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Problem-based learning supported by arguments scaffolding that affect critical thinking teacher candidates

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Abstract

This study aims to determine the effect of the PBL model with argumentation scaffolding on changes in the critical thinking of teacher candidates teachers in terms of personality type and gender. This research is a quasi-experimental research with one group pretest-posttest design. 28 prospective teachers who take the algebraic structure course are the samples of this study. Critical thinking skills scores were analyzed descriptively and statistically with normality test and paired t-test. The results showed that the application of PBL with argumentation scaffolding was effective in increasing the critical thinking of prospective teachers from the criteria of "less critical" to "critical enough" and the n-gain results were categorized as moderate when viewed from the aspect of personality type. and gender. The existence of differences in critical thinking that is influenced by gender and personality type is a research finding that must be considered to determine the learning model.

Keywords: Problem-based learning, gender, critical thinking, personality type;

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1. Introduction

In the industrial era 4.0, a country needs to move quickly to adapt and solve problems with new alternatives to anticipate technological developments. The human resources of a country will have high competitiveness if they have good abilities in problem-solving and logical thinking (critically and creatively). This can be seen from the results of several studies which state that the ability to think critically will determine a person's endurance/competitiveness to be the highest in achieving success in learning, working, and living in the industrial era 4.0 (Bermingham, 2015; Kivunja, 2015; Wahyudi et al., 2019; Zare & Othman, 2015). Good critical thinking and communication skills will help a person adapt to changing conditions in the academic context and the workplace (Mason, 2007; F. A. Yusuf & Adeoye, 2012). In recent years, The ability to think critically has become a top priority for the Indonesian government, especially in the field of education (R. M. Sari et al., 2019). This priority can be seen in the learning objectives that exist in the Indonesian national curriculum, critical thinking skills are one of the standards for student learning mastery (Saputri et al., 2019; Wahyudi et al., 2019)

Critical thinking skills are an important element for understanding new information and acquiring knowledge (Alwehaibi et al., 2017). According to Ennis, critical thinking skills can be observed through the basic elements that critical thinkers must have in problem-solving, namely; Focus, Reason, Inference, Situation, Clarity, and Overview (Fisher, 2000). One of the important skills that students must have in problem-solving is critical thinking (Johnson & Johnson, 2009). Other researchers (Fisher, 2000; Suripah & Retnawati, 2019) states that cultivating students to solve problems in the learning process is an effective way to improve critical thinking. Arend states that (Richard I. Arends, 2008) The training provided to students consistently by the instructor through focused discussion is a good way to ensure students have good thinking and problem-solving skills. Critical thinking skills are intellectual potential that can be improved by using appropriate learning methods (Saputra et al., 2019). The success of students in improving their critical thinking skills will be greatly influenced by the skills of the teacher in determining appropriate and appropriate learning methods (Darling-hammond et al., 2020; Munawaroh et al., 2018; Sofiani et al., 2017).

Problem-based learning models can train students' critical thinking, this has been shown from previous studies. Because this learning model encourages students to construct their knowledge so that students better understand what they are learning (Hardiyanto & Santoso, 2018). The steps in applying the problem-based learning model include 5 phases: (1) Students are given orientation about a problem; (2) Directing and conditioning students to research; (3) Students conduct investigations individually and in groups with the assistance of the teacher; (4) Develop and present artifacts/findings; (5) Analyze and examine every step that has been taken (evaluation) in the process of overcoming the problem (Richard I. Arends, 2008).

The success of students in problem-based learning models varies, some can be trained quickly and some can be slow. Abdurrahman (Abdurrahman et al., 2018) states that teachers must provide stimulus or assistance (treatment) according to the difficulties associated with each student. Scaffolding provides the possibility for students to reach the zone of proximal development (ZPD) through the help of teachers or peers to solve problems (Belland & Evidence, 2017; Frederick et al., 2014; Reynolds, 2017). Assistance is given in full at an early stage, and assistance is gradually reduced until finally, students can complete themselves without assistance is the concept of scaffolding by Wood, Bruner, and Ross (Anghileri, 2006). The ability to solve problems of low and high ability students develops well through the application of scaffolding so that all students are able to solve problems (Cheng et al., 2015). So that the problem-based learning model will get maximum results if

its application is followed by the use of scaffolding. Mathematics is one of the fields of study that needs to apply to the scaffold. Mathematics is formed from human experience in his world empirically. Algebra is one of the parts studied in mathematics besides analysis and geometry. However, not all material in algebra, especially algebraic structures, can be understood by students. Students who have just entered the university level have low critical thinking skills (Nold, 2017).

