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PAPER

Problem-Based Learning Management System (PBLMS): A Mobile Learning Application to Facilitate Creative Thinking Skills (CTS) of Prospective Physics Teachers

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ABSTRACT

Creative thinking is a 21st-century skill that lecturers should facilitate since the current challenge and conditions are getting more complex. These skills can be facilitated using technology through mobile learning using Problem-Based Learning Management System (PBLMS). This study aimed to obtain an overview of the improvement in the creative thinking skills of prospective physics teachers after participating in mobile learning using PBLMS. This is a quasi-experimental study with a non-equivalent control group design. The population of this study consisted of 80 first-year students at a university in Tasikmalaya. The sample consisted of 50 students who were selected using purposive sampling. They were 16 men and 34 women with an age range of 19–21 years. The data were collected using tests, observations, and interviews. The instruments used in this study included Creative Thinking Skill (CTS) tests, that is, the sheets of learning process observation, and interview guidance. The enhancement of CTS was processed using normalized gain and strengthened statistically by two mean difference tests. The group that took lectures using PBLMS had a higher score with an N-Gain of 0.72 (high category), while the group without PBLMS had an N-gain of 0.61 (medium category). Statistically, the two mean difference tests showed that the significance obtained was 0.003, so it can be concluded that there was a significant difference between the groups using PBLMS and without PBLMS. The research can provide an overview of the usefulness of PBLMS in supporting the achievement of learning objectives and other related skills.

KEYWORDS

Creative Thinking Skills, Learning Management System, mobile learning, prospective physics teachers, problem-based learning

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1 INTRODUCTION

The current technological developments are marked by industrial revolution 4.0, which provides many changes in the way of work by emphasizing industrial work systems through advanced digital technology. Furthermore, the industrial revolution 4.0 has become a global trend, significantly impacting people's lifestyles and necessities [1]. It also constructs a community model requiring skills and competence in taking the maximum positive benefits from the potential current technologies and taking part in the economic, social, and culture [2]. Besides, it induces new challenges for the competency development of human resources in optimizing digital technology functions in various life sectors. In addition to challenges in maximizing the use of digital technology, the industrial revolution 4.0 also induces other challenges for human resources to have many soft skills, including competence in creating innovation as a part of creativity and developing creative thinking in sustainable problem-solving [3]. Creative thinking is a cognitive activity showing an original and reflective way of finding practical solutions by synthesizing various developed ideas, creating innovative ideas, and analyzing the effectiveness of ideas [4].

The challenges of industrial revolution also impacted education, especially in implementing learning activities. In 2020, the European Commission responded to this challenge by setting Europe's main priorities and developing skills for media and digital literacy in terms of the ability to learn, create, engage, and differentiate the use of digital media as an effort to prepare human resources to face the challenges of global competition [5]. Besides, these challenges also impact teachers' competence to think and work creatively [6]. Amanto revealed that professional teachers should be able to carry out creative and practical learning activities [7]. Furthermore, teachers should be competent in asking questions, developing innovative ideas, and managing class learning [8]. Therefore, teachers should develop their CTS (creative thinking skills) because it is a 21st-century skill that teachers should master as the current challenges and conditions are getting more complex and CTS can lead teachers to think, work, and implement creative innovations in learning activities [9]. Table 1 below describes the indicators of CTS.

Table 1. The indicators of the CTS aspects [10]

No	Aspect of CTS	Student Activities
1	Fluency	• thinking of more than one answer. • responding to the questions with many alternative questions
2	Flexibility	• generating ideas, answers, or varied questions. • analyzing a problem from a different perspective. • searching many different alternatives or directions. • changing approach or thought.
3	Originality	• revealing new and unique ideas • thinking of unusual ways to express themselves • making unique combinations of parts or elements.
4	Elaboration	• working and developing a product or idea. • adding details to an object, an idea, or a situation to make it more interesting

Considering the importance of CTS for professional teachers in current conditions, these competencies need to be trained for prospective teachers through lecture activities. In physics learning, these CTS are related to mastering physics concepts.

To understand physics concepts, students need thinking skills [11]. Khalil stated that CTS cannot be separated from conceptual understanding. Someone cannot think creatively in specific problem-solving without understanding specific content and theory [12]. It means that creative thinking skills, as part of higher-order thinking skills, cannot be separated from understanding the specific concept.

