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Development of problem based learning with peer assessment model to enhance creative thinking and piano skills for non-piano college students

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Abstract: This study aimed to develop a Problem-Based Learning (PBL) model integrated with peer assessment to enhance creative thinking and piano skills among non-piano college students. The study employed a research and development approach combined with a quasi-experimental design to evaluate the effectiveness of the developed instructional model. The participants consisted of 40 second-year non-piano major students from a university in Yuncheng City, China, who were divided into an experimental group (n = 20) and a control group (n = 20). The experimental group was taught using the PBL with peer assessment model, while the control group received traditional piano instruction. The intervention lasted for eight weeks. Data were collected through piano performance assessments and a creative thinking questionnaire, and analyzed using multivariate analysis of variance (MANOVA) and independent samples t-tests. The results indicated that students in the experimental group demonstrated significantly higher scores in both piano skills and creative thinking compared with the control group ($p < .001$). The experimental group achieved higher mean scores in rhythm and timing ($M = 23$) and style and mood ($M = 8$), compared with the control group ($M = 18$ and $M = 6$, respectively). Creative thinking scores increased to a mean of 4.46 in the experimental group, while the control group scored 2.97. These findings suggest that the developed PBL with peer assessment model effectively improves musical performance and creative thinking. Future research should examine the long-term impact of the model and explore its applicability in other music education contexts.

Keywords: *Creative thinking, Peer assessment model, Peer assessment, Piano skills, Problem based learning with, Problem based learning.*

1. Introduction

Piano education holds a central place in higher music programs in China, especially for non-piano major undergraduates who need foundational keyboard skills to support broader musicianship, including harmony analysis, accompaniment, and compositional understanding. Traditional piano instruction has mainly relied on teacher-centered approaches characterized by demonstration, imitation, and one-to-one guidance. These methods effectively develop technical accuracy and basic execution but often limit opportunities for creative exploration, collaborative interaction, and self-directed problem-solving, particularly in large enrollment classes common in Chinese universities [1].

Existing research in music education has increasingly explored student-centered pedagogies to address such constraints. Problem-Based Learning (PBL), originally developed in medical education and later adapted to arts disciplines, emphasizes authentic, ill-structured problems to foster inquiry, collaboration, and deep conceptual understanding. In music contexts, PBL has been applied to composition, vocal training, and general classroom activities, promoting experiential learning and higher-order skills. Peer assessment, a formative strategy where students evaluate peers' work using

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structured criteria, has demonstrated benefits in enhancing reflective practice, critical listening, and self-regulation in performance-based settings, including higher music education [2]. Studies indicate that peer feedback improves musical achievement and meta-cognitive awareness, particularly when integrated with collaborative tasks.

Despite these advancements, applications of PBL and peer assessment remain limited in piano courses for non-majors, where the dual goals of technical skill development and creative thinking cultivation are essential but underexplored.

Traditional piano teaching for non-piano majors in China faces persistent challenges, including overemphasis on rote imitation, insufficient attention to interpretive depth and originality, and restricted feedback mechanisms in group settings. Recent literature highlights the utility-driven nature of much piano education, which prioritizes skill acquisition for examinations or professional utility over holistic musical growth, leading to limited development of creative capacities [3]. While some studies have examined PBL in adult keyboard learning or online vocal-piano accompaniment, few integrate PBL with peer assessment specifically for non-major piano curricula. Key achievements include evidence that PBL enhances learning satisfaction and engagement in music courses, and that peer assessment supports vocal and performance refinement through reflection. However, these approaches often remain isolated, with shortcomings such as inadequate scaffolding for novices, limited empirical validation in Chinese higher education contexts, and insufficient focus on measurable gains in both piano performance dimensions (notes, rhythm, articulation, dynamics, style/mood) and creative thinking facets (originality, flexibility, fluency, elaboration). Moreover, traditional models struggle to accommodate diverse learner needs and large-class dynamics, resulting in passive learning and underdeveloped autonomy [4].

However, there has been less previous evidence for the development of an integrated PBL with peer assessment model tailored to non-piano major undergraduates in Chinese universities. Existing studies rarely combine these elements into a cohesive, validated framework that addresses both technical piano proficiency and creative thinking simultaneously, nor do they provide detailed, replicable instructional designs grounded in prior needs assessments [5]. Filling this gap is important because such a model could shift pedagogy toward more interactive, inclusive practices, better preparing students for collaborative musical professions while fostering transferable creative skills. This research bridges the gap by developing and expert-validating a structured PBL with a peer assessment model to offer a practical alternative to conventional methods.

Therefore, this study aims to develop a Problem-Based Learning model with peer assessment to enhance creative thinking and piano skills among non-piano college students. The research seeks to answer the following questions:

(1) How can a PBL model with peer assessment be developed for piano instruction?

(2) To what extent does the developed model improve students' creative thinking and piano performance skills compared with traditional teaching methods?

To address these questions, the study adopted a research and development approach combined with a quasi-experimental design. A group of non-piano major students participated in an instructional intervention using the developed model, and their learning outcomes were compared with those of students receiving conventional piano instruction.

2. Literature Review

2.1. Problem-Based Learning

Problem-Based Learning (PBL) is a student-centered instructional approach in which learning begins with complex and meaningful problems that require students to analyze situations, identify learning needs, and collaboratively develop solutions [6]. Over time, it has been widely adopted in higher education because it encourages students to take responsibility for their learning and apply theoretical knowledge to real-world contexts. In piano education, especially for non-piano major students, learning often relies on repetitive technical practice guided by teacher demonstration. While

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this method may help students acquire basic performance skills, it may not fully support the development of creative thinking or active engagement [7]. Therefore, introducing PBL into piano instruction has the potential to create more interactive learning environments and enhance both technical and creative aspects of musical learning.

