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Enhancing high school students' critical thinking skills through the flipped-guided inquiry learning model with concept mapping

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Abstract

Critical thinking is a key 21st century skill vital for students' academic and professional development. Preliminary studies at SMA Negeri 1 Singosari indicate that students' critical thinking skills are moderate and need improvement. This study examines the effect of the flipped-guided inquiry learning (FGIL) model integrated with concept mapping on the critical thinking skills of 11th-grade students. A quasi-experimental design with a nonequivalent control group was applied, involving pre- and post-tests. The critical thinking test comprised six essay items evaluated using Ennis's rubric. ANCOVA results ($p < 0.05$) demonstrated a significant difference in performance among the FGIL-concept map group, FGIL-only group, and guided inquiry group. The FGIL model with concept maps showed the most substantial improvement. These findings suggest the potential of integrating concept mapping into flipped-guided inquiry to enhance students' critical thinking in biology education.

Abstrak. *Berpikir kritis merupakan keterampilan utama abad ke-21 yang sangat penting bagi perkembangan akademis dan profesional siswa. Studi pendahuluan di SMA Negeri 1 Singosari menunjukkan bahwa keterampilan berpikir kritis siswa tergolong sedang dan perlu ditingkatkan. Studi ini mengkaji pengaruh model pembelajaran inkuiri terbimbing terbalik (FGIL) yang diintegrasikan dengan pemetaan konsep terhadap keterampilan berpikir kritis siswa kelas 11. Desain kuasi-eksperimental dengan kelompok kontrol non-ekuivalen diterapkan, yang melibatkan tes pra dan pasca. Tes berpikir kritis terdiri dari enam item esai yang dievaluasi menggunakan rubrik Ennis. Hasil ANCOVA ($p < 0,05$) menunjukkan perbedaan yang signifikan dalam kinerja antara kelompok peta konsep FGIL, kelompok hanya FGIL, dan kelompok inkuiri terbimbing. Model FGIL dengan peta konsep menunjukkan peningkatan yang paling substansial. Temuan ini menunjukkan potensi mengintegrasikan pemetaan konsep ke dalam inkuiri terbimbing terbalik untuk meningkatkan pemikiran kritis siswa dalam pendidikan biologi.*

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A. Introduction

The progress of science and technology in the 21-st century has encouraged individuals to continuously enhance their skills in order to tackle various global challenges (Lavi et al., 2021). One of the most important institutions is education, which plays a role in preparing knowledgeable and skilled human resources (Pradana et al., 2021). Critical thinking skills are basic and important for students in 21-st century learning (Hardianto et al., 2023).

Critical thinking is a very important skill for learners to have as it contributes greatly to students' educational and career development in the 21-st century (Shaw et al., 2020). Critical thinking plays a role in helping students solve problems faced both in the scientific, social, and other complex problems in everyday life effectively which can help students develop their potential (Kardoyo et al., 2020). In addition, by thinking critically, students will find it easier to connect the facts obtained into a knowledge concept (Reynders et al., 2020).

In several countries, students' critical thinking skills remain low. A study conducted in Turkey revealed that 53 out of 79 students (67%) demonstrated low critical thinking skills, with an average score of 28.05 (Demircioglu et al., 2023). Meanwhile, a preliminary study conducted in class XI at SMA Negeri 1 Singosari The results showed that the critical thinking skills of students were still in the low category, with an average score of 41.68%. This suggests that the critical thinking skills of students at SMA Negeri 1 Singosari are still considered moderate and need further improvement. The poor critical thinking skills of students are strongly related to the weaknesses of the learning in the classroom (Astalini et al., 2023) such as students are still accustomed to learning by using memorization techniques and habits in completing tests without analyzing questions (Seventika et al., 2018). In addition, during learning students are unable to evaluate and combine information that has been obtained and their difficulty in connecting concepts and knowledge (Tseng, 2020).

