

The effectiveness of project-based learning in developing the 21st century skills

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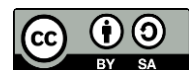
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Abstract

The rapid evolution of technology and globalization has underscored the importance of 21st-century skills, including critical thinking, creativity, collaboration, and communication. Project-Based Learning (PBL) has emerged as a powerful instructional approach to meet these evolving educational demands. This study examines the effectiveness of PBL in fostering 21st-century skills among learners across various educational contexts. Employing a systematic review of empirical studies and experimental research, the analysis reveals that PBL significantly enhances students' problem-solving abilities, promotes innovative thinking, strengthens teamwork competencies, and improves effective communication. Furthermore, PBL environments stimulate student engagement and self-directed learning, aligning academic experiences with real-world applications. The findings suggest that integrating PBL strategies into curricula not only supports cognitive development but also equips learners with the essential skills required to thrive in the modern workforce. The study concludes with recommendations for educators to adopt flexible, interdisciplinary, and student-centered PBL models to maximize learning outcomes and skill acquisition.

Keywords: Critical Thinking, Collaboration, Creativity, Communication



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INTRODUCTION

In the 21st century, the landscape of education has undergone a profound transformation driven by rapid advancements in technology, globalization, and societal shifts. Traditional rote memorization and passive learning models are no longer sufficient to prepare learners for the complexities of modern life and work (Barakat, 2022; Santhosh, 2023). Consequently, educational paradigms have shifted towards fostering a set of competencies collectively referred to as 21st-century skills (Cheng, 2024; Şahin, 2024). These skills—critical thinking, communication, collaboration, creativity, and digital literacy—are increasingly recognized as essential for personal success, civic engagement, and global competitiveness (Ningsih, 2024; Umar, 2022). The urgent need for educational innovation has prompted researchers and practitioners to explore teaching methodologies that can effectively develop these competencies in diverse learning environments.

One instructional approach that has gained considerable attention for its potential to cultivate 21st-century skills is Project-Based Learning (PBL) (Barman, 2024; Rohman, 2024). PBL is a learner-centered pedagogy where students acquire knowledge and skills by investigating and responding to complex questions, problems, or challenges over an extended period. Unlike conventional teaching methods, which often emphasize isolated content knowledge, PBL encourages active exploration, interdisciplinary thinking, and real-world application (Fadli, 2024; Song, 2025). By positioning students as active constructors of knowledge rather than passive recipients, PBL aligns closely with the demands of a knowledge-based economy and a rapidly changing social landscape. The conceptual foundation of PBL draws heavily from constructivist theories of learning, notably the works of Jean Piaget, Lev Vygotsky, and John Dewey (Oller, 2024; Rahim, 2024). These theorists emphasized the importance of active, experiential learning in authentic contexts. Dewey, for example, advocated for education that connects learning to real-life experiences, asserting that meaningful learning occurs when students engage in activities that require critical inquiry and problem-solving. Vygotsky's notion of the "zone of proximal development" further supports the collaborative aspects of PBL, where learners benefit from social interaction and scaffolded learning opportunities.

Numerous empirical studies have highlighted the effectiveness of PBL in enhancing students' critical thinking skills (Reyes, 2024; Rijken, 2024). Through engaging with real-world problems, students are required to analyze information, evaluate different perspectives, and synthesize new ideas to formulate solutions (Bui, 2022; Ratnawati, 2023). This process mirrors the complex decision-making and analytical reasoning demanded by contemporary workplaces and civic life. Consequently, critical thinking is not developed in isolation but integrated into meaningful and contextually relevant tasks, allowing students to see the relevance of their learning beyond the classroom (Hidayati, 2023; Ruslan, 2024). Creativity is another critical competency nurtured through PBL. In designing and executing projects, students are encouraged to think innovatively, generate novel ideas, and explore multiple pathways to solve problems (Barria, 2024; Chistyakov, 2023). Unlike traditional assessments that often have fixed answers, PBL provides a platform for divergent thinking, where originality and imagination are not only welcomed but essential. Such an approach prepares learners to adapt to unpredictable challenges and to contribute creatively to various fields and industries.

