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Effect of Problem-Based Digital Learning and Musical Intelligence on Art Appreciation Outcomes

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Abstract: Traditional teacher-centered approaches in music education often struggle to address diverse student capabilities and the demands of 21st-century digital pedagogy. This study analyzes the effectiveness of the Problem-Based Digital Learning (PDBL) method compared with Direct Instruction in improving learning outcomes in an Art Appreciation and Criticism course, considering students' musical intelligence and controlling for initial ability. Employing a quasi-experimental design with ANCOVA on a sample of 96 music education students, the results reveal that PDBL yields significantly higher overall achievement than Direct Instruction. Additionally, students with high musical intelligence outperform those with lower aptitude. Crucially, a significant interaction effect demonstrates that PDBL is highly effective for students with high musical intelligence, whereas Direct Instruction is significantly more appropriate for students with low musical intelligence. This study concludes that instructional methods must be aligned with students' internal intelligence profiles to optimize outcomes. Scientifically, this research contributes to contemporary pedagogy by providing empirical evidence for classroom differentiation and showing how digital problem-solving frameworks can be systematically paired with student aptitude profiles in higher music education.

Keywords: *problem-based digital learning; direct instruction; musical intelligence; learning outcomes; art appreciation and criticism*

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INTRODUCTION

Educational developments in the 21st century demand continuous innovation in teaching methods, with pedagogical approaches that center on students as active participants in the learning process. This paradigm emphasizes critical thinking, collaboration, creativity, and digital literacy as key competencies that must be developed (Kusuma et al., 2024; Widiastuti et al., 2025). One learning method that aligns with these demands is Problem-Based Learning (PBL). PBL not only encourages students to solve real-world problems but also trains them to integrate knowledge, skills, and attitudes holistically. PBL was first developed in medical education at McMaster University in Canada (Barrows & Tamblyn, 1980). They defined PBL as a problem-based learning approach that encourages students to learn independently and collaboratively in solving clinical problems. Through PBL, students are expected to face the complexities of the modern world, adapt to technological changes, and improve learning outcomes that are more meaningful and contextual (Kek & Huijser, 2017; Savin-Baden, 2007).

Problem-Based Digital Learning extends Problem-Based Learning (PBL) by integrating digital technology. Problem-Based Digital Learning is a problem-based learning approach integrated with digital technology to enhance learning outcomes, digital literacy, and problem-solving skills (Gitadewi, 2024; Mardiyah et al., 2026; Sentriyo et al., 2023). This method uses real-world problems as the starting point for learning, after which students use digital platforms, applications, multimedia, and online resources to explore, analyze, and discover solutions (Kolbaek, 2020). This digital integration takes a highly practical form. Students might be tasked with evaluating a complex musical composition using audio analysis software to deconstruct harmonic layers and acoustic properties visually. They can use digital discussion forums to debate aesthetic choices with peers, or virtual reality (VR) concert simulations to immerse themselves in diverse acoustic environments before drafting objective critiques. Hidayat et al. (2025) found that student engagement improves problem-solving quality but does not affect the attitudes or strategies used.

Furthermore, digital skills and problem-solving abilities have been shown to be strongly related to self-competence. Digital skills and problem-solving abilities have been shown to have a strong relationship with self-competence, as does musicality (Wan et al., 2022). Musicality not only reflects a person's sensitivity to musical elements such as melody, rhythm, and harmony but also helps build self-confidence through the ability to express ideas, collaborate, and overcome creative challenges in the musical process (Camerlinga et al., 2022;

Stozhok, 2024). In contrast, students with high musical intelligence have greater sensitivity to musical structure, harmony, and expression, making them well suited to excel in artistic appreciation and critique. In the digital age, this potential can be enhanced through technologies such as music software and machine learning-based systems that provide real-time feedback (Acquilino, 2025;Chen & Sun, 2024;Yun et al., 2022). Integrating musical intelligence with digital literacy makes music education more adaptive, creative, and aligned with modern-generation needs (Argyriou, 2025;Tian, 2025b,2025a). However, without the right teaching methods, this potential often fails to develop optimally. Astuti et al. (2022) found that using Encore technology can enhance the musicality and creativity of the Nasheed group, as indicated by a P-value of 0.004 at a significance level of 0.05%. Through the software, students not only practice technical skills but also become more sensitive to musical elements and better able to evaluate their work critically.