The low critical thinking ability of students can be addressed by applying an innovative guided inquiry-based learning model that is integrated with blended learning, specifically the flipped classroom model. Flipped-guided inquiry learning is an innovative approach that combines the flipped classroom and guided inquiry learning models (Aumi & Mawardi, 2021). Flipped-Guided Inquiry Learning (FGIL) consists of five learning stages which are divided into 2 sessions, namely asynchronous sessions including the preparation stage, orientation stage and exploration and concept formation stage, and synchronous sessions including the application stage and closing stage (Ramadhansyah & Mawardi, 2021). Based on these stages, the FGIL learning model will train and hone students' thinking skills in producing a concept obtained through observation and data collection activities and linking the concepts that have been obtained with similar problems to test their effectiveness (Mawardi & Nur, 2022). However, FGIL has a weakness in terms of finding ideas from the problems found or presented (Nurlaila & Lufri, 2021). According to Artayasa et al. (2021) that the FGIL model makes it difficult for students to relate concepts to one another so that it has an impact on planning experimental strategies for problem-solving. Therefore, the FGIL learning model needs to be given an innovation in the form of using concept mapping techniques.

A concept map is a depiction of how certain concepts of a topic are interrelated through hierarchical or web-based relationships (Pruett & Weigel, 2020). According to the research results, making concept maps in the learning process has a positive effect on students' critical thinking skills (Tseng, 2020). Making concept maps related to the material studied will help students to identify, evaluate and connect various concepts obtained into knowledge or conclusions (Damayanti et al., 2022).

Biology is a subject that is composed of complex material, directly related to students' real life both in the context of technology, science and society (Afni et al., 2017; Narbutaev, 2020). Some biological material is sometimes still considered difficult to understand because of its abstract nature, a lot of scientific language and a complicated working mechanism of the process, for example the material of excretory system (Gnidovec et al., 2020). The results of a preliminary study on grade XI students of SMA Negeri 1 Singosari related to critical thinking skills on the material of the human excretory system showed an average value of 41.68% of the maximum score of 100%.

Based on the above background, this study aims to examine the effect of integrating concept mapping into the flipped-guided inquiry learning (FGIL) model on the critical thinking skills of 11th-grade students in biology. This research is expected to fill the gap in current literature by providing empirical evidence on the combined impact of these pedagogical strategies, particularly in the context of complex biological topics such as the excretory system."

B. Material and method

This is quasy experiment method with nonequivalent control group design. The research design can be viewed in Table 1.

Table 1 Research design

Pretest	Treatment	Posttest
O1	X1	O2
03	X2	04
05	X3	06

(Source: Leedy & Ormord: 2021)

Description:
X1 = FGIL model with concept map class
X2 = FGIL model class
X3 = GI model class
O1, O3, O5 = Pretest
O2, O4, O6 = Posttest

This research was conducted at SMA Negeri 1 Singosari, Singosari sub-district, Malang city, East Java. This research took place from September to November in the academic year 2024/2025 odd semester. The population in this study consisted of all grade XI students at SMA Negeri 1 Singosari with a total of 411 students spread across 12 classes. After that, three classes were selected as treatment classes using random sampling technique. However, before that, an equality test was carried out first using ANOVA test and Least Difference Significance further test on the even semester report card scores of the 2023/2024 school year. The three selected treatment classes include class XI K as a class taught with the FGIL model with concept maps, class XI L as a class taught with the FGIL model and class XI G as a class taught with the GI model. The learning process of FGIL model with Concept Map, FGIL, and GI is described in Table 2. Hypothesis testing used the Ancova test after conducting prerequisite tests including normality and homogeneity tests.

Table 2 Syntax of FGIL-CM, FGIL, and GI learning models

FGIL-CM (Modified from Mawardi et al., 2021)		FGIL (Mawardi et al., 2021)		GI (Sanjaya, 2020)	
Step	**Student activity**	**Step**	**Student activity**	**Step**	**Student activity**
Preparation	Students create a learning management system (LMS) account asynchronously.	Preparation	Students create a learning management system (LMS) account asynchronously	Orientation	Students use the worksheet to investigate the phenomenon presented.
Orientation	Students watch the orientation video asynchronously.	Orientation	Students watch the orientation video asynchronously.	Formulate a problem	Students discuss in groups to identify problems in worksheet.
Exploration and concept formation with concept maps	Students answer a key question in the form of a phenomenon presented asynchronously Students create a concept map to connect the key issue with the necessary disciplines to help answer the key question.	Concept exploration and formation	Students answer key questions in the form of a phenomenon presented asynchronously.	Hypothesize	Students formulate hypotheses based on the problem formulation.
Application	Students answer other questions on the worksheet by using the concepts that have been acquired synchronously in class	Application	Students answer other questions on the worksheet by using the concepts that have been obtained in an organized manner. synchronous in class	Collecting data	Students conduct a literature study to solve the problem on the worksheet.
Closure	Students present the results that have been obtained synchronously in class.	Closure	Students present the results that have been obtained in an organized manner. synchronous in the classroom.	Analyzing data	Students analyze the findings with the hypothesis that has been formulated.
				Drawing conclusions	Students draw conclusions and present their findings to the class.