Some of the application of problem-based learning models and scaffolding by previous researchers are described as follows; The application of the Team Assisted Individualization model supported by scaffolding is able to improve students' mathematics learning achievement (Ihechukwu, 2020), Scaffolding innovation to help solve problems (Cheng et al., 2015), designing scaffolding forms that consider students' ability to control cognitive abilities for reflective thinking skills (An & Cao, 2014), achieving independence through the application of scaffolding and effectiveness of metacognitive scaffolding in mathematics learning (Dagoc & Tan, 2018), Problem-based learning is a good solution to improve critical thinking skills (Aini et al., 2019). Although there are many studies on the application of problem-based learning (PBL) and scaffolding, no research has been found that collaborates with problem-based learning models with scaffolding arguments. The scaffolding used considers metacognitive abilities and considers ZPD in the application of problem-based learning models in group theory and subgroup theory in algebraic structure courses. In addition to learning strategies and models, many factors influence students' critical thinking, namely factors that exist in students called internal factors, including personality type and gender.

Some research results state that students' critical thinking skills in Indonesia are still low (Hidayati & Sinaga, 2019; Syahrial et al., 2019; Tanudjaya & Doorman, 2020). Students' critical thinking skills in solving problems that are influenced by differences in personality types show different results (Fitriana et al., 2018; Rosidin et al., 2019; Thadea et al., 2018). In fact, in the learning process, many teachers do not pay attention to the personality/characteristics of students (Halder et al., 2010).

Gender was not found to be a significant predictor of posttest scores on critical thinking ability (Rudd et al., 2000). The results Permani & Prabawanto showed that (Wahyudi et al., 2019) there was no difference in the critical thinking skills of male and female students who tended to fulfill the four determined critical thinking indicators, however, in solving questions, female students are more systematic and careful than male students (Permani & Prabawanto, 2019). Sacli and Demirhan (Scali & Derirhan, 2011) found no difference between gender in critical thinking skills. The results of Yousefi and Mohammadi's research (Yousefi, 2016) stated that critical thinking and reading comprehension had a significant correlation, but students' critical thinking did not differ significantly when viewed from gender and level of proficiency. In contrast to the results of Shubina & Kulakli which state that gender differences and levels of trust between teachers and students affect the development of the quality of critical and creative thinking (Shubina & Kulakli, 2019). Male students have better critical thinking and problem-solving skills (Rodzalan & Saat, 2015). The mathematical critical thinking of female students who use the Knisley mathematical model is higher than that of male students (V. T. A. Sari & Nurfauziah, 2019). So there is still a debate about the results of using gender as a predictor in describing students' critical thinking skills. This study aims to explore the effectiveness of problem-based learning models with scaffolding to improve the critical thinking skills of teacher candidates in terms of personality types and gender.

Hypothesis:

H0: Students' critical thinking is no different before and after the application of problem-based learning models with scaffolding Argumentation;

H1: Students' critical thinking is different before and after the application of problem-based learning models with scaffolding Argumentation.

The criteria are as follows:

If sig. ≥ 0.05 then H1 is accepted;

If Sig. < 0.05 then H0 is rejected.

2. Methodology

2.1. Research design

This research belongs to the type of quasi-experimental research, in which a one-group pretest-posttest only design was carried out (Gall et al., 2003). In this study, the subjects received the same treatment, namely problem-based learning model (PBL) with scaffolding argumentation. The experimental design used is the one group pre-post test version only.

2.2. Participants

The subjects of this study were prospective teachers of the Mathematics Education Study Program, Faculty of Science and Technology, Universitas Islam Negeri (UIN) Walisongo. The research sample consisted of 28 students (12 boys and 16 girls) in the fourth semester who took the algebraic structure course for the 2020-2021 academic year.