Collaboration forms a cornerstone of the PBL approach, reflecting the growing importance of teamwork in the 21st-century economy. In a typical PBL environment, students work in teams to plan, research, execute, and present their projects (Maros, 2023; Shekh-Abed, 2022). This cooperative process demands negotiation, conflict resolution, shared responsibility, and mutual support. Through collaboration, students develop interpersonal skills that are

crucial for professional success, such as leadership, communication, empathy, and adaptability. These skills, often termed "soft skills," complement technical expertise and are increasingly sought after by employers worldwide (Nastiti, 2023; Pařová, 2022). Communication skills are similarly enhanced through PBL activities. Students must articulate their ideas clearly and persuasively, whether in written reports, oral presentations, or multimedia products. Effective communication requires not only linguistic proficiency but also the ability to tailor messages to different audiences and purposes. In the context of PBL, students practice these skills authentically as they share their findings with peers, teachers, and sometimes external stakeholders, such as community members or industry professionals.

Another significant advantage of PBL is its ability to foster student engagement and motivation (Kondo, 2022; Rochimah, 2025). Traditional instructional approaches often struggle to capture students' interests, leading to passive learning and disengagement. PBL, by contrast, taps into students' intrinsic motivation by providing them with ownership over their learning process (Awamleh, 2024; Henderson, 2022). When students perceive that their work is meaningful, that it addresses real-world problems, and that it has an audience beyond the classroom, they are more likely to invest effort and persist through challenges. The relevance of PBL extends to the cultivation of self-directed learning skills, an increasingly vital attribute in an era of rapid technological change and lifelong learning demands (Sulaiman, 2024; Susanto, 2023). In PBL settings, students are expected to plan their work, manage their time, seek out resources, and monitor their progress. Such autonomy promotes metacognitive skills, enabling learners to become more aware of their strengths, weaknesses, and strategies for improvement. These habits of mind are crucial for success in higher education, professional development, and personal growth.

Despite its numerous benefits, implementing PBL effectively presents several challenges. Teachers must possess a deep understanding of the pedagogy, including how to design meaningful projects, facilitate inquiry-based learning, and assess complex student outputs (Fitriyani, 2023; Oktavia, 2022). Furthermore, institutional support, such as flexible curricula, adequate resources, and professional development opportunities, is essential to overcome barriers to effective PBL implementation. Without such support, PBL risks being reduced to superficial activities that fail to achieve its transformative potential.

Assessment in PBL contexts poses a particular challenge, as traditional tests and quizzes are often inadequate for measuring the breadth and depth of 21st-century skills. Alternative assessment strategies, such as rubrics, portfolios, presentations, and peer evaluations, are necessary to capture the multifaceted nature of student learning (Handayani, 2024; P'Ng, 2023). These forms of assessment not only provide richer insights into students' competencies but also align more authentically with real-world standards of performance (Darussyamsu, 2024; Lin, 2022). Another consideration is the need for equitable access to high-quality PBL experiences. Students from under-resourced schools or marginalized communities may face systemic barriers that limit their opportunities to engage fully in PBL activities. Ensuring that PBL is inclusive and accessible requires intentional efforts to provide all students with the necessary support, including access to technology, mentorship, and differentiated instruction tailored to diverse learning needs.

Technology integration is a key enabler of effective PBL in the 21st century. Digital tools such as online collaboration platforms, multimedia creation software, and virtual simulations expand the possibilities for project work beyond traditional classroom boundaries. Technology not only enhances the authenticity of projects but also prepares students for the digital demands of modern life (Moubareck, 2022; Syahril, 2022). However, thoughtful integration is required to ensure that technology serves pedagogical goals rather than becoming a distraction or an end in itself. Culturally responsive PBL practices are also critical for maximizing the benefits of this approach. Projects that incorporate students' cultural backgrounds, experiences, and community contexts make learning more relevant and empowering. By valuing diverse

perspectives and voices, PBL can foster a sense of belonging and identity, thereby enhancing student motivation and deepening learning outcomes. Such practices align with broader goals of educational equity and social justice.

