THE CRITICAL THINKING ABILITY OF STUDENT WITH LOW PRIOR KNOWLEDGE WHO LEARN USING PROBLEM BASED LEARNING

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Abstrak

Kemampuan berpikir kritis merupakan kemampuan yang diperlukan pada abad 21 sehingga diharapkan dimiliki oleh siswa, tidak terkecuali siswa dengan kemampuan awal yang rendah. Penelitian ini bertujuan untuk menganalisis kemampuan berpikir kritis mahasiswa yang belajar menggunakan PBL (*Problem Based Learning*) dengan kemampuan awal matematis rendah. Penelitian ini merupakan penelitian kualitatif dengan pendekatan deskriptif melibatkan dua orang mahasiswa pendidikan matematika yang mengulang mata kuliah analisa vektor. Instrumen penelitian terdiri dari tes kemampuan berpikir kritis dan pedoman wawancara. Hasil yang diperoleh adalah subskil kemampuan berpikir kritis *inference* tercapai oleh mahasiswa. Sementara itu, sub-skill *analysis*, *applying gained solution, inference* dan *concluding the solution* belum tercapai. Hasil tersebut mengindikasikan bahwa mahasiswa dengan kemampuan awal rendah yang belajar menggunakan PBL masih memiliki kemampuan berpikir kritis yang rendah.
Kata kunci: Berpikir Kritis; Kemampuan Awal; *Problem Based Learning*

Abstract

In the twenty-first century, having an ability for thinking critically is essential. Students, including those with low prior knowledge in mathematics, are expected to have this ability. Therefore, the purpose of this study is to evaluate students' critical thinking abilities when they learn using PBL (Problem Based Learning). This study uses a qualitative approach. his research is a qualitative research with a descriptive approach involving two mathematics education students repeating vector analysis courses. The research instrument consists of tests of critical thinking skills and interview guidelines. The results obtained are the subskills of inference critical thinking skills achieved by students. Meanwhile, the sub-skills of analysis, applying gained solutions, inference and concluding the solution have not been achieved. These findings show that PBL learners with low prior knowledge still have limited critical thinking abilities.

Keywords: Critical Thinking; Prior Knowledge, Problem-Based Learning

INTRODUCTION

In twenty first century, student must able to achieve certain skill to enter the labor market. One of the abilities required is an ability for critical thinking (Khoiri et al., 2021). According to Uribe-Enciso et al., this capacity is often helpful for assisting someone in decision-making and engaging in social, political, business, and other connections (Uribe-Enciso et al., 2017). Critical thinking specifically in mathematics entails acts like creating hypotheses, alternate perspectives on an issue, questions, potential answers, and plans for studying the subject (Ennis, 1985). Critical thinking is therefore crucial for making decisions and developing alternate viewpoints on certain problems. Due to the importance of critical thinking abilities, developing these abilities has been one of the most important learning objectives for more than a century (Kaliky & Juhaevah, 2018; Jatmiko et al., 2018).

Problem-based learning (PBL) is one of the lessons that is thought to be able to enhance students' critical thinking abilities (Mulyanto & Indriayu, 2018; Saputra et al., 2019; Sholihah & Lastariwati, 2020). PBL steps are made up of five ladders: (1) presenting the problem to the student, (2) setting up the student's learning environment, (3) assisting the students as they conduct independent and group investigations, (4) designing and presenting the problem-solving procedures, and (5) critically evaluating the problem-solving process. Because PBL employs main problem as a beginning point for learning and the pursuit of knowledge, it is an effective teaching strategy for the development of learners in the 21st Century (Afdareza et al., 2020). Students are able to solve problems through this learning by considering a variety of variables and making the best choices (Razak et al., 2022).

The effectiveness of problem-based learning in developing critical thinking abilities depends on several of factors. Prior knowledge is one of them (Kania & Bonyah, 2023). This factor becomes one of the keys to effective learning (Mahanal et al., 2019). Meanwhile, students will encounter numerous new situations in PBL.

Students will recall their prior knowledge stored in long-term memory when presented with unexpected information (Alreshidi, 2023). By making connections between prior knowledge and new information, students create new knowledge (Rach & Ufer, 2020).