The Art Appreciation and Criticism course equips students to understand, evaluate, and critique works of art objectively and systematically (Broome et al., 2018; Tam, 2018). Students are trained to develop aesthetic sensitivity, master critical theories and methods, and compose well-reasoned academic analyses, particularly of musical works. The Art Appreciation and Criticism course aims to foster an appreciative, critical, and professional attitude toward the diversity of art, particularly in musical works (Iriaji, 2017; Lomas, 2016; Yu et al., 2024). Therefore, students must possess foundational skills before taking the Art Appreciation and Criticism course, such as a basic understanding of art theory, aesthetics, and art history, as well as the ability to read and write simple analyses. This foundation is essential so that students can more easily develop aesthetic sensitivity, evaluate works of art objectively, and compose systematic critiques. With these foundational skills, the learning process will be more effective, and students will be able to achieve the expected learning outcomes.

The Art Appreciation and Criticism course in the Music Education Program at Unimed still uses the Direct Instruction method. This poses challenges in the learning process, including: weak critical and analytical skills; insufficient utilization of digital technology to support the learning process; variations in musical intelligence; passive learning; underutilization of digital technology; irrelevant teaching methods; suboptimal learning outcomes; and students' inability to systematically express Art Appreciation and Criticism, particularly regarding musical works. Challenges in music education within multicultural classrooms (such as language barriers and differences in aesthetic perceptions) result in less comprehensive learning of Art Appreciation and Criticism (Bond, 2017; Huong & Loan, 2025; Kelly, 2018). This situation demands adaptive and inclusive teaching methods so that students can develop Art Appreciation and Criticism holistically amidst cultural diversity.

Therefore, implementing the Problem-Based Digital Learning method is considered a way to make students more active through digital problem-solving while also adapting to their level of musical intelligence in the Art Appreciation and Criticism course. Meanwhile, the Direct Instruction method emphasizes clear, structured, teacher-centered steps to ensure mastery of basic concepts, limiting student creativity and active participation (Woods & Copur-Gencturk, 2024). Structured, monotonous learning patterns often leave students unmotivated, make it difficult to meet individual needs, and leave little room to develop 21st-century skills such as critical thinking, collaboration, and problem-solving (Blume, 2025). Thus, while effective for mastering foundational concepts, the Direct Instruction learning method is less than optimal in fostering independence and creativity in learning (Bhardwaj et al., 2025; Stockard et al., 2018). If this phenomenon is not addressed immediately, it may lead to several serious consequences in the Art Appreciation and Criticism learning process, including: low quality of learning outcomes, a lack of critical and analytical thinking skills, disparities in learning outcomes among students, minimal use of digital technology, and a decline in competitiveness. Without implementing the Problem-Based Digital Learning method integrated with musical intelligence, the Art Appreciation and Criticism learning process will stagnate and fail to meet the challenges of 21st-century education.

Previous research has identified several innovative teaching methods suitable for music education, including: Chen (2025), who found that static traditional music teaching approaches are less effective; consequently, the Deep Fuzzy Music Training (DFMT) system was introduced, utilizing a Recurrent Neural Network (RNN) algorithm to predict teaching patterns based on the Kodály method through analysis of frequency, pitch accuracy, dynamics, and articulation; the prediction results are used by a Fuzzy system to provide personalized teaching recommendations, assessing students' abilities, preferences, and learning styles, thereby supporting more precise instructional decisions in music education at the university level. da Fonsêca Barros & Penna (2023) argue that PBL in music teacher education can enrich the learning process by presenting real-world problems relevant to practice in elementary, middle, and high schools. Its success depends on institutional support, curriculum, culture, and an understanding of the PBL framework. This approach transforms the teacher-student relationship, fosters independent learning, strengthens music teachers' professional identity, and develops teamwork skills that cultivate collaboration, shared analysis, and reflective practice. Özer & Demirbatir (2023) found that digital-based STEAM (Science, Technology, Engineering, Arts, and Mathematics) in music education has proven effective in enhancing creativity, deepening learning, and fostering student interest by providing enjoyable learning experiences. As technology advances, music teaching methods and techniques must adapt. Integrating arts education within the STEAM framework alongside other disciplines