As one of the main subjects in physics concept understanding, the Basic Physics lecture can be optimized to train the CTS of prospective physics teachers without compromising their cognitive abilities. The learning activity in introductory physics lectures the previous year did not support practicing creative thinking skills. It is reinforced by some initial findings, where the category of CTS for prospective physics teachers is still poor, with an average score of 43.75 on a maximum scale of 100 [10]. The results of lecturer and student interviews showed that many components of introductory physics lectures required optimization, such as (a) the implementation of traditional lecture methods (presentation and discussion), (b) monotonous and less challenging lecture activities, (c) The prospective physics teachers' inability in expressing clearly and giving a detailed explanation, and (d) the implementation of less exciting and challenging media.

Therefore, a strategic effort is needed to solve the problem by improving the lecture process using a supportive learning model. In this case, Problem-Based Learning (PBL) can be optimized to increase prospective physics teachers' creative thinking skills. Kardoyo et al. [13] implemented face-to-face PBL in two-cycle lectures with two different issues for each cycle, and then students solved each problem through group discussions. The study found an increase in thinking skills significantly. Putra et al. [14] integrated a scientific approach to PBL in physics learning. He found a moderate rise in the CTS profile, with 0.6 of N-Gain. The results of statistical tests on CTS scores also showed that integrating the scientific approach in PBL differed significantly from traditional learning. In the pressure theme, Nulhakim et al. [15] used interactive multimedia-assisted PBL. The study found that the CTS and pressure concept understanding increased by 68%. PBL facilitates students to express various ideas according to their level of knowledge so that the CTS can be trained optimally. Wahyu & Eli [15] also implemented PBL in their teaching of water purification to improve creative thinking skills. In their study, the increase in CTS shown was 70.12%.

A learning method that has been developed by utilizing technological developments includes mobile learning. Mobile learning is an alternative learning service that can be implemented without being limited by place and time [16]. Mobile learning provides excellent flexibility in carrying out learning because it is held online. Every user can utilize technology to access and store various relevant information without being limited by the user's location. The use of personal learning can be carried out by connecting students with cloud computing via mobile technology without having to sit and watch the teacher in a traditional classroom [17]. Students can access the materials used in learning without having to wait for the study schedule and go to a designated place.

To promote the successful implementation of mobile learning, the use of technology-based learning media is essential. One technology widely used to support mobile learning is the Learning Management System (LMS). LMS has some advantages when implemented in learning activities [18] such as 1) LMS can reduce transportation costs and time needed for a trip, 2) Students have the flexibility in determining the material according to their interests and knowledge needs, 3) Students can study any time when they can access computers and the internet, 4) Learning modules can be adapted to various student learning styles, 5) LMS users can join flexibly in the discussion room and chat room to communicate directly with classmates or their lecturer, 6) LMS can facilitate a variety of learning styles through various learning activities, and 7) students' skills in using digital devices can be optimally trained.

In science mobile learning, the LMS use has been widely applied to facilitate students in representing natural phenomena, encourage experimental activities, and provide good opportunities for discovery learning and problem-solving [19]. Students can learn science anytime and anywhere with access to digital devices and an internet connection. It enables students to work independently, quickly, and flexibly. Besides, LMS provides lots of opportunities for students and their instructors to interact, accommodate diverse learning styles, facilitate learning through various activities, develop knowledge about the internet and computers, help students throughout their lives and careers, build knowledge independently and confidently, and encourage students to take responsibility for their learning. Ekici et al. [20] used Moodle as a learning media to improve the effectiveness of teaching Basic Physics. It showed that prospective teachers had positive ideas concerning the use of Moodle, and Basic Physics learning using the LMS. Oguguo et al. [21] examined Moodle effectivity in improving students' cognitive ability. This research was conducted at Imo State University with 232 students. It indicated that there was a significant increase in student learning outcomes. It was proved by their commitment to implementing Moodle in their learning activities. The motivational support and constructivist nature of the Moodle platform stimulated students to spend time interacting and collaborating with other students everywhere and anytime. The availability of various materials accessed through Moodle gave students learning discretion inside or outside classrooms. Students learning with technology tend to improve their learning outcomes more than those learning without technology [22]. LMS accessed online provides a learning environment so that students can construct more comprehensive knowledge.

