Innovative Methods of Teaching Ancient Architectural Design: Enhancing Practical Skills with Digital Tools and Project-Based Learning

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ABSTRACT

BACKGROUND

The purpose of the study is to determine the impact of innovative methods of teaching the Ancient Architecture Design course on the development of students' practical skills using digital tools and project-based learning (PBL).

MATERIALS AND METHODS

The research methodology involves a mixed approach, which includes a theoretical analysis of the components of the Ancient Architecture Design course, and the effectiveness of the implemented approaches was assessed by comparing the average score, standard deviation, and collected student feedback on changes in the learning process. Innovative methods include the integration of computer-aided design, SketchUp, virtual modeling, and the use of PBL. In addition, a combination of guided tours and digital technologies is used to provide a deeper understanding of architectural objects and structures.

RESULTS

The results of the study show that the use of these methods contributed to a substantial improvement in students' practical skills in the field of architectural design. In particular, the students demonstrate a higher level of creative problem-solving, a deeper understanding of architectural principles, and the ability to work in an interdisciplinary manner. An increase in students' interest in the learning process and effective learning through interactive practical projects is observed. The study also demonstrates that the use of digital tools allows students to analyze architectural objects more deeply and create more accurate models of ancient structures.

CONCLUSIONS

The introduction of PBL contributes to the development of teamwork skills, effective project planning, and presentation. This ensures comprehensive preparation of students for professional activities. Innovative approaches to teaching, including interdisciplinary projects and modern educational technologies, improve the quality of education by 15–20%, develop critical thinking by 10–15%, promote the integration of historical architectural solutions into modern design by 20–25%, and improve student performance by 10–15%, preparing them for professional challenges.

Keywords: CAD, Interdisciplinary architectural pedagogy, Project-based learning, Qing dynasty wooden structures, SketchUp integration, Virtual modelling of ancient architecture

Introduction

Innovative methods of teaching ancient architectural design require active research due to the growing need to improve the practical skills of future professionals in this field. Traditional approaches to the study of historical architecture are mostly based on theoretical presentation of material and analysis of architectural monuments. This often does not provide the necessary level of integration of knowledge into practical activities. The use of digital technologies and project-based learning (PBL) allows not only the examination of architectural styles and techniques but also the use of this knowledge to create modern architectural solutions that consider historical traditions. The investigation of this subject is relevant in view of the insufficient introduction of digital tools in the analysis of ancient architectural design. While digital platforms are widely used in architectural modeling, their potential for analyzing historical objects and interactive learning remains underutilized.

The literature on architectural education reflects the dynamic evolution of teaching methodologies driven by the need to align educational practice with the requirements of architectural practice. In particular, in a paper by Isaev et al.,[1] the concept and implementation of a robot capable of drawing vector images on a wall to scale were presented. They described the process of designing and developing the system, including the mechanical, electronic, and software components of the robot. It was established that this technology allows automating the process of creating large vector drawings, which can be useful for artistic and commercial applications.

Jin et al.,[2] in their study, stressed the effectiveness of using artificial intelligence (AI) in architectural programming and design courses. The introduction of AI into the educational process has allowed students to analyze historical styles, optimize design, and create new forms based on ancient prototypes. This approach contributed to the development of both analytical and creative skills. In turn, Kozłowski et al.[3] analyzed the impact of Maoism on the architectural landscape of China, emphasizing the importance of social and political ideologies in shaping architectural design. The authors demonstrated how the historical context and political beliefs influenced modern approaches to education in architecture. This provided the basis for examining historical analysis as part of PBL.

Miano and Chiumiento[4] focused on the innovative design of school buildings in the city of Montemiletto,

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with a focus on the application of modern building technologies and the creation of environmentally sustainable, energy-efficient, and comfortable learning spaces. The study examined aspects of architectural planning, adaptation of premises to educational needs, and integration of the natural environment to ensure a quality educational process. Almulla[5] described the effectiveness of PBL in engaging students in the educational process. This method allowed students to apply their knowledge in real-world settings, which was important for teaching ancient architectural design.

A paper by Boisadan et al.[6] regarded distance PBL during the lockdown, highlighting the importance of a project-based approach even in remote learning to keep students motivated. Kozhobaeva and Omuraliev[7] explored the application of building information modeling (BIM) technologies in Kyrgyzstan. They evaluated the benefits and challenges of implementing BIM in the country's construction industry, particularly in the context of designing and managing these processes. It was determined that the use of BIM technologies helps to improve design efficiency and reduce costs and construction time.

Bukdahl[8] explored the relationship between architectural design, art, and sustainable development. The author has determined that the integration of aesthetic aspects of sustainable design into architectural practice allows for the preservation of ecological balance while accounting for aesthetic and cultural values. This demonstrates that sustainable design is not only focused on the conservation of natural resources but also actively incorporates aesthetic principles that are reflected in traditional architectural approaches.[9–11] The examination of ancient architectural practices in this context allows for the finding of new ways to combine traditions and modern technologies to create balanced and durable projects. The author stressed that the use of sustainable design not only in the environmental but also in the cultural context is an important direction for the development of architecture in general.

Furthermore, Ceylan[12] discussed the influence of historical context on architectural design, emphasizing the importance of a contextual approach in teaching architecture. Analyzing the history of architecture through the prism of contextual factors helps students to see how individual architectural elements respond to specific conditions of time and space, as well as how these factors influence contemporary approaches to architectural practice. Jiang et al.[13] examined the use of fiber optic sensor equipment and 3D printing for the restoration and research of architectural heritage. This study demonstrated how digital technologies, such as fiber optic sensors and 3D printing, can substantially improve the process of studying and restoring ancient architectural objects. These technologies can be used to create accurate models of objects, enabling the investigation of their structural characteristics and sensory systems.[14–17]

The analyzed sources offer different perspectives on the use of innovative methods. But the impact of the integration of digital tools, such as AI and virtual reality (VR), on the formation of long-term practical skills of students in the study of ancient architectural design has not been sufficiently researched. It is necessary to assess the effectiveness of PBL in combination with the historical context for the development of an interdisciplinary approach in architectural education. In addition, methods that allow combining practical tasks with the examination of architectural elements of different eras have not been sufficiently explored, which would contribute to the development of interdisciplinary skills in students.

