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Virtual Reality in Experiential Learning Models to Develop Students' Computational Thinking: A Systematic Literature Review

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Abstract

Computer network learning in vocational schools is considered difficult because the material is abstract. This often causing confusion for students when solving problems systematically. Based on these problems, this study aims to systematically review and synthesize evidence regarding the effectiveness of Virtual Reality (VR) integrated with the Experiential Learning (EL) Kolb model in developing Computational Thinking (CT) abilities. Using the Systematic Literature Review (SLR) method and PRISMA protocol. we analyzed 26 selected articles from 2,479 initial results (search on May 26, 2026). The results indicate that immersion-based VR serves as a real simulator, providing a Concrete Experience and facilitating Active Experimentation through hands-on practice. For school with limited VR devices in schools, collaborative learning methods are an effective alternative solution. This approach strengthens group memory, which effectively fulfills the Reflective Observation stage in Kolb's theory. Furthermore, manipulating digital objects in VR supports Abstract Conceptualization, helping students stimulate pillars of decomposition, abstraction, and algorithmic reasoning. In conclusion, this study analyze the trends and development in current research to demonstrate how the collaboration between VR and EL models offers a new scientific contribution. These findings provide a clear guide for teachers and curriculum developers to design more effective teaching strategies in vocational schools.

Keywords: Computational Thinking, Experiential Learning, Systematic Literature Review, Virtual Reality, Vocational Education.

1. Introduction

Technological advances in the 21st century require the world of education, especially vocational schools, to apply immersive learning media such as Virtual Reality (VR) which is able to present concrete 3D visualization (concrete experience) to facilitate the understanding of abstract and complex materials [1]–[3]. VR is one example of technological advances that can be used in the world of education. In vocational education, the use of VR technology is considered to have the potential to increase student involvement in the learning process, authentic experiences and students' problem-solving abilities through a more realistic learning environment [4], [5]. The 3D virtual environments contained in VR are able to make students feel "present" in real life in the digital content being studied [2]. This results in students feeling helped to get concrete experience directly (concrete experience) in the learning cycle which has been considered quite difficult to get in learning in ordinary classrooms [3].

In line with the statement above, vocational school students are also required to have Computational Thinking (CT) skills as a handle to deal with technological developments and the world of work. CT consists of components of decomposition, pattern recognition, abstract and preparation of logical problem-solving steps [6], [7]. This ability is considered very crucial so that students are able to solve problems logically and also in a structured way [8]. The integration of CT components into the vocational curriculum is considered very effective if it is directly related to the real practice and technical competence of productive students [9].

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However, the reality in the field shows that in the learning process of computer networks, there are still obstacles, especially in Peer-to-Peer materials. The abstract and invisible nature of the concept of data networks, handshake between computers and problem-solving processes is one of the challenges that must be faced. Conventional learning methods that rely only on explanations through text on the board often leave students confused and just memorize the configuration steps without understanding the logic. This results in low critical thinking skills and students' CT in the field. Not only the issue of abstract content, another challenge arises for schools in the form of a lack of specific implementation guidelines for teaching these thinking skills in vocational settings [9], [10].

Kolb's Experiential Learning (EL) theory defines learning as a continuous process where knowledge is created through the transformation of experience (Kolb, 1984). This theoretical framework consists of four cyclical stages: Concrete Experience, where learners engage in sensory activities; Reflective Observation, which encourages them to analyze their virtual interactions; Abstract Conceptualization, where these experiences are synthesized into theoretical understanding; and Active Experimentation, where learners apply these insights to practical challenges.

In an effort to overcome these constraints, the integration of VR with Kolb's Experiential Learning (EL) model began to be developed extensively to create a more active and immersive learning experience [3], [11], [12]. Furthermore, collaborative learning approach have been implemented to divide students roles such as VR users and observers, ensuring that the learning process remains effective despite limited availability of VR devices [13], [14]. This collaborative strategy is considered to increase student interaction, reflection, and engagement within the virtual environment [15]–[17].