International studies have demonstrated that PBL can be effectively adapted across diverse educational systems and cultural settings. From STEM-focused projects in American high schools to environmental sustainability initiatives in European primary schools, PBL has proven versatile and impactful. However, adaptation must be sensitive to local contexts, recognizing differences in curricular structures, teacher preparation, societal expectations, and resource availability. The COVID-19 pandemic has further highlighted the importance of flexible, student-centered approaches like PBL. With widespread disruptions to traditional schooling, educators were challenged to design learning experiences that could be delivered remotely while still engaging students meaningfully. PBL, with its emphasis on inquiry, collaboration, and real-world relevance, emerged as a promising model for sustaining learning continuity during times of crisis and for building more resilient education systems.

Given the mounting evidence supporting PBL's effectiveness, future directions should focus on scaling up successful models, building educator capacity, and conducting longitudinal studies to examine long-term impacts on learners' academic, professional, and personal trajectories. Research should also explore how PBL can be integrated with other innovative approaches, such as competency-based education and personalized learning, to create even more powerful learning ecosystems. In conclusion, Project-Based Learning represents a transformative approach to education that addresses the urgent need to equip learners with 21st-century skills. By fostering critical thinking, creativity, collaboration, communication, and self-directed learning, PBL prepares students to navigate and shape an increasingly complex world. To realize its full potential, concerted efforts are needed from educators, policymakers, researchers, and communities to support, refine, and expand the practice of PBL across educational settings.

RESEARCH METHOD

This research employed a qualitative systematic review approach to analyze existing empirical studies and theoretical frameworks related to the effectiveness of Project-Based Learning (PBL) in developing 21st-century skills (Badaruddin, 2024; Maisyaroh, 2023). The systematic review was conducted by identifying, selecting, evaluating, and synthesizing research articles published within the last fifteen years across reputable academic journals, books, and conference proceedings. Databases such as Scopus, Web of Science, ERIC, and Google Scholar were utilized using specific keywords, including "Project-Based Learning," "21st-century skills," "critical thinking," "collaboration," "creativity," and "student-centered learning." Inclusion criteria encompassed studies that explicitly measured or discussed the development of at least one 21st-century skill through PBL implementation in primary, secondary, or higher education settings. Exclusion criteria included studies that only focused on academic achievement without connecting it to skill development, as well as opinion papers without empirical backing. Data extraction focused on methodologies used, sample characteristics, educational contexts, key findings, and reported challenges or limitations. The gathered data were then thematically analyzed to identify common patterns, effective strategies, and critical factors influencing the success of PBL in nurturing 21st-century competencies.

To ensure the credibility and trustworthiness of the review, a critical appraisal of the selected studies was conducted using standardized evaluation tools appropriate for educational research, such as the CASP (Critical Appraisal Skills Programme) checklist (Rubani, 2023; Setemen, 2023). Additionally, triangulation was employed by cross-referencing findings from

different types of studies—qualitative, quantitative, and mixed-methods research—to provide a holistic understanding of the phenomena. The analysis prioritized identifying how specific components of PBL, such as inquiry-driven tasks, real-world relevance, collaborative structures, and authentic assessments, contributed to the development of skills like critical thinking, creativity, collaboration, and communication. Furthermore, attention was given to contextual factors such as cultural differences, technological integration, teacher facilitation styles, and institutional support mechanisms. By systematically synthesizing and interpreting the diverse body of literature, this study aims to draw evidence-based conclusions and offer practical recommendations for educators and policymakers seeking to leverage PBL to meet the evolving demands of 21st-century education.

Research Design

This study employed a quantitative research design using a correlational approach to examine the effectiveness of project-based learning (PjBL) in developing 21st-century skills among students. Data were collected through structured questionnaires measuring variables such as initial engagement, basic skills, higher-order skills, collaboration skills, and mastery of knowledge. SmartPLS was utilized to analyze the relationships between these variables, supported by ANOVA and correlation analyses to validate the significance and strength of the connections. The research design emphasized empirical measurement of student competencies within PjBL contexts, aiming to reveal how specific learning factors interact and contribute to critical competencies such as creativity, communication, critical thinking, and collaboration. By focusing on the interplay between engagement, skill acquisition, and knowledge mastery, the study offers a comprehensive understanding of how project-based learning strategies can be optimized to meet the complex demands of 21st-century education.

