of the normality test of pretest and posttest critical thinking data from the three schools showed that the data was normally distributed. Differences in data on students' critical thinking skills are also known from the sig value. $0.000 < \alpha 0.05$, which can be concluded that students' critical thinking skills are higher before and after being taught compared to classes with conventional learning.

Keywords: Critical thinking; Bioinformatics; Mutation; Worksheets

Introduction

The era of globalization brings many cultural, political, and environmental changes that are influenced by advances in science and technology. Thus, life in this century demands various skills that must be mastered by a person. 21st-century education, a global educational era, is dedicated to nurturing skills and abilities crucial in an increasingly intricate and dynamic world (Pare & Sihotang, 2023). These skills are not just academic but

also essential for various aspects of life (Mardhiyah et al., 2021). The 21st-century education system aims to produce graduates who can think critically, innovate, collaborate, communicate, and adapt to the changes in the global landscape (Alhamuddin et al., 2022). In alignment with the US-based Partnership for 21st Century Skills, (2007), the competencies required in the 21st century are "The 4Cs" - communication, collaboration, critical thinking, and creativity. The demands of 21st-century learning have profound

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implications, necessitating the development of students' critical thinking skills. Critical thinking skills encompass the ability to access, analyze, and synthesize information, are fundamental and can be learned, trained, and mastered (Zubaidah, 2016).

The current state of critical thinking skills among Indonesian students remains a pressing issue in education. Susilawati et al. (2020) revealed that 21% of students demonstrated critical thinking skills in the medium category, 64% were in the low category, and 15% had very low critical thinking skills. This aligns with Husnita et al. (2023) research, which found that students from four schools in Palembang still have critical thinking skills that can be categorized as low. The average results of some critical thinking skills tests were as follows: SMA Negeri 4 Palembang at 25.95% in the low category, SMA Negeri 8 Palembang at 42.55% in the low category, SMA Negeri 9 Palembang at 34.20% in the low category, and SMA Negeri 19 Palembang at 27.55% in the low category. In the context of 21st-century learning, problem-based learning is highly emphasized. The Problem-Based Learning (PBL) model is an innovative learning approach that aligns with 21st-century competencies (Hendarwati et al., 2021; Artama et al., 2023). Therefore, learning objectives that apply a problem-based model enable students to apply their knowledge and skills in real-world situations.

Previous research by Husnita et al. (2023) has shown promising results in developing e-worksheets based on the PBL learning model. This innovative approach can potentially enhance students' critical thinking abilities compared to control classes that rely solely on conventional learning methods. The evidence is clear from the N-gain value analysis, where the control class scored 0.61 (medium criteria), and the experimental class scored 0.74 (high criteria). However, further effectiveness testing is needed to fully understand the impact of e-worksheets, as there are still some limitations, such as its use only for the 2013 curriculum. Therefore, an updated version of the previous e-worksheets is necessary to assess its effect on students in Muhammadiyah schools that implement the Merdeka curriculum. Additionally, the use of bioinformatics to design phylogenetic trees in e-worksheets is being emphasized. Bioinformatics, a field not introduced at the high school level, can significantly contribute to students' critical thinking skills.

Bioinformatics is a computational tool for managing and analyzing biological information. Bioinformatics has a role in the clinical field in the form of clinical information, gene identity, causes of mutations, and gene therapy (Hardison, 2005). Bioinformatics is important for students to use data processing programs (Genbank) for sequencing. Hardware and software devices greatly support the

ability to understand and manipulate the DNA genetic code. The e-worksheets teaching material packaging that has been designed integrates learning models to help the learning process by learning objectives. Thus, it is necessary to conduct further research in revising e-worksheets based on the PBL model assisted by bioinformatics for students and implementing e-worksheets on students' critical thinking skills at SMA Muhammadiyah Palembang. Hopefully, this biological database information technology integrated teaching material can be used to prepare students to master various skills, especially critical and problem-based thinking.

Method

Research Type

The type of research that will be used is research and development research using the 4D model (Thiagarajan, 1974) through 4 stages, namely define, design, develop, and disseminate. The final stage of this research is to determine the effect of electronic student worksheet assisted by bioinformatics on students' critical thinking skills.

Research Subject

The research population includes Muhammadiyah High Schools 1, 5, and 6 in Palembang, while the research sample is 110 students. Research design are presented in Table 1.

Table 1. Research Design

Class	School	Pretest	Experiment	Posttest
Experiment	SMA Muhammadiyah 1, 5, 6 Palembang	O ₁	X ₁	O ₂
Control	SMA Muhammadiyah 1, 5, 6 Palembang	O ₃	X ₂	O ₄

source: Adapted from Yohanis et al. (2013) and Majdi (2018)

X1 : Treatment in the experimental class (using PBL integrated e-worksheet)

X2 : Treatment in conventional classes (using conventional teaching materials)

Test the Effectiveness of Development Products

Data analysis was carried out quantitatively using the SPSS version 24 program. Before analyzing the effectiveness, validity and reliability tests were first carried out to determine the validity of the questions to be tested. Then, proceed with carrying out a normality test using the Kolmogorov Smirnov test, homogeneity test, Wilcoxon test, and Mann-Whitney Test.

