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Development of Learning Achievement and Home Space Design
Skills among Chinese Vocational College Students
Using a Project-Based Learning Approach

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บทคัดย่อ

เพื่อตอบสนองต่อช่องว่างระหว่างทฤษฎีและการปฏิบัติในการศึกษาการออกแบบอาชีวศึกษา การวิจัยนี้มีวัตถุประสงค์เพื่อ 1) เปรียบเทียบผลสัมฤทธิ์ทางการเรียนของนักเรียนก่อนและหลังการใช้ การเรียนรู้โดยโครงการ และ 2) เปรียบเทียบทักษะการออกแบบพื้นที่ภายในบ้านของนักเรียนก่อนและหลัง การใช้การเรียนรู้โดยโครงการ กลุ่มตัวอย่างประกอบด้วยนักเรียนชั้นปีที่ 2 จำนวน 33 คน ที่ลงทะเบียนเรียน ในสาขาการออกแบบพื้นที่ภายในบ้าน คณะการศึกษาและการออกแบบ วิทยาลัยอาชีวศึกษาการสื่อสารแห่ง ฉงชิ่ง ในภาคการศึกษาที่ 2 ของปีการศึกษา 2567 โดยใช้วิธีการสุ่มแบบมีจุดประสงค์ การวิจัยนี้ใช้ การออกแบบการวิจัยแบบกลุ่มเดียวก่อนและหลังเพื่อประเมินประสิทธิผลของการแทรกแซงทางการสอน เครื่องมือวิจัยประกอบด้วย 1) แผนการจัดการเรียนรู้โดยโครงการ 2) แบบทดสอบผลสัมฤทธิ์ทางการเรียน และ 3) แบบประเมินทักษะการออกแบบพื้นที่ภายในบ้าน ข้อมูลเชิงปริมาณวิเคราะห์โดยใช้ร้อยละ ค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน และการทดสอบค่าเฉลี่ยของกลุ่มตัวอย่างที่สัมพันธ์กัน ส่วนข้อมูลเชิงคุณภาพ วิเคราะห์โดยใช้การวิเคราะห์เนื้อหา ผลการวิจัยพบว่า 1) นักเรียนที่เข้าร่วมกิจกรรมมีผลสัมฤทธิ์ทาง การเรียนสูงขึ้นอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับผลก่อนเข้าร่วมกิจกรรม และ 2) ทักษะ การออกแบบพื้นที่ภายในบ้านของนักเรียนพัฒนาขึ้นอย่างมีนัยสำคัญหลังจากเข้าร่วมกิจกรรม ผลลัพธ์เหล่านี้ ยืนยันถึงประสิทธิผลของการเรียนรู้โดยโครงการในการเสริมสร้างทั้งความรู้ทางวิชาการและทักษะปฏิบัติด้าน การออกแบบในบริบทของการศึกษาระดับอาชีวศึกษา ผลการวิจัยนี้ยังยืนยันว่าการเรียนรู้โดยโครงการเป็น วิธีการสอนที่มีประสิทธิภาพสำหรับการศึกษาการออกแบบอาชีวศึกษาในประเทศจีน

คำสำคัญ: การเรียนรู้แบบโครงการ; ผลสัมฤทธิ์ทางการเรียนรู้; ทักษะการออกแบบพื้นที่บ้าน; การศึกษาด้าน อาชีวศึกษา

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ABSTRACT

In response to the gap between theory and practice in vocational design education, this research aimed to: 1) compare the learning achievement of students before and after applying project-based learning (PBL); and 2) compare the home space design skill of students before and after applying PBL. The sample group consisted of 1 group total of 33 second-year students enrolled in the Higher Vocational Architectural Home Space Design major, School of Education and Design, Chongqing Telecom Vocational College, during the second semester of the 2024 academic year. The sample was selected using purposive sampling. The study adopted a one-group pretest-posttest design to assess the effectiveness of the instructional intervention. The research instruments consisted of three components: 1) The project-based learning management plan, 2) the learning achievement test, and 3) the home space design skill assessment form. Quantitative data were analyzed using percentage, mean, standard deviation, and independent sample t-test. Qualitative aspects were analyzed through content analysis. The findings revealed that: 1) students who participated in the PBL intervention demonstrated significantly higher learning achievement scores compared to their pretest results, with statistical significance at the .01 level; and 2) students' home space design skills significantly improved after engaging in the PBL activities, also at the .01 level. These results confirm the efficacy of project-based learning in enhancing both academic and practical design skills within a vocational education context. These findings validate PBL as an effective pedagogy for vocational design education in China.