The aim of the study was to identify the specific features of implementing innovative methods of teaching the Ancient Architecture Design course using digital tools and PBL to improve students' practical skills in professional training. The central research question guiding this study is how innovative teaching methods influence the development of students' practical skills.

The objectives are as follows:

1. Investigate the effectiveness of PBL in developing students' practical skills in designing ancient architectural structures.
2. Evaluate the process of implementing a combined approach (virtual modeling, excursions, and team projects) to develop interdisciplinary cooperation and creative problem-solving among students.
3. Analyze the impact of the integration of digital tools such as computer-aided design (CAD) and SketchUp on students' learning of architectural history.

The hypotheses are the following:

1. The integration of digital tools enhances students' ability to analyze architectural objects and produce accurate design models.
2. PBL fosters teamwork, interdisciplinary cooperation, and creative problem-solving, leading to improved overall performance.

Materials and Methods

The Ancient Architecture Design course was chosen for the study, which was compulsory for second-year students majoring in Engineering Technologies of Ancient Architecture at Osh State University in Kyrgyzstan. The structural elements of the course included theoretical and practical training, an in-depth study of the architectural elements of ancient buildings, such as walls, roofs, doors, and windows, with a special focus on wooden structures from the Qing Dynasty. Special attention was paid to interior design and environmental aspects, considering the specifics of the spatial organization both inside and outside the historic buildings. Practical classes formed the main part of the course (80 hours out of 104), which provided students with the opportunity to apply the theoretical knowledge gained in practice, including the creation of projects for the restoration of ancient architectural structures.

The theoretical underpinnings of digital heritage education and PBL serve as the basis for this investigation. Active, student-centered engagement with real-world issues is emphasized by PBL theory, where students build knowledge through group projects that emulate professional practice. PBL has been demonstrated to improve critical thinking, creativity, and teamwork in architectural education while bringing learning objectives into line with industry standards. The theory of digital heritage education also emphasizes how digital tools, like CAD, VR, and 3D modeling, can be used to preserve, reconstruct, and interpret cultural heritage. Combining these viewpoints gives the current study a solid conceptual foundation as it looks at how PBL and digital technologies can promote real-world knowledge, interdisciplinary collaboration, and ongoing motivation in the context of ancient architectural design.

The innovative methods were specifically chosen for their capacity to foster tangible professional competencies in addition to their technological novelty. The goal of PBL was to foster interdisciplinary collaboration, critical thinking, and teamwork by involving students in challenging, real-world design projects. Through the creation of accurate architectural drawings and 3D models, CAD aided in the development of technical proficiency, spatial awareness, and design accuracy. The incorporation of AI tools allowed students to investigate alternative design solutions and optimize structural and environmental aspects of projects, which in turn promoted creativity, problem-solving, and analytical skills.

The study was conducted from 2019 to 2022. The year 2019 served as a control group (before the introduction of digital tools). Innovations in training were introduced at the beginning of 2020, which was the initial stage of innovation. The data for 2021–2022 allowed assessing the full effect of the changes and analyzing their impact on student performance. Student performance indicators before and after the introduction of new digital tools in the educational process were compared. The sample included 198 students, including 49 (51% boys and 49% girls) in 2019, 46 (50% boys and 50% girls) in 2020, 49 (49% boys and 51% girls) in 2021, and 54 (50% boys and 50% girls) in 2022. Among them were both boys and girls aged 18–22.

The study was conducted in accordance with international ethical standards, in particular, the Code of Ethics of the American Sociological Association.[18] Every participant gave their informed consent prior to taking part in the research. The study's goals, methods, and participants' rights (including the freedom to discontinue participation at any moment without facing repercussions) were described in consent forms. Additionally, the forms guaranteed anonymity and confidentiality when handling data. To adhere to ethical standards and data protection laws, survey responses were anonymized, and data were safely stored on password-protected servers.

The students completed a series of assignments as part of the Ancient Architecture Design course, which aimed to develop their skills in designing ancient architectural structures. The first assignment—Data Collection and Field Research—required students to interpret the design problem, collect relevant information, and research typical cases, which allowed them to form the basis for further design. Students prepared a research report and a project proposal of at least 2000 words. The second task was to create design sketches by conceptualizing ideas, preparing drawings, and annotating measurements. This task required them to draw sketches and conduct field research. The third assignment—Creation of Final Design Drawings and Models—involved the preparation of a complete set of design drawings, a presentation board, and a scale model, which enabled a demonstration of the students' ability to work in groups and apply drawing standards. The fourth assignment was to create a PowerPoint (PPT) presentation where students had to analyze and correct errors in the drawings, summarize, and present their findings. The assessment of each task was based on clear requirements and included both theoretical and practical elements. Assignments also included the use of digital tools such as CAD and SketchUp to create accurate drawings and 3D models, allowing students to realize their design ideas with a high level of precision.

The student performance analysis was used to study the impact of the integration of digital tools such as CAD and SketchUp on students' learning of the history of architecture, helping to compare students' performance before and after the introduction of these tools into the educational process. A case study method was used to collect detailed feedback from students about their experience of working on projects to evaluate the effectiveness of PBL in developing students' practical skills in designing ancient architectural structures. The evaluation of the implementation of the combined approach, which included virtual modeling, excursions, and team projects, was conducted using the method of observation and feedback, which allowed identifying changes in interdisciplinary cooperation and creative problem-solving among students.