makes music lessons more effective and memorable. This study emphasizes that music teachers' optimal use of digital applications will significantly contribute to the quality of music education. Fu et al. (2025) found that Task-Based Learning (TBL) and Blended Learning (BL) proved effective in improving the experimental group's ability to read sheet music and play musical instruments, with moderate to large effects. This model not only supports technical skills but also artistic expression and independent learning. Together, they show strong flexibility and coherence, making them a valuable guideline for developing performance-oriented music curricula. Arini and Adi (2024) found that implementing Bloom Digital can improve students' argumentation and collaboration skills while also fostering social values. Furthermore, digitization can more effectively support documentation, publication, and interactive activities, thereby supporting modern, reflective music learning that meets current educational needs.

This study acknowledges several gaps that need to be addressed: (1) previous studies have primarily focused on problem-based learning (PBL) methods; (2) the integration of digital technology in the application of PBL in music education remains very limited; (3) PBL research generally only assesses the method's effectiveness in improving music learning outcomes, without addressing its impact on students' creative behaviors, particularly in Art Appreciation and Criticism courses, which encompass activities such as listening to, understanding, evaluating, expressing, and analyzing musical works or performances. The learning outcomes instrument used in this study is explicitly designed to go beyond basic cognitive or theoretical testing. Rather than merely assessing rote memorization of art theory, the instrument measures these creative behaviors through practical assessments that require students to systematically analyze audio tracks, evaluate musical expressions, and compose well-reasoned aesthetic critiques using digital media. This article was written with a thorough understanding of the current roadmap for music education research in Indonesia (Riyadi et al., 2025).

Based on the phenomena observed in the Art Appreciation and Criticism learning process within the Music Education Program at Universitas Negeri Medan (Unimed), this study is designed to investigate the influence of learning methods and musical intelligence on students' learning outcomes. To provide a systematic investigation, this research establishes seven interconnected objectives. First, it aims to analyze the overall differences in learning outcomes in Art Appreciation and Criticism between students taught using the PDBL method and those taught using the Direct Instruction method. Second, it examines the disparity in learning outcomes between students with high musical intelligence and those with low musical intelligence. Third, the study investigates the potential interaction effect between the chosen learning methods and the students' level of musical intelligence on their learning achievements. In the conditional analyses, the fourth and fifth objectives evaluate differences in learning outcomes between the PDBL and Direct Instruction methods for students with high musical intelligence and those with low musical intelligence, respectively. The sixth and seventh objectives assess how musical intelligence levels (high versus low) affect learning outcomes within each instructional environment by analyzing students in the PDBL cohort and the Direct Instruction cohort independently.

METHODS

This study falls under the quasi-experimental category (quasi-experiment), as defined by Creswell (2019), and aims to identify differences in learning outcomes in Art Appreciation and Criticism between students using the Problem-Based Digital Learning method and those using the Direct Instruction method, taking into account their level of musical intelligence (high or low). Fabrigar et al. (2024) define a quasi-experiment as a study similar to a randomized experiment but without random assignment of conditions, highlighting differences and similarities with randomized experiments and non-experimental studies, discussing strengths, weaknesses, and threats to causal validity, and explaining the general design of quasi-experiments and how to use them to assess the impact of independent variables. The research subjects are students in the 2024 cohort of the Music Education Program who are taking the Appreciation and Criticism of Art course in the even semester of the 2025/2026 academic year. The research population includes all 96 students in the 2024 cohort, broken down as follows: Class A (42 students), Class B (37 students), and Class C (17 students). The sample was selected randomly, with Class A serving as the control group, Class B as the experimental group, and Class C as the instrument pilot group. The sampling technique used was Cluster Random Sampling, as randomization occurred at the class level rather than the individual student level to maintain naturally occurring instructional groups (Bhardwaj et al., 2025;Sugiyono, 2022). Through this cluster randomization process, Class A was randomly designated as the control group (Direct Instruction), Class B as the experimental group (Problem-Based Digital Learning), and Class C as the pilot group for instrument validation.

