

# PEN III.A.1.b.2.c (JPPIPA 7.SI.2021)

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**Submission date:** 29-Aug-2022 07:45PM (UTC+0800)

**Submission ID:** 1888759242

**File name:** PEN\_III.A.1.b.2.c\_JPPIPA\_7.SI.2021.pdf (240.9K)

**Word count:** 5216

**Character count:** 29024



## Problem-Based Learning in Phytochemistry Courses: Its' Effectiveness in Improving Medical Students' Critical Thinking Ability Viewed from Cognitive Style

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DOI: [10.29303/jppipa.v7iSpecialIssue.1124](https://doi.org/10.29303/jppipa.v7iSpecialIssue.1124)

### Article Info

Received: October 28<sup>th</sup>, 2021

Revised: November 25<sup>th</sup>, 2021

Accepted: November 27<sup>th</sup>, 2021

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**Abstract:** The implementation of the Problem-Based Learning (PBL) model for medical students has long been initiated to be integrated into the learning system and curriculum, however, empirical support for the application of the PBL model to medical students is still weak, becoming an obstacle. On the one hand, the need for critical thinking development among medical students is increasingly urgent, this is related to their future assignments in a more complex health care system that requires critical thinking ability. Our current study aims to evaluate the effectiveness of the problem-based learning (PBL) model on improving the critical thinking ability of medical students in terms of cognitive style. This study is an experimental study (one group pretest-posttest design) involving 21 medical students (medical students) in phytochemistry courses at one of the universities providing medical and nursing science programs in Indonesia. The study started by giving a cognitive style test using the GEFT (Group Embedded Figure Test) instrument to classify students into FD and FI cognitive styles, pretest, learning implementation using the PBL model (carried out for five meetings), and posttest. The pretest and posttest used a critical thinking ability test instrument in the form of an essay test. Descriptive and statistical analyzes were performed to evaluate the effectiveness of the PBL model. The results of the study show that the PBL model has been convincingly effective in improving students' critical thinking ability in phytochemistry courses for both FD/FI cognitive style modes. Based on these findings, we recommend the use of the PBL model in extensive and intensive learning to develop the critical thinking ability of medical students.

**Keywords:** Problem-Based Learning; Critical Thinking; Cognitive Style

**Citation:** Menap, M., Bayani, F., & Prayogi, S. . (2021). Problem-Based Learning in Phytochemistry Courses: Its' Effectiveness in Improving Medical Students' Critical Thinking Ability Viewed from Cognitive Style. *Jurnal Penelitian Pendidikan IPA*, 7(SpecialIssue), 118-125. <https://doi.org/10.29303/jppipa.v7iSpecialIssue.1124>

### Introduction

Critical literacy in the health and medical fields is a challenge for science teaching today (Rubinelli et al., 2021), and an important mission of the medical education planning system has led to critical thinking (Jafari et al., 2020). On the one hand, science as the front

line in the education system must be prioritized, this is in line with the development of modern society as well as concerns about the decline in the quality of achievement and interest in science (LaForce et al., 2017). The current focus of science teaching is on developing students' critical thinking. Critical thinking is the most important skill to successfully face the 21st century

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(Prayogi et al., 2018a). These skills are achieved through a learning process. Furthermore, this mode of thinking is important for developing cognitive abilities and more effective information retention (Arifin et al., 2020). However, based on research in various fields such as science, it was found that students who graduated from various countries did not have the ability to compete on a global scale because they did not have the ability to think critically (Frijters et al., 2008). In the learning process in schools, science education has not been oriented towards habituation and improvement of critical thinking skills, and still focuses on low-level cognitive learning outcomes (Kurniahtunnisa et al., 2016).

Critical thinking is a predictor of a person's excellence in learning (Leest & Wolbers, 2021). Critical thinking is a form of systematic and precise thinking, which follows the rules of logic and scientific reasoning (Lau, 2011). For this reason, critical thinking is one component of intelligence that is very calculated (Albergaria-Almeida, 2011). Critical thinking is even recognized as a mode of need in thinking as an asset in solving problems, and in learning the critical thinking training process is most effective when course material is presented with the right method (Berdaahl et al., 2020). In the perspective of educational psychology, critical thinking is seen as "reasonable reflective thinking focused on deciding what to believe or do (Ennis, 2018). Based on previous studies, critical thinking indicators as the most intense cognitive dimension used to assess students' critical thinking ability are in the aspects of analysis, inference, evaluation, and decision making (Prayogi et al., 2018b; Prayogi & Verawati, 2020; Verawati et al., 2018b; Prayogi & Verawati, 2020; Verawati et al., 2019).