Keywords: Project-based learning; learning achievement; home space design skill; vocational education ; digital tools; CAD and 3D modeling

1.Introduction

The rapid advancement of digital technologies and the growing demand for customized living environments have raised expectations for graduates of vocational design programs. Employers now seek not only solid theoretical knowledge but also creativity, CAD proficiency, and 3D modeling skills. However, many Chinese vocational colleges remain teacher-centered, focusing on rote memorization, which often creates a gap between classroom learning and professional practice.

Project-Based Learning (PBL) has been widely adopted as a learner-centered strategy to address this gap. By engaging in authentic projects, PBL promotes collaboration, independent inquiry, and the integration of theory with practice. Research shows it enhances problem-solving, creativity, and professional readiness, particularly in design-oriented fields. In China, PBL also aligns with reform initiatives emphasizing innovation, practical competence, and school-enterprise collaboration.

Despite these advantages, few studies have examined PBL's impact on both academic outcomes and applied design skills, especially integrating digital tools like CAD and 3D modeling.

This study investigates the effectiveness of PBL in improving second-year students' learning achievement and home space design skills—including creative design, CAD drafting, and 3D modeling—at Chongqing Telecom Vocational College. It aims to provide empirical evidence for advancing vocational education and a model for embedding industry-relevant digital skills into the curriculum.

2.Literature Review

Building upon the research gap identified in the Introduction, this section reviews relevant literature on project-based learning (PBL), its theoretical underpinnings, and its application in design-related vocational education. The review emphasizes how PBL enhances both learning achievement and practical design skills, particularly in relation to digital tools such as CAD and 3D modeling, which are increasingly essential for vocational training in architectural and interior design.

The swift progression of digital technology and the increasing demand for personalized living spaces have transformed expectations for contemporary home designers. Vocational education institutions are increasingly tasked with developing professionals who possess both theoretical knowledge and practical design abilities, enabling them to respond effectively to real-world challenges in architectural and interior contexts (Liu & Zhang, 2021). However, conventional teacher-centered instructional approaches at many vocational colleges often prioritize memorization and passive knowledge acquisition, creating a gap between academic learning and professional performance (Wang, 2023).

Project-based learning has emerged as a student-centered teaching approach that emphasizes active investigation, collaboration, and the practical application of knowledge to bridge this gap (Bell, 2010; Thomas, 2000). PBL facilitates deep conceptual understanding and practical skill development by engaging learners in meaningful, extended projects aligned with authentic professional contexts. This methodology has demonstrated notable efficacy in creative and design-centric fields, where the integration of complex skills is crucial (Han et al., 2021; Boss & Krauss, 2018).

In residential design, students must master fundamental design theory alongside a range of interrelated technical skills, including creative thinking, CAD drafting, and 3D modeling, to meet the requirements of clients and construction professionals (Chen, 2023). Their ability to conceptualize spatial arrangements, design operationally efficient layouts, and communicate design ideas through renderings and working drawings is essential for professional success (Zhang, 2024; Lin, 2023).

Numerous studies demonstrate the positive impacts of PBL on both learning outcomes and design proficiency. Doppelt (2003) and Wongyai & Pattaphon (2019) found that PBL enhances students' ability to integrate theory with practice, leading to improved design outcomes and professional readiness. In China, where vocational education reform emphasizes school-enterprise collaboration and skill-based innovation (The State Council, 2019), applying PBL in courses like "Home Space Design" aligns education with industry demands while promoting creativity, autonomy, and collaboration among students.

Moreover, Krajcik and Blumenfeld (2006) and Helle, Tynjälä, and Olkinuora (2006) assert that PBL fosters greater cognitive engagement than traditional methods, particularly in fields requiring both abstract and procedural knowledge. Recent research by Yu & Hu (2022) indicates that integrating digital design tools such as AutoCAD and SketchUp within PBL enhances technical accuracy and student engagement. These findings align with contemporary trends in design education, emphasizing technology-mediated, inquiry-based learning (Lee & Lim, 2021).