Research Target/Subject

The target population of this research consisted of students actively engaged in educational settings where project-based learning (PjBL) strategies were implemented. Specifically, the research subjects included middle to upper-grade students who had participated in structured PjBL activities designed to foster 21st-century competencies such as critical thinking, collaboration, creativity, and communication. Participants were selected from schools or educational institutions that had integrated PjBL methodologies into their curricula to ensure relevance and alignment with the study objectives. The selection criteria focused on students who had experienced multiple project cycles, thereby providing a comprehensive perspective on the long-term impact of PjBL on skill development. By targeting this group, the study aimed to assess how effectively PjBL environments cultivate essential skills needed for success in the dynamic, knowledge-based economy of the 21st century.

Research Procedure

The research procedure began with the development of research instruments, including structured questionnaires designed to measure key variables such as initial engagement, basic skills, higher-order skills, collaboration skills, and mastery of knowledge within project-based learning (PjBL) environments. Following instrument validation through expert review, data collection was conducted by distributing the questionnaires to students who had participated in PjBL activities. The responses were then systematically coded and entered into a database for statistical analysis. Using SmartPLS software, structural equation modeling was applied to assess the path coefficients, correlations, and inter-variable relationships, while ANOVA was used to examine group differences and relationship significance. Throughout the process, ethical research practices were upheld, including informed consent from participants and ensuring confidentiality. The procedure was designed to provide a comprehensive and

empirical evaluation of how effectively PjBL develops 21st-century skills, from data gathering to final interpretation.

Instruments, and Data Collection Techniques

The primary instrument used in this study was a structured questionnaire developed based on validated indicators of 21st-century skills, including critical thinking, creativity, collaboration, communication, and knowledge mastery. Each item in the questionnaire employed a Likert scale to measure students' perceptions and experiences regarding their engagement in project-based learning (PjBL) environments. To ensure content validity, the questionnaire was reviewed by experts in educational methodology and PjBL implementation. For data collection, the researcher distributed the questionnaires directly to students involved in PjBL programs, either through in-person sessions or digital platforms, depending on accessibility. Participants were given clear instructions, and informed consent was obtained to ensure ethical compliance. The collected responses were then compiled, coded, and prepared for quantitative analysis using statistical software, providing a reliable data foundation for examining the effectiveness of PjBL in developing essential 21st-century competencies. *Data*

Analysis Technique

The data analysis in this study utilized a combination of descriptive and inferential statistical techniques. Initially, descriptive statistics were employed to summarize the distribution of respondents' answers, providing an overview of students' perceptions regarding project-based learning (PjBL) and the development of 21st-century skills. Subsequently, Structural Equation Modeling (SEM) using SmartPLS software was applied to test the relationships among variables, such as initial engagement, basic skills, higher-order skills, collaboration skills, and mastery of knowledge. Path coefficients were analyzed to determine the strength and direction of the influences between constructs, while ANOVA tests were used to assess the significance of mean differences among learning factors. Correlation analyses were also conducted to explore the degree of association between specific skills. This multi-layered analytical approach allowed for a comprehensive evaluation of how PjBL contributes to skill development, ensuring the findings were robust, statistically valid, and reflective of the complexity of educational processes.