Considering the global conditions in this century, it seems that the transformation of students to be able to think critically is increasingly urgent (Aránguiz et al., 2020). Recently, a bibliometric study of 51 articles measured critical thinking in health and medical students, where the results showed that 48 articles reported students' critical thinking was at low levels (Jafari et al., 2020). Furthermore, this study recommends the importance of pedagogical interventions that lead students to be able to think critically. Therefore, the need for teaching critical thinking becomes a priority for learning at the higher education level. More extensively, this is called for by academics who support scholars as agents of change in critical thinking in society (Jenkins et al., 2018). It is widely acknowledged that the classical pedagogical model cannot develop students' critical thinking abilities. Finally, the pedagogical model offered to train critical thinking is a student-centered interactive learning model, one of which is Problem-based Learning (PBL) (Suhirman et al., 2020). This model has actually

been proposed for a long time to be integrated into the teaching system and curriculum for health or medical students (Christopher et al., 2002; Kinkade, 2005), it's just that empirical support for the application of the PBL model to medical students is still weak. Therefore, its implementation effect needs to be further explored.

PBL is a student-centered learning model where a series of learning processes in PBL directs students to explore, apply knowledge, and integrate theory and practice (Savery, 2006). In problem-solving, a series of discrete tasks are completed by the learner to produce a knowledge product (Hung, 2011). PBL has long been used as a mode of active and constructivist learning through problem-solving in real-world contexts (Barrows, 1996). In its development, PBL is directed at increasing content knowledge, developing effective problem solving, creating independence and collaboration (Hmelo-Silver, 2004). Previous studies have found that PBL can increase students' interest and involvement in science (Cerezo, 2015; Mergendoller et al., 2006), PBL implementation can train students' creativity (Bell, 2010), problem-solving, and critical thinking skills (Ertmer et al., 2014; Prayogi & Asy'ari, 2013), reflective thinking (Domínguez & Jaime, 2010), communication and collaboration skills (Lou et al., 2011) and creating student independence in learning (Norman & Schmidt, 2000).

It is widely recognized that practicing critical thinking requires good learning strategies and planning, this is not only done by teachers (instructors or lecturers) but also more needed by students. In this context, learning strategies are the key to determining the information processing of each learner (George et al., 2018). Moving on from the theory of self-efficacy (Bandura, 1982), we believe that information processing in each learner's learning is different, this depends on their cognitive style. This is supported by some previous research, where cognitive style is related to their acceptance of information processing (George et al., 2018), and information processing plays a role in individuals' acceptance of information and their behavior (Armstrong et al., 2012).

Cognitive style is identified with the level of individual consistency in how to understand, organize, and process information (Rayner & Cools, 2011), and is believed to affect individual performance (Armstrong et al., 2012). Previous research has linked cognitive style to many fields and the most prominent is psychology (Cools et al., 2014). In the aspect of cognitive regulation, cognitive style plays a role in mediating individual cognitive abilities in learning and receiving information (Viator et al., 2020). Individual cognitive styles are categorized into field-dependent and field-independent (Witkin, 1967; Witkin et al., 1977). The connection with our current study is that we evaluate the effectiveness of

the learning model that we conduct on students to improve critical thinking ability in terms of cognitive style.

This study specifically aims to evaluate the effectiveness of the problem-based learning (PBL) model on improving the critical thinking ability of medical students viewed from cognitive style.

**Method**

This study is an experimental study involving 21 medical students in phytochemistry courses at the University of Qamarul Huda Badaruddin Bagu, Indonesia. One group pretest-posttest design was used, where the effect of Problem-based Learning (PBL) was evaluated from the critical thinking ability scores on the pretest and post-test. The research design is presented in Table 1. The study began with giving a cognitive style test using the GEFT (Group Embedded Figure Test) instrument (Witkin et al., 1977), pretest, implementation of learning using the PBL model (carried out for five meetings on phytochemistry material), and posttest. Next, the analysis of the results is carried out.

**Table 1.** Research design

Sampling	Cognitive style test	Pretest (O1)	Treatment (X)	Posttest (O2)
N = 21	GEFT	CT Essay Test	PBL Model	CT Essay Test

The critical thinking instrument consists of 8 items in the form of essays with indicators of analysis, inference, decision making, and evaluation (Prayogi & Verawati, 2020). This critical thinking question is presented at the pretest and posttest. The critical thinking score uses a graded scale starting from +3 (maximum score) and -1 (minimum score). Analysis of individual critical thinking scores was averaged and categorized into very critical, critical, moderately critical, less critical, and uncritical criteria. This scoring and categorization system was adapted from a previous study (Verawati et al., 2019) as presented in Table 2.

