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Meta-Analysis: The Impact of Problem-Based Learning (PBL) Models on Students' Critical Thinking Skills

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Abstract: Critical thinking is an essential skill in the modern information era, enabling individuals to analyze complex information, evaluate arguments, and make informed decisions. In educational contexts, particularly in geography, fostering critical thinking equips students to address real-world environmental and social challenges. Problem-Based Learning (PBL) has emerged as a transformative teaching approach to develop these cognitive abilities through active, problem-centered learning. This meta-analysis aimed to evaluate the effectiveness of PBL in enhancing students' critical thinking across various educational levels. Using OpenMEE software and a continuous random-effects model, the study synthesized findings from 20 peer-reviewed studies published between 2020 and 2024. Statistical analyses focused on the standardized mean difference (SMD) as the primary metric to measure effect sizes. The results demonstrated that PBL significantly enhances critical thinking skills, with an overall SMD of 1.254 (95% CI: 0.875 to 1.633, $p < 0.001$). However, notable heterogeneity was observed, attributed to variations in educational levels, implementation fidelity, and study contexts. Subgroup analyses revealed that junior high school students experienced the greatest improvement, followed by university, senior high school, and elementary school students. These findings affirm PBL's potential as an effective pedagogical strategy for fostering critical thinking. The study highlights the need for tailored PBL implementations and further research into its long-term effects and applicability across diverse educational contexts. The results provide robust evidence supporting PBL as a vital tool in modern education.

Keywords: Problem-Based Learning, Critical Thinking, Geography, Effective Teaching

INTRODUCTION

Critical thinking is a fundamental skill in education, enabling students to process information, evaluate arguments, and form sound conclusions. Its significance spans across various disciplines, where students are required not only to acquire knowledge but also to apply it effectively in problem-solving contexts. Problem-Based Learning (PBL) has emerged as a teaching approach that enhances critical thinking by immersing learners in real-world problems, promoting active engagement and analytical reasoning (Thorndahl & Stentoft, 2020).

PBL emphasizes inquiry-driven and collaborative learning, allowing students to engage deeply with the material and develop critical thinking skills. In mathematics education, research indicates that students exposed to PBL demonstrated significant improvements in their ability to address complex problems compared to those taught with traditional methods (Widyatiningtyas et al., 2015). Similarly, a meta-analysis in science education showed that PBL had a substantial positive effect on critical thinking, with physics, chemistry, and biology students achieving enhanced analytical and reasoning capabilities (Miterianifa et al., 2019).

In the healthcare field, PBL has been widely applied to prepare students for the complexities of clinical practice. A review of nursing programs found that PBL significantly enhanced critical thinking, enabling students to approach healthcare challenges methodically and collaboratively (Kong et al., 2014). Another study in Korea reported that nursing students engaged in PBL exhibited growth not only in critical thinking but also in problem-solving and self-directed learning abilities, which are crucial for professional development (Choi et al., 2014).

The application of PBL in secondary education also demonstrates its potential to foster critical thinking. In biology education, high school students showed improved problem-solving abilities after participating in PBL sessions focused on analyzing complex biological concepts (Harahap et al., 2023). A similar study in economics education found that students developed advanced analytical skills by exploring topics like national income and unemployment, facilitated by PBL activities (Narmaditya et al., 2018).

The adaptability of PBL across diverse disciplines highlights its strength as an educational approach. In visual arts education, students benefited from the creative aspects of PBL, with noticeable improvements in their ability to think critically and generate innovative solutions (Ulger, 2018). Additionally, business education has incorporated guided PBL models, where students solve problems before receiving theoretical explanations. This method has been shown to improve both individual and group performance in critical thinking tasks (Nargundkar et al., 2014).

Frameworks like Bloom's Taxonomy and SOLO taxonomy offer valuable structures for PBL, guiding educators in fostering critical thinking through targeted cognitive processes. These models prioritize skills such as evaluation and synthesis, which are crucial for developing higher-order thinking. Studies implementing these frameworks in economics and biology classrooms reported enhanced student engagement and more robust critical thinking outcomes (Arifin, 2021).

Implementing PBL is not without challenges, and educators often encounter obstacles related to time management, resource allocation, and the need for professional training. For instance, a study in English language education highlighted barriers such as teacher preparedness and student readiness, which can hinder the success of PBL sessions (Emiliasari et al., 2019). Addressing these challenges requires institutional support and investment in training programs to equip educators with the skills necessary to facilitate effective PBL.

The benefits of PBL are further supported by its ability to foster transferable skills. In vocational training, students engaged in PBL demonstrated improvements in both technical competencies and cognitive abilities, reflecting the approach's dual focus on academic and practical learning outcomes (Sholihah & Lastariwati, 2020). This dual focus makes PBL particularly valuable in preparing students for real-world challenges across industries and professions.

Educational institutions play a pivotal role in ensuring the effective implementation of PBL. By providing necessary resources, fostering collaboration among educators, and prioritizing professional development, schools and universities can maximize the potential of this approach. Research underscores that when PBL is integrated thoughtfully into curricula, it equips students with critical thinking and problem-solving skills that are essential for their academic and professional success (Kek & Huijser, 2011).

The growing body of evidence supports the idea that PBL is a transformative educational strategy. By engaging students actively in their learning journey, PBL not only enhances their understanding of subject matter but also prepares them to think critically and address complex issues in real-world settings. While challenges in implementation persist, addressing these through systemic changes can further amplify the impact of PBL, making it an invaluable tool in modern education.

METHOD

This research applies a meta-analysis approach, a statistical technique that integrates findings from multiple studies to derive quantitative conclusions. Meta-analysis provides a systematic, objective method for synthesizing data to address specific research questions or test hypotheses (Hedges & Vevea, 1998). This study employs the continuous random-effects model, which accounts for variations across studies by assuming a distribution of true effects rather than a fixed outcome. This model is particularly effective for aggregating diverse research findings, ensuring robust and generalized results (Fleiss, 1993).

The primary metric used in this meta-analysis is the Standardized Mean Difference (SMD). SMD allows for the comparison of effect sizes across studies with different measurement scales, facilitating direct and meaningful comparisons (Bakbergenuly et al., 2019). This metric is particularly advantageous as it standardizes the results, making them comparable irrespective of the original units of measurement (Boedeker & Henson, 2020).