Additionally, PBL has developed into one of the most popular teaching models at the university level, even for students who are retaking a course. Those student mostly have low prior knowledge on the subject they are repeating. Student with low prior knowledge cause learning activities focus on giving scaffolding to them about the situation in the problem (Jailani et al., 2017). Peters also agree that from cognitive load theory, if learners do not have the basic mathematical knowledge to support the problem-solving process, they will find it incredibly difficult to participate, resulting in minimal advantage from the learning environment (Peters, 2015).

Several studies have examined the effect of increasing critical thinking skills using PBL in mathematics including Saputra et al. (2019), Kertiyani et al. (2022), Thorndahl & Stentoft (2020), Miterianifa et al. (2019). However, few studies analyze critical thinking abilities of students who study using PBL by taking consideration of their prior knowledge. Additionally, there has not been much study done at the university level on PBL-based critical thinking abilities for students who are repeating courses. Those student mostly have low prior knowledge on the subject they are repeating. Thus, this study intends to analyze the critical thinking skills of students who learn to use PBL with low prior knowledge.

Meanwhile, a person's critical thinking ability can be seen from indicators of critical thinking ability. Many experts offer indicators of critical thinking skills, including Ennis (1985) and Facione (2015). Furthermore, some researchers have combined several indicators of critical thinking skills according to research needs. Seventika's research conducted an analysis of critical thinking skills based on indicators from Angelo (1995) and Facione (2015) (Seventika et al., 2018). On the other hand, another study from Basri (2019) examines critical thinking abilities

using the critical thinking skills sub-skills from Facione (2015) by modifying the indicators of these sub-skills according to research needs. In this study, the ability to think critically is seen from a combination of indicators and sub-skills offered by Facione (2015) Angelo (1995) and Basri (2019) namely interpretation, analysis, applying gained solutions, inferences and concuding the result.

According to several research (Jailani et al., 2017; Peters, 2015), students with low prior knowledge find it challenging to engage in learning, particularly in learning models that foster critical thinking, like PBL. The purpose of this study was to analyze student critical thinking abilities who learn PBL with low prior knowledge. The findings of this study can be utilized to help decide whether problem-based learning is the effective learning model to help students with low prior knowledge develop their critical thinking abilities.

METHOD

This study aims to obtain an analysis of critical thinking skills of students with low prior knowledge who learn using PBL. Thus, this research is a qualitative research with descriptive approach.

The subjects of this study were two students who attended an intermediate semester course in Vector Analysis courses. The two students had previously received vector analysis course material, but repeated it again in the intermediate semester. The two people were in the same class before and were taught by the same lecturer. The two people are said to have low prior knowledge because they previously received a D score (below 55 out of 100) in the previous course. The intermediate semester lecture this time is the first intermediate semester lecture in vector analysis courses.

The research instruments in this study were tests of critical thinking skills and interview guidelines. The critical thinking ability test was conducted in the form of an essay question which had one question as indicated in Figure 1. Unstructured

interviews were conducted in between to gather data related to responses that did not show up in the writing.

First, the subjects studied using PBL for 7 meetings to study two topics, namely vectors in geometric studies and vectors in coordinate systems. Then, at the 8th meeting, the subject was given a critical thinking ability test. Subjects were also interviewed regarding the answers to the tests and the experience gained during the learning process.

Perhatikan situasi berikut

Saat UTS Analisa Vektor dilakukan, terdapat soal sebagai berikut

Misalkan dimiliki dua vektor $\vec{A}$ dan $\vec{B}$. Tunjukan bahwa $\left|\vec{A}+\vec{B}\right| \leq \left|\vec{A}\right| + \left|\vec{B}\right|$

Seorang mahasiswa menjawab sebagai berikut

Berikan pendapat Anda mengenai jawaban mahasiswa tersebut. Jika ada yang keliru, berikan perbaikan atas jawaban tersebut.