However, previous research still tended to address VR, EL, and CT separately. Previous researchers have only looked at the potential of these variables in isolation, for example, studies focusing on the effectiveness of VR media to help the process of visualizing materials and increase students' motivation to learn have been widely conducted [1], [2]. Similarly, in studies using the EL Kolb model, several studies have proven that EL provides sufficient facilities to accommodate students' practical understanding [3], [11]. However, research generally only stops at the level of conceptual understanding and does not link it to CT skills.

To fill these theoretical and practical gaps, this study uses the Systematic Literature Review (SLR) approach to analyze and synthesize scientific literature on a national and international scale. Specifically, this study aims to map the real contribution of incorporation VR and the Kolb EL model through collaboration learning scheme in improving students' CT abilities on computer network materials in vocational school. Furthermore, this research synthesize current findings to identify existing research gaps and future challenges associated with the integration of these experiential immersive technologies. To achieve this goal in a measurable way, this research is guided by two research questions, namely:

- RQ_1: How is VR technology implemented in supporting Kolb's EL stages?
- RQ_2: How does the use of immersive VR media contribute to the stimulation of students' CT skills?

2. Method

2.1 Types of Research

This study uses the Systematic Literature Review (SLR) method to collect, evaluate, and synthesize all previous scientific articles relevant to the topic of experiential VR integration to improve CT skills. In order for the literature review process to be objective, transparent and replicable by other researchers, this study adopts the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) standard protocol. The use of the PRISMA framework helps authors in conducting rigorous article screening, starting from the initial search stage to determining a sample of final articles that are worth analysis.

2.2 Literature Search Strategy

The systematic literature search utilized a two-tiered strategy to balance academic rigor with broad coverage. We selected the ACM Digital Library as a primary bibliographic database for its high-quality, peer-reviewed technical literature, while Google Scholar served as a comprehensive academic

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search engine to capture a wider range of interdisciplinary and recent conference outputs. To ensure transparency, we distinguish the ACM Digital Library's curated metadata from Google Scholar's expansive indexing.

Given the distinct indexing mechanisms of these platforms, we applied adapted search strings to maximize retrieval. We used ("Virtual Reality" AND "Experiential Learning" AND "Computational Thinking") for the ACM Digital Library, and ("VIRTUAL REALITY" OR "VR") AND ("EXPERIENTIAL LEARNING" OR "KOLB") AND ("COMPUTATIONAL THINKING" OR "CT") for Google Scholar. The publication period was limited to 2006–2026. This process yielded 2,479 potential documents. Our methodology focused exclusively on these sources to maintain a robust and reproducible search process; other databases were excluded due to limited relevance to our research scope. This approach highlights the research gap in the domestic context and underscores the originality of this study.

2.3 Search Keywords

Search keyword formulation is designed using Boolean operators (AND, OR) to improve the interconnectedness between key variables. Given the distinct indexing mechanism of our selected platforms, we applied adapted search strings to maximize retrieval. The specific search strings applied in the literature tracking process are as follows:

- ACM Digital library: ("Virtual Reality" AND "Experiential Learning" AND "Computational Thinking").
- Google Scholar: ("VIRTUAL REALITY" OR "VR") AND ("EXPERIENTIAL LEARNING" OR "KOLB") AND ("COMPUTATIONAL THINKING" OR "CT").

These initial searches were employed to capture a broad yet relevant body of literature. Subsequently, a systematic eligibility assessment was applied to filter the results. We ensured that our inclusion criteria directly aligned with the core variables of our search strings by focusing strictly on studies that integrate VR, Experiential Learning, and Computational Thinking. This clear methodological transition—from database-specific search strategies to precise, variable-aligned eligibility criteria—ensures the consistency and reproducibility of our review process.

2.4 Inclusion and Exclusion Criteria

To filter the hundreds of articles that emerge from automated search results, authors set clear boundaries through inclusion (articles accepted) and exclusions (articles rejected) criteria. Details of the screening can be seen in Table 1.

