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The Philosophy of Critical Thinking in Problem-Based Science Learning

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Abstract

Exploration of effective pedagogical methods is the main focus aimed at cultivating not only specific knowledge of the subject matter but also critical thinking skills. Referring to the dynamics of exploring critical thinking skills, the role of critical thinking is considered highly important as a support for individual success, even regarded as a crucial skill. The current study aims to examine the role of critical thinking philosophy in Problem-Based Learning (PBL) in science education. This study is a literature review, where information and relevant data were sourced from Scopus and Google Scholar databases. The review findings reveal that science education is not just about knowledge of subject matter content but also about thinking skills. Critical thinking is deemed essential in the 21st century and requires stimuli to develop. One of the learning models that support the development of critical thinking is PBL. The literature review results also disclose the context of critical thinking philosophy, the concept of critical thinking, and critical thinking philosophy in PBL. Critical thinking is reflected in four key indicators: the ability to analyze, evaluate, inference, and decision-making. The review highlights how PBL facilitates critical thinking through engagement with complex problems, active learning, student autonomy, reflection, and repeated problem-solving. Thus, PBL aligns with philosophical principles emphasizing active engagement and experiential learning, inherently fostering students' critical thinking skills.

Keywords: Philosophy, Critical thinking, Science learning, Problem-based learning, Literature review

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INTRODUCTION

In the realm of science education, the primary focus revolves around the exploration of effective pedagogical methods. This endeavor seeks to cultivate not only a comprehensive understanding of subject matter content but also the development of critical thinking skills (Biazus & Mahtari, 2022; Prayogi et al., 2023; Sarkingobir et al., 2023). This dual emphasis is grounded in the recognition that the study of scientific phenomena necessitates a robust array of thinking skills encompassing both the content-specific knowledge and the inherent processes within the domain of science itself (Arends, 2012). In light of the dynamic nature of the quest to enhance thinking skills, the role of critical thinking emerges as particularly pivotal, as it not only bolsters individual success but is also hailed as an indispensable skill for thriving in the 21st century (Almazroa & Alotaibi, 2023; Mäkiö & Mäkiö, 2023).

However, it is crucial to acknowledge that a person's attainment of success in the realm of thinking does not materialize in isolation; rather, it necessitates a stimulus that serves as a catalyst for the thought process. This assertion, articulated by Solso et al. (2008), underscores the notion that thinking is a pervasive cognitive process involving the contemplation of problems within the confines of one's mind. The outcome of this mental deliberation is the formation of novel mental representations, which, crucially, do not naturally evolve but instead must be enriched through exposure to diverse environmental stimuli and varied situational contexts. Thus, the cultivation of effective pedagogical methods in science education not only hinges on imparting knowledge but also on nurturing the cognitive faculties essential for critical thinking and problem-solving, recognizing that these skills are forged through a dynamic interplay between the mind and its surroundings.

In the rhythm of education and science learning, stimuli are expanded through various interactive and innovative modes or methods of learning for the purpose of training learners' critical thinking. One of the learning models that supports the development of critical thinking is Problem-Based Learning (PBL), as revealed by a systematic review conducted by Anggraeni et al. (2023) in a research article examining the impact of the PBL model on learners' critical thinking in the last 5 years (2018 – 2022). PBL has emerged as a dynamic learning model to engage learners in facing real-world challenges while deepening their understanding of the subject matter.

The emergence of PBL (Problem-Based Learning) aligns with significant developments in science education, surpassing traditional didactic methods that often limit learning to passive information reception. PBL is an authentic approach to learning that embraces an innovative paradigm, emphasizing active participation and independent exploration by learners. PBL encourages learners to confront various challenges that reflect real-life scientific cases, problems, or dilemmas. As learners grapple with these challenges, they not only uncover the intricacies of the subject matter but also sharpen their abilities to analyze, evaluate, and make decisions regarding problem-solving, which is a crucial skill in nurturing critical thinking.