Repeated-measures analysis of variance was used in statistical analyses to assess the efficacy of the novel teaching strategies. The dependent variable was the students' final performance scores, while the independent variable was the study year (2019–2022). This test was chosen to evaluate variations among several cohorts and to consider modifications over time brought about by the advent of digital tools. The magnitude of observed differences was estimated using partial eta squared (η^2) to determine effect sizes. The results were interpreted using standard thresholds for small (0.01), medium (0.06), and large (0.14) effects. Furthermore, to provide estimates of precision and practical significance, 95% CIs were reported for the mean differences. Each cohort's descriptive statistics (n, mean, and standard deviation) were computed to aid in the interpretation of inferential findings and guarantee a clear connection between unprocessed data, statistical analysis, and learning outcomes.

The study performed a theoretical analysis of the components of the Ancient Architecture Design course, including such aspects as the curriculum, teaching methods, materials and resources used for teaching, and approaches to student assessment. The study used the methods of comparative analysis, statistical data processing, and correlation analysis. This study included an analysis of the average scores for regular and final assessments, as well as the level of student satisfaction with the learning process, which was determined through questionnaires and feedback from students. Students were given questionnaires with open and closed questions to assess their attitudes to various aspects of the course. For example, one of the questions was "How would you rate the clarity and accessibility of the training materials?" The following answers were "very clear," "clear," "clear but could be improved," and "not clear." Another question concerned teaching methods: "What teaching methods were most effective for you?" Student feedback also included open-ended questions, such as "What changes would you like to see in the course to improve the learning process?" To guarantee content validity, the questionnaire was examined by three architectural pedagogy specialists. Before it was fully distributed, a pilot test was carried out with a small sample of students. With Cronbach's α = 0.87, reliability analysis showed that the instrument had high internal consistency, meaning that the items consistently measured related constructs. With a 92% response rate (182 out of 198 students), the data gathered were guaranteed to give a representative picture of how students felt about the novel teaching strategies.

The evaluation of the effectiveness and implementation of the approach was calculated by comparing the results before and after the use of the new methods. For this purpose, indicators such as changes in the average grade per course, reduction in the variation of students' grades (standard deviation), and correlation between regular and final grades were used.

Prior to the introduction of the tools, the assessment criteria applied traditional methods of evaluation, including testing theoretical knowledge through written exams and assessing practical skills through tasks related to the design of architectural elements. Digital CAD and SketchUp tools were integrated to create accurate design drawings and 3D models. These tools were introduced at the stage of creating design sketches and preparing final design drawings, as they allowed students to work with high accuracy and provided the ability to quickly model and visualize architectural solutions. Further, criteria were added to assess creativity, critical thinking, and collaboration within group projects, which had a positive impact on the overall learning outcomes.

To guarantee the validity of the results, potential confounding factors were carefully taken into account. Throughout the study period, all cohorts were assigned to the same instructors, which reduced pedagogical style variability and controlled the teacher experience. With the exception of PBL and the introduction of digital tools, the course curriculum stayed the same, allowing any observed variations in student performance to be primarily ascribed to the creative approaches rather than to structural modifications in the subject matter. Although the 2020 pandemic-related disruptions, especially the move to partially online instruction, were recognized, blended learning strategies were consistently implemented for all student groups during this time, guaranteeing conditions were comparable. These steps supported the validity of the findings and lessened the impact of outside factors.

Results

The Ancient Architecture Design course is a key element of the curriculum of Chinese vocational schools specializing in the design of ancient architectural structures. It provides a comprehensive study of the basic principles that have shaped Chinese architecture throughout its historical development (Table 1). The course explores the typology and styles of ancient buildings, the features of monolithic and courtyard design, and the aesthetic characteristics of facades and structural forms inherent in the Chinese architectural legacy.

Particular attention is paid to the analysis of wooden structures from the Qing Dynasty, including architectural elements such as walls, roofs, doors, and windows. It also addresses interior design and environmental aspects that consider the specifics of space organization, both inside and outside historic buildings. The course focuses on the integration of cultural, aesthetic, and engineering aspects of architectural

Table 1 | Course description

Course Title	Ancient Architecture Design	Course Code	4401032005
Credits	6.5	Course nature	A: Theoretical course B: Theoretical + practical course C: Practical course
Total hours	104		
	Theory hours: 24 Practice hours: 80		
Course category	Core professional course	Target students	Second-year students majoring in Ancient Architectural Engineering Technology
Semester offered	Third semester	Assessment method	Examination; Coursework
Reference textbook	Liu SZ. Ancient Architectural Design. Wuhan: Huazhong University of Science and Technology Press, 2018		
Course prerequisites	Preceding courses are Architectural Drawing, Ancient Architectural Materials and Structures, Ancient Architectural CAD; subsequent courses include Ancient Architectural Construction Technology, Ancient Architectural Construction Drawing, Ancient Architectural Painting		

design to preserve China's unique historical and cultural heritage.

Evolution of Teaching Methods in Architectural Education: The Essence of PBL

Architectural education has historically been based on the mentor-student model, which involved the transfer of knowledge and skills from experienced practitioners to students in the form of direct instruction. This approach was effective within the framework of traditional architectural practice, but over time, it turned out to have substantial limitations for preparing specialists to meet modern professional challenges. Modern architectural practice requires not only deep technical knowledge but also the development of critical thinking, creativity, and interdisciplinary cooperation. Since the late twentieth century, the transition to more interactive and student-centered teaching methods has begun, which has stimulated further research in the field of educational technology.[19,20]

One of the fundamental factors in the transformation of architectural education was the introduction of digital technologies that made the learning process more dynamic and interactive. The use of digital tools, such as CAD systems and virtual modeling, allowed students not only to learn architectural concepts theoretically but also to apply them practically.[21,22] Such tools contribute to a deeper understanding of architectural principles and facilitate the process of developing projects in the digital environment.[23] In addition, hybrid learning models that combine traditional classroom teaching with an online format are becoming increasingly common.