The variables used in this study consisted of independent variables and dependent variables. The independent variables include FGIL model with concept map, FGIL model, and GI model. While the dependent variable is critical thinking skills. Data on critical thinking skills were derived from an essay test with a total of 6 questions related to the excretory system material. The answers obtained by each student will be assessed using an assessment rubric that refers to the indicators of critical thinking skills according to Ennis (1996) which include focus, inference, situation, clarity, and overview. The essay test used has previously been tested which includes validity test with Pearson product moment test and reliability test with Cronbach's-Alpha test. The results of the Pearson product moment test show that all items

have a value> r_{tabel}. The r_{table} value with N = 30 is 0.361 and the r_{count} value of all items is in the range of 0.555 to 0.797. While the reliability test results show a value of 0.725> 0.600 which means that all items are reliable.

The data that has been obtained is then analyzed quantitatively using analysis of covariance (ANCOVA). This test is carried out with the aim of knowing whether there is a significant influence between FGIL classes with concept maps on critical thinking skills. However, after conducting the test, it must first conduct a prerequisite test, namely the normality test (Kolmogorov-Smirnov) with the aim of knowing whether or not the distribution of research data is normal, and the homogeneity test (Levene's-Test) to find out that the data from the three groups used come from the same population. If the independent variable affects the dependent variable, then a further test is carried out, namely the Least Significant Difference (LSD) test. In addition to being explained quantitatively, the research data that has been obtained is also explained qualitatively.

C. Results and discussion

The research data on critical thinking skills that have been obtained are tested for normality using the Kolmogorov-Smirnov test. Based on the normality test results in Table 3, it shows that the pretest value of critical thinking skills that has been obtained has a significant value of .200*> 0.05 and the posttest obtained a significance value of 0.60> 0.05. These results indicate that the critical thinking skills data is normally distributed. After the data is normally distributed, then the homogeneity test is carried out using the Levene's-Test test. The results of the homogeneity test based on Table 3 show that the significant value of the critical thinking skills posttest is 0.104> 0.05. These results indicate that the data on students' critical thinking skills are homogeneous.

The critical thinking skills data that has been obtained has met the prerequisite test so that it can be continued to the next test, namely the test to determine whether the FGIL model with concept maps affects students' critical thinking skills through hypothesis testing. Hypothesis testing uses the help of SPPS version 27.0 by using the one-way ANCOVA test. The results of the critical thinking skills hypothesis showed a significant value of 0.000 <0.05. These results mean that there is a significant difference in the critical thinking skills of the experimental class with the positive control class and the negative control class. In more detail, the hypothesis test results are presented in Table 4.

Based on the ANCOVA test results, it shows that various learning methods have a significant influence on students' critical thinking skills. Therefore, a further test was conducted to determine the type of learning method that has the most significant effect on students' critical thinking skills. The results of further tests conducted using the LSD test as in Table 5 show that the FGIL model with Concept Maps produces the largest corrected mean value of 74.325 and these results are significantly different from the classes applied with the FGIL and GI models. In addition, the corrected mean in the initial test and the final test are also different, there is an increase in the average score in the three classes and the highest increase is obtained in the class taught with the FGIL model with concept maps. Based on these results, the FGIL model with Concept Map has a higher potential in improving students' critical thinking skills.