Figure 1. The Problem in Critical Thinking Test

This study uses data analysis techniques in the form of descriptive narrative using the Miles and Huberman models ((Miles et al., 1994). This model consists of data collection, data reduction, data presentation and conclusions. Data was collected through written tests and interviews. Then the data is reduced. Reduction is done by grouping data into categories of critical thinking skills sub-skills in Table 1. The reduced data is then presented in the form of tables or graphs for later conclusions.

Table 1. The Category of Critical Thinking Sub-skill (Adapted from Facione 2015, Angelo 1995 dan Basri (2019))

Number	Critical Thinking Sub Skill	Indicator
1	Interpretation	Student understand the mathematical symbol used in problems
2	Analysis	Students can correlate information with concepts that will be used to solve the problem
3	Applying gained solution	Student uses the concept correctly in the solution
4	Inference	Students understand the logic of each step used to draw valid conclusions
5	Concluding the results	Student can write valid conclusion

RESULT AND DISCUSSION

Critical thinking test was conducted to research subject after they learn using PBL for 7 meetings. The student answer from critical thinking test was analyzed by researcher. After that, the part of the answer was grouped to the subskill of critical thinking adapted Facione (2015) Angelo (1995) and Basri (2019) as shown in Table 1 at data analysis section. Then, the researcher conducted interviews to understand more deeply about the students' answers on the test.

Below the analysis of student critical thinking from first subject (S1) and second subject (S2).

1. **First Subject (S1)**

The answer of S1 is presented in Figure 2. Below the analysis of student answer in Figure 2 according to the indicator of critical thinking.
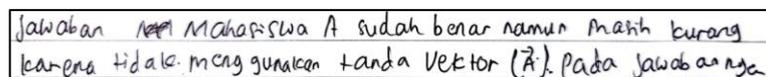

Figure 2. The Answer of S1

Subskill Interpretation of S1

According to Figure 2, S1 write the answer using mathematics symbol. It means that the critical thinking skill, namely interpretation has emerged in S1. Furthermore, the researcher conducted interviews to find out students' understanding of the meaning of the symbols used in the questions. The following are interviews conducted by researchers and S1.

Researcher   : What is this symbol refers to? (Pointing at $|\vec{A}|$)
S1   :The length of vector
Researcher   : Isn't that the symbol for absolute value?
S1   : Yes, but not in this case. Because, we are talking about vector.

In the interview excerpt, S1 understands that the symbol used is a symbol for the length of a vector. Therefore, S1 able to do the interpretation skill accurately because S1 understand all the symbol provided in question.

Subskill Analysis of S1

In the subskill analysis, the data in Figure 2 shows that S1 analyzes concepts which need to be corrected in the answers provided on the test, namely the concept of vector length. Nevertheless S1 did not correlate the dot product concept and the concept of maximum value of cos α to fix the answer. To examine the idea of S1, the researcher interviews S1.

Researcher   : What concept need to be corrected to fixed the answer?
S1   : The concept of how to write the length of vector symbol
Researcher   : Do you thing there is another concept that include in the answer process that we need to add in the proof?
S1   : No, I think all the steps are right
Researcher   :Why $\left|\vec{A}+\vec{B}\right|^2 = \left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$?
S1   :Hmm, because we multiplied $\left|\vec{A}+\vec{B}\right|$ by $\left|\vec{A}+\vec{B}\right|$?
Researcher   :What is the result?
S1   : $\left|\vec{A}^2 + \vec{B}^2 + 2\vec{A}\vec{B}\right|$
Researcher   :What is the operation between vector A and B in this $(2\vec{A}\vec{B})$?
S1   : The multiplication

Researcher	:Yeah, we know there are two operation between two vectors, the dot and cross. Which one?
S1	:Hmmm, the dot?
Researcher	: Why?
S1	:Because there is $\cos \alpha$ in the next step.
Researcher	: What if there is no $\cos \alpha$ in the next step? Are you sure that operation between vector A and B in $(2\vec{A}\vec{B})$ from $\left\vert \vec{A}^2 + \vec{B}^2 + 2\vec{A}\vec{B} \right\vert$ is the operation of dot?
S1	: No, I'm not really sure about that.