This study investigates the influence of PBL on students' academic development and spatial design competencies. Specifically, it examines students enrolled in a Higher Vocational Architectural Home Space Design program to explore how PBL may improve both academic understanding and practical design skills in three key domains: design creativity, CAD drafting, and 3D modeling.

Although prior research provides valuable insights, few studies have simultaneously examined the impact of PBL on academic performance and practical design abilities in

Chinese vocational education. Evidence is particularly limited regarding how PBL supports students in applying digital tools such as CAD and 3D modeling in home space design. Furthermore, while international studies report positive effects of PBL, empirical research in Chinese vocational colleges is scarce, and cultural and institutional factors may influence outcomes.

Therefore, this study aims to address these gaps by investigating the impact of PBL on learning outcomes among Chinese vocational college students. The research seeks to provide empirically grounded insights into instructional design for vocational education in design-related fields by addressing two core questions: 1) Does PBL improve students' academic performance? 2) Does it enhance their proficiency in home space design?

Ultimately, this project assesses the efficacy of PBL within a specific educational context while offering a reproducible instructional model for other vocational training environments facing similar challenges in linking theory with practice.

3. Research objectives

3.1 To compare learning achievement of students before and after using learning to the project-based learning.

3.2 To compare home space design skill of students before and after using learning to the project-based learning.

4. Research Methodology

4.1. Research Design

This study employed a quantitative research method using a one-group pretest-posttest design to investigate the effect of PBL on students' learning achievement and their home space design skill. The design aimed to measure changes after the instructional intervention without a control group.

4.2 Scope of the Study

4.2.1 The duration of the study is the second semester of the academic year 2024 for 4 weeks, 8 hours per week, a total of 32 hours. This timeline was sufficient to cover theoretical instruction, group-based project implementation, and presentation of student work.

4.2.2 The instructional content focused on the subject of home space design and included the following three modules:

4.2.2.1 Design creative skills: fostering student creativity in planning interior and spatial layouts based on ergonomic and aesthetic principles.

4.2.2.2 CAD drawing skills: enhancing students' precision and technical drafting ability using AutoCAD and related design software.

4.2.2.3 3D drawing skills: teaching digital modeling for spatial representation using 3D simulation tools.

5. Research Variables

5.1 Independent Variable: Project-based learning.

5.2 Dependent variables:

1) Learning achievement

2) Home space design skill

6. Population

The population consisted of second-year students in the higher vocational architectural home space design major, School of Education and Design, Chongqing Telecom in

Vocational College in the second semester of the 2024–2025 academic year, totaling 111 people in 3 classes.

7. Sample Group

The sample group consisted of 33 second-year students enrolled in the Higher Vocational Architectural Home Space Design major, School of Education and Design, Chongqing Telecom Vocational College, during the second semester of the 2024–2025 academic year. The participants were selected through purposive sampling because they were currently studying the home space design module and shared comparable academic backgrounds. In addition, they were taught by the same instructor, followed stable class schedules, and studied in a relatively consistent teaching environment, which ensured that they possessed the foundational conditions necessary for implementing the PBL intervention and enhanced the controllability and validity of the study. While purposive sampling facilitated the selection of an appropriate group for this instructional intervention, the limited sample size and absence of random assignment remain constraints that should be acknowledged when interpreting the findings and considering their generalizability.

8. Research Instruments

This research employed three main instruments to collect data and assess the outcomes of the project-based learning intervention:

8.1 Project-Based Learning Management Plan: The learning plan was structured into three core modules—Creative design skills, CAD drawing Skills, and 3D drawing skills—each integrated into a project-based framework. The lesson plans were developed and validated by three experts in curriculum design and vocational education. The experts assessed the appropriateness of the objectives, content, and project steps using a 5-point scale. The average rating across components was above 4.67, indicating high validity and suitability for instruction.

8.2 Learning Achievement Test: A 30-item multiple-choice test was developed by the researcher to evaluate students' cognitive understanding based on Bloom's taxonomy (knowledge, comprehension, and application). The test focused on theoretical knowledge related to creative design, CAD drawing standards, and 3D modeling. The Index of Item-Objective Congruence (IOC) for each item was validated by three experts and found to be 1.00, meeting academic rigor and construct validity requirements.

8.3 Home Space Design Skill Assessment Form: The skills assessment form evaluated students in three dimensions: 1) Creative design skills, 2) CAD drawing Skills, and 3) 3D drawing skills. Each dimension included four observable indicators scored on a 3-point scale (1=Needs Improvement, 2=Satisfactory, 3=Excellent). This rubric was applied during student presentations and final evaluations, ensuring consistency and objectivity in performance appraisal.