The research treatment was implemented in three stages: preparation, treatment, and final evaluation and data collection. During the preparation stage, the researcher developed the Semester Lesson Plan (RPS) aligned with the Outcome-Based Education (OBE) curriculum for two distinct instructional approaches: Problem-Based Digital Learning and Direct Instruction. Concurrently, the researcher prepared and pilot-tested instruments to measure musical intelligence and learning outcomes in Art Appreciation and Criticism with students outside the research sample (Class C) to ensure validity and reliability. The musical intelligence

instrument was a structured questionnaire adapted from Howard Gardner's Multiple Intelligences framework, specifically tailored to measure rhythmic sensitivity, pitch recognition, and musical memory. Following the pilot test, the instrument demonstrated strong construct validity (Pearson's r > 0.30 for all items) and high internal consistency reliability (Cronbach's Alpha = 0.86).

To categorize students as having 'High' or 'Low' musical intelligence, the researchers applied a median-split technique to the questionnaire scores: students scoring above the median were classified as having high musical intelligence, while those scoring below were classified as low. Following this preparation, the treatment phase was conducted over eight sessions. The initial session was utilized to assess the participants' baseline abilities (initial ability) through a standardized pre-test covering fundamental art theory and aesthetic concepts. The pre-test scores were then used as a covariate in the ANCOVA analysis to control for pre-existing differences between groups. In the eighth session, the study entered its final phase, in which the Art Appreciation and Criticism learning-outcome test was administered to both groups under an identical schedule and duration of 100 minutes to evaluate students' mastery of the material accurately. Ultimately, these learning outcome tests were used to gauge academic achievement, alongside specialized musical intelligence instruments that categorized students into high or low levels of musical intelligence.

The data analysis techniques in this study comprise descriptive analysis, prerequisite testing, and inferential statistical analysis. First, descriptive statistics are employed to examine the mean, median, mode, standard deviation, range, and minimum and maximum values of the dataset, with frequency distributions visualized through tables and histograms. Second, to ensure the data satisfies the assumptions required for parametric statistical analysis, several prerequisite tests are systematically conducted. The normality of the data distribution is evaluated using the Lilliefors test, where data are considered normally distributed if $L_0 < L_{\text{table}}$ at a significance level of 0.05. The homogeneity of variance is assessed using Bartlett's test, establishing homogeneity if $\chi^2_{\text{calculated}} < \chi^2_{\text{table}}$, with an alternative F-test utilized if this condition is not met. Additionally, the regression linearity test uses the least squares method to determine if the model is linear, indicated by $F_{\text{calculated}} < F_{\text{table}}$ at a significance level of 0.05, while the regression significance test applies an F-test to evaluate the effect of the prior knowledge covariate (X) on the learning outcomes (Y), requiring $F_{\text{calculated}} > F_{\text{table}}$ for significance. A final linearity test using a heterogeneous regression model is performed to examine potential differences in the linear effects of prior ability on learning outcomes across the groups based on learning methods and musical intelligence.

Third, the inferential analysis for hypothesis testing is executed through Analysis of Covariance (ANCOVA) at a significance level of $\alpha = 0.05$. Because the treatment and moderator variables are expected to interact, the study uses a post-hoc Scheffé test to address differences in sample sizes across groups. Through this analytical framework, the study evaluates seven distinct statistical hypotheses related to the differences in learning outcomes based on learning methods, Problem-Based Digital Learning (A_1) versus Direct Instruction (A_2) and musical intelligence levels, categorized as high (B_1) and low (B_2). These hypotheses specifically examine: (1) the difference in mean learning outcomes between groups A_1 and A_2; (2) the difference in mean learning outcomes between groups B_1 and B_2; (3) the presence of an interaction effect between the learning model A and musical intelligence B; (4) the difference between A_1B_1 and A_2B_1 to evaluate learning methods for students with high musical intelligence; (5) the difference between A_1B_2 and A_2B_2 to assess learning methods for students with low musical intelligence; (6) the difference between A_1B_1 and A_1B_2 to contrast musical intelligence within the digital learning environment; and (7) the difference between A_2B_1 and A_2B_2 to compare musical intelligence within the direct instruction framework.