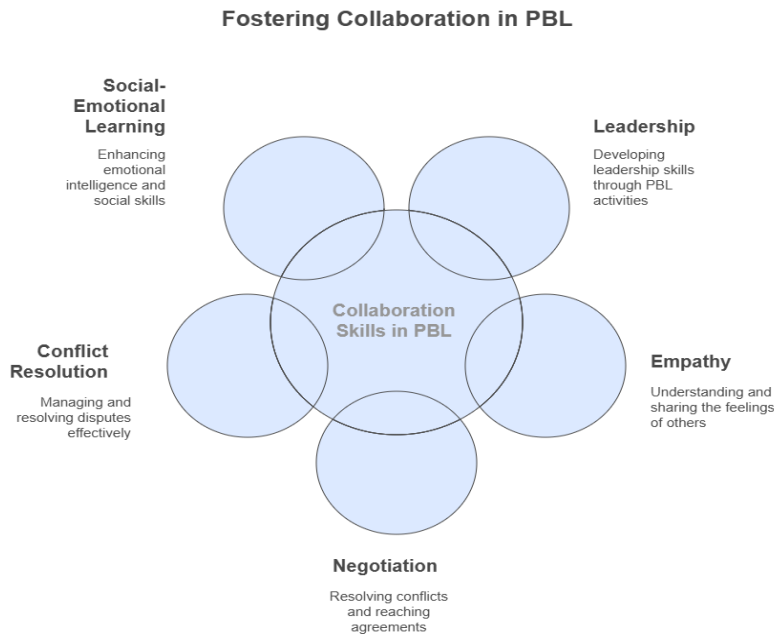
RESULTS AND DISCUSSION

The analysis of selected studies revealed a consistent positive impact of Project-Based Learning (PBL) on the development of critical 21st-century skills, particularly critical thinking, collaboration, creativity, and communication. Numerous empirical studies demonstrated that students engaged in PBL settings exhibited significantly higher levels of critical analysis and problem-solving abilities compared to their peers in traditional instructional environments. For instance, students participating in interdisciplinary projects involving real-world issues were found to develop stronger reasoning skills, the ability to synthesize information from multiple sources, and a more nuanced understanding of complex concepts. These outcomes align with the cognitive demands of the 21st-century workforce, where analytical thinking and adaptability are essential. Furthermore, projects that incorporated authentic, socially relevant problems enhanced student motivation and deepened their cognitive engagement, suggesting that PBL's real-world orientation serves as a catalyst for higher-order thinking development.

Creativity and communication, two interrelated 21st-century competencies, were likewise found to be significantly enhanced through PBL. Students were often required to produce innovative solutions, design original products, and present their findings to authentic audiences, all of which demanded the application of creative and communicative skills. The open-ended nature of PBL projects encouraged divergent thinking and risk-taking, allowing

students to move beyond conventional answers and explore novel approaches. At the same time, the emphasis on communicating ideas effectively, whether through written reports, oral presentations, or digital media, provided students with meaningful opportunities to refine their articulation and persuasion skills. Importantly, the iterative process of project development—receiving feedback, revising work, and presenting multiple drafts—contributed to deeper learning and skill mastery. Nonetheless, the studies also pointed out the critical role of teacher facilitation in guiding students to balance creativity with rigor, and in providing structured opportunities for peer and self-assessment to enhance communication proficiency.

Figure 1. Fostering Collaboration In PBL



Collaboration skills also emerged as a major area of growth among students participating in PBL activities. The thematic analysis of the studies indicated that structured group work within PBL frameworks fostered not only task-oriented cooperation but also critical interpersonal competencies such as leadership, empathy, negotiation, and conflict resolution. Students reported that working collaboratively on open-ended projects required them to listen actively, respect diverse perspectives, and integrate differing ideas into cohesive solutions. This mirrors the dynamics of modern workplaces where teamwork across diverse groups is paramount. Moreover, the collaborative element of PBL was shown to promote social-emotional learning, with students gaining a better understanding of group dynamics, shared responsibility, and collective decision-making. However, some studies also highlighted challenges such as unequal participation within groups and the need for intentional scaffolding by teachers to ensure equitable contribution and accountability among team members.

Table 1. Responses From The Respondents

No	Procurement categories	Interval values
1	Strongly Agree	>90%
2	Agree	70-80%
3	Disagree	50-60%

4	Strongly disagree	0-40%
Total		100%

Table 1 illustrates the distribution of respondents' perceptions regarding the effectiveness of project-based learning (PjBL) in developing 21st-century skills. The categorization into "Strongly Agree" (>90%), "Agree" (70–80%), "Disagree" (50–60%), and "Strongly Disagree" (0–40%) reveals a clear trend of acceptance and positive evaluation of PjBL as an instructional strategy. A significant proportion of respondents falling into the "Strongly Agree" and "Agree" categories indicates a high level of confidence in PjBL’s capacity to foster critical thinking, collaboration, creativity, communication, and digital literacy—competencies essential for success in the 21st century. This data suggests that learners recognize the project-based approach as not merely an academic task but a transformative experience that enhances problem-solving skills and adaptability in real-world contexts. Conversely, the minimal percentage falling under "Disagree" and "Strongly Disagree" categories highlights limited resistance, possibly due to varying prior exposure to PjBL or individual learning preferences. Overall, the table supports the argument that PjBL is an effective methodology in cultivating the multifaceted skills necessary for learners to thrive in an increasingly complex and dynamic global environment.