Table 3 Prerequisite test results

Variabel	Test type		N	Alpha	Infomation
Critical thinking skills	Normality	Pretest	97	.200*	Normal
	Normality	Posttest	97	.060	Normal
	Homogeneity	Posttest	97	.104	Homogeneous

Table 4 ANCOVA test result on critical thinking skills of students of SMA Negeri 1 Singosari

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	3638.480[a]	3	1212.827	66.158	.000
Intercept	3690.196	1	3690.196	201.296	.000
XLS	601.102	1	601.102	32.789	.000
Class	3205.559	2	1602.779	87.430	.000
Error	1704.897	93	18.332		
Total	435857.806	97			
Corrected Total	5343.377	96			

Table 5 Post hoc test results of critical thinking skills

Class	Pretest		Posttest	
	Mean	SD	Mean	SD
FGIL-CM	29.391	5.018	74.325	5.786
FGIL	32.928	4.267	65.544	4.847
GI	36.177	3.764	60.639	4.175

The implementation of FGIL model with Concept Maps acts as a facilitator for students to identify problems and design strategies to solve problems found or presented. Concept maps help students connect prior knowledge with new knowledge (Alsuraihi, 2022). The FGIL model assisted by concept maps is based on the constructivist learning theory put forward by Vygotsky, which states that the learning process will run effectively if learning is linked to real situations that will encourage students to seek and construct their own knowledge based on interactions with their environment.

The FGIL model with concept maps makes students have a strong basic concept of the material being studied through concept map-making activities before learning begins. Concept maps act as a mind mapping framework for associating information (Mapman, 2023). Each activity of the FGIL learning model with concept maps aims to increase students' critical thinking skills individually and collaboratively starting from the preparation, orientation, Exploration and concept formation, application, and closing stages (Khairunnisak et al., 2023).

The first stage of the FGIL model with concept maps is preparation. The learning management system in the FGIL model is used to share videos that contain orientation to learning materials that will be studied in synchronous classes (Ismail & Mawardi, 2021) At this stage, students have the opportunity to hone critical thinking skills through the process of analyzing, evaluating, and reflecting on the information provided in creating and setting up an LMS account. The activity of analyzing information obtained and applied directly in learning is one of the activities that can improve students' critical thinking skills (Sutiani et al., 2021).

The second step is orientation. This orientation video contains greetings, motivation, apperception, basic competencies, learning objectives, and an overview of the material to be learned (Khairunnisak et al., 2023). The orientation stage aims to introduce the learning material while building students' motivation and curiosity towards the topic to be learned. This motivation and curiosity contribute to improving cognitive abilities (Förster et al., 2022) as well as students' problem-solving skills (Hsia et al., 2021). This is in line with Resnick (1981) theory, which states that seeing and paying attention to learning materials helps students improve their understanding more deeply.

The third stage of the FGIL model with concept maps is exploration and concept formation with concept mapping asynchronously. This is done through problem solving activities. Thus, students will indirectly enrich their insight about the material to be learned through the exploration of new information from various learning sources (Khairunnisak et al., 2023). The exploration process encourages students to think critically and analytically so that the information obtained will be more based on relevant situations and facts. This analyzing activity can help students develop critical thinking skills (Valladares, 2021).

After solving the problems given, students create concept maps individually. This concept map contains the new knowledge that students acquire as they answer the key questions. Therefore, making concept maps really helps students organize the new knowledge they gain and connect it with the knowledge they already have. According to Gunawan et al. (2020), making concept maps encourages studens to use their critical thinking skills. The use of concept maps helps students summarize the subject matter in a way that they understand (Izci & Akkoc, 2024). In short, concept maps are a learning technique that helps students remember, understand and develop critical thinking (Azizah et al., 2020).

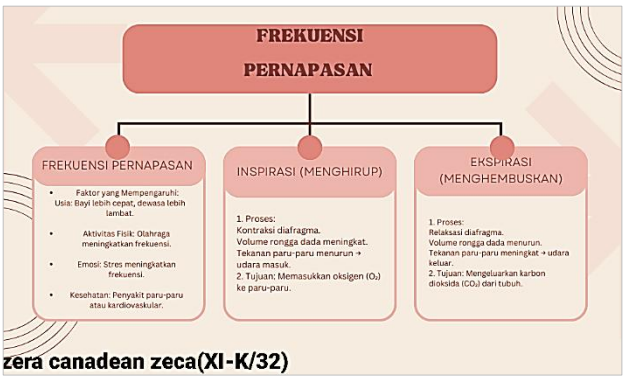

Figure 1
Results of students' concept map work on the excretory system material (in Indonesian)

The fourth stage of the FGIL model with concept maps is application (see Figure 1). According to (Mahanal et al., 2019) that the activity of applying the concepts that have been obtained to new problems can help students understand the problem and develop their critical thinking skills in solving problems. At this stage, students produce solutions quickly compared to other learning models because previously students already have a strong basic concept of the subject matter. Real problem solving is reviewing the answers or solutions that have been obtained in different cases. That this exercise provides an opportunity for students to build their confidence in solving simple problems and in the same context.