1.3. Data collection tools

The grouping of students into personality types according to Galen classifies human personality into four types, namely sanguine, choleric, melancholy, and phlegmatic using a test instrument adopted from Florence Littauer (Thadea et al., 2018). The critical thinking ability test instrument used was developed from the main elements of FRISCO (Focus, Reason, Inference, Situation, Clarity, and Review) (Fisher, 2000; Fitriana et al., 2018) and problem-solving cycle using Stenberg's opinion ('Problem identification, problem definition, strategy formulation, organization of information, allocation of resources, monitoring, and evaluation') (Sternberg & Sternberg, 2015) so that it refers to the skill indicators critical thinking include 1. Acknowledge that there is a problem that needs to be solved; 2. Identify the existence of important information in the problem; 3. Organize existing information to formulate problems; 4. Organizing/revealing, definitions, axioms, formulas, or rules to develop problem-solving strategies; 5. Decide or implement a plan to solve the problem; 6. Establish assumptions/conjectures based on the facts that have been learned as a problem-solving solution to predict the time required; 7. Checking the certainty of the steps taken in the problem-solving process by the strategy that has been designed; 8. Review each step in determining the solution by providing valid logical arguments for each conclusion drawn; and 9. Formulate alternative solutions (Cahyono et al., 2019).

1.4. Research procedure

This research procedure goes through a sequential process as follows; sample selection, pretest, learning treatment through a problem-based learning model (PBL) with scaffolding argumentation, posttest, and analysis of results. Reliability, expert validity and construct validity tests were carried out on the test instrument consisting of 4 pretest questions and 4 posttest questions, before being used by the sample.

Stratified scale (four scales) with the lowest score of 0 and the highest of 3 was used to analyze the score of critical thinking skills. Students' total critical thinking score (TBK) is interpreted into the critical category (64 <TBK ≤ 84), quite critical (43 <TBK ≤ 64), less critical (21 <TBK ≤ 43), and not critical (TBK ≤ 21). The effectiveness of the PBL model with argument scaffolding to improve critical thinking skills is marked with an increase in critical thinking scores.

The class is given teaching treatment through PBL (problem-based learning) model with argumentation scaffolding which aims to develop students' critical thinking. Teaching through the PBL (problem-based learning) model with metacognitive scaffolding through group material is carried out in four meetings, one meeting lasted 120 minutes. The stages of the problem-based learning model in this study through 5 phases consisting of; (1). Provide orientation about the problem to students; (2). Directing and conditioning students to research; (3). Students conduct investigations individually and in groups with the assistance of the teacher; (4). Develop and present the results/artifacts; (5). Analyze and examine every step that has been taken (evaluation) in the process of overcoming the problem. The following is a description of the steps using the problem-based learning model with argumentation scaffolding given by the teacher;

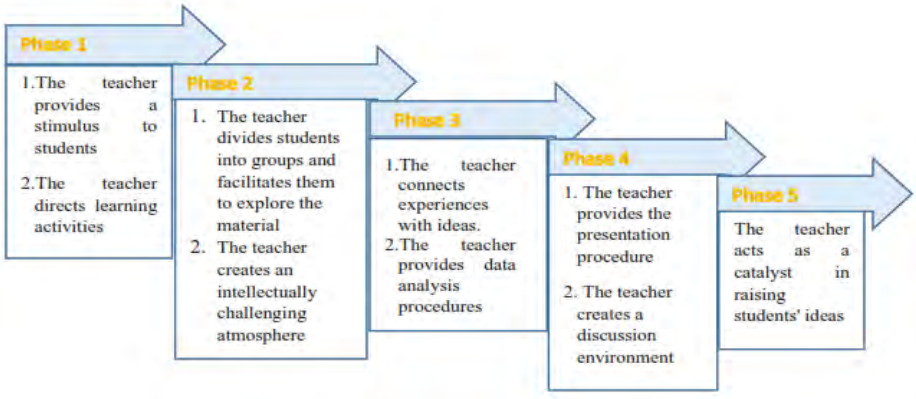

Image 1; Stages of the teacher using a problem-based learning model with argumentation Scaffolding