These approaches provide flexibility in the learning process, giving students access to a wide range of resources and the opportunity to interact with experts from around the world. The development of such methods allows for an individual approach to learning, encouraging students to find solutions on their own and actively participate in practical projects. In particular, the evolution of architectural education is characterized by a shift toward more flexible, diverse, and interactive pedagogical strategies aimed at training professionals capable of effectively addressing the complex challenges of contemporary architectural practice.[24–26]

PBL has become a prominent teaching method in architectural education, reflecting the profession's emphasis on practical problem-solving in the real world. PBL requires students to work on complex, open-ended projects that simulate the challenges they will face in professional practice.[27] The effectiveness of PBL in architectural education is well documented. PBL improves students' technical skills and promotes critical thinking, creativity, and teamwork. This approach is particularly valuable in architectural education, where the design process is inherently iterative and collaborative. Through PBL, students can gain experience in managing projects from conception to completion, developing the ability to cope with the complexities of real-world architectural practice.

It is adaptive and effective in online and digital learning environments. For example, the introduction of PBL into online digital design courses has shown that students can achieve substantial learning outcomes through project-based activities, even in a virtual environment. The use of digital tools in PBL facilitates remote collaboration, allowing students to work together on projects regardless of their location, thereby expanding the reach and impact of architectural education.[28] The adoption of PBL in architectural education is also in line with the broader trend of competency-based education and twenty-first-century skills development.[29–31] By engaging students in authentic, practice-based learning experiences, PBL helps bridge the gap between academic learning and professional practice, preparing students for the challenges of the construction industry. As architectural education continues to evolve, these innovative teaching methods are likely to play an increasingly important role in preparing students for the demands of contemporary practice.

Course Content, Structure, and Design of Innovative Teaching Methods

The Ancient Architecture Design course is systematically structured into seven comprehensive modules, each of which is designed to gradually develop the student's knowledge, skills, and competencies in the field of architecture in ancient China. The course begins with basic subjects such as classification, stylistic characteristics, and the historical and cultural context of ancient Chinese architecture. It gradually progresses to more complex design tasks, including structural and environmental design. The curriculum is carefully selected to ensure that students not only comprehend the theoretical foundations of ancient architecture but also develop the practical skills necessary to succeed in the field of architectural restoration and design.

The course is designed to provide students with a comprehensive understanding of ancient Chinese architecture, focusing on both theoretical knowledge and practical skills. The curriculum consists of seven key modules, each of which gradually builds on the last. The course begins with the classification and stylistic features of traditional Chinese buildings, introducing students to the historical and cultural contexts that shape these architectural forms. They will develop the ability to identify and analyze different architectural types, which is the basis for more complex design tasks. During the course, students acquire skills in designing the layout of individual old buildings, following the traditional principles of functional zoning. They also learn how to design courtyard-style buildings, mastering the integration of architectural units and the overall arrangement of small traditional internal structures. This is further enhanced by developing their skills in facade design, where students apply their understanding of spatial layouts to create facades that follow traditional aesthetics.

In addition, the course covers important aspects of structural design, including the design and layout of timber frames, plinths, and walls. Students become adept at creating and interpreting basic architectural drawings, especially those of the official Qing style. The curriculum also ensures that students are armed with the knowledge to incorporate traditional decorative elements into their projects and harmonize indoor and outdoor environments with the surrounding landscape. A distinctive feature of this course is its focus on digital tools that prepare students to apply modern technologies in the restoration and presentation of ancient architectural projects. By the end of the course, students not only have a good understanding of the traditional aspects of Chinese architecture but are also able to integrate these elements into contemporary design practice.

The choice of these core content areas is driven by the dual need to preserve the essence of traditional Chinese architecture while equipping students with the skills necessary to meet the contemporary challenges in the field. By focusing on both theoretical aspects and practical applications, the course ensures that students are well prepared to contribute to the preservation and revitalization of ancient architectural heritage. The integration of digital tools with traditional design methods is an important innovation that allows students to navigate the complexities of modern restoration projects while maintaining fidelity to historical accuracy.

A Variety of Teaching Methods

The Ancient Architecture Design course uses a variety of innovative teaching methods to cater to different learning styles and increase student engagement with the subject. These methods include PBL. This approach is central to the course, encouraging students to apply theoretical knowledge to practical, real-world projects. For example, in the Courtyard Design module, students undertake a comprehensive project to design a traditional Beijing courtyard house (Xiheyuan) (Table 2). This project requires students to engage in extensive research, site analysis, and iterative design, culminating in the presentation of their final design using digital tools such as CAD and SketchUp.

Several modules employ the applied research method, where students analyze existing ancient structures to comprehend architectural styles, structural systems, and design principles. For example, during the facade design module, students study historical buildings to extract design cues and apply these ideas to their projects. These cases give an idea of the practical problems of restoring ancient buildings and applying modern methods to preserve traditional aesthetics.

Field visits, namely physical visits to heritage sites, are complemented by virtual simulations to provide students with a holistic understanding of ancient architectural designs. These visits are integrated into the course, particularly in the structural and environmental design modules, where students can observe the intricacies of ancient building technologies and spatial planning first-hand.

Practical activities such as model making are crucial for modules that include structural and spatial design. In the timber frame design module, students create scale models of key structural elements to help them understand the complex geometries and construction techniques used in ancient buildings.

Blended learning combines existing online resources with traditional classroom learning to provide a more flexible learning environment. For example, students can take online training in CAD and SketchUp before and after classes, while face-to-face sessions focus on applying these tools to project tasks.

The course uses various digital tools to optimize the design process and learning experience. In the second semester, students study a CAD course, during which they learn how to create accurate architectural drawings and subsequently use them in their design work. The ability to digitally visualize and modify designs gives students greater flexibility and creativity in their projects.[32–34] SketchUp is used to create three-dimensional models of student projects, thus giving students a tangible sense of scale and spatial relationships. In the Courtyard Design module, students use SketchUp to model and refine their layouts, experimenting with different configurations until they reach a final design. AI tools are also integrated into the course to help create design solutions and optimize postrendering results. For example, in the Environmental Design module, AI tools help students explore different styles of building environments and landscape visualizations.