The fifth stage of the FGIL model with concept maps is closure. This communicating activity requires each group member to reflect on the findings that have been obtained. This activity is a form of empowering students' critical thinking skills through activities to reflect on the findings that are equipped with explanations supported by evidence and facts (Rosmiati et al., 2020). Reflection activities carried out increase students' understanding of the concepts that have been obtained, understanding of themselves, assessing themselves and increasing self-confidence (Davis & McDonald, 2019; Zulfikar & Mujiburrahman,

2018). In addition, at this stage, questions and answers between presenters and audiences are also carried out which can significantly improve their critical thinking skills (Wati & Anggraini, 2019).

The results of the critical thinking skills test in the positive control class using the FGIL learning model showed that students' critical thinking skills were slightly different compared to students taught using the FGIL model with concept maps. This difference is clearly visible at the application stage. This happens because students have difficulty in solving problems and take longer to complete the assigned tasks (Khairunnisak et al., 2023). Concept mapping facilitates students to interpret, identify key ideas and use their abilities in creating metacognitive regulatory strategies such as planning identified hierarchical information systems ((Powell et al., 2021; Sannathimmappa et al., 2022)), as well as understanding relationships and knowledge structures (Schroeder et al., 2018). This indicates that the FGIL model with concept maps is more effective in helping students develop critical thinking skills, especially in the application stage. This is in line with research from (Harris et al., 2020) which states that making concept maps in the learning process has a positive effect on students' critical thinking skills.

In the negative control class that applied the guided inquiry (GI) model, the results critical thinking skill of student showed quite nice development, although it was below students who were taught with the FGIL model with concept maps and the FGIL model itself. This happens because the GI model is not integrated with the flipped classroom and is not with concept maps as in the experimental and control classes. Flipped classroom facilitates students to explore prior knowledge related to the material being studied through reading and watching videos (Chis et al., 2018). While concept maps are used to help students decipher the relationship between ideas (Machado & Carvalho, 2020). This shows that although the GI model provides the development of critical thinking skills, it is not effective enough in supporting students to think deeply and solve problems independently.

According on the discussion above, it can be concluded that each stage of the FGIL model with concept maps can facilitate students to develop critical thinking skills because the FGIL model with concept maps aims to find solutions appropriately and effectively through activities to strengthen understanding or basic concepts related to the material to be studied.

This research has implications for the development of science, especially in effective learning strategies to improve students' critical thinking skills, where the Flipped-Guided Inquiry model of Concept Map-assisted learning has been proven to be able to encourage active involvement and in-depth thinking processes. Practically, these findings are useful for society in an effort to form a generation that is able to think logically, analytically, and provide solutions in dealing with real problems, so that it can support the improvement of the quality of education and the competitiveness of human resources.

Limitations in the implementation of the Flipped Guided Inquiry learning model Concept map-assisted learning is that students need to learn independently by making concept maps at home and the ability to adapt to technology well in supporting the learning process. Students have not practiced making concept maps based on material exploration activities carried out on the internet. This is a challenge for teachers and schools to be able to integrate various effective and appropriate learning methods in the future to support the success of the learning process.

D. Conclusion

This study concludes that integrating concept mapping into the Flipped-Guided Inquiry Learning (FGIL) model significantly enhances the critical thinking skills of high school students, particularly in learning complex biology concepts such as the excretory system. The combination of asynchronous concept exploration and synchronous application fosters deeper understanding and reasoning. These findings contribute to the growing body of research on blended inquiry-based learning and highlight the pedagogical value of visual tools in flipped classroom settings. Given the promising results, future research is encouraged to explore the effectiveness of this model across different science topics, educational levels, and student populations to assess its generalizability and long-term impact on higher-order thinking skills.

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