Although LMS is widely used to support the mobile learning process, the LMS implemented in lectures has the following limitations: 1) LMS functions as a supporting media to make easy learning administration, 2) LMS does not facilitate synchronous online so it is less interactive, 3) LMS cannot facilitate complete implementation of models or methods, and 4) LMS does not facilitate strict learning supervision so that it can reduce students' learning motivation and learning outcome achievement.

Considering the potential of PBL and LMS in supporting mobile learning activities and any LMS deficiencies, it is necessary to develop a PBL-based LMS. Therefore, an LMS application is designed to integrate PBL syntax into the LMS system that can be accessed by smartphones. The application was named Problem-Based Learning Management System (PBLMS). PBLMS can be accessed using a smartphone and can be used as the primary learning tool and regulates the lecture process. PBLMS in learning provides a learning environment to search, evaluate, and store information; perform communication and collaboration synchronously; and develop digital content. This learning environment can reinforce and stimulate training in new skills [23].

Learning activities directed by PBLMS also facilitate students in practicing cognitive abilities and CTS because all actions are student-centered learning. Students can get a form of freedom to express their thoughts under the provision of previous knowledge so that they get space to develop their thinking skills [24]. Schunk [25] argued that students produced meaningful activities to construct diverse knowledge through communication and collaboration activities between students and lecturers. The students reached a higher cognitive level by slowly reducing their dependence on others in problem-solving.

Based on the described problem, the study aims to obtain an overview of the improvement in the CTS of prospective physics teachers after participating in mobile learning using PBLMS. It is expected that this research can provide an overview of the usefulness of PBLMS in supporting the achievement of learning objectives and other related skills.

2 METHODS

This research is a quasi-experimental study with a non-equivalent control group design [26]. The research design is shown in Table 2 below.

Table 2. The PBLMS implementation research design in Basic Physics lectures

Group	Pretest	Treatment	Post-Test
Experiment	O_1	X_1	O_2
Control	O_1	X_2	O_2

Notes: O_1 = The pretest of CTS before the treatment; O_2 = The post-test of CTS after the treatment; X_1 = The lecture using PBLMS; X_2 = The lecture using conventional methods.

The Basic Physics lecture using conventional methods was conducted using several synchronous and asynchronous online learning applications with the lecturer's presentation and discussions. The traditional lecture activities were carried out with several main activities, such as 1) opening of lectures conducted by the lecturer to explain the expected learning outcomes, 2) presenting the learning materials done by the lecturer, 3) discussion between students regarding the topic, 4) reinforcement carried out by the lecturer and stimulating students in making conclusions, and 5) closing of lecture activities carried out by the lecturer.

The population of this study consisted of 80 first-year students at a university in Tasikmalaya. The sample in this study consisted of 50 students who were selected using purposive sampling. They consisted of 16 men and 34 women with an age range of 19–21 years. The participants in this study came from various regions in West Java with sufficient experience in using LMS due to the demands of online learning during the Covid-19 pandemic.

The data were collected using some techniques, including tests, observations, and interviews. The instruments used in this study were CTS tests, the sheet of learning process observation, and interview guidance. The CTS test comprised many aspects, such as fluency, flexibility, originality, and elaboration. The CTS tests were prepared using 14 open-ended questions related to direct current concepts. It was validated by five experts and analyzed using the Content Validity Ratio (CVR). The analysis of the results of the reliability test showed a reliability value of 0.95 with a very good category. The design of a sheet of learning process observation was used to evaluate the activities of students and lecturers in carrying out Basic Physics lectures using PBLMS. The design of the observation sheet included five PBL syntaxes, namely problem finding, group discussion, independent study, problem-solving, and presentation of results [27], which were implemented for three weeks. The interview guide was utilized to explore in-depth information on quantitative data obtained through tests and sheets of learning process observation.

The enhancement of CTS was processed using normalized gain, which can be calculated using equation 1 [28], and continued with statistical tests.

$$<g> = \frac{<\%S_{post}> - <\%S_{pre}>}{100 - <\%S_{pre}>} \quad (1)$$

Where $<g>$ = Normalized gain; S_{post} = posttest score; and S_{pre} = pretest score. Table 3 below showed the categorization of normalized gain.