Table 1. Entry Criteria and Exclusions for Article Selection

Criteria	Inclusions (Accepted)	Exclusion (Rejected)
Time Range	Articles published between 2006-2026.	Articles published before 2006.
Document Type	Peer-reviewed scientific journal articles and conference proceedings.	Popular books, book chapters, these dissertations, and articles.
Language	Uses Indonesian or English.	Articles other than Indonesian ar English.
Subject/Context	Vocational school students, vocational students, or secondary education students.	Early childhood education or non-IC primary school.
Content Focus	Discuss at least two interrelated variables (VR, EL, or CT).	An article that only discusses VR i general without any pedagogical conte: or critical thinking.

2.5 Article Selection Procedure (PRISMA Diagram)

The article selection process in the SLR research follows the standard guidelines of the PRISMA protocol. The stages of document screening from the initial search to the determination of the final article are presented systematically in Figure 1.

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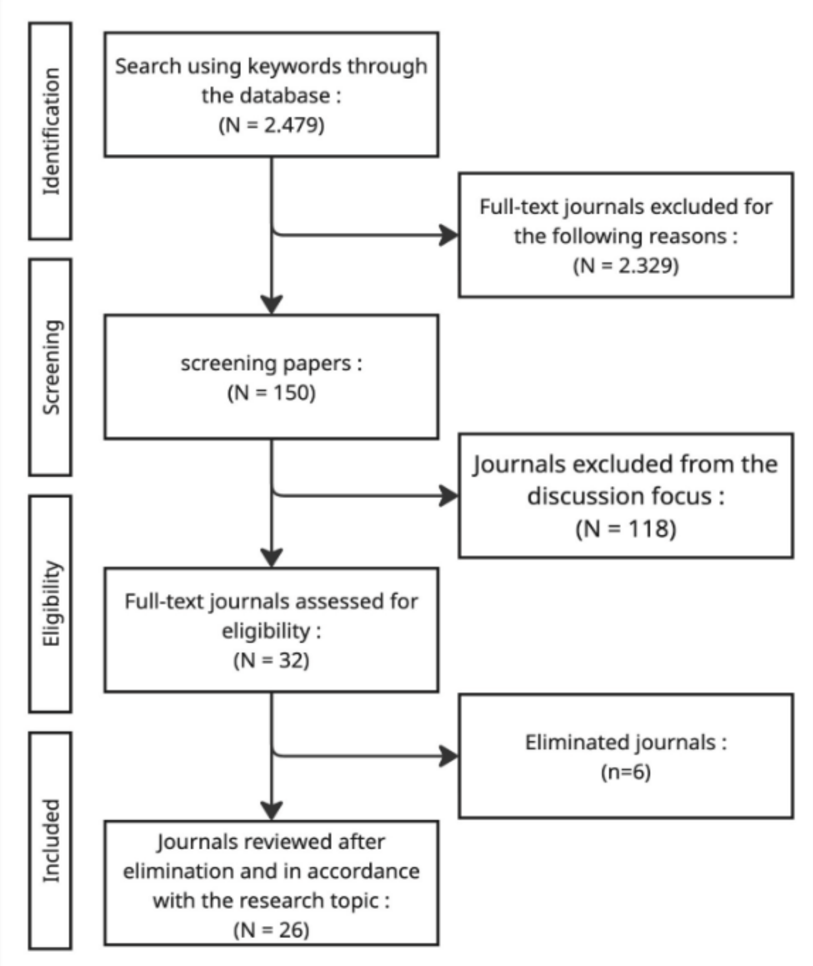

Figure 1. PRISMA Flowchart

Based on Figure 1, the stages of article selection are explained into four main phases as follows:

- Identification: Initial search yielded a total of 2,479 articles (Google Scholar: 2,330, ACM: 149). After removing duplicate documents and filtering for the suitability of the initial title, 150 articles remained.
- Screening: The author studied abstracts from 150 articles. A total of 118 articles were excluded because the focus of the discussion was outside of educational technology, subjects that were not vocational school students, or were constrained by prepaid access. This phase leaves 32 articles.
- Eligibility: The author read the full text of the remaining 32 manuscripts. A total of 6 journals were eliminated because they applied conventional learning models without integrated collaborative interactions between students.
- Includes: The final process resulted in 26 valid articles discussing the integration of VR, Experiential Learning, and collaborative VR mechanisms. This collection of manuscripts was extracted and synthesized to answer the research questions (RQ).