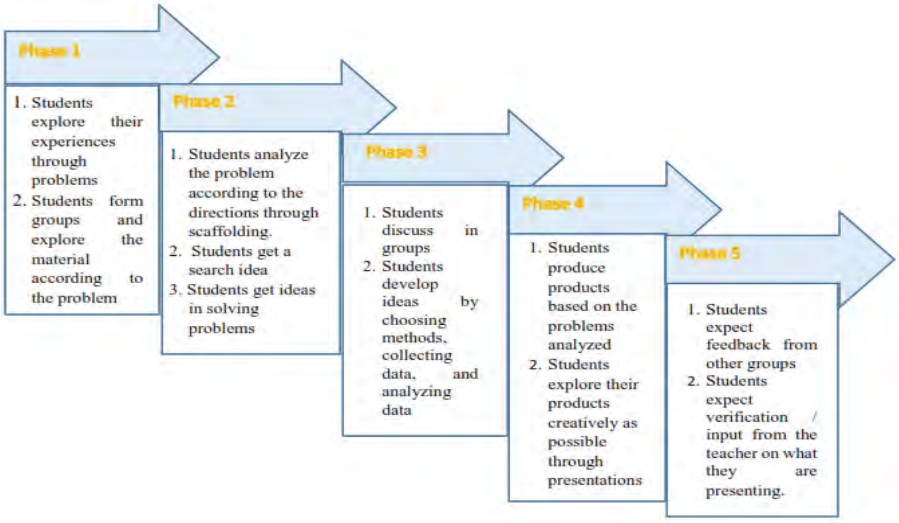

Image 2; Student Activities in Applying Problem-Based Learning (PBL) Model with argumentation Scaffolding

2.5. Data analysis

Analysis of critical thinking score was carried out descriptively and statistically, where the normality test and t-test were performed. If the normality test states that the data is normally distributed then the t-test can be used. The score improvement analysis uses the n-gain equation, including the criteria for a high score if the n-gain > 0.70, moderate if the score is in the range 0.30-0.70, and low if the score is <0.30.

3. Results and Discussion

The validation of students' critical thinking instruments was carried out by three mathematics education experts who are accustomed to teaching algebraic structures. The validation results of three experts stated that the instrument was able to measure students' critical thinking or was suitable for use with a little revision. The average score of an expert judgment obtained is 4.74 on a scale of 5, the complete data can be seen in the following table 1;

Table 1. The average score of instrument validation by experts

No	Validator	Conformity with indicators of critical thinking	Use of language	average score	Criteria
1	Validator 1	4,85	4,82	4,83	Worth using with a little revision
2	Validator 2	4,75	4,72	4,74	Worth using with a little revision
3	Validator 3	4,67	4,65	4,66	Worth using with a little revision
average score				4,74	Worth using with a little revision

The results of critical thinking tests on 28 research respondents consisting of 12 (43%) male teacher candidates and 16 (57%) female teacher candidates and classified based on Galen's personality type, data before and after being given the PBL model treatment with argumentation scaffolding from each student are presented in tables 2 and 3. The average critical thinking pretest score was 26.71 included in the "less critically" criteria, the average post-test score of critical thinking skills was 61.03 included in the "quite critically" and the average n-gain test was in the category of 0.61. "moderate". This shows a change in critical thinking towards the better of students (prospective teachers) after applying the problem-based learning model (PBL) with model scaffolding.

Table 2. Test results measuring critical thinking skills

No	Gender	Personality types	Pretest		Posttest		n-gain	Criteria
			Score	Criteria	Score	Criteria		
1	Male	Melancholy	35	less critical	74	critical	0,80	High
2	Female	Sanguinis	25	less critical	68	quite critical	0,73	High
3	Male	Sanguinis	20	less critical	52	quite critical	0,50	Moderate

4	Female	Phlegmatic	20	less critical	54	quite critical	0,53	Moderate
5	Female	Choleric	18	less critical	51	quite critical	0,50	Moderate
6	Male	Phlegmatic	16	less critical	48	quite critical	0,47	Low
7	Male	Choleric	18	less critical	56	quite critical	0,58	Moderate
8	Female	Phlegmatic	30	less critical	58	quite critical	0,52	Moderate
9	Female	Choleric	24	less critical	56	quite critical	0,53	Moderate
10	Female	Choleric	25	less critical	58	quite critical	0,56	Moderate
11	Female	Sanguinis	33	less critical	70	critical	0,73	High
12	Female	Choleric	34	less critical	72	critical	0,76	High
13	Male	Choleric	32	less critical	60	quite critical	0,54	Moderate
14	Male	Sanguinis	27	less critical	54	quite critical	0,47	Low
15	Female	Melancholy	26	less critical	59	quite critical	0,57	Moderate
16	Female	Sanguinis	38	less critical	70	critical	0,70	High
17	Female	Sanguinis	25	less critical	63	quite critical	0,64	Moderate
18	Male	Sanguinis	24	less critical	62	quite critical	0,63	Moderate
19	Female	Sanguinis	26	less critical	62	quite critical	0,62	Moderate
20	Male	Phlegmatic	36	less critical	72	quite critical	0,75	High
21	Female	Sanguinis	36	less critical	70	critical	0,71	High
22	Female	Melancholy	38	less critical	74	critical	0,78	High
23	Female	Choleric	24	less critical	60	quite critical	0,60	Moderate
24	Male	Sanguinis	18	less critical	60	quite critical	0,64	Moderate
25	Male	Sanguinis	24	less critical	58	quite critical	0,57	Moderate
26	Female	Phlegmatic	30	less critical	60	quite critical	0,56	Moderate
27	Male	Melancholy	28	less critical	58	quite critical	0,54	Moderate
28	Male	Choleric	24	less critical	57	quite critical	0,55	Moderate