Early work by Barrows established the theoretical and pedagogical foundations of PBL (**Fig. 1**), showing that students in problem-based environments develop stronger problem-solving abilities and independent learning skills [8]. Building on this foundation, Savery further clarified the principles of PBL and emphasized that knowledge is constructed through inquiry and collaboration rather than passive reception [9]. These studies provided important theoretical support for adopting PBL in diverse educational contexts and highlighted its potential to transform traditional teaching practices.

More recently, researchers have begun exploring the use of PBL in arts and music education. Some studies have applied problem-based tasks in music theory and ensemble classes, suggesting that PBL can encourage students to analyze musical structures and explore different interpretative possibilities [10]. However, other researchers have noted practical challenges in implementing PBL within performance-based disciplines. Instrumental learning often involves individual practice and technical skill development, which may make it difficult to design collaborative problem-solving tasks [11]. These contrasting perspectives suggest that although PBL has strong theoretical potential in music education, its application in instrumental instruction requires further exploration.

Overall, existing studies confirm that PBL is an effective pedagogical approach for promoting active learning, collaboration, and higher-order thinking. However, most research has focused on classroom-based subjects or theoretical aspects of music education, while relatively little attention has been given to its application in piano instruction for non-piano major students. In particular, there is limited research on how PBL can be systematically integrated into piano courses to support both technical skill development and creative thinking. Therefore, this study aims to address this gap by developing and examining a PBL-based instructional model designed for piano learning among non-piano college students.

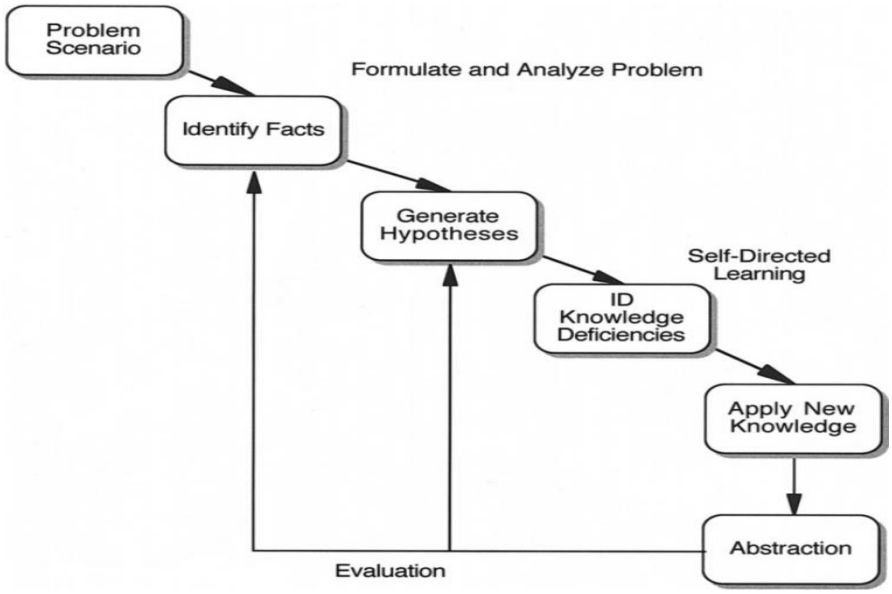

Figure 1.
The problem-based learning cycle.
Source: Barrows [8].

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2.2. Peer Assessment

Peer assessment refers to an evaluation process in which students assess and provide feedback on the work or performance of their peers according to predefined criteria [12]. As a formative assessment strategy, peer assessment has been widely adopted in higher education to promote active participation in the learning process and to develop students' evaluative judgment. By evaluating the performance of others, students are required to apply assessment criteria, critically analyze strengths and weaknesses, and reflect on their own learning. In music education, where performance and interpretation are central components of learning, peer assessment offers opportunities for students to receive diverse feedback and develop critical listening skills. Therefore, incorporating peer assessment into instrumental instruction may help create a more collaborative learning environment and support the improvement of both performance skills and reflective learning.

Topping conducted influential research on peer assessment and found that the process encourages students to engage more deeply with assessment criteria and develop greater responsibility for their own learning [13]. Building on this foundation, Falchikov and Goldfinch [14] examined the reliability of peer assessment compared with teacher evaluation and found that, when appropriate criteria and training are provided, peer assessments can produce results that are reasonably consistent with instructor evaluations [14]. These studies established peer assessment as a credible and valuable tool for formative evaluation in educational settings. Nicol and Macfarlane-Dick emphasized that peer feedback helps students understand assessment standards and develop self-regulation skills [15]. Similarly, Liu and Carless [16] investigated the role of dialogic feedback in peer assessment and found that interactive feedback processes promote deeper learning and greater student engagement [16].

Studies in instrumental and ensemble settings suggest that peer feedback can enhance students' listening abilities, musical interpretation, and performance awareness [5]. However, other scholars have raised concerns regarding the reliability and effectiveness of peer assessment in performance-based subjects. Differences in students' musical experience and evaluation skills may influence the quality of feedback provided [17]. Overall, existing literature demonstrates that peer assessment is an effective strategy for promoting reflective learning, collaborative interaction, and performance improvement. Most studies emphasize its role in enhancing feedback processes and developing students' evaluative skills. However, research focusing specifically on the integration of peer assessment within piano instruction for non-piano major students remains limited. In particular, few studies have examined how peer assessment can be systematically combined with instructional approaches such as problem-based learning to support both performance development and creative thinking. Therefore, this study seeks to address this gap by incorporating peer assessment into a structured problem-based learning model for piano courses. In addition, to understand the cognitive processes involved in peer assessment, this study adopts the 'Assessment Cycle' model proposed by Reinholz [18], which emphasizes how peer feedback stimulates evaluative judgment through iterative analysis and revision Table 1.