In the interview, it was seen that S1 did not have sufficient understanding of the operations used to produce $\left\vert \vec{A}^2 + \vec{B}^2 + 2\overrightarrow{\vert A\vert\vert B\vert} \cos \alpha \right\vert$. This means that students still do not understand the dot multiplication concept used in the problem. Therefore, S1 unable to do sub skill analysis because S1 can't correlate all the concept used to solve the problem.

Subskill Applying Gained Solution of S1

In subskill applying gained solution, Figure 2 indicates that S1 give the right answer to fix the wrong answer in the problem. S1 fix the symbolization for the length of vector. The interview was conducted to S1 to investigate the answer.

Researcher	: In which part the symbol of length vector needed to be fixed?
S1	: In all vector
Researcher	:Why you just write the symbol for vector A?
S1	: I mean for vector B, too

The interview show that the symbol of length vector for vector A and B required to be fixed. It suggest that S1 did not apply the gained solution because S1 did not write the detail in which part need to be fixed.

Subskill Inference of S1

In subskill inference, student have to understand the logic of each step used to draw valid conclusions. According to Figure 2 and the interview of S1

in subskill analysis section before, S1 missed the steps between $\left|\vec{A} + \vec{B}\right|^2 = \left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$. S1 don't know how to get $\left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$ from $\left|\vec{A} + \vec{B}\right|^2$. It indicates subskill inference did not emerge in S1 because S1 did not understand all the logic of each step in the answer.

Subskill Concluding the Solution of S1

In subskill concluding the solution, Figure 2 shows that S1 write the conclusion, namely "the answer is right but there are some parts that need to be fixed because the answer does not use the symbol $|\vec{A}|$". Although S1 write the conclusion, the conclusion not really decide weather S1 agree or not with the proof provide in the problem. Researcher conduct interview to and deep understanding about the conclusion from S1.

Researcher   : do you agree with the proof given in the problem?
S1   : Yes, but there are some parts that need to be fixed
Researcher   : So, do you agree or not with the proof given?
S1   :No, I disagree

From the interview above, S1 conclude that the answer is wrong, but the conclusion not really decide weather S1 agree or not with the proof provide in the problem. It suggest that S1 was unable to concluding the solution because S1 did not write the valid conclusion.

2. Second Subject (S2)

The answer of S2 is shown in Figure 3.

Figure 3. The Answer of S2

Below is presented about interviews conducted by researchers on each sub-skill of critical thinking skills according to S2 answer in Figure 3.

Subskill Interpretation of S2

Accorfing to Figure 3, S2 understand how to read the symbols of the things asked in the problem. This sort of answer similar to S1 answer. The following are excerpts of interviews between researchers and S2.

Resercher : *Do you know what information provide in problem and the thing that asked in problem?*
S2 : *Ya, there are problem and student answer. We have to conclude weather the student answer is right or wrong.*
Researcher : *What is the student answer about in here? (Pointing the problem)*
S2 : *Student prove that the length of vektor A plus B equals to the length of vektor A plus the length of vector B*
Resercher : *So, this is the symbol of length vector? Not absolute value of A?*
S2 : *No, it is not.*

The interview show that S2 understand about the information provide in test and the problem asked. Therefore, the sub skill interpretation emerged in S2 because S2 understand the mathematical symbol used in the question.

Subskill Analysis of S2

In the subskill analysis, Figure 3 indicates S2 unable to correlate all the the information and concept to slve the problem. S2 also found the difficulties in understanding the concept of dot product which used in the problem. Here is the interviewed between S2 and researcher.

Researcher : Why $\left|\vec{A} + \vec{B}\right|^2 = \left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$?

S2 : Hmm, because we multiplied $\left|\vec{A} + \vec{B}\right|$ by $\left|\vec{A} + \vec{B}\right|$?

Researcher : What is the result

S2 : $\left|\vec{A}^2 + \vec{B}^2 + 2\vec{A}\vec{B}\right|$

Researcher : What is the operation between $\left|\vec{A} + \vec{B}\right|$ by $\left|\vec{A} + \vec{B}\right|$

S2 : The multiplication

Researcher : So, we multiplied like this $\left|\vec{A} + \vec{B}\right| \times \left|\vec{A} + \vec{B}\right|$

S2 : Hmmm, yea

Researcher : So what is the result?

