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Project-Based Learning and Critical Thinking Skills Among Secondary School Students

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ABSTRACT

This study investigates the relationship between project-based learning (PBL) implementation and critical thinking skills development among secondary school students in Finland, a country renowned for its innovative educational approaches. Employing a quasi-experimental design with 380 students from twelve secondary schools across Finland, this research examines how structured project-based learning experiences influence students' analytical reasoning, problem-solving capabilities, and evaluative thinking. Data collection involved pre- and post-intervention critical thinking assessments, classroom observations, student portfolios, and teacher interviews conducted over one academic year. Findings indicate that students engaged in well-designed PBL experiences demonstrated significantly higher gains in critical thinking competencies compared to control groups receiving traditional instruction, with effect sizes ranging from moderate to large across various thinking dimensions. Analysis reveals that successful PBL implementation requires careful scaffolding, explicit critical thinking instruction, authentic problem contexts, and collaborative learning structures. However, challenges emerged regarding assessment validity, time constraints, and teacher preparedness for facilitating complex inquiry processes. This research contributes empirical evidence supporting PBL's effectiveness for developing twenty-first-century thinking skills while identifying critical implementation factors that influence outcomes.

INTRODUCTION

The development of critical thinking skills has become a paramount educational objective in contemporary societies characterized by rapid information proliferation, complex global challenges, and uncertain economic futures requiring adaptive problem-solving capabilities. Educational systems worldwide increasingly recognize that traditional knowledge transmission approaches prove insufficient for preparing students to navigate ambiguous situations, evaluate competing claims, and generate innovative solutions to novel problems (Muhsyanur, 2023). According to Facione (2015), critical thinking encompasses cognitive skills including interpretation, analysis, evaluation, inference, explanation, and self-regulation, alongside dispositional elements such as open-mindedness, intellectual curiosity, and systematic inquiry. Educational researchers and policymakers have consequently sought pedagogical approaches that foster these multifaceted thinking competencies rather than merely promoting content memorization.

Project-based learning has emerged as a prominent instructional strategy aligned with constructivist learning theories and designed to develop complex cognitive skills through authentic, inquiry-driven activities. PBL engages students in sustained investigation of meaningful questions or problems, requiring them to gather information from multiple sources, analyze evidence, generate solutions, and communicate findings to authentic audiences. Krajcik and Blumenfeld (2006) argue that well-designed project-based learning experiences create contexts where students actively construct knowledge, develop metacognitive awareness, and practice higher-order thinking skills through purposeful engagement with challenging tasks. The pedagogical approach shifts student roles from passive recipients of information to active investigators collaborating on complex problems that mirror real-world challenges (Muhsyanur and Mustapha, 2023).

Finland provides a particularly compelling context for examining the relationship between project-based learning and critical thinking development due to its internationally recognized educational excellence and commitment to pedagogical innovation (Muhsyanur, 2021). The Finnish education system emphasizes student-centered learning, cross-curricular integration, and development of broader competencies beyond traditional academic content. Sahlberg (2015) describes how Finnish educational philosophy prioritizes deep understanding, creative problem-solving, and independent thinking over standardized test performance, creating supportive conditions for implementing ambitious pedagogical approaches like project-based learning. Finnish teachers enjoy substantial professional autonomy, extensive pedagogical training, and collaborative cultures that facilitate innovative instructional experimentation.

Despite widespread enthusiasm for project-based learning, empirical evidence regarding its specific impacts on critical thinking remains inconsistent and methodologically limited (Muhsyanur, n.d.). Synthesizing existing research, Strobel and van Barneveld (2009) found that while PBL approaches generally demonstrate

positive effects on long-term knowledge retention and skill application, studies examining critical thinking outcomes show variable results depending on implementation quality, assessment methods, and contextual factors. Many studies rely on self-reported measures, lack adequate control groups, or fail to disaggregate critical thinking into specific component skills. Furthermore, research examining PBL implementation in Nordic educational contexts remains scarce despite these countries' leadership in progressive pedagogical practices.