RESULT AND DISCUSSION

To understand the initial distribution of the data, descriptive statistics of the learning outcomes were calculated. The following table summarizes the sample size, mean scores, and variance for students in both the Problem-Based Digital Learning (PDBL) and Direct Instruction (DI) groups, which are further categorized by their level of musical intelligence.

Table 1. Summary of Learning Outcomes in Art Appreciation and Criticism

Musical Intelligence (B)		Learning Method (A)				Total	
		Problem-Based Digital Learning (A_1)		*Direct Instruction* (A_2)			
		X	Y	X	Y	X	Y
High (B_1)	N	11	11	10	10	21	21
	M	86.36	89.50	82.10	84.30	85.00	86.57
	Mo	85.83	85.50	79.50	81.50	85.00	87.17
	Me	86.66	88.50	77.75	83.50	85.00	86.57
	Var	55.45	41.60	30.04	28.62	47.50	37.86
	Sb	7.45	6.45	5.48	5.35	6.89	6.15
	Min	73.33	80	73.33	76	73.33	76
	Max	96.67	100	90.00	92	96.67	100

Musical Intelligence (B)		Learning Method (A)				Total	
		Problem-Based Digital Learning (A_1)		*Direct Instruction* (A_2)			
		X	Y	X	Y	X	Y
Low (B_2)	N	11	11	10	10	21	21
	M	53.41	61.82	59.30	67.00	59.36	63.80
	Mo	59.50	60.83	60.50	70.50	49.00	69.17
	Me	53.00	61.67	59.50	68.50	49.00	64.36
	Var	63.49	66.36	62.40	37.78	63.43	54.76
	Sb	7.96	8.14	7.89	6.15	7.96	7.40
	Min	40.00	48	46.67	54	40.00	48
	Max	66.67	74	70.00	74	70.00	74
Total	N	22	22	20	20		
	M	69.77	76.50	68.90	74.85		

As shown in Table 1, the sample sizes for the PDBL group (N=22) and the Direct Instruction group (N=20) differ. This discrepancy occurred because two students from the Direct Instruction group did not attend the final evaluation session (post-test) and were therefore excluded from the final data analysis to maintain data integrity. The descriptive data indicate that the overall mean score for the PDBL group (76.50) is higher than that of the DI group (74.85). Furthermore, students with high musical intelligence consistently show substantially higher mean scores across both instructional methods than their peers with low musical intelligence. After meeting the prerequisites for normality and homogeneity, inferential statistical analysis was conducted. An Analysis of Covariance (ANCOVA) was employed to test the main research hypotheses regarding the effects of learning methods and musical intelligence on learning outcomes. In this analysis, students' initial ability scores were used as a covariate to statistically control for pre-existing differences among groups.

Table 2. Summary of ANCOVA Test Results

Source of Variance	df	Mean Square (MS)	Fcalculated	Ftable (α=0.05)	Conclusion
Learning Methods (A)	1	42.33	14.11	4.105	Significant Difference
Musical Intelligence (B)	1	39.87	13.29	4.105	Significant Difference
Interaction (A × B)	1	69.87	23.29	4.105	Significant Interaction

The ANCOVA results presented in Table 2 demonstrate significant findings across all measured parameters. First, the learning method has a significant main effect (Fcalculated = 14.11 > Ftable = 4.105), indicating that PDBL yields significantly higher overall achievement than Direct Instruction. Second, musical intelligence also presents a significant main effect (Fcalculated = 13.29 > Ftable = 4.105). Crucially, the analysis reveals a strong and highly significant interaction effect between the instructional model and musical intelligence (Fcalculated = 23.29 > Ftable = 4.105). This significant interaction suggests that the effectiveness of a teaching method is not absolute but depends heavily on the student's level of musical intelligence. Because the ANCOVA revealed a significant interaction between learning method and musical intelligence, a post-hoc analysis is required to determine which subgroups differ significantly. To evaluate these specific group comparisons while accounting for the unequal sample sizes, the Scheffé post-hoc test was conducted.