The data collection process began by identifying relevant articles from high-quality, peer-reviewed journal databases. Inclusion and exclusion criteria were rigorously applied to ensure the relevance and methodological rigor of the selected studies. The criteria focused on parameters such as the study's alignment with the research objective, methodological quality, and the availability of quantitative results necessary for meta-analytic computation (Lin & Aloe, 2021).

Once selected, the articles underwent a qualification process to evaluate their suitability for inclusion. This step included assessing study designs, sample sizes, and reported outcomes to ensure consistent and valid comparisons (Rubio-Aparicio et al., 2018). The heterogeneity of the studies, or the variance between study results, was measured using Cochran's Q statistic and tau-squared (τ^2), which indicate the degree of variability attributable to differences across studies rather than sampling error (Marín-Martínez & Sánchez-Meca, 2010).

For data synthesis, the study utilized OpenMEE (Meta-Win 2.0) software, a specialized tool designed for advanced meta-analytic computations. This software was employed to calculate effect sizes, perform heterogeneity analysis, and generate confidence intervals. The inclusion of OpenMEE ensured precise statistical handling and enhanced the validity of the results (Biggerstaff & Tweedie, 1997).

The methodology also accounted for the estimation of sampling variance, a critical aspect in calculating weighted effect sizes. Methods such as the DerSimonian-Laird and restricted maximum likelihood (REML) estimators were applied to ensure accurate variance estimation (Bonett, 2009). These techniques allowed for robust inferences, even when sample sizes varied significantly across studies.

By synthesizing data from multiple studies, this meta-analysis aims to produce a comprehensive understanding of the research question, providing reliable conclusions that can inform future research and practice. The rigorous application of statistical models and software tools ensures the reliability and generalizability of the findings, addressing both the methodological challenges and the goals of the study.

RESULTS

Overview of Analyzed Studies

This meta-analysis examined 20 studies published between 2020 and 2024, each focusing on the impact of Problem-Based Learning (PBL) on students' critical thinking abilities. The studies covered diverse educational levels, including elementary school, junior high school, senior high school, and university. All the included studies were peer-reviewed and employed the standardized mean difference (SMD) as the primary metric to assess effect sizes, enabling consistent comparisons across studies with varying measurement scales. This approach ensured a rigorous and reliable analysis of PBL's effectiveness in fostering critical thinking (Table 1).

The participant groups represented a wide range of educational contexts, reflecting the adaptability of PBL across different age groups and learning stages. At the elementary school level, eight studies focused on applying PBL to younger learners, emphasizing foundational critical thinking skills necessary for early cognitive development. The effect sizes for these studies ranged from -0.498 to 2.747, indicating variability in outcomes, potentially due to differences in implementation and classroom settings. For junior high school students, three studies highlighted PBL's role in enhancing middle-grade students' critical thinking. These studies reported effect sizes ranging from 1.374 to 4.229, showcasing a robust improvement in critical thinking at this transitional educational stage.

Table 1. Characteristics of Studies Analyzing the Impact of Problem-Based Learning on Critical Thinking Across Educational Levels

Authors (year)	Participant (Category)	Publication Type	SC Measure	Nc (Count)	Xc (Mean)	SDc (SD)	Ne (Count)	Xe (Mean)	SDe (SD)	d (Effect Size)	Var(d)
(Mauludiyah et al., 2021)	Senior	Article	Standardized	32	69.84	6	26	74.77	7	0.752	0.075
(Fauziah et al., 2024)	Senior	Article	Standardized	36	60.56	13	36	73.47	13	0.982	0.062
(Hasanah et al., 2023)	Senior	Article	Standardized	33	71.36	13.1	33	83.87	9.64	1.069	0.071
(Silviariza et al., 2021)	University	Article	Standardized	38	63.21	9	40	73.95	7	1.323	0.063
(Rahmawati & Airlanda, 2023)	Elementary	Article	Standardized	26	35.61	15	26	39.1	17	0.214	0.077
(Susanto & Airlanda, 2023)	Elementary	Article	Standardized	28	91.07	6	28	87.5	8	-0.498	0.074
(Puspitawati & Mawardi, 2022)	Elementary	Article	Standardized	26	83.08	9	23	88.04	7	0.601	0.086
(Tabbu et al., 2023)	University	Article	Standardized	33	78.63	5	32	86.5	4	1.714	0.084
(Mustofa et al., 2021)	Junior	Article	Standardized	16	55.5	10	19	72	13	1.374	0.142
(Fadhilah et al., 2022)	University	Article	Standardized	15	69.2	9.17	15	85.67	8.46	1.816	0.188
(Nursidik, 2021)	Junior	Article	Standardized	30	74.83	4	30	84.33	5	2.071	0.102
(Lestari et al., 2021)	Elementary	Article	Standardized	24	10.42	2.04	22	16.68	2.44	2.747	0.169
(Mariskhantari et al., 2022)	Elementary	Article	Standardized	40	70.38	12	41	78.54	11	0.703	0.052
(Sitompul, 2021)	Junior	Article	Standardized	22	67.91	5	22	87.41	4	4.229	0.294
(Hartono et al., 2023)	Senior	Article	Standardized	26	3	12	34	40.49	15	2.719	0.129
(Binasdevi, 2022)	Elementary	Article	Standardized	19	73	6	20	78	8	0.69	0.109
(Kusumawardani et al., 2022)	Senior	Article	Standardized	32	48.28	16	32	57.19	18	0.517	0.065
(Rauf et al., 2022)	Elementary	Article	Standardized	20	56.2	13.98	20	82.6	13.63	1.874	0.144
(Yampap & Hasyda, 2023)	Elementary	Article	Standardized	32	77.5	10	32	85.63	11	0.764	0.067
(Melindawati et al., 2021)	University	Article	Standardized	20	65	19.9	20	74.5	14.4	0.536	0.104

Senior high school students were the focus of five studies, which consistently demonstrated improvements in critical thinking through PBL. The effect sizes in this group ranged from 0.517 to 2.719, indicating positive outcomes across various implementations. Meanwhile, four studies at the university level explored PBL's impact on advanced critical thinking development among tertiary education students. These studies reported effect sizes between 0.536 and 1.816, reflecting the effectiveness of PBL in cultivating higher-order thinking skills required for complex problem-solving in academic and professional contexts.