2.6 Bibliometric Mapping and Network Visualization

To understand the broader landscape of this research domain before applying strict inclusion criteria, a preliminary bibliometric analysis was conducted. We processed the raw metadata from our initial search results using VOSviewer software. Rather than examining each paper individually, this stage mapped the co-occurrence of key terms extracted from the titles and abstracts of the larger dataset.

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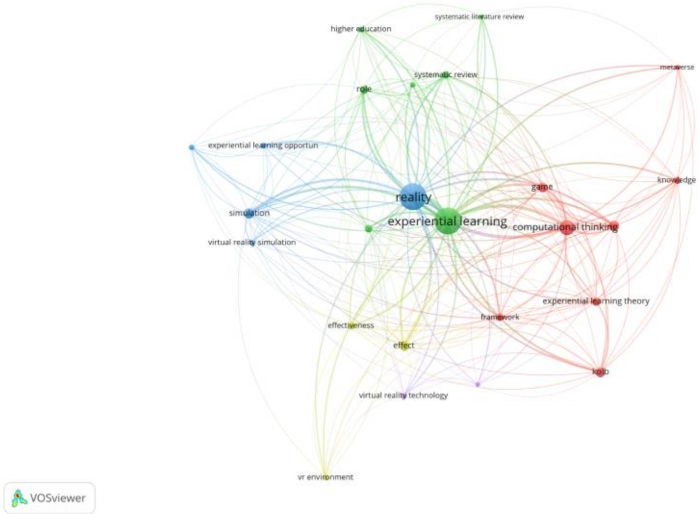

Figure 2. Bibliometric Map of Research Trends Based on Text Data Co-Occurrence

This Figure 2 presents a macroscopic view. In the resulting network, the size of each circular node reflects the frequency of occurrence of a term in the collected literature. Meanwhile, the connecting lines and distance between nodes illustrate how strongly these concepts are linked in recent studies. Through this visualization, key thematic clusters surrounding virtual reality, experiential learning, and computational thinking can be clearly observed. This mapping provides a solid conceptual foundation and highlights current research focal points before we explore the selected articles in depth.

3. Result and Discussion

As a result of the literature selection, there are 26 articles met the inclusion criteria and are in accordance with the research focus of this review. The selected articles were grouped by research theme and year of publication to see developments related to VR, CT, EL and VR-based collaborative learning research. The results of the grouping show that research related to Collaborative VR Learning has noticeably increased in the range of 2022-2026. The distribution of articles by research category and year of publication is presented in Table 2.

Table 2. Distribution of Articles by Research Category and Year of Publication.

Research Categories	2006-2019	2020-2022	2023-2024	2025-2026
VR and EL	0	3	1	1
VR and CT	2	2	5	1
Collaborative VR	0	1	5	3
VR in Vocational Education	0	1	4	1

Table 2 shows the distribution of articles by research theme category and year of publication. An article can fall into more than one category if it covers multiple research focuses at once, so the total distribution of categories does not directly represent the number of articles.

3.1 Implementation of VR in Supporting Kolb EL (RQ$_1$)

Across the reviewed literature, a recurring pattern emerged regarding VR's alignment with the Kolb Experiential Learning (EL) model, particularly its capacity to offer a more concrete, interactive, and contextual learning experience [3], [18]. However, the extent of this alignment is not uniformly established for instance, Fromm et al. [11] note that prior studies have often failed to distinguish how VR supports each of the four EL stages individually, leaving open the question of whether VR primarily affords concrete experience or the full experiential cycle. Where the immersive nature of VR

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is more consistently supported is in its capacity to let students interact directly with virtual objects and perform activities resembling real-world conditions, with evidence of skills transferring to physical, non-virtual contexts [19]. This suggests the learning experience extends beyond theoretical understanding into direct, applied experience. The picture is less conclusive, however, when VR is combined with collaborative learning structures: while such integration has been explored through asymmetric, role-based configurations, findings indicate a trade-off rather than a straightforward engagement gain—collaborative VR use can support theoretical knowledge acquisition while potentially undermining practical skill development when technology exposure is limited [13].