S2 : $\left|(\vec{A} + \vec{B}) \times \overrightarrow{(A + \vec{B})}\right|$

Researcher : Is that the multiplication between number or vector?

S2 : Vector …. I think vector

Researcher : So this is cross product

S2 : No, but wait, yes this is the symbol for cross product

Researcher : What is the result?

S2 : (silent)
I don't know the result is too complex, I don't know why cos α appear in the next step of proof.

From the interview between S2, S2 also found difficulties in understanding the concept of dot and cross product. This is similar to S1. Therefore, the S2 was unable to correlate all the concept used to solve the problem.

Subskill Applying Gained Solution of S2

In subskill applying gained solution, S2 give the right answer to fix the wrong answer in the problem. S2 fix the symbolization for the length of vector. But, S2 did not write all the part that need to be fixed. S2 did not write the revision

for $|A + B| = |A| + |B|$ and $|A + B| < |A| + |B|$. An interview conducted to S2 to ensure S2 answer.

Researcher   :*Do you think the symbol in this $|A + B| = |A| + |B|$ and $|A| + |B| < |A| + |B/$ needed to be fixed?*
S2   :*Hmm, yes*
Researcher   :*But, why don't you write that part in your answer?*
S2   : *I thought, the fixation part is sufficient enough. But, now I think I should write all.*

From the interview, S2 did not write all the fixation part. Hence, S2 unable to applying gained solution because there is another fixation that was not written by S2.

Subskill Inference of S2

Similar to S1, the answer of S2 in the test and the interview provided in analysis section of S2 indicated that they both missed the steps between $\left|\vec{A} + \vec{B}\right|^2 = \left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$. They don't know how to get $\left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$ from $\left|\vec{A} + \vec{B}\right|^2$. S2 also did not understand why $-1 \le \cos\alpha \le 1$ must be written, instead of using $\cos\alpha \le 1$. The interviewed conduct to ensure S2 answer in test.

Resercher   : *In this part, are you sure that the symbol of vector length is the only thing that need to be fixed?*
S2   : *Yes, I think just that*
Resercher   : *How about the part$-1 \le \cos\alpha \le 1$? Is that all necessary in the proof given?*
S2   : *Ya, we need that*
Resercher   : *Is that okay if we just write $\cos\alpha \le 1$ to proof that the length of vektor A plus B equals to the length of vektor A plus the length of vector B?*
S2   : *Hmm, I think the statement $-1 \le \cos\alpha \le 1$ is right. We can use that in that proof.*
Resercher   : *Yes, but if I just write $\cos\alpha \le 1$, is the proof still right?*
S2   : *Yes, maybe*
Researcher   : *If I just write $-1 \le \cos\alpha$, is the proof still right?*

S2   :Hmm, I think yes, sorry I'm confused.

From the interview, the S2 did not know the logical effect of $-1 \leq \cos\alpha \leq 1$ written in the proof. It indicate that S2 unable to logically understand each step to draw a conclusion.

Subskill Concluding the Solution of S2

In subskill concluding the solution, S2 write the conclusion, namely "the answer is right but incomplete". S2 similarly write the same answer as S1. Even though S2 wrote the conclusion, it wasn't really clear from the conclusion whether S1 agreed or disagreed with the evidence presented in the problem. Interviews were conducted by the researcher to fully comprehend S2's findings.

Researcher : do you agree with the proof given in the problem?

S2   : Yes, some part need to be fixed, such as the symbol of vector
Researcher : So, in the end, do you agree or not with the proof given?
S2   :Maybe I almost agree
Researcher : If there are only two options, agree and disagree, which one you choose?
S2   : hmmm, I agree

From the interview above, S2 still confused to give the conclusion. It suggest that S2 uanbel to give the valid conclusion.

According to the study's findings, in subskill interpretation, S1 and S2 understand all the symbol provided in question. However in the indicator analysis, the subjects unable to correlate all the information and concept used to solve the problem. In subskill applying gained solution, S1 and S2 unable to give the detail of the revision answer. Furthermore, in subskill inferences, both S1 and S2 unable to logically understand each step to draw a conclusion. Meanwhile, in the subskill concluding the solution, the subjects unable to give a valid conclusion. It implies that students with little prior information still have limited critical thinking skills because one of five indicator achieved by S1 and S2.