The sample sizes varied across the studies, with control group sizes (Nc) ranging from 15 to 40 participants and experimental group sizes (Ne) ranging from 15 to 41 participants. The means (Xc and Xe) and standard deviations (SDc and SDe) also varied widely between control and experimental groups, reflecting the diverse characteristics of the studies included. The calculated effect sizes (d) provided a quantitative measure of PBL's impact, with positive values indicating a significant improvement in critical thinking skills among students exposed to PBL interventions. These findings further emphasize the role of PBL in bridging the gap between traditional teaching methods and the development of critical thinking (Table 1).

The comprehensive dataset analyzed in this study underscores the adaptability and effectiveness of PBL across different educational levels. From early cognitive development in elementary school to the advanced analytical needs of university students, the findings highlight PBL's broad applicability in fostering critical thinking. This meta-analysis provides robust evidence supporting the integration of PBL into curricula across educational stages, paving the way for improved teaching strategies and learning outcomes.

Table 2. Subgroup Analysis of Standardized Mean Difference (SMD) Across Educational Levels

Subgroup	Estimate (SMD)	Lower Bound (95% CI)	Upper Bound (95% CI)	Std. Error	p-Value
Elementary School	0.847	0.263	1.432	0.298	0.005
Junior High School	2.501	1.099	3.904	0.716	< 0.001
Senior High School	1.175	0.543	1.806	0.322	< 0.001
University	1.327	0.789	1.865	0.274	< 0.001
Overall	1.254	0.875	1.633	0.193	< 0.001

The subgroup analysis provided detailed insights into the effectiveness of Problem-Based Learning (PBL) on enhancing critical thinking across various educational levels. The overall standardized mean difference (SMD) was 1.254 (95% CI: 0.875 to 1.633) with a standard error of

0.193, indicating a statistically significant improvement in critical thinking (p < 0.001). These findings highlight the broad applicability of PBL in fostering critical thinking across diverse educational contexts (Table 2).

For senior high school students (SMA), the effect size was 1.175 (95% CI: 0.543 to 1.806) with a standard error of 0.322, demonstrating a significant positive impact of PBL (p < 0.001). At the university level (PT), students exhibited an SMD of 1.327 (95% CI: 0.789 to 1.865) with a standard error of 0.274, indicating that PBL effectively supports the development of advanced critical thinking skills (p < 0.001). Elementary school students (SD) showed a smaller but significant improvement, with an SMD of 0.847 (95% CI: 0.263 to 1.432) and a standard error of 0.298 (p = 0.005), highlighting the potential of PBL in building foundational critical thinking skills among younger learners.

Junior high school students (SMP) experienced the largest effect size, with an SMD of 2.501 (95% CI: 1.099 to 3.904) and a standard error of 0.716 (p < 0.001). This finding underscores the substantial impact of PBL on critical thinking during this transitional educational phase.

The overall analysis indicates that while PBL significantly enhances critical thinking across all levels, its effects vary depending on the educational stage. Junior high school students showed the greatest benefit, suggesting that contextual factors such as age and curriculum design may influence the outcomes of PBL implementation.

Main Findings

The meta-analysis demonstrated a substantial positive effect of Problem-Based Learning (PBL) on students' critical thinking skills across various educational levels. The overall standardized mean difference (SMD) was 1.254, with a 95% confidence interval (CI) of 0.875 to 1.633, indicating a significant improvement in critical thinking outcomes (p < 0.001) (Table 3). These results provide strong evidence supporting PBL as an effective teaching strategy for cultivating critical thinking skills in diverse educational contexts.

Table 3. Overall Effect Size (Standardized Mean Difference)

Estimate	Lower Bound (95% CI)	Upper Bound (95% CI)	Std. Error	P-Value
1.254	0.875	1.633	0.193	<0.001

This significant overall effect highlights the versatility of PBL as an instructional approach. By emphasizing active, problem-centered learning, PBL promotes higher-order cognitive processes that contribute to the development of critical thinking. The consistent positive outcomes observed across studies confirm the broad applicability of PBL, regardless of the participants' educational level or the subject matter. This makes it a valuable teaching method for educational systems seeking to foster critical thinking in preparation for the challenges of the 21st century.

The subgroup analysis (referenced in Table 2) further illustrates the variability in effect sizes across educational stages, suggesting that PBL impacts different age groups and learning contexts to varying degrees. For instance, junior high school students demonstrated the largest gains in critical thinking (SMD = 2.501, 95% CI: 1.099 to 3.904), reflecting the developmental readiness of this group to engage deeply with the problem-solving and collaborative elements of PBL. By contrast, elementary school students showed smaller but still meaningful gains (SMD = 0.847, 95% CI: 0.263 to 1.432), which can be attributed to the foundational stage of cognitive development and their limited prior exposure to structured critical thinking activities.

University students also exhibited significant improvements in critical thinking, with an SMD of 1.327 (95% CI: 0.789 to 1.865). This finding underscores the importance of PBL in higher education, where students are expected to engage with complex, discipline-specific problems that require advanced analytical and evaluative skills. Meanwhile, senior high school students showed an effect size of 1.175 (95% CI: 0.543 to 1.806), reinforcing the efficacy of PBL during this transitional educational phase as students prepare for tertiary-level challenges.

The variability in effect sizes across subgroups emphasizes the importance of tailoring PBL implementation to meet the unique needs of different educational levels. For younger students, incorporating scaffolding techniques and simplifying problems can enhance engagement and skill development, while older students may benefit from more complex, interdisciplinary problem-solving tasks. Despite these differences, the overall findings consistently highlight PBL's capacity to foster critical thinking across educational settings.

In addition to the quantitative results, the meta-analysis findings emphasize the potential of PBL to bridge the gap between traditional teaching methods and the critical thinking demands of modern education. Traditional lecture-based approaches often emphasize rote memorization and lower-order cognitive skills, whereas PBL actively engages students in processes that stimulate analysis, synthesis, and evaluation. These higher-order cognitive skills are essential for addressing real-world challenges, making PBL a critical tool for equipping students with the competencies necessary for lifelong learning and professional success.

Overall, the results of this meta-analysis affirm the effectiveness of PBL as a pedagogical approach, with significant benefits across educational levels. This evidence provides a strong foundation for educators and policymakers to advocate for broader implementation of PBL as a means to enhance critical thinking skills in diverse learning environments.