At the concrete experience stage, several studies show that VR provides students with the opportunity to gain hands-on learning experience through exploration of virtual environments, observation of simulated objects and the implementation of collaborative tasks with group members. The characteristics of such activities allow students to be actively involved in the learning process so that the experiences gained by students are not only theoretical, but also contextual and authentic [3], [19], [20]. Activities reported in previous research include creating and using avatars, role-playing, group discussions, designing solutions to a problem, and solving challenges in VR game environments [20], [21]. The activity allows students to build an initial understanding based on the experience gained during the simulation. In addition, the immersive characteristics of VR also trigger an increased sense of presence and student engagement caused by the ability of virtual environments that can simulate experiences resembling real conditions [3]. However, while the technical capability of VR to provide these concrete experiences is well-documented, a synthetic analysis reveals that the successful scaling of these interactions remains a challenge; while not specific to vocational settings, reported struggles with usability and scalable collaboration [15], [16] are particularly relevant given the infrastructure and resource constraints typical of vocational education.

After students get direct experience, then students will enter the reflective observation stage through reflection activities on the experience that has been gained during the simulation. This process can be carried out through group discussions, exchange of observations, evaluation of actions that have been taken, and giving feedback from fellow students [14], [22], [23]. This analytical process is pivotal, as it enables students to bridge the gap between their virtual actions and the resulting outcomes, effectively transforming raw simulation data into meaningful conceptual understanding. However, the synthesis of recent studies indicates that translating this into practice is non-trivial; while reflection is theoretically emphasized, current VR-based collaborative designs frequently struggle to provide the necessary pedagogical scaffolding to sustain deep, structured inquiry—a persistent gap that suggests reflection is often treated as an incidental rather than an intentional component of the learning cycle [14]. This is consistent with broader findings on collaborative VR design, which report a lack of clear didactic justification and structured facilitation of social interaction [15], [16].

Next, students will enter the abstract conceptualization stage. This stage occurs when students relate the experiences gained in a virtual environment with the concepts, theories and principles underlying the learning material [11]. The visualizations presented in VR help students to understand abstract concepts by transforming them into more concrete and observable representations [3], [19]. This transformation allows students to process raw simulation data into structured knowledge, effectively bridging the cognitive gap between virtual practice and theoretical mastery [11]. However, a significant gap remains in current research: without deliberate pedagogical scaffolding to connect these collaborative interactions back to theoretical frameworks, students may struggle to fully internalize the abstract principles. This concern aligns with broader design-gap findings in collaborative VR literature [15], [16], and underscores the need for learning designs that explicitly bridge immersive practice and theoretical conceptualization—a need arguably more acute within the resource-constrained environment of vocational education, given that cooperative, role-specialized VR designs relevant to vocational training remain comparatively underexplored [15].

The last stage that students will go through is the active experimentation stage. This stage occurs when students apply the understanding they have gained to try strategies, make decisions as well as test various solutions in a simulated environment [19], [21]. For example, students can try different alternative solutions, improve strategies after failures and repeat experiments to obtain more effective results [19], [21]. The opportunity to repeat experiments in a virtual environment allows students to evaluate the results of their actions directly without the risk of real conditions [19]. This characteristic makes VR a medium that supports the EL process in a sustainable manner [11].

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However, the success of this implementation is not determined by the technology alone; it relies heavily on the design of learning activities and collaboration mechanisms that can maintain student involvement throughout the process [20]. Broader research on collaborative VR similarly finds that maintaining structured engagement remains difficult in practice [16]. Developing adaptive learning models that address these design challenges thus remains a significant research gap—one that is especially pressing in vocational education, where cooperative and role-specialized VR approaches are still comparatively underexplored [15].