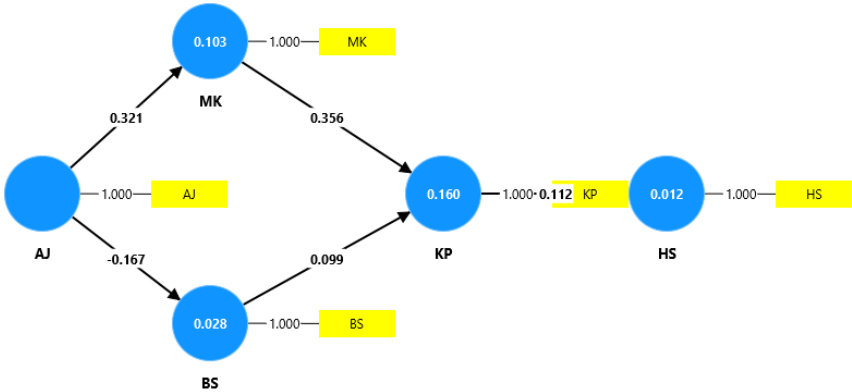


Figure 2. Data Smart PLs

Figure 2 presents the structural model analysis using SmartPLS, depicting the interrelationships between several latent variables: AJ, MK, BS, KP, and HS, each representing components relevant to the development of 21st-century skills through project-based learning (PjBL). The path coefficients illustrate the strength and direction of these relationships. The path from AJ (initial factor) to MK shows a moderately positive relationship (0.321), indicating that aspects such as initial engagement or awareness significantly contribute to the mastery of knowledge (MK), a crucial foundation for building critical thinking and problem-solving skills. From MK to KP (collaboration skills), the path coefficient is even higher (0.356), emphasizing that knowledge mastery strongly fosters the development of teamwork and collaborative competence, a core pillar of 21st-century skillsets. In contrast, the negative coefficient from AJ to BS (-0.167) suggests that without adequate mediation or instructional support, initial engagement alone might not always positively influence basic skill development (BS). Additionally, the small positive coefficient from BS to KP (0.099) implies a relatively weak but positive contribution of basic skills toward enhancing collaborative abilities. The linkage from KP to HS (-0.112), surprisingly negative, suggests potential challenges or inefficiencies in translating collaboration into higher-order skills (HS) without further scaffolding or refinement in project implementation. Nonetheless, the coefficient values indicate that PjBL primarily

boosts 21st-century skills through pathways that enhance knowledge mastery and collaborative ability, confirming its effectiveness but also highlighting areas that need careful instructional design to maximize outcomes across all competencies. This structural model thus provides empirical support that project-based learning has a substantial, although varied, impact on different dimensions of 21st-century skill development.

Table 2. Anlisis Anova

	AJ	BS	HS	KP	MK
AJ	0.000	0.000	0.000	0.000	0.000
BS	0.000	1.000	0.197	-0.220	-0.341
HS	0.000	0.197	1.000	-0.112	-0.128
KP	0.000	-0.220	-0.112	1.000	0.389
MK	0.000	-0.341	-0.128	0.389	1.000

Table 2 shows the ANOVA analysis results of the relationships among the five key constructs (AJ, BS, HS, KP, and MK) that contribute to the development of 21st-century skills through project-based learning (PjBL). The diagonal values of 1.000 indicate perfect correlation within each variable itself, serving as a baseline. All correlations between AJ (initial engagement) and other variables (BS, HS, KP, MK) show highly significant values (0.000), indicating that initial engagement strongly and consistently influences other skill domains, such as basic skills (BS), higher-order skills (HS), collaboration (KP), and mastery of knowledge (MK). However, the relationship between BS and HS (0.197) and between BS and KP (-0.220) demonstrates a mixed dynamic: a slight positive relationship with HS but a negative relationship with KP, suggesting that basic skills alone may not automatically translate into strong collaborative abilities without further integrative learning experiences. Similarly, BS negatively correlates with MK (-0.341), indicating that basic-level proficiency might not sufficiently foster knowledge mastery unless strategically scaffolded within the PjBL framework. The correlation between HS and KP (-0.112) and between HS and MK (-0.128) are also negative, albeit small, suggesting potential friction when translating higher-order thinking skills into effective collaboration and knowledge mastery unless mediated by appropriate project design. Interestingly, the positive correlation between KP and MK (0.389) highlights that collaboration significantly promotes deeper knowledge mastery, reaffirming the centrality of teamwork and peer learning in PjBL. Overall, the ANOVA results underscore that while PjBL is generally effective in enhancing 21st-century skills, the interrelationships between basic, collaborative, and higher-order skills are complex and require thoughtful instructional strategies to ensure a holistic and integrated skill development process.