Heterogeneity and Subgroup Analysis

The meta-analysis revealed significant heterogeneity among the included studies, indicating considerable variability in the reported effect sizes. The tau-squared (τ^2) value was 0.644, and the Q statistic was 154.934 (df = 19), with an associated heterogeneity p-value of < 0.001. Additionally, the I^2 value was 87.737%, signifying that a substantial proportion of the observed variance across studies was attributable to differences in study characteristics rather than random sampling error (Table 4). These findings highlight the necessity of examining potential sources of heterogeneity to better understand the factors influencing the impact of Problem-Based Learning (PBL) on critical thinking.

Table 4. Heterogeneity Statistics

τ^2	Q (df = 19)	Heterogeneity P-Value	I^2 (%)
0.644	154.934	<0.001	87.737

To explore this variability, a subgroup analysis was conducted based on the educational level of participants, providing insights into the differential impact of PBL across various contexts. The results indicated that junior high school students (SMP) exhibited the largest effect size, with a standardized mean difference (SMD) of 2.501 (95% CI: 1.099–3.904) and a p-value of < 0.001. This finding suggests that PBL is particularly effective for fostering critical thinking in this age group, possibly due to their developmental readiness to engage in structured problem-solving and collaborative learning.

University students (PT) also demonstrated a strong positive effect, with an SMD of 1.327 (95% CI: 0.789–1.865) and a p-value of < 0.001. This result highlights the suitability of PBL in higher education, where students are expected to tackle complex, discipline-specific problems that require advanced critical thinking and analytical skills. High school students (SMA) showed an SMD of 1.175 (95% CI: 0.543–1.806, $p < 0.001$), indicating that PBL effectively supports the development of critical thinking during this critical transitional phase as students prepare for higher academic challenges.

In contrast, elementary school students (SD) demonstrated the smallest effect size, with an SMD of 0.847 (95% CI: 0.263–1.432) and a p-value of 0.005. Although the effect was smaller compared to older students, it still signifies that PBL can positively influence foundational critical thinking skills among younger learners. This difference may stem from the limited prior exposure of elementary students to structured analytical tasks, as well as their developing cognitive abilities.

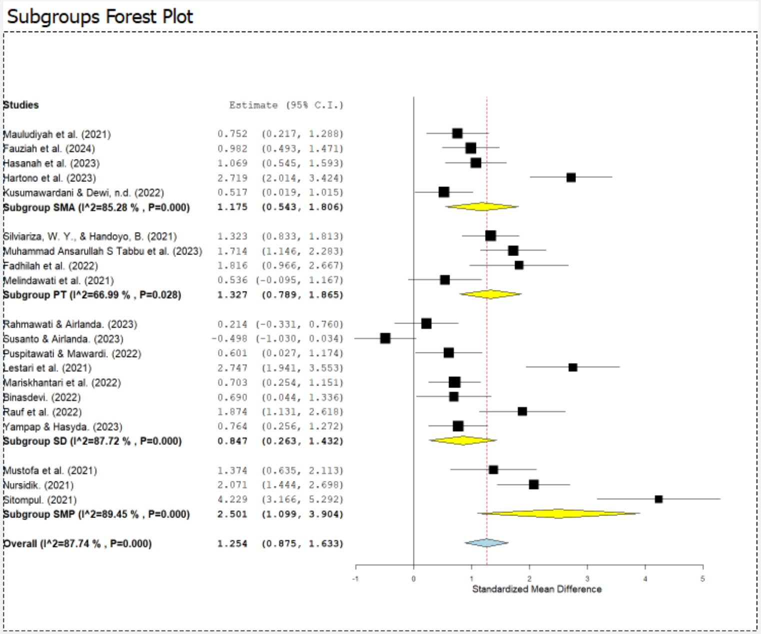

Figure 1. Forest Plot of Standardized Mean Differences (SMD) Across Educational Levels, Highlighting Effect Sizes and 95% Confidence Intervals for Each Study.

The forest plot (Figure 1) visually represents the effect sizes and confidence intervals for each study, grouped by educational level. The plot clearly illustrates the variability in effect sizes across subgroups, highlighting the differential impact of PBL. Factors such as curriculum structure, fidelity in the implementation of PBL, and the age of participants likely contributed to these variations. For instance, junior high school students may benefit from PBL's balance of structure and independence, while elementary students may require additional scaffolding to fully engage with problem-solving activities.

The findings confirm that PBL is an effective strategy for enhancing critical thinking across all educational levels. However, the magnitude of its impact varies, with particularly strong effects observed in junior high school and university settings. These results underscore the importance of tailoring PBL implementations to the developmental and contextual needs of different age groups. Future research should delve into the specific factors contributing to these variations, such as differences in teacher training, classroom resources, and cultural attitudes toward collaborative learning. Understanding these factors will help optimize the design and delivery of PBL to maximize its benefits for diverse student populations.

DISCUSSION

Interpretation of Findings

The findings of this meta-analysis strongly affirm the effectiveness of Problem-Based Learning (PBL) in enhancing critical thinking skills across all educational levels. PBL provides students with real-world problems that serve as a platform for developing analytical, reasoning, and evaluative abilities. Its iterative approach—problem identification, data collection, analysis, and solution development—pushes students to engage in deeper learning while fostering critical cognitive skills. The five core phases of PBL—orienting problems, organizing research, assisting group investigations, developing solutions, and evaluating outcomes—create a structured yet flexible framework that facilitates skill development (Arifin, 2021).

The success of PBL in geography education is particularly notable, as the subject inherently requires students to analyze complex spatial, environmental, and socio-political phenomena. Studies have shown that geography education utilizing PBL models—such as Spatial Problem-Based Learning (SPBL)—enhances students' critical thinking by training them to orient, analyze, and solve problems with a spatial perspective. This allows students to better understand global challenges, such as urbanization and climate change, and equips them with the skills necessary to propose solutions (Silviariza et al., 2021).

The scaffolding provided in PBL further amplifies its impact. Instructors play a crucial role by guiding students through stages of inquiry, reflection, and collaborative problem-solving. This structured yet student-centered approach ensures active participation, helping students develop core elements of critical thinking, such as analyzing arguments, synthesizing data, and evaluating evidence (Hussin et al., 2018). Furthermore, studies in primary education settings have revealed significant improvements in geography skills and learning outcomes through PBL, highlighting its applicability across diverse educational levels (Sonrum & Worapun, 2023).