Table 3. Summary of Scheffé Post-Hoc Test Results

Comparison Group	Fcalculated	Ftable (α=0.05)	Description / Significance
PDBL High vs. DI High (A1B1 vs A2B1)	2.71	2.859	Not Significant
PDBL Low vs. DI Low (A1B2 vs A2B2)	17.52	2.859	Significant (DI is higher)
PDBL High vs. PDBL Low (A1B1 vs A1B2)	13.03	2.859	Significant (High is higher)
DI High vs. DI Low (A2B1 vs A2B2)	5.40	2.859	Significant (High is higher)

Table 3 provides a detailed breakdown of the interaction effect. Notably, for students with high musical intelligence, learning outcomes do not differ significantly between the PDBL and Direct Instruction methods (Fcalculated = 2.71 < Ftable = 2.859). Conversely, for students with low musical intelligence, the Direct Instruction method produces significantly higher learning outcomes than PDBL (Fcalculated = 17.52 > Ftable = 2.859). Additionally, the results confirm that students with high musical intelligence significantly outperform those with low musical intelligence, regardless of whether they are taught using the PDBL or Direct Instruction framework. To clarify the significant interaction between teaching methods and musical intelligence levels, the data are visually represented. Figure 1 shows how mean learning outcomes for each instructional method shift depending on students' musical aptitude.

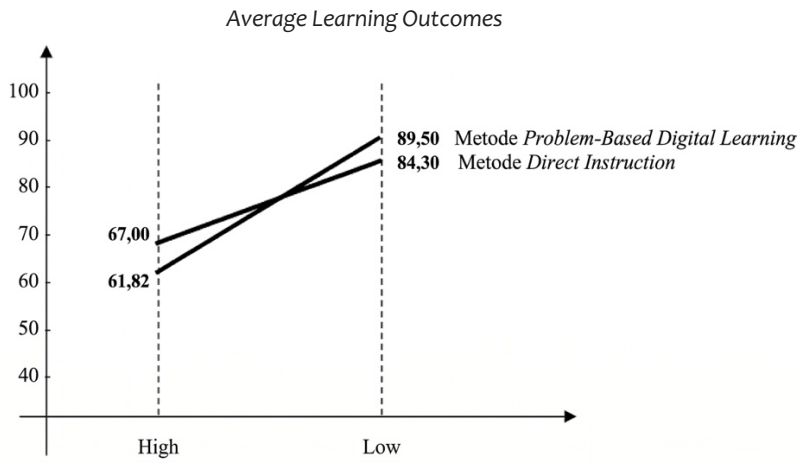


Figure 1. Interaction Between Instructional Models and Musical Intelligence on Learning Outcomes

Figure 1 visually confirms the quantitative findings from the ANCOVA and Scheffé tests. The line trajectories clearly illustrate the interaction effect: while the PDBL method is highly effective and yields the highest scores for students with high musical intelligence, its effectiveness drops sharply for students with low musical intelligence. In contrast, the line representing Direct Instruction shows a much more stable trend, proving that its structured approach offers better support and prevents cognitive overload for students with lower baseline musical aptitude. The findings reveal that the Problem-Based Digital Learning (PDBL) method is generally more effective than Direct Instruction in improving learning outcomes in Art Appreciation and Criticism. This aligns with Constructivism theory, which posits that students learn best when they actively construct their own knowledge. By integrating digital literacy, PDBL transforms passive listeners into active participants. Students are no longer just memorizing aesthetic theories; they are directly utilizing digital tools to dissect musical layers, analyze soundscapes, and collaboratively construct critiques.