**Table 2.** Criteria for critical thinking ability

No	Score range	Category
1	$X > 17.6$	Very critically
2	$11.2 < X \leq 17.6$	Critically
3	$4.8 < X \leq 11.2$	Enough critically
4	$-1.6 < X \leq 4.8$	Less critically
5	$X \leq -1.6$	Not critically

Increased scores of students' critical thinking ability were analyzed using the n-gain equation with the criteria of high (>0.7), moderate (0.3-0.7), and low (<0.3) (Hake, 1999).

Statistical data analysis (inferential statistics) was conducted to analyze student critical thinking ability test data. The test used is the t-test which aims to examine the impact of the learning model on critical thinking ability. The rejection criterion is  $H_0$  if the statistical significance or p-value of the t-test is less than 0.05. If  $H_0$  is rejected then  $H_1$  is accepted, or vice versa. The condition before the t-test is that the data is normally distributed with the criteria if the significance (p-value) is greater than 0.05. All data analysis statistically using SPSS 23.0 software.

**Results and Discussion**

Cognitive style test results are presented in Table 3. Referring to the categorization (Witkin et al., 1977), in the score range 0-11 individuals are categorized into Field Dependent (FD) cognitive style, and in the score range 12-18 individuals are categorized into Field Independent (FI) cognitive style. In this score range, the results show that of the 21 students as the research sample, 12 students were categorized into the FD cognitive style and 9 students were categorized into the FI. The tendency is that there are more students in the FD category than FI (see Table 3). The FI cognitive style is a characteristic of individuals who are able to analyze in separating elements from their context more analytically, while the FD cognitive style is a characteristic of individuals who process information globally so that their perceptions are easily affected by environmental changes (Purnomo et al., 2017). The results of this study are in line with the findings of previous studies, that the tendency of students' cognitive styles to vary and relatively balanced between FD and FI cognitive styles (Verawati et al., 2021).

**Table 3.** Cognitive style test results

No	Cognitive style	Score	n (21)
1	Field Dependent	0-11	12
2	Field Independent	12-18	9

The measurement of each individual's critical thinking based on cognitive style shows the results as presented in Table 4. Each student's critical thinking ability is measured before learning using PBL (as pretest) and after learning using PBL (as posttest).

**Table 4.** Results of measuring students' CT ability for each cognitive style

No	Cognitif Style	Pretest		Posttest		n-gain	Criteria
		CT score	Criteria	CT score	Criteria		
1	FI	-3	Not critically	18	Very critically	0.78	High
2	FI	0	Less critically	16	Critically	0.67	Moderate
3	FI	-4	Not critically	14	Critically	0.64	Moderate
4	FI	-2	Not critically	13	Critically	0.58	Moderate
5	FI	-1	Less critically	16	Critically	0.68	Moderate
6	FI	-1	Less critically	15	Critically	0.64	Moderate
7	FI	-5	Not critically	15	Critically	0.70	High
8	FI	-3	Not critically	13	Critically	0.60	Moderate
9	FI	-2	Not critically	14	Critically	0.62	Moderate
10	FD	-3	Not critically	15	Critically	0.67	Moderate
11	FD	0	Less critically	13	Critically	0.54	Moderate
12	FD	-1	Less critically	15	Critically	0.64	Moderate
13	FD	-4	Not critically	19	Critically	0.82	High
14	FD	2	Less critically	12	Critically	0.45	Moderate
15	FD	-5	Not critically	17	Critically	0.76	High
16	FD	-5	Not critically	15	Critically	0.69	Moderate
17	FD	-4	Not critically	22	Very critically	0.93	High
18	FD	-2	Not critically	18	Very critically	0.77	High
19	FD	0	Less critically	15	Critically	0.63	Moderate
20	FD	-2	Not critically	13	Critically	0.58	Moderate
21	FD	-1	Less critically	18	Very critically	0.76	High
Averages		-2.20	Not critically	15.45	Critically	0.67	Moderate

Measurement of students' critical thinking ability for each cognitive style has been carried out (see Table 4). From the 12 students classified as FD, the results of the pretest showed as many as 7 students with not critically criteria and 5 students with less critically criteria. In the posttest, it was found that 9 students had critical criteria and the rest (3 students) were very critical. On the one hand, in the group of students belonging to FI (9 students), in the pretest, it was found that 6 students had no critical criteria and 3 students were less critical. In the posttest, it was found that 8 students had critical criteria and only 13 students were very critical.