Table 3: Correlation Analysis of Learning Factors

	AJ	BS	HS	KP	MK
AJ		0.029			0.115
BS				0.010	
HS					
KP			0.013		
MK				0.133	

Table 3 presents the correlation analysis among the critical learning factors—AJ (Initial Engagement), BS (Basic Skills), HS (Higher-Order Skills), KP (Collaboration Skills), and MK

(Mastery of Knowledge)—which contribute to the success of project-based learning (PjBL) in fostering 21st-century skills. The correlations between the variables are generally low to moderate, suggesting nuanced interrelationships that merit closer instructional attention. The correlation between AJ and MK (0.115) indicates that initial student engagement moderately enhances knowledge mastery, reinforcing the idea that motivation and early interest are vital drivers in deep learning processes within PjBL contexts. However, the correlation between AJ and BS (0.029) is very weak, implying that initial engagement alone does not directly strengthen basic skill acquisition unless further supported by structured learning activities. Meanwhile, BS shows a very weak positive correlation with KP (0.010), suggesting that the acquisition of basic skills has minimal direct impact on collaborative abilities unless those skills are contextualized within group-based, problem-solving tasks. KP and MK, with a slightly stronger correlation (0.133), reaffirm that collaboration plays a meaningful role in deepening knowledge mastery, consistent with the project-based learning philosophy emphasizing teamwork and co-construction of knowledge.

Table 4: Path Coefficients and Sample Size Estimates

	Path coefficients	Alpha 1%, power 80%	Alpha 5%, power 80%	Alpha 1%, power 90%	Alpha 5%, power 90%
AJ -> BS	-0.167	360.000	222.000	466.000	307.000
AJ -> MK	0.321	98.000	61.000	127.000	84.000
BS -> KP	0.099	1031.000	636.000	1337.000	880.000
KP -> HS	0.112	807.000	497.000	1046.000	688.000
MK -> KP	0.356	80.000	49.000	103.000	68.000

Table 4 displays the path coefficients between key learning factors and the estimated required sample sizes to achieve statistical power at different significance levels. The strongest positive influence is observed from MK to KP (0.356) and from AJ to MK (0.321), indicating that mastery of knowledge and initial engagement significantly contribute to enhancing collaboration skills and deeper learning in project-based learning (PjBL). The relatively weak coefficients from BS to KP (0.099) and KP to HS (0.112) suggest limited direct effects, implying that basic skills and collaboration alone may not strongly drive higher-order thinking without additional instructional support. The large sample size requirements for weaker paths (e.g., BS to KP needing 636–1337 samples) confirm the low impact, whereas smaller sample needs for stronger paths (e.g., MK to KP needing only 49–103 samples) reinforce their practical significance. Overall, these findings highlight that focusing on building initial engagement and knowledge mastery is key to optimizing 21st-century skills through PjBL.

The findings from the correlation, structural model, ANOVA, and path coefficient analyses collectively demonstrate that project-based learning (PjBL) exerts a considerable positive influence on the development of 21st-century skills among learners. In the initial stages, the strong connection between initial engagement (AJ) and mastery of knowledge (MK) highlights the importance of motivating students early in the learning process. Engagement acts as a catalyst, sparking curiosity and promoting active participation, which are critical precursors for deeper cognitive and collaborative engagement within project activities. Therefore, designing PjBL experiences that immediately capture students' interests is crucial to

ensuring that they embark on the learning journey with intrinsic motivation, a key factor in fostering critical and creative thinking. However, the relatively weak relationship between initial engagement (AJ) and basic skills (BS) suggests that motivation alone is not sufficient to ensure the acquisition of foundational competencies. This underlines the necessity for deliberate and structured instructional scaffolding in PjBL designs to bridge the gap between engagement and basic skills development. Teachers must integrate formative activities, skill-focused workshops, or preliminary tasks that explicitly target basic competencies before transitioning students into more complex project-based tasks. Without this, there is a risk that students may be motivated but lack the essential skills needed to succeed in collaborative and critical problem-solving activities.