The result of this is consistent with Kania's research, which showed that mathematical background knowledge and critical thinking skills are positively correlated (Kania & Bonyah, 2023). Additionally, Dong et al.,(2020) demonstrated how prior knowledge affects the learning engagement. Moreover, another study from Rijal, et. al. also in line with ther result of this study. They found that PBL are more suitable for student with high prior knowledge, meanwhile student with low prior knowledge are recommended to use another learning model, such as Numberd Head Together to enhance the critical thinking skill (Rijal et al., 2021).

The correlation between problem-based learning and the emergence of critical thinking indicator

Furthermore, the tnterviews were conducted to find the correlation between problem-based learning and the emergence of critical thinking indicator in S1 dan S2.

Researcher : is the learning model used in the class really help you to understand all the symbol in vector?

S1 : Yes, the problem asks us to corelate the real world to the symbol. It makes us still remember that longer.

Researcher : Why you find difficulties to answer $\left|\vec{A} + \vec{B}\right|^2 = \left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$? Is there something in the learning that contribute to this difficulty?

S1 : Because the topic is quite hard. Although the learning gives us the chance to see the relation of the material with real world, and make us easier to understand the concept but we still have to remember the procedural step such as the definition of dot product. Besides, we still have to understand the idea where to start to proof, so that it still difficult to do the procedural step.

Researcher : So, the learning model help you to understand the concept?

S1 : Yes.

Researcher : But, doesn't really help you fluent in doing the procedural steps?

S1 : Yes, we still have to do the exercise by our self

Furthermore, researcher also do the interview to S2 about the emergences of critical thinking indicator related to the problem based learning.

Researcher   : *is the learning model used in the class really help you to understand all the symbol in vector?*

S2   : *Because when learn in class, we have many times to understand every problem given. The discussion really helps us to understand the problem, including the symbol use to solve the problem.*

Researcher   : *If the discussion really helps you to understand the problem, why you find difficulties to answer* $\left|\vec{A} + \vec{B}\right|^2 = \left|\vec{A}^2 + \vec{B}^2 + 2\overrightarrow{|A||B|}\cos\alpha\right|$ *?*

S2   : *Because I never experience or exercise about. (silent). I understand we have to multiplied the* $\left|\vec{A} + \vec{B}\right|$, *but I don't know the detail of the work after we multiplied that.*

According to the results of the interviews with S1 and S2 above, PBL help student to enhance conceptual understanding which required in subskill interpretation. This result in line with Suyanto (2019) who found that PBL can improve conceptual understanding. However, interview with S1 and S2 also revealed that does not completely aid students in to become fluency in procedural step. Procedural step is the capacity to carry out procedures adaptably, precisely, efficiently, and appropriately (Lee et al., 2019). The lack of procedural fluency cause students have difficulty in analysis, apply gained solution and inferences, especially for low prior knowledge student. Procedural fluency can be enhanced by practise repetitive exercises (Foster, 2018) which is lacking in the PBL employed in this study.

CONCLUSION

According to the study's findings, the subskills of inference critical thinking skills achieved by students because student comprehend each symbol that has been given in question when performing subskill interpretation. Meanwhile, the sub-skills of analysis, applying gained solutions, inference and concluding have not been achieved. In the analysis subskill, the subjects unable to correlate all the information and concept used to solve the problem. In subskill applying gained

solution, student unable to give the detail of the revision answer. Furthermore, in subskill inferences, student unable to logically understand each step to draw a conclusion. Meanwhile, in the subskill concluding the solution, the subjects unable to give a valid conclusion.

The finding of this study also suggested that PBL used in this research unable to enhance procedural step required in critical thinking subskill, such as analysis, apply gained solution and inferences. Future research may concentrate on examining how PBL, when combined with repetitive practice at the end of learning, improves student critical thinking subskill, such as analysis, apply gained solution and inferences.

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