Table 3. The normalized gain category

No	N-Gain	Category
1	$<g> \geq 0.7$	High
2	$0.3 \leq <g> < 0.7$	Medium
3	$<g> < 0.3$	Low

The statistical test was processed using IBM SPSS version 20 and followed several stages: the normality test, the homogeneity test, and the mean difference test.

3 RESULTS AND DISCUSSION

The results of this study were presented in two parts, namely, an enhancement of CTS in general and an enhancement of CTS for each aspect. Table 4 below showed the increase in CTS in general.

Table 4. The mean of CTS pretest, posttest, and N-gain

No	Group	N	Mean of Score			N-Gain Category
			Pretest	Posttest	N-Gain	
1	Experiment	25	30.36	81.07	0.72	High
2	Control	25	32.50	74.17	0.61	Medium

Table 4 showed that there was a significant difference in improving students' CTS between the experimental group and the control group, where the experimental group had a higher N-gain score than the control group. The CTS enhancement in the experimental group belonged to the high category, while the control group was in the medium category.

The result of the statistical test for CTS N-gain in the experimental and the control class, including normality, homogeneity, and independent t-tests, are shown in Table 5 below.

Table 5. The results of normality and two mean difference tests CTS in experimental and control classes

No	Group	N	Distribution ($\alpha = 0.05$)		Two Mean Difference Tests ($\alpha = 0.05$)	
			Sig (α)	Conclusion	Sig (α)	Conclusion
1	Experiment	25	0.047	not normally distributed	0.003	There is a significant difference
2	Control	25	0.200	normally distributed		

Table 5 showed that the N-gain in the experimental class was not normally distributed, while in the control class, the N-gain data was normally distributed. Due to the non-fulfillment of the data normality requirements, data processing was carried out to determine the significance of the difference in the mean N-gain, followed by non-parametric statistics for two independent samples, namely the Mann-Whitney test. The results of the Mann-Whitney test showed that the magnitude was 0.003, so it was concluded that there was a significant difference in CTS improvement between the experimental class that applied PBLMS and the control class that used the conventional lecture technique.

The enhancement in CTS for each aspect in both the experimental and control classes is shown in Figure 1 below.

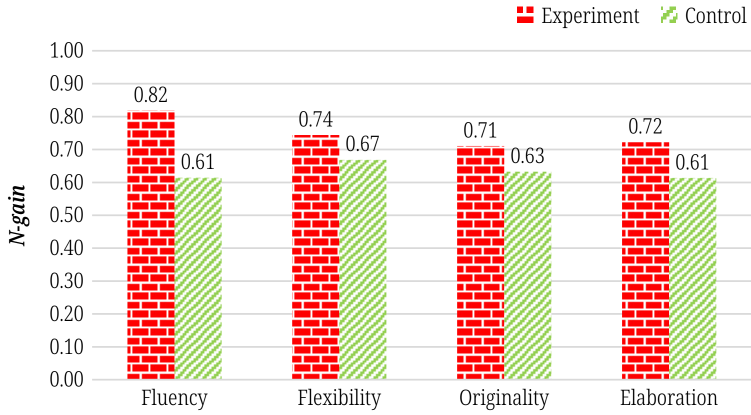

Fig. 1. N-gain for each aspect of CTS in the experimental and control classes

Figure 1 showed that every aspect of CTS increased more in the experimental class than in the control class. In the experimental group, the highest improvement was found in aspects of fluency, with an average N-gain of 0.82 in the high category. In contrast, the lowest improvement was found in originality, with an average N-gain reaching 0.71 in the high category. In the control group, the highest improvement was found in aspects of flexibility, with an average N-gain of 0.67 in the medium category. In contrast, the lowest improvement was found in fluency and elaboration, with an average N-gain, each reaching 0.61 in the medium category.

The significance of differences in the enhancement of each aspect of CTS in the experimental and control classes was found by a statistical test carried out on the N-gain data for both groups. The results of the normality test and the two mean difference tests in the experimental and control group are shown in Table 6 below.