Table 1.
Key Aspects of Peer Assessment.

Component	Examples of how it supports self-assessment
Task Engagement	Performance awareness: students explain their ideas Gap closure: revisions during engagement/ problem solving
Peer Analysis	Goal awareness: experience analyzing a variety of examples
Feedback Provision	Performance awareness: explaining ideas and receiving feedback on explanations Gap closure: developing constructive feedback to improve work, not just critique it
Feedback Reception	Performance awareness: students are able to view their own work from another perspective
Peer Conferencing	Opportunities to discuss analyses and feedback can increase the impact of peer analysis, feedback provision, and feedback reception.
Revision	Gap closure: students use analyses and feedback to improve their work

Source: Reinholz [18].

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2.3. Problem Based Learning with Peer Assessment Model

The importance of integrating innovative teaching strategies supports active learning, collaboration, and reflective practice. Among these strategies, Problem-Based Learning (PBL) and peer assessment have attracted considerable attention because both approaches promote student-centered learning and encourage deeper engagement with knowledge construction [19]. While PBL focuses on learning through the process of solving authentic problems, peer assessment emphasizes students' active participation in the evaluation and feedback process. Therefore, combining PBL with peer assessment has the potential to create a comprehensive learning environment in which students collaboratively explore problems, develop solutions, and continuously improve their performance through feedback and reflection [18].

A number of researchers have explored the pedagogical benefits of combining problem-based learning with various forms of collaborative assessment. For example, research in higher education has demonstrated that integrating peer assessment within PBL frameworks can enhance students' critical thinking, self-regulation, and collaborative learning skills [20]. Students are not only required to propose solutions to problems but also to evaluate the quality of their peers' ideas and performances, which encourages deeper reflection and more active participation in the learning process.

Some researchers have found that when peer assessment is embedded within PBL activities, students become more aware of evaluation criteria and develop stronger analytical skills [21]. In these learning environments, peer feedback helps students refine their ideas and improve the quality of their final outcomes. Other studies have reported that the integration of these two approaches increases students' motivation and engagement because learners feel more responsible for both their own learning and the learning of their peers [22]. Compared with traditional teacher-centered instruction, this integrated approach encourages a more dynamic and collaborative learning atmosphere. However, despite these positive findings, some scholars have pointed out challenges associated with implementing integrated PBL and peer assessment approaches. One concern relates to the reliability and quality of peer feedback, particularly when students lack sufficient experience in evaluation [14]. Without clear guidelines and assessment criteria, peer feedback may become superficial or inconsistent. This concern highlights the importance of carefully structured instructional models that guide students through the processes of problem analysis, collaborative learning, performance practice, and reflective evaluation.

Overall, the integration of problem-based learning and peer assessment has shown promising potential for promoting active learning, critical thinking, and collaborative engagement. Therefore, combined with the previous review, the problem-based learning with peer assessment model incorporates the following steps (Figure 2): 1) Preparation: it includes an introduction to the problem of PBL and assessment criteria and standards of peer assessment. 2) Problem analysis and practice: it covers problem analysis of PBL and the implementation step from peer assessment. 3) Draft performance within groups: this process is an assessment and evaluation procedure from both PBL and peer assessment. 4) Problem solving and final performance: This step involves problem solving from PBL and outcomes from peer assessment. 5) Reflection and continuous improvement: it combines reflection and improvement from both PBL and peer assessment.

2.4. Students' Creative Thinking

Creative thinking has long been recognized as a crucial component of education, particularly in fields related to the arts and music. In general terms, creative thinking refers to the ability to generate new ideas, explore multiple perspectives, and develop original solutions to problems. Early research by scholars such as Guilford emphasized the role of divergent thinking in creativity, highlighting abilities such as fluency, flexibility, originality, and elaboration as core dimensions of creative thought [23]. In educational contexts, fostering creative thinking is considered essential because it helps students move beyond rote learning and encourages them to engage in deeper cognitive processes. In music education, creative thinking is particularly important because musical performance and interpretation often require

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students to make expressive decisions, explore different stylistic possibilities, and develop personal artistic understanding [24].

Over the past decades, researchers have explored various approaches to developing creative thinking in educational settings. Torrance conducted influential studies on creativity and developed the Torrance Tests of Creative Thinking, which have been widely used to assess students' creative abilities [25]. In the field of music education, creative thinking is closely connected to musical interpretation and performance. Researchers have emphasized that music learning should not only focus on technical accuracy but also encourage students to develop expressive and imaginative interpretations of musical works [26]. For example, some researchers have found that when students are given opportunities to analyze musical problems and propose different interpretative solutions, they demonstrate greater originality and flexibility in their performances [27].