A particularly compelling finding (Hypothesis 5) is that PDBL is actually less effective for students with low musical intelligence compared to Direct Instruction (Mean = 61.82 vs. 67.00). This phenomenon can be explained through the lens of Cognitive Load Theory. Students with lower musical aptitude lack the foundational cognitive schemas needed to process musical complexities effortlessly. When these students are thrust into a PDBL environment—which demands simultaneous mastery of complex digital analysis tools, independent problem-solving, and abstract aesthetic critique—they experience severe cognitive overload. The lack of explicit step-by-step guidance overwhelms their working memory. Conversely, the Direct Instruction method provides essential scaffolding. The highly structured, teacher-led approach reduces extraneous cognitive load, allowing students with low musical intelligence to grasp fundamental concepts gradually without being overwhelmed by the dual demands of digital navigation and independent problem-solving.

For students with high musical intelligence, the statistical analysis (Hypothesis 4) showed no significant difference between the PDBL and Direct Instruction methods ($F_{calculated} = 2.71 < 2.859$). This occurs because musically gifted students already possess robust internal cognitive schemas and intrinsic motivation regarding music. These students are highly adaptable; in a Direct Instruction setting, their strong foundational knowledge allows them to absorb theoretical material efficiently, while in a PDBL setting, they thrive using digital tools to explore advanced artistic nuances. This study's findings offer a nuanced extension of previous literature. Digital-based learning (STEAM) consistently enhances creativity and student interest across the board; however, this study challenges the universality of that claim by showing that without appropriate aptitude (musical intelligence), complex digital problems can hinder learning (Özer & Demirbatir, 2023). However, our findings strongly support Chen (2025), who emphasized the need for personalized, adaptive instructional decisions based on students' abilities, like the Deep Fuzzy Music Training system. Just as Chen's model adapts to student proficiency, our results empirically prove that a "one-size-fits-all" pedagogical approach is flawed: advanced digital problem-solving (PDBL) must be targeted towards students with sufficient cognitive schemas (high musical intelligence), whereas structured scaffolding (Direct Instruction) remains indispensable for those requiring foundational support.

CONCLUSION

Based on the research findings, the Problem-Based Digital Learning (PDBL) method generally yields significantly higher learning outcomes in Art Appreciation and Criticism compared to Direct Instruction, and students with high musical intelligence consistently outperform those with lower aptitude. Crucially, a significant interaction effect demonstrates that instructional effectiveness is not universal but depends heavily on students'

baseline aptitude. While students with high musical intelligence achieve excellent outcomes under both PDBL and Direct Instruction, those with low musical intelligence require the highly structured scaffolding of Direct Instruction to prevent cognitive overload and achieve optimal results. The practical impact of these findings is substantial for higher music education: digital problem-solving platforms should be strategically paired with classroom differentiation rather than implemented mindlessly. Consequently, it is recommended that university study programs conduct diagnostic musical intelligence mapping at the beginning of the semester to design customized pedagogical tracks—deploying collaborative PDBL for advanced students and structured Direct Instruction for those needing foundational support. Acknowledging the limitation of a localized sample from a single university cohort, future research should expand to multi-institutional studies and investigate other moderating variables, such as learning motivation and visual/auditory learning styles, to further optimize personalized pedagogy in the 21st century.

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DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

CONFLICTS OF INTEREST

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

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AUTHOR CONTRIBUTIONS

The authors' contributions in this study can be summarized as follows: Uyuni Widiastuti, as the principal investigator, was responsible for conceptualization, methodology development, formal analysis, and writing the original draft of the manuscript. Mukhlis, contributed to formal analysis, resource provision, and data visualization management. Adina Sastra Sembiring contributed to validation, manuscript review and editing, and overall research supervision. Lanang Riyadi actively participated in validation activities and supported the implementation of formal analysis. Akbar Bagaskara contributed to the critical review and editing of the manuscript and provided valuable international perspectives for the discussion and theoretical framework.

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