The average pretest score of female students' critical thinking was 28.25 (16 respondents) with the criteria "less critically" (21 <TBK ≤ 43) and the posttest average critical thinking was 62.81 with the criteria "quite critically" (43 < TBK ≤ 64) with (n-gain) an average increase in critical thinking of 0.63 with "moderate" criteria. Meanwhile, the average pretest score for male students' critical thinking was 25.17 (12 respondents) with the criteria "less critically" (21 <TBK ≤ 43), and the posttest average for critical thinking was 59.25 with the criteria "quite critically". (43 <TBK ≤ 64) with (n-gain) an average increase in critical thinking of 0.59 with "moderate" criteria.

Table 3. Comparison of male and female critical thinking average scores

Gender	Num	Pretest		Posttest		n-gain	Criteria
		Score Average	Criteria	Score Average	Criteria		
Male	12	25,17	less critical	59,25	quite critical	0,59	Moderate
Female	16	28,25	less critical	63,13	quite critical	0,63	Moderate

Average	26,71	less critical	61,19	quite critical	0,61	Moderate

The average critical thinking of prospective teachers in each Galens' personality type has improved after being given a PBL model with argumentation scaffolding of learning with argumentation scaffolding, the average n-gain score with moderate criteria are presented in tables 4. The average increase in critical thinking scores for each personality type was different, although not significant. The phlegmatic personality type experienced an increase in the lowest average critical assessment score, with an average critical thinking pretest of 26.4 (5 respondents) with “less critical” criteria (21 <TBK 43) and an average critical thinking posttest of 52.4 with “Criteria is quite critical” (43 < TBK 64), with (n-gain) an average increase in critical thinking of 0.56 with “medium” criteria. Melancholic personality type has the highest increase in the average critical thinking score with an average critical thinking pretest of 32.75 (4 respondents) with “less critical” criteria (21 <TBK 43) and an average critical thinking posttest of 66.25 with “critical enough” criteria (43 < TBK 64), with (n-gain) an average increase in critical thinking of 0.67 with “medium” criteria.

Table 4. Comparison of the mean score of critical thinking skills for Personality types

Personality types	Num	Pretest		Posttest		n-gain	Criteria
		Score Average	Criteria	Score Average	Criteria		
Phlegmatic	5	26,4	less critical	52,4	quite critical	0,56	Moderate
Sanguinis	11	26,9	less critical	62,6	quite critical	0,63	Moderate
Choleric	8	24,59	less critical	58,75	quite critical	0,58	Moderate
Melancholy	4	31,75	less critical	66,25	critical	0,67	Moderate

The results of the Liliefors test (normality test) shown in table 5 conclude that the pretest and posttest data are normally distributed. Paired t-test with a significance level of 5% was used to show that there was a difference in the average score of students' critical thinking.

Table 5. Normality Test Results

Data	L_{count}	L_{table}	R	Ket.
Pretest	0,128802	0,167438	$L_{count} < L_{table}$	Normal
Postest	0,141454		$L_{count} < L_{table}$	Normal

The *t*-test results obtained at a significance level of 4.46804E-26 < 0,05 which is smaller than that means that H_1 is accepted, and H_0 is rejected. This means that there are differences in the critical thinking of teacher candidates before and after applying the problem-based learning model with argumentation scaffolding. The average critical thinking of prospective teachers in learning the algebraic structure of group material increases and gets better after applying problem-based learning with scaffolding. The PBL model with argumentation scaffolding is effective for increasing the critical thinking power of male and female teacher candidates groups.