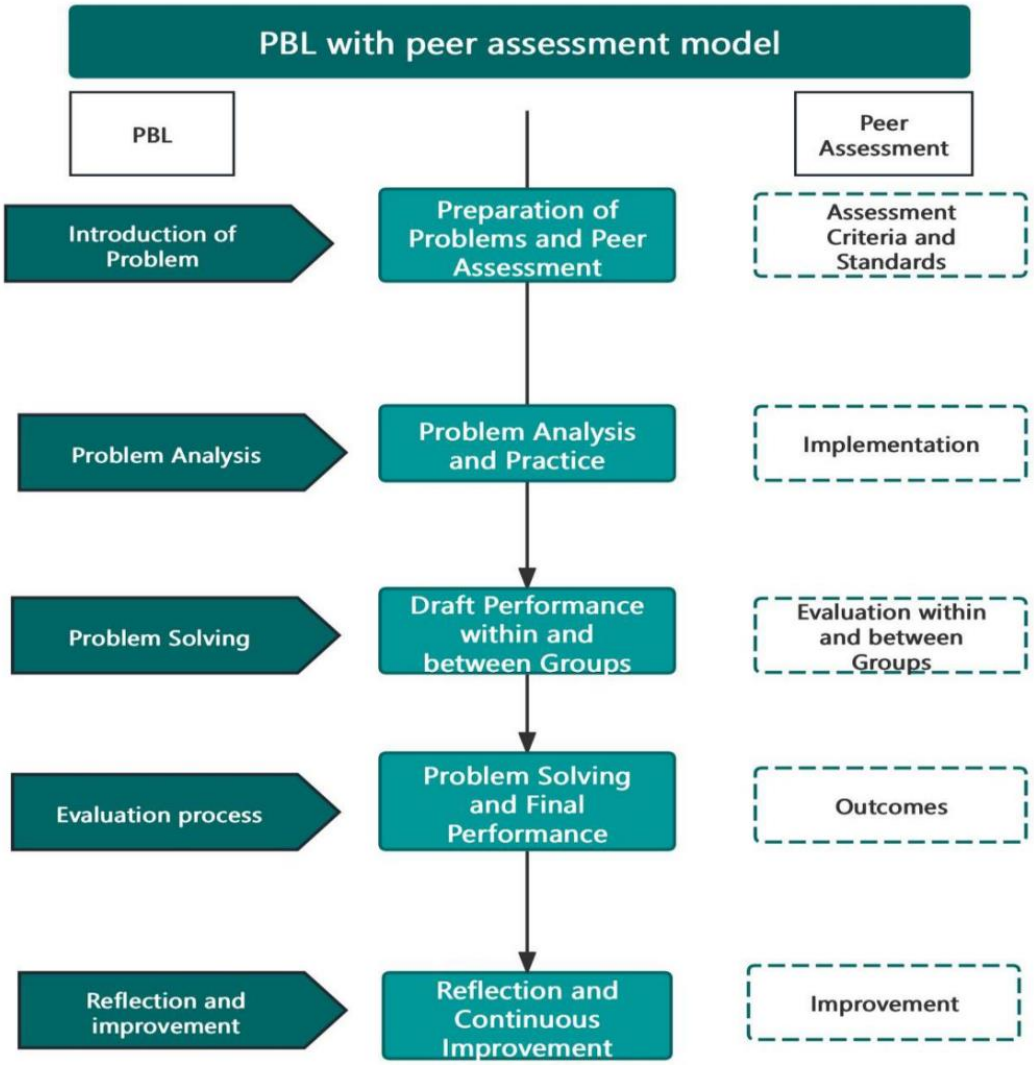

Figure 2.
Problem-based learning with peer assessment model.

However, other scholars have pointed out that traditional teaching approaches in instrumental music education may limit the development of creative thinking. In many piano classes, instruction is

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often dominated by teacher demonstration and repetitive practice aimed at achieving technical accuracy [28]. Some studies have therefore suggested that more student-centered teaching strategies are needed to encourage creativity in instrumental learning. Approaches such as collaborative learning, inquiry-based instruction, and problem-solving activities have been proposed as ways to create learning environments that stimulate creative thinking. Nevertheless, relatively little research has focused specifically on how creative thinking can be enhanced in piano instruction for non-piano major students. In particular, there is a need for teaching models that integrate active learning strategies with performance practice to support both technical skill development and creative expression. Therefore, this study seeks to examine how the integration of problem-based learning and peer assessment may contribute to the improvement of students' creative thinking in piano education.

2.5. Piano Skills for Non-Piano Students

For non-piano major students, piano learning serves as a foundational tool for developing general musicianship, including understanding harmony, rhythm, and musical structure [27]. Through piano practice, students can strengthen their ability to read musical notation, coordinate both hands, and interpret musical expression. Therefore, piano instruction for non-piano students is not only aimed at developing technical proficiency but also at enhancing overall musical competence.

Previous studies have identified several core elements that define basic piano performance skills for non-piano learners. These commonly include note accuracy, rhythm and timing, articulation, dynamics, and musical expression [29]. Note accuracy and rhythm represent fundamental technical requirements that ensure correct performance of the written score, while articulation and dynamics contribute to the expressive quality of the performance. Researchers have emphasized that effective piano instruction should balance technical practice with opportunities for expressive interpretation so that students can develop both mechanical control and musical understanding [30].

However, traditional piano teaching for non-piano majors often focuses heavily on repetitive technical exercises and teacher demonstration. While these methods may help students develop basic playing skills, they may not fully encourage active engagement or a deeper understanding of musical interpretation. Some scholars, therefore, suggest that instructional approaches incorporating collaborative learning, problem-solving activities, and reflective feedback may better support the development of both technical and expressive piano skills [31]. Such approaches may be particularly beneficial for non-piano students, who often have limited prior experience with instrumental performance and require more interactive learning environments to build confidence and competence [32].

3. Research Methods

3.1. Participants

The participants in this study were 40 second-year undergraduate students enrolled in the music department at Yuncheng University, located in Shanxi Province, China. All participants were non-piano majors, meaning their primary instruments were other than piano, including violin, guitar, bass, Chinese flute, and erhu. The selection of second-year students was purposeful, as these individuals had completed foundational music theory courses and possessed basic musical knowledge but had limited formal piano training, making them ideal candidates for examining the effectiveness of the instructional model.