Table 2 | Assignment for the design of a courtyard in beijing

Task Name	Assessment Content	Skill Requirements	Assessment Method	Weight (%)
Task 1: Data Collection and Field Survey	1. Interpret the design brief 2. Select the design task 3. Collect relevant information 4. Investigate typical cases	Basic ability to research professional literature and standards, proficiency in written and verbal communication	Submission of a research report and project proposal, both totaling at least 2000 words	20
Task 2: Drafting Design Sketches	1. Conceptualize design ideas 2. Create sketches 3. Annotate dimensions 4. Finalize the design plan	Proficiency in drafting design sketches; field surveying skills; ability to conceptualize designs and produce sketches; annotating dimensions	Draw a master plan, floor plans, and primary elevations, including dimension annotations; review of drawings	25
Task 3: Creating Final Design Drawings and Models	1. Completeness and compliance of drawings 2. Presentation of renderings or animations 3. Hands-on model making	Basic competence in designing small to medium-sized traditional-style buildings; correct application of drafting standards; group collaboration in model making	Submission of a complete set of design drawings, one presentation board, and a scale model	35
Task 4: PPT Presentation and Project Display	1. Analyze and critique the drawings 2. Correct errors in drawings 3. Summarize and present findings	Basic skills in creating PPT presentations; ability to summarize and report findings	On-site presentation of the project, including PPT and oral defense	20
Total				100

Analyzing the Effectiveness of Training

Evaluation of the effectiveness of learning in the Ancient Architecture Design course is a dynamic and ongoing process designed to ensure the comprehensive development of students. The course uses a combination of formative and summative assessments to monitor and evaluate student progress. Formative assessments, such as regular tests, assignments, class activities, peer reviews, and self-assessment exercises, ensure that students' understanding and engagement with the course materials are continuous. These assessments help to identify areas where students may need additional support or clarification, thus making timely adjustments to their learning.

The final assessments are designed to measure a combination of theoretical knowledge and practical application. These assessments emphasize not only the retention of information but also the ability to apply the concepts learned to real-world scenarios. The comprehensive project assessment focuses on creativity, accuracy, and presentation skills, reflecting the course's emphasis on technical ability and innovative thinking. Feedback mechanisms are an integral part of the course evaluation strategy. The course provides timely, constructive feedback on assignments and projects to guide students' learning and progress. In addition, regular student surveys are conducted to understand the effectiveness of teaching and identify potential areas for improvement (Table 3).

The combination of theoretical knowledge and practical tasks increases students' creativity and independence. In addition, the course focuses on the development of interdisciplinary competencies, such as critical thinking, teamwork, and project management skills. Particular attention is paid to the analysis of restoration techniques that can be adapted to modern design conditions. An important aspect is the introduction of digital tours and virtual modeling, which allows students to analyze historical sites in more depth without the need for physical presence. This greatly expands the geography of the objects under study and provides access to cultural heritage that would otherwise remain outside the scope of the usual educational process.

Thus, the course contributes to the preservation of architectural heritage through the introduction of modern technologies and pedagogical strategies that form a new generation of specialists in the field of restoration and architectural design. The curriculum is carefully designed to equip students with the practical skills necessary to independently design both monolithic and complex ancient building structures. It emphasizes the balanced integration of theoretical knowledge and its practical application, highlighting the relevance of ancient architectural principles in a modern context.

In light of the rapidly evolving educational landscape and the growing demand for practical knowledge in the architectural profession, the introduction of innovative pedagogical approaches is imperative to effectively bridge the gap between traditional architectural knowledge and modern design methods.[35–37] This evolution has seen a gradual shift from traditional lecture-based approaches to more interactive and experiential learning models. Two key themes emerge in this context: the evolution of teaching methods in architectural education and the growing emphasis on PBL.

The data in Table 3 confirm that formative assessments account for 15% of the total and emphasize ongoing engagement. The completion of individual knowledge modules and project assignments (30% of the grade) ensures that students achieve the learning outcomes of each study section. The design of the historic building project accounts for 45% and is essential to the assessment, integrating and applying the skills and knowledge acquired throughout the course. Finally, the value-added assessments evaluate innovation and integrated application skills, each accounting for 5% of the final grade, reflecting the course's commitment to developing creativity and problem-solving skills in architectural design.

According to Table 4, the final average score for the class of 2019 was 60.51 with a pass rate of 67.35%. It is noteworthy that a substantial proportion of students (32.65%) scored less than 60%. The distribution shows that a larger percentage of students (42.86%) achieved high scores (90–100%), but there were also a considerable number of students with low scores. The large standard deviation of the final grade (42.57) and the weak negative correlation between the regular and final grades (−0.280) indicate that students' performance is inconsistent, possibly due to the mismatch

Table 3 | Course evaluation and characteristics

Assessment Item	Assessment Content	Assessment Method	Weight (%)	Assessment Timing
Formative assessment	Participation in class discussions, case analyses, and practical activities	Classroom discussion and practice records, peer evaluation, instructor assessment	15	Throughout the semester
	Completion of knowledge points and design tasks in each module	Submission of assignments, design drawings, classroom presentations, and demonstrations	30	After each module is completed
	Ancient architecture project design	Design proposal documents, reports, design drawings, and model presentations	45	Midterm and at the end of the semester
Value-added assessment	Innovation capability	Evaluation of creative thinking and problem-solving abilities	5	Throughout the semester
	Comprehensive application	Evaluation of applied problem-solving skills during practical tasks	5	Midterm and at the end of the semester