PBL's effectiveness extends beyond geography, as demonstrated by its positive impact across multiple disciplines. In science education, for instance, PBL enhances critical thinking by encouraging students to evaluate scientific evidence and design experiments. Similarly, in mathematics, PBL has been shown to improve critical thinking through activities such as analyzing controversial issues and engaging in debates (Aini et al., 2019). This cross-disciplinary relevance underscores the universal applicability of PBL as a pedagogical tool.

Moreover, PBL fosters long-term cognitive and personal growth. By involving students in problem-solving scenarios that mimic real-world challenges, PBL cultivates higher-order thinking skills essential for professional success. Students exposed to PBL have reported greater confidence in their ability to synthesize information, evaluate solutions, and collaborate effectively, making it an invaluable strategy for developing critical thinking in the 21st century.

These findings collectively highlight the transformative potential of PBL in modern education. Its ability to align teaching methods with real-world demands makes it a powerful tool for fostering critical thinking skills across diverse contexts and disciplines. As educational systems continue to emphasize student-centered learning, PBL is poised to play an increasingly vital role in shaping critical thinkers equipped to navigate complex global challenges.

Comparison with Previous Research

The findings of this meta-analysis align closely with research across various disciplines, further validating the efficacy of Problem-Based Learning (PBL) in enhancing critical thinking skills. Studies in mathematics education have highlighted significant improvements in students' ability to evaluate arguments, synthesize evidence, and solve problems through PBL. For instance, structured debates and the exploration of controversial issues in mathematics classrooms have been shown to improve critical thinking capabilities, underscoring PBL's adaptability to numerically-driven disciplines (Aini et al., 2019).

Similarly, in science education, PBL has demonstrated a transformative impact on critical thinking. By integrating inquiry-based problem-solving activities, students were able to engage more deeply with scientific concepts, leading to an improved ability to evaluate hypotheses and apply analytical reasoning to real-world scenarios (Sholihah & Lastariwati, 2020). This alignment across science and mathematics emphasizes the interdisciplinary potential of PBL to foster higher-order cognitive skills.

Beyond traditional classrooms, the impact of PBL extends to online and blended learning environments. Studies have shown that integrating PBL into online platforms enhances collaborative problem-solving and interactive learning. For instance, an investigation into online PBL courses revealed significant improvements in students' critical thinking scores compared to traditional instructor-led methods. This outcome reflects PBL's effectiveness in fostering engagement and critical evaluation skills, even in virtual learning contexts (Şendağ & Odabaşı, 2009).

The findings also resonate with research in the humanities and social sciences, where PBL has been employed to address multifaceted societal challenges. In civic education, for example, PBL encourages students to critically analyze social and political phenomena, promoting skills such as ethical reasoning and evidence-based decision-making (Razak et al., 2022). These results reinforce the versatility of PBL as a pedagogical tool, capable of addressing complex problems across varied contexts.

Moreover, the findings from this meta-analysis are consistent with broader educational research that highlights the role of PBL in fostering 21st-century competencies. By emphasizing collaboration, problem-solving, and self-directed learning, PBL prepares students to navigate the demands of modern academic and professional environments (Soyadı & Birgili, 2015). The iterative and reflective cycles inherent in PBL not only improve critical thinking but also nurture metacognitive awareness, further contributing to its pedagogical value (Gholami et al., 2016).

These parallels suggest that PBL is not confined to any single discipline or educational format but is instead a robust, adaptable approach that transcends traditional boundaries. The consistent evidence of its effectiveness across domains affirms its role as a cornerstone of modern pedagogy, making it an indispensable strategy for cultivating critical thinking in diverse learning environments.

Implications for Practice

The results of this meta-analysis underscore the transformative potential of Problem-Based Learning (PBL) in geography education. By situating learning in real-world contexts, PBL challenges students to analyze geographic problems such as urban planning, climate change, and resource management. This approach fosters critical thinking while enhancing students' ability to propose evidence-based solutions. For instance, studies have demonstrated the effectiveness of using PBL to teach geographic information systems (GIS), where students analyze spatial problems and develop actionable plans, such as new school district proposals (Drennon, 2005).

Implementing PBL in geography curricula requires a structured framework to ensure success. Teachers must be equipped to design meaningful, real-world problems and facilitate discussions that promote inquiry without dominating the learning process. This dual role of facilitator and mentor requires comprehensive professional development. Training programs focused on PBL have been shown to significantly improve teachers' understanding and implementation of the method, particularly when it comes to integrating interdisciplinary content (Morgado & Leite, 2013).

Adequate classroom resources, such as access to spatial data and analytical tools, are also crucial. In the absence of these resources, students' ability to engage in meaningful problem-solving may be compromised. A case study involving secondary geography students highlighted the benefits of using data-rich environments for PBL exercises, which not only improved their understanding of geographic concepts but also enhanced their skills in data analysis and interpretation (Tulloch & Graff, 2008).

However, challenges such as limited time, large class sizes, and the traditional assessment systems can hinder the implementation of PBL. Studies in geography education have identified these barriers and recommended solutions such as restructuring curricula to prioritize active learning and providing institutional support for PBL initiatives. For example, reducing class sizes or incorporating collaborative technologies can enhance the feasibility of PBL in diverse educational settings (Bentil, 2018).

Incorporating PBL in geography education also opens up opportunities to engage students in fieldwork activities, which are an essential part of the discipline. PBL-based fieldwork allows students to connect theoretical knowledge with practical applications, such as investigating river systems or urban landscapes. These experiences not only deepen students' understanding of environmental complexities but also promote ecologically literate citizenship (Raath & Golightly, 2017).

Furthermore, fostering a collaborative inquiry-oriented classroom atmosphere is key to maximizing the benefits of PBL. Research has shown that collaborative group work enhances critical thinking and problem-solving skills. This finding is particularly relevant for geography, where teamwork is often essential for tackling large-scale spatial issues (Yeung, 2010).

While the implementation of PBL presents certain challenges, the long-term benefits for students' cognitive and problem-solving skills are substantial. To optimize its impact, geography educators should focus on designing engaging, real-world problems, equipping teachers with the necessary skills and resources, and addressing systemic barriers within educational institutions. These steps will help ensure that PBL continues to be a vital strategy for developing critical thinkers capable of addressing the complex challenges of the modern world.