Participants were selected through cluster sampling from three existing classes within the music department. From the pool of eligible students, two classes were randomly selected and then randomly assigned to either the experimental group or the control group, with 20 students in each condition. The experimental group consisted of 5 male students and 15 female students, while the control group comprised 6 male students and 14 female students. The gender distribution reflected the typical demographic pattern observed in Chinese music education programs, where female students constitute the majority. All participants were between 18 and 20 years of age and had no prior experience with

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Problem-Based Learning or structured peer assessment in their music studies. Written informed consent was obtained from all participants after they received detailed explanations of the research purpose, procedures, and their rights to withdraw at any time without consequences.

Table 2.
Demographic Analysis Results.

Location	**Yuncheng City, Shanxi Province**	
University	Yuncheng University	
Type of university	Public University	
Participants	Male	11
	Female	29
Course name	Piano 1	
Ages	18-20	
Sampling	40	Cluster sampling
Experimental	20	
Control	20	

3.2. Experimental Procedure

This study adopted a quasi-experimental design using a pre-test and post-test control group structure to evaluate the effectiveness of the PBL with peer assessment instructional model. The experimental intervention lasted for eight weeks (see lesson outline in Table 3) during the regular piano course. Both the experimental and control groups received the same learning content and instructional time, but the teaching approaches differed.

Students in the control group were taught through traditional piano instruction, which mainly involved teacher demonstrations, explanations of playing techniques, and individual practice guided by the instructor. Feedback was primarily provided by the teacher during the learning process.

In contrast, students in the experimental group participated in learning activities based on the PBL with peer assessment model. The instructional process consisted of several stages, including problem presentation, collaborative analysis of musical challenges, group practice, peer evaluation of draft performances, and final performance improvement. Students worked in small groups to discuss performance problems such as rhythm accuracy, articulation, and musical expression. During the peer assessment stage, students evaluated each other's performances according to predefined criteria and provided constructive feedback. Through repeated practice and reflection, students refined their performances and developed a deeper understanding of musical interpretation.

Table 3.
Lesson Outline.

Piano Course	
Duration	8 Weeks (1 Lesson per week, 1.5 Hours per Lesson)
Objectives	Improve piano playing skills and musicality. Develop creative thinking and problem-solving skills. Foster a collaborative learning environment through peer assessment.
Week 1	Introduction to Piano Basics
	Objective: Familiarize students with the keyboard layout and note values. Task: Learn the names of the keys and basic note values (whole, half, quarter). Activities: 1) Interactive demonstration of the keyboard. 2)Create a color-coded diagram showing the notes on the keyboard. Peer Assessment: Share diagrams in pairs, providing constructive feedback on clarity and creativity.
Week 2	Simple Melodies
	Objective: Create simple melodies using the C major scale. Task: Understand melody construction and pitch. Activities: 1) Group brainstorming session to create a melody together. 2) Use note cards to arrange the melody in groups. Peer Assessment: Perform melodies in small groups, with peers providing feedback on melody flow and engagement.

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Week 3	Rhythm and Timing
	Objective: Comprehend rhythm patterns and their significance. Task: Practice identifying and creating rhythms with quarter and eighth notes. Activities: 1) Clap and count rhythmic patterns as a class. 2) In groups, create an original rhythmic pattern and perform it. Peer Assessment: Evaluate performances based on rhythm accuracy and creativity, providing feedback on execution.
Week 4	Chords and Harmony
	Objective: Introduce major and minor chords and their emotional impact. Task: Learn the formation of basic chords and their usage. Activities: 1) Demonstration of chord progressions on the piano.2) Collaborative activity to create a short progression that conveys an emotion (e.g., happy, sad). Peer Assessment: Groups present their progressions, with classmates assessing emotional impact and musicality.
Week 5	Composition Basics
	Objective: Write a short piece incorporating learned concepts. Task: Utilize melodies, rhythms, and chords in composition. Activities: 1) Guided session on structuring a simple composition.2) Work in pairs to refine and finalize pieces. Peer Assessment: Perform compositions in front of the class; peers evaluate on creativity, coherence, and execution.
Week 6	Exploring Styles
	Objective: Investigate various piano styles and their characteristics. Task: Research different genres (classical, jazz, pop) and select one to present. Activities: 1) Groups research and prepare a presentation on their chosen style.2) Include musical examples and historical context. Peer Assessment: Presentations are rated on engagement, clarity, and depth of knowledge; peers give constructive feedback.
Week 7	Improvisation Techniques
	Objective: Develop improvisation skills using learned scales and chords. Task: Experiment with improvisation in a structured format. Activities: 1) Group improvisation session where students take turns leading. 2) Explore different emotions through improvisation. Peer Assessment: Class evaluates improvisations, focusing on creativity and expressiveness, providing feedback on comfort and confidence.
Week 8	Final Performance and Reflection
	Objective: Synthesize skills learned throughout the course. Task: Prepare a final performance showcasing individual or group work. Activities: 1) Final rehearsal with peer feedback on performance.2) Reflection session on individual growth and learning. Peer Assessment: Performances are evaluated on technical skill, expression, and overall presentation; include a self-reflection component for personal insights.