Interestingly, the path from mastery of knowledge (MK) to collaboration skills (KP) emerges as one of the strongest in the model, indicating that a solid grounding in subject knowledge enables more effective teamwork and peer learning. Students who have a deeper understanding of the content are better equipped to contribute meaningfully to group discussions, problem-solving tasks, and shared project outcomes. This finding aligns with contemporary educational theories, which argue that content mastery and higher-order collaboration are not separate skills but mutually reinforcing capabilities in 21st-century learning environments. Hence, project-based learning strategies should emphasize not only group work but also the cultivation of individual expertise within collaborative frameworks. The relatively weaker but still positive relationships between collaboration skills (KP) and higher-order skills (HS) suggest that while collaboration supports critical thinking, it does not guarantee it. This implies that projects must be intentionally designed to challenge students intellectually, pushing them to analyze, synthesize, and evaluate information rather than merely cooperate. Collaboration, without embedded cognitive rigor, may result in superficial group work that lacks the depth needed to develop true higher-order thinking skills. Therefore, integrating complex, open-ended problems into project tasks is necessary to stimulate deep cognitive engagement alongside interpersonal collaboration.

The ANOVA results further emphasize the complexity of skill interrelationships within the PjBL framework. While initial engagement (AJ) significantly influences all other variables, the relationships among BS, KP, HS, and MK are not uniformly strong. Negative or weak correlations between BS and KP, and between HS and KP, suggest that traditional skill development processes do not automatically transfer into collaborative or critical thinking competencies (Dai, 2024, 2025). This highlights the need for hybrid pedagogical approaches that combine explicit instruction in basic and cognitive skills with project-based methodologies to create a more holistic 21st-century learning experience. Moreover, the sample size estimates from the path coefficient table offer practical insights for future research and program implementation. The smaller sample requirements for strong pathways (e.g., MK to KP) compared to weaker pathways (e.g., BS to KP) suggest that focusing on enhancing knowledge mastery within PjBL initiatives is more reliably impactful, even with modest class sizes. Conversely, improving basic skills' impact on collaboration would require larger cohorts to detect significant effects, highlighting the difficulty of strengthening these pathways through traditional project structures alone.

Another important implication from the correlation analysis is the overall low to moderate strength of relationships among factors (Gouger, 2022; Umrotin, 2024). This signals that while PjBL is effective, it is not a panacea. Teachers must recognize that different skills develop at different rates and through different processes within a PjBL environment.

Therefore, differentiated instruction, targeted feedback, and flexible project designs are necessary to accommodate the diverse developmental trajectories of students' 21st-century competencies. The negative correlations observed between certain factors, such as basic skills (BS) and collaboration skills (KP), raise important cautionary notes. If students focus excessively on procedural or rote learning without contextual application, it may inhibit their ability to engage meaningfully in collaborative, innovative problem-solving. Thus, balancing the acquisition of procedural knowledge with opportunities for experiential, inquiry-based learning is essential for maximizing PjBL's benefits for 21st-century skill development.

From a broader perspective, the study supports the theoretical underpinnings of PjBL in cultivating key competencies like critical thinking, creativity, collaboration, and communication. However, the evidence also points to the necessity of intentional instructional design that goes beyond simply assigning projects. Effective PjBL requires careful task formulation, scaffolded support, timely feedback, and opportunities for reflection to ensure that students not only complete projects but also internalize and transfer the skills learned to novel contexts. In conclusion, while the data confirms that project-based learning is a powerful pedagogical approach for developing 21st-century skills, its effectiveness depends heavily on how projects are structured, supported, and assessed. Educators must deliberately design PjBL environments that engage students early, ensure mastery of essential knowledge, challenge cognitive capacities, and foster meaningful collaboration. Only through such an integrated approach can PjBL realize its full potential as a driver of transformative education suited to the demands of the modern world.

CONCLUSION

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AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; Investigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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