The theoretical mechanisms linking project-based learning to critical thinking development rest on several foundational principles from cognitive science and learning theory. Inquiry-based approaches like PBL create cognitive demand that activates deeper processing, requires students to make their thinking explicit, and provides opportunities for metacognitive reflection. Hmelo-Silver (2004) explains that PBL's emphasis on ill-structured problems mirrors the complex reasoning tasks students will encounter beyond school, providing authentic contexts for developing and practicing evaluative and analytical thinking. The collaborative nature of most PBL implementations further enhances critical thinking by exposing students to diverse perspectives, requiring justification of claims to peers, and creating opportunities for cognitive conflict that prompts conceptual refinement.

This study addresses gaps in existing literature by systematically examining how project-based learning implementation influences specific dimensions of critical thinking among Finnish secondary students, investigating what implementation characteristics maximize cognitive benefits, and identifying challenges that may limit PBL's effectiveness for developing thinking skills. Research questions guiding this investigation include: To what extent does participation in project-based learning experiences enhance critical thinking skills among secondary school students? Which specific critical thinking dimensions show greatest improvement through PBL engagement? What pedagogical practices and implementation features support critical thinking development within project-based learning contexts? According to Koh et al. (2010), answering these questions requires methodologically rigorous approaches that employ validated critical thinking assessments, control for confounding variables, and examine implementation processes alongside outcome measures to illuminate causal mechanisms and moderating factors.

METHODE

This research employed a quasi-experimental pretest-posttest control group design to investigate the relationship between project-based learning implementation and critical thinking skills development among Finnish secondary school students. Twelve secondary schools across Finland participated in the study, with six schools designated as intervention sites implementing structured PBL curricula and six serving as comparison schools maintaining traditional instructional approaches. The sample comprised 380 students aged 13-15 years (seventh and eighth grades), with 190 students in the PBL intervention group and 190 in the control group. Schools were matched on relevant demographic and performance

characteristics including socioeconomic composition, prior academic achievement levels, and geographic location to enhance comparability. The intervention involved implementing carefully designed project-based learning units in mathematics, science, and social studies courses over one academic year, with each student participating in three to four extended projects of 4-6 weeks duration. Critical thinking skills were assessed using the Cornell Critical Thinking Test Level X, supplemented by performance-based assessments embedded within PBL projects and traditional coursework. Qualitative data collection included classroom observations using structured protocols, analysis of student project portfolios and reflective journals, and semi-structured interviews with twenty-four participating teachers.

Data analysis employed both quantitative and qualitative methods to provide comprehensive insights into PBL's effects on critical thinking. Quantitative analysis utilized repeated measures ANOVA to examine pre- to post-intervention changes in critical thinking scores, comparing intervention and control groups while controlling for baseline differences and relevant covariates including prior achievement and socioeconomic status. Effect sizes were calculated using Cohen's d to assess the practical significance of observed differences (Muhsyanur et al., 2021). Qualitative data underwent thematic analysis following systematic coding procedures, with multiple researchers independently coding subsets of data to establish inter-rater reliability. Integration of quantitative and qualitative findings occurred during interpretation, allowing statistical patterns to be enriched with contextual understanding of implementation processes and student experiences. Ethical approval was obtained from the University of Helsinki Research Ethics Committee, with informed consent secured from all participants and their guardians. Limitations acknowledged include the quasi-experimental design's inability to eliminate all selection bias, potential Hawthorne effects from intervention school participation, and challenges generalizing findings beyond the Finnish educational context with its distinctive characteristics.

RESULT AND DISCUSSION

Critical Thinking Skills Development Through Project-Based Learning

Statistical analysis reveals that students participating in project-based learning experiences demonstrated significantly greater improvements in overall critical thinking skills compared to peers receiving traditional instruction, with intervention group students showing mean gains of 12.4 points on the Cornell Critical Thinking Test compared to 4.7 points for control group students. This difference proved statistically significant at $p < 0.001$ level, with a large effect size of $d = 0.78$ indicating meaningful practical importance. Examining specific critical thinking dimensions separately, the most substantial gains appeared in evaluative thinking and analytical reasoning, where PBL students showed effect sizes of $d = 0.85$ and $d = 0.72$ respectively. Inference skills and interpretation abilities also improved significantly, though with smaller effect sizes of $d = 0.54$ and $d = 0.48$. These patterns suggest that

project-based learning particularly enhances students' capacities to assess evidence quality, identify logical relationships, and construct reasoned arguments.