3.3. Instruments

Two main instruments were employed for data collection in this study. The first instrument was the Bronson Piano Performance Achievement Rubric, adapted for this study to assess piano skills across five dimensions: Notes, Rhythm and Timing, Articulation, Dynamics, and Style and Mood. Each dimension was allocated specific point values based on its relative importance in foundational piano performance: Notes (30 points), Rhythm and Timing (25 points), Articulation (20 points), Dynamics (15 points), and Style and Mood (10 points), yielding a total possible score of 100 points. Each dimension was evaluated on a five-level scale with specific behavioral descriptors for each level. For the Notes dimension, the levels ranged from "Correct notes were rarely played" at the Needs Improvement level to "Correct notes were always played" at the Excellent level. For Rhythm and Timing, descriptors addressed tempo consistency and precision of rhythmic patterns. Articulation descriptors focused on clarity of staccatos, smoothness of slurs, and proper execution of accents. Dynamics descriptors addressed volume variation, crescendos and diminuendos, and melodic voicing. Style and Mood descriptors focused on the extent to which performances represented the correct character and emotion of the music.

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The rubric was validated through Index of Item-Objective Congruence analysis by five experts in piano education and assessment, with all items achieving IOC values above 0.6, confirming content validity. To establish inter-rater reliability (Table 4), two experienced piano teachers independently assessed 20 student performances using the rubric. Pearson correlation analysis yielded a coefficient of r = 0.744 (p = 0.002), indicating strong agreement between raters and confirming that the rubric can be applied consistently.

The second instrument was the Creative Thinking Questionnaire, adapted from the Runco Ideational Behavior Scale and modified for the piano learning context. The questionnaire comprised 20 items measuring four dimensions of creative thinking. Originality, referring to the distinctness and novelty of thoughts generated, was measured through five items, including "I come up with an idea or solution other people have never thought of" and "I have ideas about new inventions or make further improvements on existing work." Flexibility, referring to the ability to transition between concepts and perspectives, was measured through six items, including "I try to think about learning problems from different perspectives" and "I am good at combining ideas in assorted ways that others have not tried." Fluency, referring to the ability to generate a great number of ideas, was measured through six items, including "I come up with a lot of ideas or solutions to playing problems during discussion" and "I may develop a variety of ideas at once." Elaboration, referring to the expansion and development of basic ideas, was measured through three items, including "I often get excited by my own new musical ideas with application in composing."

All items were scored on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was validated through IOC analysis by five experts, with all items achieving values above 0.6. Reliability analysis yielded a Cronbach's Alpha coefficient of 0.963, indicating excellent internal consistency and confirming that the items reliably measured the intended constructs.

Table 4.
Inter rater reliability of piano skills.

Inter rater reliability of piano skills			
Correlations			
		Score1	**Score2**
Score1	Pearson Correlation	1	0.744
	Sig. (2-tailed)		0.002
	n	20	20
Score2	Pearson Correlation	0.744	1
	Sig. (2-tailed)	0.002	
	n	20	20

3.4. Data Collection and Analysis

Data collection proceeded systematically throughout the experimental period. Pre-test and post-test piano performances were recorded in the piano laboratory under standardized conditions, with all students performing the same pieces at each testing point. Recordings were stored securely and subsequently evaluated by two independent raters who were blind to group assignment. Each rater evaluated all performances using the Bronson Piano Performance Achievement Rubric, with the final score for each performance calculated as the average of the two raters' scores. The creative thinking questionnaire was administered online through the Wenjuanwang platform immediately following the post-test, with all 20 experimental group students completing the questionnaire anonymously to encourage honest responses.

Data analysis employed multiple statistical techniques using SPSS software version 26. Prior to conducting the main analyses, all data were screened for missing values and outliers, with no substantial issues identified. Normality of distributions was assessed using Shapiro-Wilk tests for both pre-test and

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post-test scores. For the pre-test, Shapiro-Wilk statistics were calculated separately for experimental and control groups, with non-significant p-values indicating normal distributions appropriate for parametric analysis. Homogeneity of variances between groups was tested using Levene's test for each dependent variable.

To establish baseline equivalence between groups, pre-test piano skill scores were compared using independent samples t-tests. This analysis confirmed that any post-test differences could be attributed to the instructional intervention rather than pre-existing ability differences. For post-test piano skill comparisons, multivariate analysis of variance was employed to examine overall group differences across the five skill dimensions simultaneously. MANOVA was selected because the five dimensions were conceptually related and statistically correlated, making separate univariate tests potentially misleading due to inflated Type I error rates. Prior to conducting MANOVA, assumptions were tested, including multivariate normality, homogeneity of covariance matrices using Box's M test, and absence of multicollinearity. Following a significant multivariate effect, univariate analyses of variance were conducted for each dimension to identify which specific skills contributed to the overall group difference. Effect sizes were calculated using partial eta squared to indicate the magnitude of group differences.

For creative thinking comparisons, independent samples t-tests were conducted to compare experimental and control group means on the overall creative thinking score. Given the directional hypothesis that the experimental group would demonstrate higher creative thinking, one-tailed tests were employed with statistical significance set at $p < 0.05$. Descriptive statistics, including means and standard deviations, were calculated for all variables and reported in tables to facilitate interpretation. All statistical assumptions were verified prior to analyses, and appropriate corrections were applied when assumptions were violated.

4. Results

This section presents the results of an experimental study examining the effectiveness of the Problem-Based Learning with Peer Assessment model in improving creative thinking and piano skills among non-piano major college students. The analysis compares the experimental group, which received instruction using the integrated PBL and peer assessment model, with the control group, which received traditional piano instruction. Statistical analyses examined differences in creative thinking and piano performance skills before and after the intervention.

4.1. Pre-Test Results on Piano Skills

Prior to conducting comparative analyses between the experimental and control groups, the normality of the pre-test piano skill scores was assessed using the Shapiro-Wilk test. This test examines whether the distribution of scores in each group deviates significantly from a normal distribution, which is a necessary condition for employing parametric statistical procedures such as independent samples t-tests and multivariate analysis of variance.