Synthesizing across the four EL stages, the reviewed literature shows an uneven pattern of support. VR's alignment with Kolb's model is most consistently evidenced at the Concrete Experience and Active Experimentation stages, where studies converge on VR's capacity to provide hands-on, repeatable, risk-free interaction with simulated environments [3], [19], [20]. Support for the reflective observation and abstract conceptualization stages is comparatively weaker: while VR-based activities can nominally accommodate reflection and concept-building [11], [14], [22], [23], the synthesis suggests these processes are rarely scaffolded intentionally, appearing instead as incidental by-products of the simulation experience. This gap is echoed in the broader literature on collaborative VR design, where studies report persistent struggles with usability, social interaction, and didactic justification [15], [16]. Although these studies are not specific to vocational education, their identified design gaps are particularly relevant to vocational contexts such as vocational school, where resource constraints and an emphasis on hands-on competency make structured, intentional design frameworks even more critical to bridging the gap between simulation-based immersion and practical vocational competency.

3.2 Contribution of VR to Students' CT (RQ$_2$)

The use of VR in the learning process contributes positively to the development of students' CT skills, a finding consistently supported across studies employing different VR implementations and CT measures [8], [21], [24], [25]. The learning environment in VR allows students to be actively involved in exploration, simulation, and problem-solving that encourages logical and systematic thinking. This activity can take the form of analyzing challenges in a simulation environment, determining task completion strategies, making decisions based on the conditions faced, and developing problem-solving steps to achieve specific goals within VR simulations [24], [26]. These activities correspond to core CT components, namely decomposition, pattern recognition, abstraction, and algorithmic problem-solving [6], [7]. Notably, this pattern holds specifically within vocational contexts: both a qualitative study on VR game-based learning in vocational classrooms [21] and a VET-focused CT integration framework [9] indicate that VR fosters habitual, sustained patterns of logical and systematic thinking aligned with vocational classroom practices, rather than CT gains being confined to isolated technical instruction.

VR not only creates a more interactive learning experience, but also supports the problem-solving process through simulations that resemble real conditions [8], [19]. VR game-based learning is consistently associated with increased student involvement in solving challenges and decision-making during the learning process [21], [25]. In vocational education specifically, this approach helps students understand technological work processes and solve technical problems in a more structured way [9], [24]. Building on this convergence, the application of VR in vocational learning functions as a pedagogical bridge with the potential to systematically strengthen CT skills within practice-based and simulation-based learning [26].

The interactive nature of VR simulations also allows students to learn through trial and error in a safe environment, testing hypotheses without real-world consequences [8], [26]. This is further supported by evidence that VR-based problem-solving skills can transfer beyond the virtual environment into physical, real-world contexts [19], suggesting the cognitive gains are not merely simulation-bound. Beyond individual engagement, the multi-user and collaborative affordances of VR appear to extend these benefits socially: a large-scale review of VR for Collaborative Learning [17] found that VR effectively engages and motivates learners while providing multi- and interdisciplinary spaces for collaborative work, and pair-learning studies similarly report gains in presence and immersion when students work through VR simulations together [22]. Taken together, these findings suggest that VR's contribution to CT operates through two reinforcing mechanisms: direct cognitive

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engagement with problem-solving tasks, and socially mediated engagement through collaborative simulation both of which appear particularly salient within the practice-oriented, technically demanding nature of vocational education [9], [21].

4. Conclusion

This review provides strong evidence that VR technology is not merely a visual tool but an effective pedagogical instrument for integrating EL with the development of CT. Analysis indicates that the immersive and interactive nature of VR facilitates a more concrete learning process, allowing students to explore concepts through trial-and-error simulations. These findings highlight VR's ability to transform abstract technical concepts into systematic learning experiences. Furthermore, the colaborative VR approach emerges as a significant finding, offering a strategic solution to hardware limitations in schools while fostering dynamic collaboration between VR users and their observing peers. The implications of these findings are highly relevant for both vocational educators and curriculum developers. VR should be integrated as a core component of technical instruction rather than treated as a mere supplement. Designers of learning environments should prioritize the development of features that support social interaction and role distribution to maximize the collaborative potential of simulations. However, this research also highlights a notable gap: existing literature is still dominated by higher education and general education contexts. The vocational education context particularly regarding technical subjects like computer networking remains under-explored. Consequently, future research needs to shift from simple media testing toward a more in-depth empirical validation of this learning model's application in vocational high schools. Ideally, future research will provide concrete evidence of VR's effectiveness in honing students' computational thinking skills, thereby better preparing them for the demands of the workforce.

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