An important finding from the research is that the PBL model with the argumentation scaffolding can improve the critical thinking of male and female teacher candidates. Gender differences influence increasing teacher candidates' critical thinking; it can be seen from the average score of female teacher candidates' critical thinking score, which is slightly better than the average score of male prospective teachers' critical thinking. Inline research results, female prospective teachers can master all indicators of critical thinking while male students only master some indicators in solving math problems, so that female students' critical thinking skills are slightly better than male students (Mawaddah et al., 2018). Although they both reveal that gender influences critical thinking (Said & Lukmana, 2020), revealed different research results because the critical thinking achievement of female students was lower than male students, namely 0.240 female students and 0.3115 male students, and the inference indicators of male and female students had shallow scores. The results of the study are different from (R. M. Sari et al., 2019; Sofiani et al., 2017) which states that male and female students have the same level of perception and critical thinking. Gender does not cause differences in students' critical thinking skills in mathematical proof problems (Feriyanto, 2018).

The application of the problem-based learning (PBL) model with argumentation scaffolding shows that the role of the problem-based learning model with scaffolding can improve the critical thinking of teacher candidates from four personality types, namely sanguinis, choleric, melancholic, and phlegmatic, but does not provide a significant difference in improvement, meaning that the PBL model can be applied to every teacher candidates with a variety of personality types. This is indicated by the results of the N-gain which states that the effectiveness of the PBL model with metacognitive scaffolding to improve critical thinking is in the moderate category. The melancholic type statistically experienced the highest and most significant increase in critical thinking skills, in line to Rosidin's research (Rosidin et al., 2019) which stated that the melancholic and phlegmatic personality types experienced the most significant increase in critical thinking. after applying Argument-Based learning. Question (ADI).

PBL model with argumentation scaffolding can improve teacher candidates' critical thinking. In accordance with the Yusuf's research results who revealed a significant effect of problem-based learning with character emphasis on higher-order thinking skills (critical and creative) and student character (S. Yusuf et al., 2019). Problem-based learning has advantages, especially in training students' thinking skills (Jailani et al., 2017). Park and Choi explain that PBL can improve learning attitudes, critical thinking dispositions, and decision-making and assessment of the problem-solving skills sub-field (Park et al., 2015). Scaffolding can optimize the critical abilities achieved by students because it can help overcome the variations in student success in problem-based learning models. After all, some students can be trained quickly and some are a little slow. According to the opinion (McCosker & Diezmann, 2009) which states that scaffolding can improve critical thinking skills, creative thinking, actively participate in problem-solving, increase self-confidence, and increase students' freedom of opinion in learning mathematics. Giving scaffolding can increase learning motivation and reduce the level of difficulty of students in solving problems (Almanza-cortés et al., 2019; Khodeir et al., 2018; Vonna et al., 2015). Social interaction between students and social interaction between students and teachers will increase after being given scaffolding treatment (Abdurrahman et al., 2018; van de Pol et al., 2015). In the application of scaffolding, students who have not been able to master one aspect of learning will be assisted by teachers and their more capable friends (Anxiety et al., 2010; Vonna et al., 2015; Wass et al., 2014). By providing good scaffolding, students can become better critical readers and more conscious thinkers as they head towards their future studies (Wilson, 2016).

4. Conclusion

The PBL (Problem-based learning) model with scaffolding is effective in improving the critical thinking skills of teacher candidates because the assistance provided is in accordance with the academic level of each student and the application of the PBL model with scaffolding, in this case, trains students to argue and is an effective means to train critical thinking. Application of PBL models with scaffolding impact on critical thinking skills math teacher candidates men and women with different personality types. The average score of critical thinking female teacher candidates was a little better than the male teacher candidates and the melancholic personality type had an average improvement of critical thinking scores better than the three other types. Differences in gender and personality types are factors that must be considered by teachers in the learning process to achieve optimal results.

5. Recommendations

This study concludes that the PBL (Problem Based Learning) model with argumentation scaffolding is effective in improving the critical thinking of teacher candidates, so it can be recommended that the ability to argue is one of the important elements that must be observed by teachers as an effort to improve the critical thinking of teacher candidates. The average score of critical thinking female teacher candidates was a little better than the male teacher candidates and the melancholic personality type had an average improvement of critical thinking scores better than the three other types, so it is necessary to analyze the critical thinking process of teacher candidates in solving problems in terms of personality type and gender, as a teacher's consideration to determine learning methods that accommodate these differences.

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