Table 6. The results for normality, homogeneity, and two mean difference test of CTS for each aspect

No	CTS Aspects	Distribution ($\alpha = 0.05$)				Variance ($\alpha = 0.05$)		Two Difference Test ($\alpha = 0.05$)	
		Experiment		Control					
		Sig (α)	Category	Sig (α)	Category	Sig (α)	Category	Sig (α)	Category
1	Fluency	0.319	Normally distributed	0.622	Normally distributed	0.442	Homogeneous	0.010	Significantly different
2	Flexibility	0.469	Normally distributed	0.742	Normally distributed	0.622	Homogeneous	0.025	Significantly different
3	Originality	0.428	Normally distributed	0.514	Normally distributed	0.330	Homogeneous	0.005	Significantly different
4	Elaboration	0.439	Normally distributed	0.947	Normally distributed	0.574	Homogeneous	0.008	Significantly different

Table 6 showed that the distribution data on each aspect of CTS was normally distributed and homogeneous. The t-test was used to see the two-mean difference test for the experiment and control groups. The t-test results showed that all aspects of CTS had a significance value of less than 0.05, so it can be concluded that there was a significant difference in the mean for each element of CTS in the two groups.

Enhancement of the CTS of prospective physics teachers in basics physics lectures using PBLMS was generally in the high category, with average N-gain reaching 0.72. The average N-gain in the experimental class was greater than the control class, where the average N-gain in the control's CTS only reached 0.62 in the moderate category. Improving the CTS cannot be separated from the lecture process through PBLMS. Rosita et al. [29] concluded that CTS was a potential skill for everyone. Hence, schools and teachers had to adopt and implement approaches supporting these skills to educate students to become creative children. PBL is a learning model that can facilitate students to hone and improve their creative thinking skills. Barret [30] revealed that PBL has provided learning facilities allowing students to construct knowledge simultaneously while the learning process runs effectively. Nuswowati & Taufiq [31] reported that PBL could improve the CTS of students who took environmental chemistry courses at Semarang State University. This condition was supported by the statement [32], which revealed that learning activities using PBL provided advantages in helping students develop creative thinking, problem-solving, and intellectual skills. The PBL was conducted by optimizing the experience of adults as simulation material, making students become independent and autonomous learners.

The use of ICT in mobile learning also encourages increased creative thinking skills. Wheeler et al. [33] stated that CTS could be honed by carrying out practical application activities and using ICT, which provided opportunities for students to practice hands-on skills independently. Many researchers have conducted studies involving technology in training creative thinking skills. Prompan [34] developed a Web-Based Instructional Model, which increased the CTS of undergraduate students. Chuathong [35] utilized six technology components in learning activities and improved students' creative thinking skills. The six technology components included a Learning Management System (LMS) in virtual classrooms, communication, and collaboration tools, electronic learning resources, media, instructor and learner roles, online learning activities, and online assessment.

PBLMS, as an application integrated into Basic Physics lectures, is one of the media that facilitates the formation of mobile learning. The use of LMS in mobile learning has had an impact on improving creative thinking skills. Students more involved in mobile learning through LMS can enhance their 21st-century competencies such as communication, complex problem-solving, and CTS [36]. The availability of a supportive environment greatly influences students to develop their skills, including creative thinking skills. This environment can motivate students to maximize their readiness in optimizing the learning process.

The Basic Physics lectures using PBLMS have provided a learning environment that can facilitate students to find and explore problems, conduct virtual experiments, and provide flexibility in communicating both between students and students and lecturers. These facilities support the training of CTS and are available in integrated syntax in the PBLMS system. Santrock [37] suggested that the first step in practicing CTS must be preparation, in which students were directed to find and explore relevant problems. De Bruin [38] emphasized that effective communication between teachers and students could increase student learning independence and collaboration skills and improve CTS. Deacon & Hajek [39] conveyed several advantages of experimental or practicum activities either directly or through a virtual lab, including problem-solving and creative thinking skills. This statement was proven by Malik et al. [40] who improved physics teacher candidates' CTS through experimental activities virtually using Higher Order Thinking (HOT) Laboratory Design.

Among the four aspects of CTS, fluency significantly improved with an N-gain of 0.82, while originality ranked lowest with an N-gain of 0.71. This condition was inseparable from the learning process in practicing CTS in Table 7.