The philosophy of critical thinking in science education involves several intriguing issues. First, how to integrate effective pedagogical methods in science education to cultivate specific subject knowledge and thinking skills. Second, how to develop the thinking skills necessary for examining scientific phenomena, including thinking about both the content and processes within science itself. Third, how to foster critical thinking as a cornerstone of individual success and an essential skill in the 21st century. While critical thinking doesn't arise spontaneously, it requires stimulation from diverse environments and contexts. Furthermore, this study aims to explore the philosophy of critical thinking within PBL applied in the field of science education. Through a philosophical framework, it uncovers the implications of PBL in science education on the development of critical thinking skills. As a crucial part of the current study, the literature related to the context of critical thinking philosophy, the concept of critical thinking, and the philosophy of critical thinking in PBL is elaborated.

METHOD

This study constitutes a comprehensive literature review, drawing inspiration from and adapting the methodologies of a bibliometric analysis study conducted by Wirzal et al. (2022). In the pursuit of assembling pertinent data for this research endeavor, two primary sources were harnessed: the Scopus database (accessible at https://www.scopus.com) and Google Scholar (accessible at https://scholar.google.com/). The selection of these data sources stemmed from a thoughtful consideration of their utility, with Scopus, in particular, emerging as a global benchmark for the evaluation of scientific article quality. The Scopus database offers a rich repository of abstracts and citations from a diverse array of scientific literature, spanning various sources and disciplines, rendering it an invaluable trove of information. Beyond its sheer comprehensiveness, the array of features within the Scopus database simplifies the process of locating experts, authors, data, metrics, and visualizations that illuminate the latest research trends across myriad scientific domains. Employing keywords closely aligned with the research focus, namely "critical thinking philosophy in problem-based learning," the researcher effectively unearthed a wealth of documents encompassing articles, conference papers, and books that pertinently align with this thematic exploration. These documents, in turn, constituted the foundational material for the ensuing review, meticulously tailored to the specific requisites of this research endeavor.

As a sequel to this meticulous data collection process, the research proceeded to engage with the trove of discovered documents. The diligent curation of these materials was conducted with an eye toward their alignment with the research's core objectives. This intricate process involved sifting through a myriad of articles, conference papers, and books, with each piece selected for its direct relevance to the theme of "critical thinking philosophy in problem-based learning." This judicious selection ensured that the review process was grounded in a robust foundation of scholarly works, poised to contribute meaningfully to the existing body of knowledge. Moreover, the utilization of both Scopus and Google Scholar as primary data sources endowed this research with a multi-faceted perspective, drawing from the rigorously peer-reviewed academic literature as well as diverse academic outputs, thereby enriching the depth and breadth of the study's analytical scope. In summary, the careful selection of data sources and the meticulous curation of relevant documents underpin the scholarly rigor and comprehensiveness of this literature review, positioning it as a valuable contribution to the discourse on critical thinking philosophy in the context of problem-based learning.

In order to ensure a comprehensive literature review, our researchers utilized both the Scopus database and the Google Scholar search engine (accessible at https://scholar.google.com/). This dual approach was undertaken to encompass all relevant literature pertaining to our research topic. These two sources were selected due to their capacity to offer extensive and in-depth coverage, facilitating the identification of pertinent material within the realm of critical thinking philosophy as it relates to problem-based learning.

Within the framework of our literature review process, this research gives specific attention to three primary facets: the philosophy of critical thinking, the essence of critical thinking, and the practical application of critical thinking philosophy within the context of problem-based learning (PBL). This focused approach enables us to delve deeply into the incorporation of critical thinking philosophy within the sphere of PBL and gauge the extent to which this theme has been explored in the scholarly literature. We anticipate that the outcomes of this comprehensive literature review will furnish valuable insights for fellow researchers, educational practitioners, and other stakeholders who share an interest in nurturing critical thinking skills within the context of problem-based learning.

RESULTS AND DISCUSSION

Philosophy of Critical Thinking

Philosophy, in English, originates from the Greek word "philosophia," which consists of two words: "philos" (love) or "philia" (friendship, attraction to) and "sophia" (wisdom, knowledge, skill). So, etymologically (based on linguistic origins), philosophy means the love of wisdom or truth. In the Indonesian language's Great Dictionary (KBBI), the word philosophy denotes knowledge and investigation with reason regarding the essence of everything that exists, its origin, and its laws. The purpose of philosophy is to gain insights into questions about knowledge, truth, reason (rationality), reality, meaning, thought, and values (Grayling, 1999). Therefore, the essence of philosophy is actually how one thinks. In the perspective of cognitive psychology, thinking is a cognitive process or mental activity to acquire or develop knowledge (Costa, 1991).