CONCLUSION

Summary of Key Findings

This meta-analysis reaffirms the effectiveness of Problem-Based Learning (PBL) as a powerful pedagogical tool for fostering critical thinking skills across educational levels. The statistical analyses conducted in this study revealed a significant positive impact of PBL, with an overall standardized mean difference (SMD) of 1.254 and a p-value of <0.001, demonstrating its robust influence on students' critical thinking abilities. Subgroup analyses further highlighted variations in effect sizes, with junior high school students experiencing the greatest benefits, followed by university, senior high school, and elementary students. These findings underscore the adaptability and efficacy of PBL in diverse educational settings and provide strong evidence for its integration into modern curricula.

The heterogeneity observed in the study results emphasizes the complexity of implementing PBL across different contexts. Factors such as age, curriculum structure, and implementation fidelity likely contribute to the variability, underscoring the importance of tailoring PBL approaches to specific educational stages and disciplines. Overall, the analysis confirmed PBL's potential to bridge the gap between theoretical knowledge and real-world application, preparing students for complex problem-solving and decision-making in academic and professional environments.

Recommendations for Future Research

While this study provides compelling evidence of PBL's efficacy, it also highlights the need for further research to expand and deepen our understanding of its impact. Future studies should investigate the effects of PBL across a broader range of educational contexts, including underserved and underrepresented student populations. This would help evaluate the generalizability of PBL and identify strategies to overcome barriers in resource-limited settings.

Additionally, longitudinal studies are needed to explore the long-term effects of PBL on students' critical thinking and cognitive development. Investigating whether the benefits of PBL persist beyond the classroom and translate into lifelong problem-solving and analytical skills would provide valuable insights. Research should also focus on integrating PBL with emerging technologies and online learning platforms to enhance accessibility and scalability, ensuring that its advantages can be leveraged in diverse educational environments.

By addressing these research gaps, future studies can contribute to optimizing PBL methodologies, ensuring their alignment with evolving educational needs and global challenges. The continued exploration of PBL's transformative potential will pave the way for its widespread adoption as a cornerstone of effective, student-centered learning.

REFERENCES

Aini, N. R., Syafril, S., Netriwati, N., Pahrudin, A., Rahayu, T., & Puspasari, V. (2019). Problem-Based Learning for Critical Thinking Skills in Mathematics. *Journal of Physics: Conference Series*, *1155*, 012026. https://doi.org/10.1088/1742-6596/1155/1/012026

Arifin, E. G. (2021). Problem Based Learning to Improve Critical Thinking. *Social, Humanities, and Educational Studies (SHEs): Conference Series*, *3*(4), 98. https://doi.org/10.20961/shes.v3i4.53288

Bakbergenuly, I., Hoaglin, D. C., & Kulinskaya, E. (2019). Pitfalls of using the risk ratio in meta-analysis. *Research Synthesis Methods*, *10*(3), 398–419. https://doi.org/10.1002/jrsm.1347

Bentil, S. (2018). Implementation of Problem-Based Learning Method in Geography Education at the University of Cape Coast: The Educator's Lens on Factors. *Journal of Education and Practice*, *9*(31), 4–11.

Biggerstaff, B. J., & Tweedie, R. L. (1997). Incorporating Variability in Estimates of Heterogeneity in the Random Effects Model in Meta-Analysis. *Statistics in Medicine*, *16*(7), 753–768. https://doi.org/10.1002/(SICI)1097-0258(19970415)16:7<753::AID-SIM494>3.0.CO;2-G

Binasdevi, M. (2022). Pengaruh Model Problem Based Learning Berorientasi Literasi Lingkungan Terhadap Keterampilan Berpikir Kritis Siswa Madrasah Ibtidaiyah. *Indonesian Journal of Islamic Elementary Education*, *2*(1), 81–90. https://doi.org/10.28918/ijiee.v2i1.5270

Boedeker, P., & Henson, R. K. (2020). Evaluation of heterogeneity and heterogeneity interval estimators in random-effects meta-analysis of the standardized mean difference in education and psychology. *Psychological Methods*, *25*(3), 346–364. https://doi.org/10.1037/met0000241

Bonett, D. G. (2009). Meta-analytic interval estimation for standardized and unstandardized mean differences. *Psychological Methods*, *14*(3), 225–238. https://doi.org/10.1037/a0016619

Choi, E., Lindquist, R., & Song, Y. (2014). Effects of problem-based learning vs. Traditional lecture on Korean nursing students' critical thinking, problem-solving, and self-directed learning. *Nurse Education Today*, *34*(1), 52–56. https://doi.org/10.1016/j.nedt.2013.02.012

Drennon, C. (2005). Teaching Geographic Information Systems in a Problem-Based Learning Environment. *Journal of Geography in Higher Education*, *29*(3), 385–402. https://doi.org/10.1080/03098260500290934

Emiliasari, R. N., Prasetyo, E., & Syarifah, E. F. (2019). Problem-based Learning: Developing Students' Critical Thinking. *Linguists: Journal of Linguistics and Language Teaching*, *5*(1), 56. https://doi.org/10.29300/ling.v5i1.1962

Fadhilah, N., Nurdiyanti, N., Anisa, A., & Wajdi, M. (2022). Integrasi STEM-Problem Based Learning melalui Daring Terhadap Keterampilan Berpikir Kritis Mahasiswa Pendidikan Biologi. *Jurnal IPA & Pembelajaran IPA*, *6*(1), 1–10. https://doi.org/10.24815/jipi.v6i1.22721

Fauziah, J. R., Astutik, S., Suratno, S., Kurnianto, F. A., & Nurdin, E. A. (2024). Pengaruh Model Problem Based Learning (PBL) Berbantuan Nearpod Terhadap Kemampuan Berpikir Kritis Dan Hasil Belajar Geografi Siswa SMA. *MAJALAH PEMBELAJARAN GEOGRAFI*, *7*(1), 12. https://doi.org/10.19184/pgeo.v7i1.46816

Fleiss, J. (1993). Review papers: The statistical basis of meta-analysis. *Statistical Methods in Medical Research*, *2*(2), 121–145. https://doi.org/10.1177/096228029300200202

Gholami, M., Moghadam, P. K., Mohammadipoor, F., Tarahi, M. J., Sak, M., Toulabi, T., & Pour, A. H. H. (2016). Comparing the effects of problem-based learning and the traditional lecture method on critical thinking skills and metacognitive awareness in nursing students in a critical care nursing course. *Nurse Education Today*, *45*, 16–21. https://doi.org/10.1016/j.nedt.2016.06.007