Calculation of pretest and posttest scores of students using N-Gain

The calculation of N-Gain is obtained from the pretest and posttest scores of the control and experimental classes with the help of the SPSS program. The N-gain test formula:

$$N\text{-Gain} = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}} \tag{1}$$

S post: Posttest score, S max: Ideal maximum score, S pre: Pretest score.

The N-gain test is conducted to find out how much improvement there is in learning outcomes (Majdi, et al., 2018). The high and low N-Gain are the results of the calculations obtained, then grouped with the criteria for obtaining the N-gain score in table 2 as follows:

Table 2. N-Gain Value Criteria

Value N-Gain	Criteria
N-gain ≥ 0.7	High
0.3 ≤ N-gain ≤ 0.7	Medium
N-gain ≤ 0.3	Low

Result and Discussion

Critical thinking is the skill of thinking rationally and logically to determine the best decision regarding something by reflecting on thoughts (Ennis, 1993).

Critical thinking encompasses a range of abilities, including but not limited to discerning the fundamental components and presumptions of an argument and their interrelationships, deriving conclusions from the available information, assessing evidence, and engaging in self-correction (Nussbaum et al., 2021). Critical thinking helps in making decisions about what is right and wrong, and giving reasons regarding this (van Peppen et al., 2021). Critical thinking is the key to the success of an educational program and is also one of the most challenging variables to optimize its potential (Tan et al., 2023). In order to engage in critical thinking, one must first become aware of their own thinking and knowledge, and then reflect on how their own thinking affects both themselves and others (Puig & Jiménez-Alexandre, 2022). Through the process of critical thinking (CT), individuals gain valuable and precise knowledge about their environment by engaging in questioning, examining, and evaluating information (Orhan & Çeviker Ay, 2023).

Critical thinking skills can be improved through the development of teaching materials based on learning models. The data in (Table 3) shows that both classes taught with integrated e-worksheet with a PBL model of mutation material based on a bioinformatics database and classes taught with conventional learning experienced an increase in critical thinking skills scores.

Table 3. Results of Descriptive Analysis of Critical Thinking Skills in Experimental and Control Classes

	Descriptive Statistics				
	N	Minimum	Maximum	Mean	Std. Deviation
Pre Test Experiment	92	5	86	44.49	23.25
Post Test Experiment	92	66	100	91.66	7.24
Pre Test control	96	8	88	40.28	20.22
Post Test control	96	43	97	76.45	14.05
Valid N (listwise)	92				

Next, an inferential statistical test was conducted to see the differences in the scores of critical thinking skills in the two classes. However, our findings from the normality test on the pre-test and post-test critical thinking skills data from the three schools (SMA Muhammadiyah 1, SMA Muhammadiyah 5, and SMA Muhammadiyah 6 Palembang) reveal a crucial aspect-the data is not normally distributed (Table 4). This non-

normal distribution holds significant implications for our research. On the other hand, the homogeneity test results indicate that the critical thinking skills data has a homogeneous variance (Table 5). As a result, our statistical tests will be based on non-parametric statistics, specifically the Wilcoxon and Mann-Whitney tests.

Table 4. Critical Thinking Skills Data Normality Test

Tests of Normality		Kolmogorov-Smirnova			Shapiro-Wilk		
Class		Statistic	df	Sig.	Statistic	df	Sig.
Critical Thinking Skills	Pre Test Experiment	.130	92	.001	.945	92	.001
	Post Test Experiment	.203	92	.000	.896	92	.000
	Pre Test control	.114	96	.004	.958	96	.004
	Post Test control	.162	96	.000	.934	96	.000

Table 5. Critical Thinking Skills Data Homogeneity Test

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Critical Thinking Skills	Based on Mean	47.259	3	372	.000
	Based on Median	42.686	3	372	.000
	Based on Median and with adjusted df	42.686	3	302.697	.000
	Based on trimmed mean	46.819	3	372	.000

Based on Table 6, it is known that the sig. value is $0.000 < \alpha 0.05$. This value means there is a difference in students' critical thinking skills scores after learning using the integrated e-worksheet with a PBL model of mutation-bioinformatics material. In the control class, similar results were also found (Table 7), where there were differences in the scores of students' critical thinking skills before and after being taught with conventional learning.

Table 6. Wilcoxon Test of Critical Thinking Skills Data for Pre-Test and Post-Test for Experimental Class

Test Statistics	
	Post Test - Pre Test
Z	-8.318
Asymp. Sig. (2-tailed)	.00

Table 7. Wilcoxon Test of Critical Thinking Skills Data for Pre-Test and Post-Test for Control Class

Test Statistics ^a	
	Critical Thinking Skills
Mann-Whitney U	1398.000
Wilcoxon W	6054.000
Z	-8.126
Asymp. Sig. (2-tailed)	.000

Grouping Variable: class

Next, the Mann-Whitney test was carried out to see the differences in the results on the posttest in the two classes/groups. Based on the results of the Mann-Whitney test in Table 8, the sig. value is known. $0.000 < \alpha 0.05$. This value can be interpreted as meaning that there are differences in the control class critical thinking skills posttest and the experimental class critical thinking skills posttest.