In a more modern perspective, philosophy is closely related to the context of thinking, as Byrd (2021) explicitly states that philosophy is a reflective activity, and conversely, reflective activity plays a crucial role in shaping and enhancing philosophical thinking. Philosophy training correlates with better performance in reflective processes in various fields (Byrd, 2021). Reflective thinking is a deep-thinking process involving logical reasoning associated with critical thinking. This is based on John Dewey's paradigm as a philosopher and psychologist who introduced critical thinking as reflective thinking (Dewey, 1933).

Early researchers connected philosophical aspects that contributed to the development of thinking skills. For example, a study by Lam (2021) shows that integrating philosophy into learning can enhance learners' critical thinking. Philosophical dialogue within peer communities provides essential conditions for the development of high-level thinking skills and dispositions (Daniel & Bergman-Drewe, 1998). Thoughts arising from philosophy can serve as engines to train thinking skills and creativity (Hołub & Duchliński, 2016). Daniel and Auriac (2011) clearly consider philosophy as an intellectual activity that requires complex cognitive skills and a tendency toward complex or critical thinking.

From the description above, it is clear that critical thinking is at the core of philosophy because with critical thinking, one can evaluate facts and develop arguments based on tested principles of truth. Philosophically, from the perspective of cognitive psychology, thinking is a natural aspect of human nature, but critical thinking skills cannot naturally develop; stimuli or triggers are needed for someone to think critically.

Critical Thinking Concept

Thinking is a cognitive process or mental activity aimed at acquiring knowledge. The ability to think cannot naturally develop, so it must be enriched by various environmental stimuli and diverse settings, including learning. Learning is the process of forming and improving an individual's thinking abilities. Experts have long explored the tendencies of individuals' thinking styles and linked them to the learning outcomes achieved. Learners solve problems in two ways of thinking: convergent and divergent (Zhu et al., 2019). Convergent thinking is identified with critical thinking patterns, while divergent thinking is associated with creative thinking (Webb et al., 2017).

John Dewey, a philosopher and psychologist, introduced the concept of critical thinking. Dewey introduced critical thinking as "reflective thinking," which is described as active thinking involving consideration, persistence, and thoroughness regarding a belief or form of knowledge from a reasoning perspective that supports it and the subsequent conclusions it tends toward (Dewey, 1910). The active process can be contrasted with an example where someone simply accepts ideas and information from others without deep thought, which does not involve an active thought process (this way of thinking is called passive thinking). In Elder and Paul's definition (2012), critical thinking is described as the way of thinking about anything, substance, or problem in which a thinker enhances the quality of their thinking by skillfully handling the inherent structures in thinking and applying intellectual standards to it. They also describe critical thinking as an art of analyzing and evaluating with the intention of improving that ability itself.

According to Facione (2020), critical thinking is essentially a detailed description of several characteristics that include the processes of interpretation, analysis, evaluation, inference, explanation, and self-regulation. One of the well-known contributors to the critical thinking tradition is Robert Ennis. Ennis (2011) provides a definition of the concept of critical thinking, which is reasonable and reflective thinking focused on deciding what to believe or do. In his essay titled 'Critical Thinking: A Streamlined Conception' (Ennis, 2015), Robert Ennis reveals the conception of critical thinking, where someone with critical thinking skills must reflect both the ability and disposition of critical thinking. The common perspective (intersection) in the context of critical thinking skills by Ennis (2015) and other experts is shown in four critical thinking indicators widely adopted in several previous studies (for example; Bilad et al., 2022; Ekayanti et al., 2022; Evendi et al., 2022; Prayogi et al., 2018b; Suhirman & Prayogi, 2023; Wahyudi et al., 2018, 2019), namely: the ability to analyze, infer, evaluate, and make decisions (decision-making). The mentioned indicators will be discussed as follows.