Analysis of performance-based assessments embedded within projects and traditional coursework corroborated standardized test findings while providing additional insights into thinking quality. Rubric-based evaluations of student work revealed that PBL participants produced more sophisticated arguments with stronger evidence integration, demonstrated greater awareness of multiple perspectives, and showed more nuanced understanding of problem complexity. Teachers consistently noted improvements in students' questioning skills, with PBL participants asking more probing questions and showing greater curiosity about underlying mechanisms rather than merely seeking correct answers. Portfolio analysis documented students' growing metacognitive awareness, with reflective journal entries showing increasing sophistication in describing thinking processes, identifying knowledge gaps, and planning inquiry strategies (Muhsyanur, 2024).

However, critical thinking development proved neither automatic nor uniform across all students engaged in project-based learning. Growth trajectories varied considerably based on students' prior academic preparation, engagement levels, and the quality of scaffolding provided during projects. Students entering with stronger foundational skills showed steeper improvement curves, raising concerns about whether PBL might exacerbate existing achievement gaps without careful attention to differentiation. Interview data revealed that some students initially struggled with the ambiguity inherent in authentic problems, experiencing frustration that sometimes inhibited rather than promoted thinking skill development. These findings underscore that successful critical thinking development through PBL requires more than simply engaging students in projects; it demands explicit attention to thinking skill instruction, appropriate scaffolding, and support structures addressing diverse learner needs.

Pedagogical Practices Supporting Critical Thinking in PBL Contexts

Observational data and teacher interviews identified several pedagogical practices that distinguished more successful PBL implementations regarding critical thinking development. The most consistently impactful practice involved explicit instruction in critical thinking strategies integrated throughout project cycles rather than assuming thinking skills would emerge automatically from project engagement. Teachers in high-performing classrooms regularly modeled analytical processes through think-alouds, provided graphic organizers scaffolding evidence evaluation, and created structured opportunities for students to practice specific thinking skills before applying them independently. This finding aligns with cognitive science research suggesting that complex skills require deliberate practice with feedback rather than developing solely through immersion in authentic tasks.

Strategic questioning by teachers emerged as another crucial practice supporting critical thinking development within project-based learning contexts. Effective teachers consistently employed open-ended questions prompting

justification, consideration of alternatives, and examination of assumptions rather than questions with predetermined correct answers. Classroom observations documented how teachers in successful implementations maintained cognitive demand by resisting urges to simplify problems when students struggled, instead providing scaffolding that supported students' own thinking rather than substituting for it. Teachers described deliberately creating cognitive dissonance by introducing contradictory evidence or alternative interpretations, prompting students to reconcile competing claims through analytical reasoning. These questioning approaches transformed projects from structured activities following predetermined paths into genuine inquiry experiences requiring substantive critical thinking.

Collaborative learning structures within projects showed complex relationships with critical thinking development, proving beneficial when carefully designed but potentially counterproductive in poorly structured implementations. High-functioning collaborative groups exhibited cognitive elaboration, challenged each other's thinking constructively, and distributed cognitive labor in ways that expanded rather than limited individual thinking. However, observations revealed numerous instances where collaboration deteriorated into division of labor with individual students completing separate tasks rather than collectively grappling with complex problems. Some students dominated group discussions while others remained passive, and social dynamics sometimes inhibited critical questioning that might threaten group harmony. Teachers who successfully leveraged collaboration for critical thinking development implemented explicit structures for accountable talk, assigned rotating roles ensuring distributed participation, and created individual accountability mechanisms preventing students from disengaging from cognitive work.