Harahap, U. K., Selaras, G. H., & Ardi, A. (2023). Meta-Analysis of the Impact of Problem-Based Learning on High School Students' Critical Thinking Abilities in Biology Education. *Journal of Digital Learning and Education*, *3*(2), 172–184. https://doi.org/10.52562/jdle.v3i2.751

Hartono, I. P., Suharto, Y., Sahrina, A., & Soekamto, H. (2023). Pengaruh Model Problem Based Learning (PBL) terhadap kemampuan berpikir kritis siswa. *Jurnal Integrasi Dan Harmoni Inovatif Ilmu-Ilmu Sosial*, *3*(8), 918–931. https://doi.org/10.17977/um063v3i8p918-931

Hasanah, U., Astawa, I. B. M., & Citra, I. P. A. (2023). Penerapan Problem Based Learning Model dalam Pembelajaran Geografi untuk Mengembangkan Keterampilan Belajar Abad 21 pada Siswa di SMA Negeri 1 Taliwang. *Jurnal Pendidikan Geografi Undiksha*, *11*(1), 11–17. https://doi.org/10.23887/jjpg.v11i1.52424

Hedges, L. V., & Vevea, J. L. (1998). Fixed- and random-effects models in meta-analysis. *Psychological Methods*, *3*(4), 486–504. https://doi.org/10.1037/1082-989X.3.4.486

Hussin, W. N. T. W., Harun, J., & Shukor, N. A. (2018). Problem Based Learning to Enhance Students Critical Thinking Skill via Online Tools. *Asian Social Science*, *15*(1), 14. https://doi.org/10.5539/ass.v15n1p14

Kek, M. Y. C. A., & Huijser, H. (2011). The power of problem-based learning in developing critical thinking skills: Preparing students for tomorrow's digital futures in today's classrooms. *Higher Education Research & Development*, *30*(3), 329–341. https://doi.org/10.1080/07294360.2010.501074

Kong, L.-N., Qin, B., Zhou, Y., Mou, S., & Gao, H.-M. (2014). The effectiveness of problem-based learning on development of nursing students' critical thinking: A systematic review and meta-analysis. *International Journal of Nursing Studies*, *51*(3), 458–469. https://doi.org/10.1016/j.ijnurstu.2013.06.009

Kusumawardani, N. N., Rusijono, R., & Dewi, U. (2022). Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Siswa Dalam Memecahkan Masalah Matematika. *Jurnal Ilmiah Mandala Education*, *8*(2). https://doi.org/10.58258/jime.v8i2.3217

Lestari, N. A. P., Sri Astika Dewi, M., & Isyarotullatifah. (2021). Pengaruh Implementasi Problem Based Learning Terhadap Motivasi Berprestasi dan Kemampuan Berpikir Kritis Pada Pembelajaran

Tematik Terpadu Kelas IV SD Gugus IV Kecamatan Mendoyo. *JURNAL PENDIDIKAN DASAR NUSANTARA*, *6*(2), 52–70. https://doi.org/10.29407/jpdn.v6i2.14669

Lin, L., & Aloe, A. M. (2021). Evaluation of various estimators for standardized mean difference in meta-analysis. *Statistics in Medicine*, *40*(2), 403–426. https://doi.org/10.1002/sim.8781

Marín-Martínez, F., & Sánchez-Meca, J. (2010). Weighting by Inverse Variance or by Sample Size in Random-Effects Meta-Analysis. *Educational and Psychological Measurement*, *70*(1), 56–73. https://doi.org/10.1177/0013164409344534

Mariskhantari, M., Karma, I. N., & Nisa, K. (2022). Pengaruh Model Pembelajaran Problem Based Learning (PBL) terhadap Kemampuan Berpikir Kritis Siswa Pada Pembelajaran IPA Kelas IV SDN 1 Beleka Tahun 2021/2022. *Jurnal Ilmiah Profesi Pendidikan*, *7*(2b), 710–716. https://doi.org/10.29303/jipp.v7i2b.613

Mauludiyah, A., Wirahayu, Y. A., Budijanto, B., & Suharto, Y. (2021). Pembelajaran Problem Based Learning berbantuan Edmodo terhadap kemampuan pemecahan masalah Geografi untuk siswa SMA. *Jurnal Integrasi Dan Harmoni Inovatif Ilmu-Ilmu Sosial (JIHI3S)*, *1*(11), 1210–1225. https://doi.org/10.17977/um063v1i11p1210-1225

Melindawati, S., Apfani, S., Suryani, A. I., Adzkia, S., & Padang, K. (2021). Pengaruh Model Problem Based Learning (PBL) Berbantuan Media Audio Visual Terhadap Keterampilan Berpikir Kritis Mahasiswa Pada Pembelajaran Konsep Dasar IPS di STKIP Adzkia. *Jurnal Inovasi Pendidikan Dan Pembelajaran Sekolah Dasar*, *5*(2), 125–137.

Miterianifa, Trisnayanti, Y., Khoiri, A., & Ayu, H. D. (2019). *Meta-analysis: The effect of problem-based learning on students' critical thinking skills*. 020064. https://doi.org/10.1063/1.5139796

Morgado, S., & Leite, L. (2013). Science and Geography Teachers' Conceptions Regarding Problem-based Learning Related Concepts. *Procedia - Social and Behavioral Sciences*, *106*, 2343–2347. https://doi.org/10.1016/j.sbspro.2013.12.268

Mustofa, M. R., Arif, S., Sholihah, A. K., Aristiawan, A., & Rokmana, A. W. (2021). Efektivitas Model Pembelajaran Problem Based Learning Berbasis STEM terhadap Peningkatan Kemampuan Berpikir Kritis Siswa. *Jurnal Tadris IPA Indonesia*, *1*(3), 375–384. https://doi.org/10.21154/jtii.v1i3.165

Nargundkar, S., Samaddar, S., & Mukhopadhyay, S. (2014). A Guided Problem-Based Learning (PBL) Approach: Impact on Critical Thinking: A Guided Problem-Based Learning (PBL) Approach. *Decision Sciences Journal of Innovative Education*, *12*(2), 91–108. https://doi.org/10.1111/dsji.12030