1) Analysis

'Analysis' is intended to identify the actual relationships between statements, questions, concepts, descriptions, or others (Facione, 2020). Forms of representation are meant to express beliefs, judgments, experiences, reasons, information, or opinions. Analysis also includes examining ideas, detecting arguments, and analyzing arguments as sub-skills of analysis. According to Ennis (2015), analyzing arguments includes identifying conclusions, identifying reasons or premises, identifying simple assumptions, identifying and addressing irrelevancies, examining the structure of arguments, and, finally, summarizing them as a form of analysis.

In 1956, Bloom (as cited in Conklin, 2005) developed a taxonomy in the cognitive domain and included analysis as the fourth cognitive level. Bloom's concept of analysis involves breaking down ideas into several parts and describing the relationships among those parts. Examples of scientific problems that lead to the process of analysis are: "Explain why a car tire does not deflate after driving several miles at high speed." Or in another topic, for instance, "Determine the size and length of cable needed to connect three switches in a junction box" (Morrison et al., 2019). Analytical skills will assist learners in solving scientific problems in their surroundings.

2) Inference

According to Facione and Facione (1994), inference is the process of identifying the elements necessary to draw reasonable conclusions, to form assumptions and hypotheses, to consider relevant information, and the consequences that flow from statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or forms of representation. Ennis (2018) emphasizes that the process of inference is more focused on drawing conclusions and evaluating deduction, generalization, and induction, considering broadly. The proposed conclusions are consistent with all known facts, logical, and straightforward. An example of a scientific problem related to inference is: "Explain your inference results when toy boats are placed at a distance from each other, then brought together and collide after water is poured in the space between the two boats!"

3) Evaluation

The evaluation is intended to assess the credibility of statements, representations, descriptions, perceptions, experiences, situations, judgments, beliefs, or opinions (Facione, 2020). Bloom (in Morrison et al., 2019) describes evaluation as the process of making judgments about material and methods. In the context of assessing critical thinking in science, indicators for evaluation may include questions like: "Before filling a container with steam at a temperature of 150°C and filling another container with oxygen at a temperature of 150°C, which gas is more likely to behave in accordance with the laws of gases?"

4) Decision-making

Decision-making is the process of choosing options or actions from a set of alternatives based on criteria or strategies (Wang & Ruhe, 2007). Making decisions is a representation of the critical thinking process, which aligns with what Sternberg (1986) stated:

"...critical thinking comprises the mental processes, strategies, and representations people use to solve problems, make decisions, and learn new concepts."

Sternberg (1986) created a matrix of experts on decision-making, accommodating the processes within it, namely stating the desired goals along with their obstacles, identifying and examining alternatives, ranking the alternatives, choosing the best alternative, and evaluating actions. An example of a science-related decision-making problem is as follows: "A craftsman has various silver raw materials in different shapes and sizes. The craftsman wants to distinguish between pure and impure materials. What actions can the craftsman take to determine the purity of the silver materials they possess based on Archimedes' principle?"

Philosophy of Critical Thinking in PBL

Issues related to philosophy in the tradition of scientific research, according to Titus et al. (1979), typically employ the theory of "pragmatism." They describe pragmatism as a philosophy that teaches that what is true is what proves itself to be true through its practical consequences. Pragmatic criteria are used by scientists to determine scientific truth (Titus et al., 1979). In the context of success in critical thinking, experts, scientists, or researchers indirectly engage in investigations related to critical thinking and benefit from innovations developed to train critical thinking. One form of innovation is the development of constructivist learning methods to train critical thinking. One of the learning methods associated with efforts to train critical thinking skills is Problem-Based Learning (PBL). PBL has been extensively used in the tradition of training critical thinking skills. Within the research framework, each researcher constructs a critical argument regarding the effectiveness of PBL in training learners' critical thinking.

Problem-Based Learning (PBL) is a learning model that encourages students to conduct investigations or explorations based on authentic problems (Evendi et al., 2022). The PBL model follows stages of learning, namely: a) orienting students to authentic problems, b) organizing students for learning, c) the investigative process to solve problems, d) presenting research results, and e) reflecting on problem-solving (Evendi et al., 2022). In its application in the classroom, the philosophy of achieving critical thinking is built on authentic problems presented. For example, new knowledge products can emerge by presenting a number of authentic problems (Hung, 2011). Additionally, presenting authentic problems and solving them through investigation impact knowledge retention and better understanding of concepts (Li & Tsai, 2017). When associated with learning content, pedagogy in PBL has a positive impact on students' reasoning performance (Wirkala & Kuhn, 2011). Specifically, in achieving critical thinking performance, problem-solving through exploration and investigation helps students develop critical thinking skills (Calkins et al., 2020).