Table 5 displays the normality test results for pre-test piano skills. For the control group, the Shapiro-Wilk statistic was 0.929 with 20 degrees of freedom and a significance value of 0.148. For the experimental group, the Shapiro-Wilk statistic was 0.930 with 20 degrees of freedom and a significance value of 0.152. Both significance values exceeded the conventional threshold of 0.05, indicating that neither group's score distribution deviated significantly from normality. These results confirmed that the data met the normality assumption required for parametric statistical analyses, enabling the appropriate use of independent samples t-tests to compare group means at pre-test.

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Table 5.
Normality test for pre-test of Piano skills.

DV	Group	Shapiro-Wilk		
		Statistic	df	Sig.
Piano skills	Control group	0.929	20	0.148
	Experimental group	0.930	20	0.152

Following confirmation of normality, an independent samples t-test was conducted to determine whether the experimental and control groups differed significantly in piano skills prior to the intervention. Table 6 presents the pre-test comparison results. The control group achieved a mean score of 73.5 with a standard deviation of 3.61, while the experimental group achieved a mean score of 74.5 with a standard deviation of 3.98. The difference between group means was 1.0 point on a 100-point scale. Levene's test for equality of variances yielded an F value of 0.044 with a significance of 0.836, which is substantially above the 0.05 threshold. This non-significant result indicated that the assumption of equal variances between groups was met, allowing for the use of the standard t-test formula assuming equal variances.

The independent samples t-test produced a t value of -0.874 with 38 degrees of freedom and a two-tailed significance value of 0.387. This p-value is well above the conventional significance level of 0.05, indicating that the observed one-point difference between group means was not statistically significant and could be attributed to random sampling error. These results confirmed that the experimental and control groups were statistically equivalent in piano skills before the intervention began.

Table 6.
Independent samples t test.

Dependent variable	Group	N	Mean	SD	Levene's Test		t	df	Sig	Result
					F	Sig.				
Piano skills	CG	20	73.5	3.605	0.044	0.836	-0.874	38	0.387	CG=EG
	EG	20	74.5	3.98						

4.2. MANOVA Assumption Test

Before conducting multivariate analysis of variance to compare post-test piano skills between groups, normality of the post-test score distributions was assessed using the Shapiro-Wilk test. This assumption testing is essential for ensuring the validity of MANOVA results. **Table 7** presents the normality test results for post-test piano skills. The control group yielded a Shapiro-Wilk statistic of 0.882 with 20 degrees of freedom and a significance value of 0.119. The experimental group yielded a Shapiro-Wilk statistic of 0.959 with 20 degrees of freedom and a significance value of 0.516. Both significance values exceeded the 0.05 threshold, indicating that neither group's post-test score distribution deviated significantly from normality. These results confirmed that the normality assumption for MANOVA was satisfied, allowing for the appropriate use of multivariate procedures.

Table 7.
Normality test for post-test of Piano skills.

DV	Group	Shapiro-Wilk		
		Statistic	df	Sig.
Piano skills	Control group	0.882	20	0.119
	Experimental group	0.959	20	0.516

With all assumptions confirmed, multivariate analysis of variance was conducted to examine whether the experimental and control groups differed significantly across the combined set of five piano skill dimensions. Prior to examining the multivariate results, Box's M test for homogeneity of covariance matrices was conducted to assess whether the covariance matrices of the dependent variables

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were equal across groups. Box's M value was 8.71 with an associated F value of 2.74, degrees of freedom of 4 and 2600, and a significance value of 0.062. This non-significant result ($p > 0.05$) confirmed that the covariance matrices were statistically equivalent across groups, satisfying an additional assumption for MANOVA. Bartlett's Test of Sphericity was highly significant ($p < 0.01$), confirming that the dependent variables were sufficiently intercorrelated to justify multivariate analysis (Table 8).

Table 8.
Testing dependent variables.

	Box's Test of Equality of Covariance Matrices					Bartlett's Test of Sphericity			
Piano skills and creative thinking	**Box's M**	**F**	**df1**	**df2**	**Sig.**	**Likelihood Ratio**	**Approx. Chi-Square**	**df**	**Sig.**
	8.71	2.74	4	2.60E	0.062	≤0.01	81.5	4	≤0.01

Table 9 presents the multivariate test results comparing the experimental and control groups on the combined piano skill dimensions. Four multivariate statistics were examined: Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root. All four statistics yielded the same F value of 2867.574 with 34 degrees of freedom for error and a significance value of $p < 0.001$.

The highly significant multivariate result ($p < 0.001$) indicates that the experimental and control groups occupied fundamentally different positions in the multivariate space defined by the five piano skill dimensions. To put it simply, this means that the overall pattern of piano skill development across notes, rhythm and timing, articulation, dynamics, and style and mood was substantially different for students who learned through the PBL with peer assessment model compared to those who received traditional instruction. This significant multivariate effect justified proceeding to univariate analyses to determine which specific dimensions contributed to the overall group difference.

Following the significant multivariate effect, univariate analyses of variance were conducted for each piano skill dimension to identify which specific skills contributed to the overall group difference. These results, previously presented in Table 9 of the model validation section, revealed that the experimental group significantly outperformed the control group in Rhythm and Timing ($F = 71.284$, $p < 0.001$), Articulation ($F = 7.600$, $p = 0.009$), and Style and Mood ($F = 32.318$, $p < 0.001$). No significant differences were found for Notes ($F = 1.506$, $p = 0.227$) or Dynamics ($F = 2.923$, $p = 0.095$). These univariate results indicate that the overall multivariate effect was driven primarily by the model's impact on the expressive and interpretive dimensions of piano performance, while foundational note accuracy remained equivalent between groups and dynamics showed a non-significant trend favoring the experimental group that did not reach statistical significance within the eight-week intervention period.