The calculation of the average score of students' critical thinking has been carried out, where the results of the pretest show that students are in the criteria of not critically and less critically, while the posttest with critically and very critically criteria. The analysis of the increase in the critical thinking ability score of each student has been measured, and the results show the

criteria for increasing the score are in the moderate and high categories. In general, the average score of students' critical thinking ability in the pretest is -2.20 with the criteria not critically, and after the implementation of the PBL model, the average posttest score is 15.45 with the critical criteria, with an n-gain score of 0.67 with moderate criteria. Descriptive analysis with average critical thinking scores based on two categories of cognitive style (FI/FD) is presented in Table 5.

The critical thinking score for the FD cognitive style (N = 12) was -2.08 in the pretest with no critical criteria, and after the implementation of the PBL model, it increased to 16.00 on the posttest with critical criteria (n gain of 0.69 with moderate criteria). For the FI cognitive style (N = 9) the pretest score was -2.33 with not critically criteria, and 14.89 for posttest with critical criteria (n gain of 0.66 with moderate criteria). Overall, the increase in students' critical thinking scores was on the same criteria, from not critically to critically.

**Table 5.** Critical thinking scores for each cognitive style

No	Cognitive Style	N	Pretest		Posttest		n-gain	Criteria
			CT score	Criteria	CT score	Criteria		
1	FD	12	-2.08	Not critically	16.00	Critically	0.69	Moderate
2	FI	9	-2.33	Not critically	14.89	Critically	0.66	Moderate
Average			-2.20	Not critically	15.45	Critically	0.67	Moderate

Statistically, the results of measuring critical thinking ability in Table 5 need to be tested. The results of the different test (t-test) of students' critical thinking

ability based on the FD/FI cognitive style as presented in Table 6. As a prerequisite for testing, homogeneity and normality tests were carried out as presented in

Table 6. The results showed that the data variance was homogeneous and normally distributed (sig. > 0.05).

**Table 6.** The results of the homogeneity and normality test based on cognitive style

Homogeneity test		Normality test	
Levene statistic	Sig.	Kol-Smir. statistic	Sig.
1.168	0.293	0.960	0.200

**Table 7.** The results of the different test (t-test) of students' CT ability based on cognitive style

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.321	1	0.321	0.084	0.775
Within Groups	72.917	19	3.838		
Total	73.238	20			

The results of the different test (Table 7) show a significance value > 0.05. In accordance with the criteria for testing the hypothesis, it can be interpreted that there is no significant difference in students' critical thinking ability between the two FD/FI cognitive styles in the posttest after the implementation of the PBL model. This means that the PBL model can train students' critical thinking ability with FD and FI cognitive styles.

The PBL model has been convincingly effective in improving students' critical thinking ability in phytochemistry courses. The conduct of the PBL model in medical students deserves consideration for its widespread use, especially to improve students' critical thinking ability (for both FD/FI cognitive style modes). The conduct of PBL in the learning system and curriculum at medicine colleges helps prepare prospective graduates with the knowledge and skills needed, it trains medical students in more complex health care systems (Hoffman et al., 2006). The implementation of the PBL model in medical students has long been initiated to be integrated into the learning system and curriculum (Christopher et al., 2002; Kinkade, 2005), however, empirical support for the application of the PBL model to medical students is still weak, becoming an obstacle. Finally, the findings in this study should be a reinforcing factor that the PBL model for medical students, especially in phytochemistry courses, has been able to improve their critical thinking ability.

Pedagogy in PBL was developed as a platform to develop problem solving skills, independent learning and the ability to work in teams (Radcliffe & Kumar, 2016). The findings from our study, it is precisely the PBL model can improve critical thinking ability. In learning, the PBL model conducts in five phases of learning, namely: student orientation to problems, organizing students to learn, guiding group

investigations, developing and presenting work, and analyzing and evaluating problem solving processes.

The interaction built in the PBL Model is student-centered learning, this emphasizes the activity and effectiveness of discussion and group work to identify effective solutions in problem solving (Luo, 2019). In our study, the interaction between individuals in a group directly motivates students in learning, and this is a strong asset to build positive learning according to the expected goals. In a previous study it was found that positive perceptions of the scaffolding approach in PBL contributed to building effective learning (Beagon et al., 2019). The presentation of theory and learning experiences with the principle of positive interaction built into PBL has an impact on superior educational outcomes (Radcliffe & Kumar, 2016).

Finally, based on the findings in our current study, we recommend applying the PBL model more intensively to medical students, this is to train them to work together, gain the required knowledge and skills, and above all to gain critical thinking, which helps them in more complex health care systems in many cases found.

## Conclusion

The results of the study show that the PBL model has been convincingly effective in improving students' critical thinking ability in phytochemistry courses for both FD/FI cognitive style modes. Based on these findings, we recommend the use of the PBL model in extensive and intensive learning to develop critical thinking ability of medical students.

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