Narmaditya, B. S., Wulandari, D., & Sakarji, S. R. B. (2018). Does Problem-Based Learning Imporve Critical Thinking Skill? *Jurnal Cakrawala Pendidikan*, *37*(3). https://doi.org/10.21831/cp.v38i3.21548

Nursidik, D. (2021). Penerapan Model Problem Based Learning (PBL) dalam Pembelajaran Menulis Teks Laporan Hasil Observasi dan Dampaknya Terhadap Kemampuan Berpikir Kritis Peserta Didik SMPN 2 Kalipucang. *Wistara: Jurnal Pendidikan Bahasa Dan Sastra*, *2*(2), 168–182. https://doi.org/10.23969/wistara.v2i2.2281

Puspitawati, Y., & Mawardi, M. (2022). Efektivitas Model Pembelajaran Problem Solving dan Problem Based Learning Ditinjau Kemampuan Berpikir Kritis Siswa. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *5*(11), 5247–5255. https://doi.org/10.54371/jiip.v5i11.1241

Raath, S., & Golightly, A. (2017). Geography Education Students' Experiences with a Problem-Based Learning Fieldwork Activity. *Journal of Geography*, *116*(5), 217–225. https://doi.org/10.1080/00221341.2016.1264059

Rahmawati, S., & Airlanda, G. S. (2023). Efektivitas Model Problem Based Learning dan Project Based Learning terhadap Kemampuan Berpikir Kritis Siswa. *Jurnal Basicedu*, *7*(6), 3450–3456. https://doi.org/10.31004/basicedu.v7i6.6332

Rauf, I., Arifin, I. N., & Arif, R. M. (2022). Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Siswa. *PEDAGOGIKA*, 163–183. https://doi.org/10.37411/pedagogika.v13i2.1354

Razak, A. A., Ramdan, M. R., Mahjom, N., Zabit, M. N. Md., Muhammad, F., Hussin, M. Y. M., & Abdullah, N. L. (2022). Improving Critical Thinking Skills in Teaching through Problem-Based Learning for Students: A Scoping Review. *International Journal of Learning, Teaching and Educational Research*, *21*(2), 342–362. https://doi.org/10.26803/ijlter.21.2.19

Rubio-Aparicio, M., Marín-Martínez, F., Sánchez-Meca, J., & López-López, J. A. (2018). A methodological review of meta-analyses of the effectiveness of clinical psychology treatments. *Behavior Research Methods*, *50*(5), 2057–2073. https://doi.org/10.3758/s13428-017-0973-8

Şendağ, S., & Ferhan Odabaşı, H. (2009). Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills. *Computers & Education*, *53*(1), 132–141. https://doi.org/10.1016/j.compedu.2009.01.008
Sholihah, T. M., & Lastariwati, B. (2020). Problem based learning to increase competence of critical thinking and problem solving. *Journal of Education and Learning (EduLearn)*, *14*(1), 148–154. https://doi.org/10.11591/edulearn.v14i1.13772
Silviariza, W. Y., Sumarmi, S., & Handoyo, B. (2021). Improving Critical Thinking Skills of Geography Students with Spatial-Problem Based Learning (SPBL). *International Journal of Instruction*, *14*(3), 133–152. https://doi.org/10.29333/iji.2021.1438a
Sitompul, N. N. S. (2021). Pengaruh Model Pembelajaran Problem Based Learning terhadap Peningkatan Kemampuan Berpikir Kritis Matematis Siswa SMP Kelas IX. *GAUSS: Jurnal Pendidikan Matematika*, *4*(1), 45–54. https://doi.org/10.30656/gauss.v4i1.3129
Sonrum, P., & Worapun, W. (2023). Enhancing Grade 5 Student Geography Skills and Learning Achievement: A Problem-Based Learning Approach. *Journal of Education and Learning*, *12*(5), 188. https://doi.org/10.5539/jel.v12n5p188
Soyadı, Y., & Birgili, B. (2015). Creative and Critical Thinking Skills in Problem-based Learning Environments. *Journal of Gifted Education and Creativity*, *2*(2), 71–71. https://doi.org/10.18200/JGEDC.2015214253
Susanto, F. S., & Airlanda, G. S. (2023). Efektivitas Model Problem Based Learning dan Problem Solving untuk Meningkatkan Kemampuan Berpikir Kritis Siswa dalam Pembelajaran IPAS. *Jurnal Basicedu*, *7*(6), 3646–3653. https://doi.org/10.31004/basicedu.v7i6.6353
Tabbu, M. A. S., Syarif, E., & Meliyana, S. M. (2023). Blended Problem Based Learning: Bagaimana Pengaruhnya Terhadap Kemampuan Berpikir Kritis Mahasiswa dalam Pembelajaran Geografi? *Jurnal MediaTIK*, 138–143. https://doi.org/10.59562/mediatik.v6i3.2329
Thorndahl, K. L., & Stentoft, D. (2020). Thinking Critically About Critical Thinking and Problem-Based Learning in Higher Education: A Scoping Review. *Interdisciplinary Journal of Problem-Based Learning*, *14*(1). https://doi.org/10.14434/ijpbl.v14i1.28773
Tulloch, D., & Graff, E. (2008). Green Map Exercises as an Avenue for Problem-Based Learning in a Data-Rich Environment. *Journal of Geography*, *106*(6), 267–276. https://doi.org/10.1080/00221340701839741
Ulger, K. (2018). The Effect of Problem-Based Learning on the Creative Thinking and Critical Thinking Disposition of Students in Visual Arts Education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1). https://doi.org/10.7771/1541-5015.1649
Widyatiningtyas, R., Kusumah, Y. S., Sumarmo, U., & Sabandar, J. (2015). The Impact of Problem-Based Learning Approach to Senior High School Students' Mathematics Critical Thinking Ability. *Journal on Mathematics Education*, *6*(2), 30–38.
Yampap, U., & Hasyda, S. (2023). PENGARUH PENERAPAN MODEL PROBLEM BASED LEARNING TERHADAP PENINGKATAN KETERAMPILAN BERPIKIR KRITIS SISWA. *Jurnal Pendidikan Dasar Flobamorata*, *4*(1), 437–443. https://doi.org/10.51494/jpdf.v4i1.853
Yeung, S. (2010). Problem-Based Learning for Promoting Student Learning in High School Geography. *Journal of Geography*, *109*(5), 190–200. https://doi.org/10.1080/00221341.2010.501112