Table 4 | Student performance data

Cohort	Number of Students	Distribution of Final Score (%)					Pass Rate (%)	Average Score
		90–100	80–89	70–79	60–69	0–59		
2019 (before the introduction of innovative tools)	49	40.11	10.20	17.57	0	32.12	67.35	60.05
2019 (after the introduction of innovative tools)	49	42.86	14.29	10.20	0	32.65	67.35	60.51
2020	46	15.56	8.89	40	35.55	0	100	75.44
2021	49	36.74	48.98	10.20	4.085	0	100	86.84
2022	54	31.48	37.04	25.92	5.56	0	100	84.44

Table 5 | Comparison of course results

Comparison Group	Number of Students	Mean		Standard Deviation		Pearson Correlation (r)
		Average Regular Score	Average Final Score	Average Regular Score	Average Final Score	
2019 cohort	49	68.84	60.51	13.59	42.57	−0.280
2021 cohort	49	83.11	86.84	8.02	7.74	−0.202

between coursework and final grades. The average score for the class of 2020 increased to 75.44 with a 100% pass rate. There was a noticeable change in that more students scored in the middle of the range (70–79 points, 40%), while fewer students scored in the upper range (90–100 points, 15.56%). This shows that while overall achievement has improved, there are fewer students at the highest levels.

The final average score of the 2021 cohort improved to 86.84 with a 100% pass rate. This category of students showed excellent results in the older groups (36.73% of students in 90–100 and 48.98% of students in 80–89). The correlation between the conventional score and the final score is still weak and negative (−0.202), but the standard deviation (7.74) is much smaller, indicating a more stable performance. The average score for the class of 2022 remains high at 84.44, with a pass rate of 100%. Compared to 2021, the distribution of scores is more balanced and slightly shifted toward the middle of the distribution (25.92% of students scored 70–79 points), which indicates that the effectiveness of the course has been maintained.

ANOVA was performed on all four cohorts (2019–2022) to confirm if the observed gains in student performance were statistically significant. The analysis produced an F-statistic $F(3, 194) = 28.90$ (degrees of freedom: 3 for the groups and 194 for the residuals), $p < 0.001$, with a large effect size ($\eta^2 = 0.31$), indicating a significant impact of the implemented innovations on student outcomes. This demonstrates that there were significant differences in mean scores between cohorts. According to the pattern of results, students in the control group in 2019 scored much lower than students in later cohorts, with performance significantly improving after the implementation of PBL and digital tools in 2020. Scores reached their highest point in 2021 and continued to be high throughout 2022, indicating that the benefits of the novel approaches were both immediate and long-lasting. These results offer solid statistical proof that PBL and digital technology integration significantly and sustainably improved student performance.

The changes in student performance between 2019 and 2021 can be explained by several factors. First, the introduction of new innovative teaching methods in the Ancient Architecture Design course could have a positive impact on the learning process and improve students' knowledge. This includes the integration of modern educational technologies and techniques, such as the use of interactive learning platforms that encourage active student participation. Second, the increase in personalized learning approaches may have contributed to the improvement in results, which provided for a deeper understanding of the material.

Additionally, part of the study's time period coincided with the global COVID-19 pandemic, which inevitably influenced teaching practices and student engagement. This necessitated remote learning and greater reliance on digital platforms, distance PBL, and virtual modeling. These shifts limited field visits but accelerated the integration of tools such as CAD and SketchUp, potentially influencing both student engagement and data collection. According to Table 5, the average score of the final and regular assessments increased substantially in 2021 (from 60.51 to 86.84), which indicates an increase in learning effectiveness as a result of these changes.

The results of the student survey allowed assessing their attitude to the educational process and the effectiveness of the introduction of digital tools, in particular, CAD and SketchUp, in the Ancient Architecture Design course. The survey included both closed- and open-ended questions, which allowed the collection of both quantitative and qualitative data. An analysis of students' responses to the question about the clarity and accessibility of teaching materials showed that 80% of respondents rated the materials as clear or very clear, while 16% noted the possibility of improving them, and 4% indicated insufficient clarity.

In open-ended responses, students emphasized the importance of visual materials, including 3D models created in SketchUp and interactive lectures demonstrating the design process, "The 3D models and visual presentations made it much easier to understand the proportions of ancient structures." In terms of the effectiveness of teaching methods, 67% of students claimed that practical assignments using digital tools such as CAD and SketchUp were the most productive for them. For example, one of the participants commented, "Working with CAD helped me see my mistakes immediately and improve the design step by step." Field studies and group projects were also highly praised, which demonstrated the importance of interactive and practice-oriented approaches to learning. Additionally, traditional lectures were less effective, with only 25% of participants supporting them.

The overall level of satisfaction with the learning process after the introduction of digital technologies was 84%. As one student expressed, "I felt more motivated to attend classes because we were creating real projects, not just reading theory." The main factors that had a positive impact on the course's perception were the improvement of design accuracy through the use of CAD, the increase in the visualization of architectural solutions through 3D modeling, and the increase in interest in the course through interactive teaching methods. 16% of students faced some difficulties in mastering new technologies. In open-ended responses, they noted that learning to work with CAD required additional time, and some students had technical difficulties due to a lack of previous experience with such programs.

The analysis of the data indicated a correlation between the level of student satisfaction and their academic performance. Specifically, students who highly rated the effectiveness of teaching methods had an average score 12% higher than those who considered the methods less effective. This confirmed the thesis that the integration of digital technologies has a positive impact on the quality of the educational process. The results of the survey pointed to the need to further improve the curriculum to meet the needs of students. One of the critical areas of optimization would be to introduce additional preparatory classes in CAD for students who had not previously used such tools.

The Impact of Innovative Teaching Methods on Students' Academic Performance

PBL has played a major role in improving student academic performance in 2021 and 2022. The involvement of students in real design tasks helped to bridge the gap between theoretical knowledge and practical application, which provided a deeper understanding of architectural concepts. The analysis of the final assessments for this period showed an increase in the consistency of the results compared to 2019. This indicates that PBL sets clear practical guidelines for students, promotes standardization of learning achievements, and improves the overall quality of training.