Table 8. Mann-Whitney Test of Critical Thinking Skills Data

Test Statistics ^a	
	Critical Thinking Skills
Mann-Whitney U	1398.000
Wilcoxon W	6054.000
Z	-8.126
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Class

Based on the Mann Whitney test it can be concluded that the critical thinking skills of students taught with mutation-bioinformatics e-worksheet are higher than those taught with conventional learning. This is in accordance with research Suan et al. (2023) which found that utilizing the PBL model in teaching materials can improve students' understanding of environmental challenges, empowering them to apply their scientific knowledge in order to identify and implement solutions that reduce their impact. The utilization of PBL worksheets in the learning environment materials also might enhance students' capacity to identify, analyze, evaluate, and plan actions related to environmental concerns (Suryawati et al., 2020). According to Iriani (2019), the experimental class, which received colloidal material learning with Problem Based Learning assistance and a sasirangan ethnoscience student worksheet, had an average N-gain of critical thinking skills in the high category, whereas the control class was in the medium categories. Activities on worksheet which contain activities that orient, investigate and apply until students discover the concept of business opportunities, have a positive impact on critical thinking skills (Dwijayanti et al., 2023).

Worksheets are a commonly used educational resource that students are familiar with. Student worksheets are a form of educational resources that are well organized and include a condensed overview of the subject matter, practical exercises or drills, assignments, and questions (Sulistiyani et al., 2020). Student worksheets are documents that consist of various components, including a title, fundamental competencies, estimated completion time, required resources, concise information, step-by-step instructions, tasks to be completed, and necessary reports (Dwijayanti et al., 2023; Muskita et al., 2020). A worksheet serves as a directive for guiding actions in the learning process, providing guidance for attaining competence, and evaluating the attainment of learning objectives (Muskita et al., 2020). A worksheet is a structured document that provides instructions or stages to follow in order to successfully complete the task, and the assignment should clearly outline the necessary skills to be achieved (Dwijayanti et al., 2023). The utilization of student worksheets centered around the Telaga Ranjeng myth has an impact on fostering a sense

of environmental stewardship among students (Sulistiyani et al., 2020). The student worksheets utilized in entrepreneurship classes, which focused on 21st-century learning skills, based the pre-test and post-test results on proved to be successful teaching materials (Dwijayanti et al., 2023). Technology also has the capacity to enhance the cultivation of advanced critical thinking in education by reducing the physical separation between students, thereby impeding their active participation (Nussbaum et al., 2021).

PBL model syntax helps students' critical thinking abilities to grow. PBL is a learning approach that bases the investigative process in the learning that is done on real-world problems (Arends, 2012). PBL is an educational technique rooted on constructivism, wherein learners are assigned the responsibility of addressing a problem that directly pertains to their area of study (Houghton, 2023). PBL utilizes constructivist ideas to promote the practical application of existing knowledge, cooperative learning, and active participation (Seibert, 2021). The PBL model integrated into student worksheet can make learning more focused and well-documented. Problem orientation activities through mutation material, especially Down syndrome and syndrome cases, encourage students to identify and analyze problems. Study organization activities direct students to design investigative activities, including determining the resources and time needed to solve a problem. Investigation activities stimulate students to carry out data and fact-collection activities related to issues. In this activity, students are also directed to conduct bioinformatics analysis on the site provided and compare it with data in the literature. In the work development and presentation activities, students present their findings, including the results of bioinformatics analysis as a phylogeny tree, in front of the class. At the end of the activity, students together evaluate and reflect on the solving activities that have been carried out. This series of activities encourages students to identify, analyze, and find solutions to problems that are part of critical thinking. Thus, critical thinking skills were higher in the experimental class than in the control class.

Problem-Based Learning (PBL) is a pedagogical approach that enhances students' critical thinking skills by actively including them in the resolution of complex challenges or scenarios that require the consideration of various factors in the decision-making process (Razak et al., 2022). Problem-Based Learning (PBL) is an optimal approach for involving Z-Generation students in advanced levels of critical thinking. The alignment between the PBL process and the notion of critical thinking is evident, since it encompasses various parts of critical thinking such as inquiry, analysis, synthesis,

interpretation, conclusion, reasoning, application, and the utilisation of intuition and creativity (Seibert, 2021).

Conclusion

Critical thinking skills are a crucial and challenging educational variable with which to be empowered. Critical thinking skills can be developed through teaching materials with a contextual approach and digital learning environments. Based on the research that has been carried out, e-worksheets with the PBL model on mutation and bioinformatics database material can significantly improve critical thinking skills. Furthermore, the e-worksheets that are developed facilitate students' development of better critical thinking skills and are significantly different from those taught with conventional teaching and learning materials. Thus, the use of this e-worksheet is highly recommended to optimize students' critical thinking skills, especially Z-Generation.

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Conflicts of Interest

No conflict interest.

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