Table 7. The activities and CTS trained in learning using PBLMS

No	PBL Syntax	Learning Activities in PBLMS	Trained CTS
1	Problem finding	• Students analyze contextual problem descriptions related to the concepts being taught. In the PBLMS application, problem descriptions can be presented as text, images, or videos. • Students find problems described in question sentences, connect the issues found with concepts they have already understood, and plan to solve problems according to their understanding.	• Students are trained to express as many questions related to problems as possible (Fluency) • Students are trained to express possible problem-solving ideas to propose based on the concepts they have already understood (flexibility)) • Students are trained to convey creative and original ideas from their minds in various ways (originality).
2	Group discussion	• Students hold group discussions to discuss their problems, find concepts relevant to the issues they see, and plan to solve problems through group discussion rooms. In group discussions, students express opinions accompanied by logical arguments based on physics concepts.	• Students are trained to express as many problem-related questions as possible (fluency) • Students are trained to express possible problem-solving ideas to propose based on the concepts they have already understood (flexibility). • Students are trained to improve each other's problem-solving plans expressed in group discussions (elaboration)
3	Independent study	• Students search for relevant information through a search engine that has been integrated into the application. The aim is to strengthen the results of the discussions carried out in groups. • Students save the information and report their search results to PBLMS. • Students carry out virtual experiments to prove problem-solving plans that have been obtained in group discussions.	• Students are trained to improve each other's problem-solving plans expressed in group discussions (elaboration)
4	Problem-solving	• Students hold discussions in group discussion forums regarding the data obtained, how the data is processed, and the conclusions of the experimental results.	• Students express ideas based on the experimental results (Fluency)
5	Presentation of results	• Students present the results of virtual experiments in class discussion forums. One person can represent the presentation of experimental results. But all participants are allowed to discuss the results of the investigation. • Students jointly draw conclusions based on the results of class discussions related to their problem-solving. • Students evaluate and reflect on the steps taken during the problem-solving process.	–

Table 8 below shows the recapitulation of the training frequency of each aspect of CTS at each meeting.

Table 8. The recapitulation of practicing CTS in school physics lectures using PBLMS

No	Aspects of CTS	The Frequency of Each Meeting	Learning Activity in PBLMS
1	Fluency	3	• Problem finding • Group discussion • Independent study
2	Flexibility	2	• Problem finding • Group discussion
3	Originality	1	• Problem finding
4	Elaboration	2	• Problem finding • Independent study

Tables 7 and 8 showed that fluency was the aspect of CTS that was most often trained with a frequency of three times in one meeting, while originality was an aspect of CTS that was prepared with the lowest frequency. This learning activity could explain that the highest N-gain was in fluency and the weakest was in originality. The training of creative thinking skills was strongly influenced by the activities experienced by students in learning activities [41]. If learning activities facilitated students to practice creative thinking skills, then these skills changed along with the intensity [42].

In addition to the learning process, student perceptions can be the reason for the different improvement conditions for each aspect of creative thinking skills. The results of the search for the perception questionnaire of prospective physics teachers found that the highest positive perceptions were in the statement, "School physics lectures using PBLMS trained me to ask various questions based on problems related to the one-way dynamic concept of electricity" as a statement representing the trainability of fluent thinking skills with a percentage of 86 %. While the lowest positive perception lies in the statement, "School physics lectures using PBLMS have trained me to think of new solutions/opinions in solving problems related to the concept of one-way dynamic electricity," representing original thinking skills with a percentage of 76%. The results showed that there was a harmonization between improving each aspect of the CTS of prospective physics teachers with the results of the perception questionnaire for physics teacher candidates involved in school physics lectures using PBLMS.

4 CONCLUSION

Based on the results of the research and the discussion, it can be concluded that PBLMS can improve creative thinking skills both in general and in detail for each aspect. The learning activities carried out using PBLMS provide a suitable learning environment for practicing the creative thinking skills of prospective physics teachers. Furthermore, the results of this study also offer several recommendations for optimizing the use of PBLMS in lecture activities with characteristics of Basic Physics so that they can support the achievement of learning objectives and other various related skills. PBLMS has several learning activities that are relevant to learning science which emphasize three things, namely, processes, attitudes, and products. In addition, PBLMS can provide more expansive learning opportunities to students without being limited by time and place.

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