Summarized in various literature, PBL is an education approach centered on exploration and real-world problem-solving as a means to facilitate the learning process. Philosophically, PBL can train critical thinking through several interconnected reasons. First, engagement with complex realities (problems): PBL often presents open, authentic, and complex problems to students that reflect real-life situations. Engaging with these real-life conditions (problems) encourages critical thinking because it requires students to analyze various dimensions, perspectives, and factors before arriving at a solution. Second, active learning through exploration: PBL transforms the role of students from passive information receivers to active investigators and problem solvers. Philosophically, this involves students in asking questions, engaging in dialogue, and challenging assumptions. This process nurtures critical thinking by encouraging students to question, investigate, and evaluate information rather than merely memorizing it. Third, autonomous decision-making: In PBL, students have a level of autonomy in how they approach problems, fostering independence and self-directed learning. Philosophically, students are encouraged to take responsibility for their choices. Critical thinking improves when students need to make sensible decisions and stand by their choices. Fourth, the process of reflection: PBL incorporates reflection on the problem-solving process, aligning with the principles of pragmatism and phenomenology that emphasize the importance of experience and reflection in learning. Students assess their thinking processes, identify biases, and refine their problem-solving strategies for the future. This is a crucial part of training students' critical thinking. Fifth, iterative problem-solving: PBL often involves multiple iterations of problem-solving as new information is discovered or initial solutions are evaluated. Philosophically, this reflects the scientific method, where hypotheses are tested and refined through observation and experimentation. Critical thinking is honed when students adjust their approach based on evidence and feedback.

In essence, PBL aligns with various philosophical principles that emphasize active engagement, investigation, reflection, autonomy, and the encouragement of critical thinking. By immersing students in this intellectual process, PBL inherently nurtures students' critical thinking skills (Fitriani et al., 2022; Suhirman & Ghazali, 2022).

CONCLUSION

The philosophy of critical thinking plays a crucial role in problem-based learning (PBL) in science education. Science education is not just about understanding the content of the subject matter but also about developing deep-thinking skills. The philosophy of critical thinking serves as a strong foundation in efforts to enhance the quality of students' thinking. Reviews of several studies outline the concept of critical thinking, which includes analytical, inferential, evaluative, and decision-making abilities. Critical thinking is a reflective and active process that requires stimuli for development. In the context of science education, the PBL model is one effective form of stimulus to train critical thinking skills.

PBL offers an authentic and interactive learning approach in which students are confronted with complex real-world problems. They must actively engage in investigation, problem-solving, and reflection. PBL encourages students to think critically by involving them in questioning, dialogue, and problem-solving. They also have autonomy in decision-making, fostering independence and self-directed learning. Furthermore, PBL incorporates reflection as an essential part of the learning process, allowing students to assess and refine their thinking. Philosophically, PBL aligns with principles that support critical thinking, such as engagement with complex realities, active learning, autonomous decision-making, reflection, and iterative problem-solving. Through PBL, students' critical thinking is honed and enhanced, which is highly important in the context of modern science education. PBL is not just about understanding facts but also about understanding how to think and solve problems in the real world.

RECOMMENDATION

Future research in the field of critical thinking in Problem-Based Learning (PBL) within science education should delve deeper into the specific strategies and pedagogical approaches that effectively enhance critical thinking skills. This could involve conducting empirical studies to assess the impact of various PBL implementations on students' critical thinking abilities, comparing different PBL models and variations to determine which ones are most conducive to critical thinking development. Additionally, investigating the long-term effects of PBL on critical thinking retention and transferability beyond the classroom would provide valuable insights in philosophy context. Furthermore, exploring the role of technology and digital tools in augmenting critical thinking within the context of PBL can be a promising avenue for research. Finally, examining the potential cultural and contextual factors that influence the effectiveness of PBL in fostering critical thinking across diverse educational settings could contribute to a more comprehensive understanding of this pedagogical approach's applicability and adaptability.

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