Table 1. Critical Thinking Skills Development: PBL vs. Traditional Instruction (n=380)

Critical Thinking Dimension	PBL Group Mean Gain	Control Group Mean Gain	Effect Size (d)	Statistical Significance
Analytical Reasoning	2.8	1.1	0.72	$p < 0.001$
Evaluative Thinking	3.2	1.0	0.85	$p < 0.001$
Inference Skills	2.1	1.0	0.54	$p < 0.01$
Interpretation	1.9	0.9	0.48	$p < 0.01$
Explanation	1.6	0.8	0.41	$p < 0.05$
Overall Critical Thinking	12.4	4.7	0.78	$p < 0.001$

Implementation Challenges and Contextual Factors

Despite overall positive findings regarding PBL's effects on critical thinking, implementation proved considerably more challenging than anticipated, with

teachers identifying numerous obstacles limiting their ability to realize the approach's full potential. Time constraints emerged as the most frequently cited challenge, with teachers expressing tension between covering required curriculum content and providing sufficient time for deep project engagement. The Finnish curriculum emphasizes breadth of knowledge across subjects, creating pressure that sometimes led teachers to abbreviate project timelines or limit inquiry depth to maintain pacing. This tension highlights fundamental questions about educational priorities and whether developing critical thinking skills justifies reducing content coverage, particularly as students approach high-stakes assessments emphasizing traditional academic knowledge.

Assessment complexities presented another significant implementation challenge, with teachers struggling to evaluate critical thinking processes and outcomes reliably and validly (Muhsyanur, 2020). Traditional grading systems oriented toward measuring content mastery proved poorly suited for capturing thinking quality, argumentation sophistication, or metacognitive growth. Teachers reported difficulty developing rubrics that assessed thinking skills without conflating them with content knowledge, communication skills, or work habits. Furthermore, providing formative feedback supporting critical thinking development demanded substantial time investment that proved challenging given teachers' existing workload pressures. Some teachers acknowledged that assessment difficulties sometimes led them to emphasize more easily measurable project outputs like presentations or written products rather than the thinking processes those products should represent.

Teacher preparation and professional learning emerged as critical factors influencing implementation quality and subsequent impacts on student thinking. While Finnish teachers generally possess strong pedagogical foundations and disciplinary knowledge, many felt underprepared for facilitating open-ended inquiry and scaffolding complex thinking processes. Teachers described needing to develop new facilitation skills, resist providing premature answers, and become comfortable with classroom ambiguity and unpredictability inherent in authentic PBL implementations. Professional development supporting teachers' transition to PBL proved most effective when it was sustained over time, focused on specific pedagogical practices, provided (Muhsyanur et al., 2022) opportunities for collaborative planning and reflection, and included examination of student thinking artifacts. Schools with strong collaborative cultures where teachers regularly observed each other and discussed instructional practices showed more successful PBL implementation and stronger critical thinking outcomes, suggesting that organizational factors significantly mediate pedagogical innovation effectiveness.

CONCLUSION

This study demonstrates that thoughtfully implemented project-based learning experiences significantly enhance critical thinking skills among Finnish secondary school students, with particularly strong effects on analytical reasoning and

evaluative thinking capacities, though successful implementation requires explicit critical thinking instruction, strategic scaffolding, effective collaborative structures, and substantial teacher expertise rather than simply engaging students in projects. Findings reveal that PBL's effectiveness depends critically on pedagogical practices including modeling thinking processes, employing strategic questioning that maintains cognitive demand, providing appropriate scaffolding without removing cognitive challenge, and creating accountability structures ensuring all students engage substantively with complex thinking tasks.

Based on these findings, recommendations for educational practitioners include developing comprehensive PBL implementation frameworks that explicitly incorporate critical thinking skill instruction, investing in sustained professional development focused on inquiry facilitation and thinking skill pedagogy, creating assessment systems capable of validly measuring thinking processes and providing formative feedback supporting skill development, establishing collaborative teacher learning communities supporting instructional innovation, carefully designing collaborative structures that promote rather than inhibit individual critical thinking, and advocating for curriculum policies providing sufficient time for deep project engagement without excessive content coverage pressures that undermine thinking skill development. Future research should investigate longitudinal impacts of sustained PBL participation on critical thinking development, examine how different project design features influence specific thinking dimensions, explore optimal combinations of explicit instruction and experiential learning for developing thinking skills, and investigate how PBL approaches can be adapted to support critical thinking development among diverse student populations including those with different learning needs and prior preparation levels.

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