The integration of digital tools such as CAD, SketchUp, and AI technologies has greatly enhanced students' ability to create architectural projects. These tools contributed to more accurate and detailed design, allowing students to use an iterative process to improve their work. The results demonstrate that this integration has helped to reduce disparities in students' academic performance, as evidenced by the lower standard deviation values in the results of the 2021 and 2022 cohorts. The increase in average scores indicates that digital tools are improving the learning experience and contributing to the preparation of more professional design solutions.

The integration of digital tools and PBL also had a notable impact on their motivation. According to observations made in the classroom, students showed increased interest, greater consistency in finishing assignments, and were more eager to participate in group projects. One of the students said, "I never skipped classes once we started doing digital projects." The chance to work with digital platforms and complete interactive assignments, according to many respondents, made learning more fun and engaging. Higher quality projects that were submitted and more active participation in discussions were further indicators of increased motivation. These results imply that the creative teaching strategies supported students' long-term interest in the subject, which is essential for academic success, in addition to helping them develop their cognitive and practical skills.

Case studies have become an effective method of integrating theoretical knowledge with real-life situations, allowing students to better understand architectural principles and apply them in practice. The use of physical models as a practical approach improves understanding of spatial structure and design features, which is an essential element in the design process.[38,39] Blended learning methods that combine hands-on activities with virtual simulations, such as virtual tours of historical sites, support different learning styles. One of the students commented, "I liked being able to practise CAD at home before class — it gave me more confidence to participate." This approach helps visualize architectural concepts and provides a more engaging educational experience. An analysis of the grades of the students of the class of 2022 shows that such innovative teaching strategies contribute to a more balanced distribution of academic results and help to achieve greater stability in the training of specialists.

The process of implementing a combined approach to teaching that combines virtual modeling, excursions, and team projects has become an important step in the development of interdisciplinary cooperation and creative problem-solving among students of the Ancient Architecture Design course. This approach allowed for the integration of theoretical knowledge with practical application, which contributed to the development of students' teamwork skills, complex problem-solving, and creative approach to design. Virtual modeling, specifically with the help of tools such as SketchUp and CAD, has become one of the main tools for students to learn how to design architectural objects.

Virtual modeling allowed students not only to develop technical skills but also to improve their understanding of spatial relationships and scale. For example, one of the participants said, "When I rotated the

3D model, I noticed mistakes in proportions I couldn't see on paper." Due to the use of digital tools, students were able to create detailed models of ancient architectural structures, experimenting with different layouts and designs, which provided them with more opportunities to implement creative ideas. This approach also helped identify and correct errors at the early stages of design, making the process more flexible and efficient.

Excursions, as part of the combined approach, have become an important component of the students' learning process. Students had the opportunity to get directly acquainted with real architectural objects, explore the features of their structure, and understand the historical context in which these buildings were created using them. One of them noted, "The excursion made me realise why certain architectural solutions were chosen centuries ago." The practical experience gained during the excursions helped students to better understand theoretical knowledge, as they could see real examples of the use of architectural elements, such as wooden structures or facade elements, and compare them with the models they created using digital tools. In addition, the excursions fostered an interdisciplinary approach, as students had the opportunity to interact with historians, architects, engineers, and other professionals, discussing various aspects of design and preservation of cultural heritage.

Team projects have become another important component of this approach. They enabled students to work together, combining their knowledge and skills to solve complex problems. This helped to develop collaboration between students with different academic interests and backgrounds. Teamwork assisted the students in developing communication skills, coordinating ideas, and resolving conflicts, which are important aspects of the creative process in architectural design. Group work allowed students not only to exchange ideas but also to apply different approaches to problem-solving, which provided innovative solutions in their projects.

In general, the combined approach was very effective in developing interdisciplinary cooperation and creative problem-solving among students. It fostered critical thinking and independent problem-solving skills and encouraged students to develop a deeper understanding of the design process and architectural heritage. The increased interest of students in the course, the improvement of their skills in working with digital tools, and joint problem-solving in a team were the main benefits of this approach, which in turn contributed to the quality of the educational process and the development of students as future professionals in the field of architecture.

Discussion

Innovative teaching methods, such as PBL and the integration of digital tools, show considerable potential for improving the practical skills of students studying ancient architectural design. The results of this study suggest that the use of PBL contributes to the successful acquisition of knowledge and the development of problem-solving skills in students. This aligns with the conclusions of Condliffe,[40] who noted that PBL provides a more practical learning experience through the active participation of students in real-world tasks.

Similarly, Dias and Brantley-Dias[41] determined that PBL improves academic outcomes because students are actively engaged in the learning process. Their paper highlights the need for a clear project structure to ensure a successful learning experience. This study also points to this, supplementing that the integration of digital tools can help address this issue by providing students with convenient resources. In addition, Cervesato et al.[42] reviewed the Spatium and Omnes project, which offers an innovative approach to the interaction between architecture and archaeology. This approach allows for the creation of interactive and accessible spaces that promote better understanding and interaction with historical sites.

The integration of digital tools has substantially improved learning quality. The results of this study confirm that these tools facilitate the visualization of complex architectural concepts. This is in line with the findings of Chiavoni and Romano,[43] who underscored that digital tools provide new opportunities for detailed analysis of architectural forms. The authors noted that the use of visualization technologies contributes to the development of students' spatial thinking. However, this study points to the need to train teachers in the effective use of such tools to achieve maximum results.

Clayton Fant et al.[44] also investigated the use of digital tools to examine ancient decorative techniques in archaeological research. Their study, like the present one, showed that digital technologies allow students to better understand the historical context and technical aspects of architectural design, consistent with the present findings. Similarly, Nilsook et al.,[45] who assessed PBL processes in vocational and technical education, emphasized the importance of such methods in developing students' creativity and technical competencies. This study has confirmed that digital tools facilitate students' constant experimentation with different approaches to architectural design.