Table 9.
Multivariate test results–post-test

Effect		**Value**	**F**	**Error df**	**Sig.**
group（experimental group & Control Group）	Pillai's Trace	0.998	2867.574b	34	0
	Wilks' Lambda	0.002	2867.574b	34	0
	Hotelling's Trace	421.702	2867.574b	34	0
	Roy's Largest Root	421.702	2867.574b	34	0

4.3. Students' Creative Thinking Results

Creative thinking was assessed using a 20-item questionnaire measuring four dimensions: originality, flexibility, fluency, and elaboration. Both the experimental and control groups completed the questionnaire to enable comparison of creative thinking abilities between students who learned through the PBL with peer assessment model and those who received traditional instruction. Table 10 presents the independent samples t-test results comparing creative thinking scores between groups. The control

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group achieved a mean creative thinking score of 2.97 with a standard deviation of 0.26 on the 5-point Likert scale. In contrast, the experimental group achieved a substantially higher mean creative thinking score of 4.46 with a standard deviation of 0.13. This mean falls within the "strongly agree" range of the scale (4.50-5.00), indicating that students who learned through the PBL with the peer assessment model strongly endorsed statements describing creative thinking behaviors.

The independent samples t-test produced a t value of -23.176 with 28 degrees of freedom and a significance value of $p < 0.001$. This highly significant result indicates that the probability of observing a difference. The findings suggest that engaging students in authentic musical problems and requiring them to give and receive structured peer feedback creates conditions that powerfully foster creative thinking, while traditional approaches leave creative capacities largely unchanged.

Table 10.
Independent sample t test of creative thinking

Dependent variable	Group	N	Mean	SD	Levene's Test		t	df	Sig.	Result
					F	Sig.				
Creative thinking	CG	20	2.97	0.255	5.051	0.03	-23.176	28	<0.001	EG>CG
	EG	20	4.46	0.131						

5. Discussion and Conclusion

5.1. Main Research Findings

This study examined the effectiveness of integrating Problem-Based Learning (PBL) with peer assessment in improving creative thinking and piano performance skills among non-piano major college students. The results indicated that students who participated in the PBL with peer assessment instructional model demonstrated significantly greater improvement in both piano skills and creative thinking compared with those who received traditional teacher-centered instruction. Specifically, the experimental group showed higher post-test scores in piano performance dimensions such as rhythm, articulation, and musical expression, as well as stronger performance in creative thinking indicators, including fluency, flexibility, originality, and elaboration [33]. These findings suggest that a student-centered instructional model that combines collaborative problem solving and structured peer feedback can effectively support both technical skill development and higher-order thinking in piano learning.

Earlier studies have shown that PBL encourages students to analyze problems, collaborate with peers, and develop independent learning skills. For example, research by Hmelo-Silver [34] demonstrated that PBL environments support the development of problem-solving abilities and deeper conceptual learning because students actively construct knowledge through inquiry and discussion [34]. Similarly, Savery emphasized that PBL shifts the focus from teacher-centered instruction to learner-centered exploration, allowing students to develop critical thinking and collaborative skills [9]. The results of the present study support these arguments by showing that students engaged in PBL activities were better able to analyze musical performance problems and refine their piano performance through collaborative practice [10].

The results related to creative thinking also align with established research on creativity in education. Torrance's work on creative thinking emphasized that creativity can be developed through learning environments that encourage exploration and idea generation [25]. By engaging students in problem analysis, collaborative discussion, and reflective evaluation, the PBL with peer assessment model created learning conditions that supported divergent thinking and creative problem solving. Therefore, the improvement in students' creative thinking observed in this study is consistent with theoretical perspectives that emphasize the role of interactive and inquiry-based learning environments in fostering creativity [35].

5.2. Theoretical Contribution and Practical Enlightenment

From a theoretical perspective, the results of this study support constructivist learning theory, which emphasizes that knowledge is actively constructed through social interaction and collaborative

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learning. In PBL environments, students are encouraged to explore problems, discuss possible solutions, and reflect on their learning experiences. These processes align with constructivist principles proposed by scholars such as Vygotsky, who emphasized the importance of social interaction in cognitive development. By integrating peer assessment into the PBL framework, the instructional model used in this study provided additional opportunities for dialogue, reflection, and collaborative knowledge construction.

In a broader educational context, the findings contribute to the growing body of research advocating student-centered teaching approaches in music education. Traditional piano instruction often emphasizes technical training and teacher demonstration, which may limit opportunities for creative exploration and collaborative learning. The present study demonstrates that integrating PBL and peer assessment can create a more interactive learning environment that supports both technical skill development and creative expression. This integrated approach may, therefore, provide a useful pedagogical model for other performance-based courses in music education.

5.3. Research Limitations and Future Research Directions

Future research could further explore the application and long-term impact of integrating Problem-Based Learning and peer assessment in music education. First, future studies may expand the sample size and include participants from different universities or educational contexts to improve the generalizability of the findings. Additionally, longitudinal research could be conducted to examine whether improvements in creative thinking and piano performance skills can be sustained over a longer period. Researchers may also investigate how different forms of peer feedback training influence the quality of peer assessment and students' learning outcomes. Finally, further studies may examine how the integrated PBL and peer assessment model can be adapted for other music courses, such as ensemble performance, music theory, or instrumental instruction, to better understand its broader applicability within music education.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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