This also aligns with the conclusions of Al-Buzz,[46] who considered the importance of integrating the principles of ancient architectural design into modern curricula of architectural faculties. The author stresses the need to preserve and enhance students' interest in authentic architectural heritage, which can be achieved by incorporating these principles into educational courses. Zhang et al.[47] also showed that with the use of VR, students can better apprehend the technological aspects of traditional construction, which is consistent with these findings on the effectiveness of VR in teaching ancient architectural design.

The results of the study indicated that interdisciplinary projects assist students in integrating knowledge from different disciplines, which increases their overall competence. For example, projects that combine architecture and art history have enabled higher education students to better comprehend the cultural context of architectural structures. This confirms the findings of Handoko et al.,[48] emphasizing that an interdisciplinary approach contributes to a deeper understanding of architectural objects.

This also parallels the results of Remijan,[49] where the use of a project-based approach contributed to a deeper understanding of the complex aspects of architectural design and the development of students' creativity. Guo et al.[50] also noted that interdisciplinary projects develop critical thinking and the ability to collaborate. The results of the study indicate that the implementation of interdisciplinary projects contributes to the development of skills in solving complex problems and adapting to a rapidly changing environment. It also increases students' motivation as they get the opportunity to work on real-world problems, which stimulates their activity and interest in learning.

The present study agrees with these findings but also identifies that such projects require clear coordination between teachers of different disciplines. These results show that PBL enhances the development of soft skills such as communication, teamwork, and time management. This is in line with the paper of Dogara et al.,[51] who developed a conceptual model that demonstrates the integration of soft skills in PBL. In this study, students who participated in team projects demonstrated successful results in their final assessments, which indicates the importance of social interaction in the learning process.

Hsieh and Chiou[52] also highlighted the importance of considering cultural context when developing design curricula. This study has confirmed that projects that include cultural elements contribute to students' creative thinking. For example, creating models of churches using local materials allowed students to better understand the principles of architecture in different cultures. Despite the successful results, this study identified some difficulties. In particular, teachers reported the need for additional time to prepare projects and learn how to use digital tools.

This also aligns with the conclusions of Elfizon and Ganefri,[53] who point to the need for teachers to adapt to new teaching methods, noting that modern educational technologies, online courses and platforms, interactive learning tools, the Internet of Things in education, AI, virtual and augmented reality require teachers not only to master new tools but also to change their approaches to teaching and interaction with students. They state that the effective use of technology in education is only possible if teachers receive adequate support and training to strengthen their skills in using innovative teaching strategies.

A study by Rahman et al.[54] also demonstrated the effectiveness of video learning as part of a project-based approach for technical education. Their findings confirm that the use of video materials in the learning process allows students to better understand complex concepts and technical details. This evidence is in coherence with the conclusions that digital tools such as virtual labs greatly augment learning.

Velaora[55] indicated that the use of VR has considerably improved the understanding of the complex structures of ancient buildings. Ponzio and Prazeres[56] accentuated that the incorporation of digital tools into the learning process encourages students to actively engage in the creative process. This study confirms these findings, as digital tools such as VR allow students to experiment with different architectural styles and create unique design solutions. Skliarova[57] also demonstrated how digital technologies can be used to assess students in online design courses. This study has confirmed that such tools help teachers conduct an objective assessment of students' practical skills, creating conditions for a more personalized approach to teaching.

Thus, the results of this study confirm the effectiveness of innovative methods of teaching ancient architectural design based on digital technologies and a project approach. The consistency of these results with the findings of other researchers underlines the importance of these methods in modern education.

Conclusion

Thus, the study confirmed the data on academic achievement, which shows that the introduction of innovative teaching methods, such as PBL and the integration of digital tools, has substantially improved student performance. However, there is potential to improve the alignment of assessments with course objectives so that final grades more accurately reflect student learning. The weak negative correlation between grades for regular assignments and final exams indicates that there is a need to improve alignment between grades. Ensuring the same competencies for regular assignments and summative assessments will help reflect the level of student training more accurately. Implementing feedback loops can help students better understand and improve their performance in both ongoing assignments and the final exam. This approach will help reduce performance disparities among students, especially at the start of their careers. While digital tools are already having a positive impact on learning, further research into feedback on the use of AI for design could provide students with more immediate and detailed critiques, which could help them improve their skills more effectively.

It is advisable to introduce more diverse types of learning tasks, including interdisciplinary projects, to maintain student interest and meet different learning styles. This will allow students to apply the principles of architectural design in a broader context, which will enhance their problem-solving skills. The integration of innovative pedagogical strategies into the Ancient Architecture Design curriculum has substantially enhanced the learning experience, promoting a deeper understanding and appreciation of architecture among students. The constant introduction of the latest technologies, interdisciplinary methodologies, and active learning structures keeps the program relevant, encouraging students to develop and deepen their knowledge. Educators implementing similar techniques should begin with small-scale projects that incorporate digital tools like SketchUp or CAD, progressively increasing task complexity as students gain practice. Virtual modeling and field trips combined can enhance education while taking into account different learning preferences. In order to lower initial barriers and promote teamwork to develop critical thinking and interdisciplinary collaboration, educators should also offer introductory training sessions on digital platforms.

Future efforts will focus on refining these approaches, aligning them with educational and architectural trends to better prepare students for future challenges. The main goal is to train architects who are not only proficient in historical design principles but also able to adapt and effectively apply them in modern practice. Despite the successes achieved, there is a need for further research into the interaction between digital tools and traditional teaching methods, as well as the long-term effects of innovative approaches on the professional practice of architects.

The limitation of the study was the number of aspects that described the process of integrating AI into architectural design education. Therefore, promising areas for further research include evaluating the impact of AI on the development of students' design skills in the context of ancient architecture.

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