9. Data Collection

The data collection process occurred over four weeks during the second semester of the 2024–2025 academic year, encompassing a total of 32 instructional hours. The following steps were followed:

9.1 Pretest Phase: Prior to the intervention, students completed the Learning Achievement Test and participated in a baseline skills assessment using the Home Space Design Skill Assessment Form. This established their initial knowledge and skill levels.

9.2 Intervention Phase: Students engaged in the structured project-based learning activities, including theoretical lessons, group planning, design development, and final

presentations. Learning artifacts such as sketches, CAD files, and 3D models were collected throughout.

9.3 Posttest Phase: Upon completion of the instructional module, the same Learning Achievement Test and skills assessment were administered. Experts evaluated the final projects using the same rubric as the pretest to measure growth in practical design performance.

10.Data Analysis

Quantitative data from the tests and assessment forms were analyzed using:

10.1 Descriptive Statistics: Mean, percentage, and standard deviation were calculated to understand the central tendency and variability of scores.

10.2 Inferential Statistics: A dependent sample t-test was used to compare pretest and posttest results for both academic achievement and design skill scores, with a significance level set at $p < .01$ to determine the effectiveness of the intervention.

10.3 Content Analysis: For qualitative elements (e.g., expert feedback and student reflections), key themes and patterns were summarized to support quantitative findings.

11.Research Results

11.1.Comparison of learning achievement of students before and after using learning to the project-based learning

11.1.1 Independent t-test analysis of students' learning achievement before and after project-based Learning

Table 1 presents the results of an independent t-test comparing students' learning achievement before and after participating in project-based learning. The table includes the mean, standard deviation, t-value, degrees of freedom (df), and significance level (p), used to assess whether the improvement is statistically significant ($\alpha=0.05$).

Table 1 : Independent t-test analysis of students' learning achievement before and after project-based Learning

Test	N	Full score	$\bar{x}$	S.D.	t-test	df	Sig.
Pre-test	33	30	12.788	2.870	-42.079	32	0.000
Post-test	33	30	25.212	1.900			

As shown in Table 1, the improvement in learning achievement after project-based learning is statistically significant ($t=-42.079$, $p<.01$). The effect size (Cohen's $d = 6.84$) indicates an exceptionally large effect, suggesting that project-based learning had a substantial positive impact on students' academic performance.

11.1.2 Descriptive statistical analysis of students' learning achievement before and after project-based learning

Table 2 presents the descriptive statistics of students' total learning achievement scores, as well as their scores across three specific dimensions: design creative skills, CAD drawing skills, and 3D drawing skills. The data provide insight into students' overall performance in the pre-test and post-test.

Table 2 : Descriptive statistics of students' learning achievement before and after project-based learning

Dimensions	Pre-test (Full score: 30)		Post-test (Full score: 30)		difference	Percentage of difference ^a
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
Design creative skills	5.000	1.275	8.212	0.650	3.212	64.24%
CAD drawing skills	4.182	1.074	8.424	0.902	4.242	101.43%
3D drawing skills	3.606	0.864	8.576	0.969	4.970	137.83%
Total	12.788	2.870	25.212	1.900	12.424	97.15%

^aPercentage increase was calculated relative to the pre-test mean.

According to the data in Table 2, students' total learning achievement improved significantly after participating in project-based learning, increasing from a mean score of 12.788 in the pre-test to 25.212 in the post-test—an increase of 12.424 points, which represents a 97.15% improvement.

Among the specific dimensions, the most substantial improvement was observed in 3D drawing skills, which rose from 3.606 to 8.576 points—an increase of 4.970 points (137.83%). CAD drawing skills also showed notable gains, improving from 4.182 to 8.424 points—an increase of 4.242 points (101.43%). Lastly, design creative skills increased from 5.000 to 8.212 points, marking a gain of 3.212 points (64.24%).

11.2 Comparison of home space design skills of students before and after using learning to the project-based learning

11.2.1 Independent t-test analysis of home space design skills before and after project-based learning

Table 3 presents the results of an independent t-test comparing students' home space design skills before and after engaging in project-based learning. The analysis includes the mean, standard deviation, t-value, degrees of freedom (df), and significance level (p), with α set at 0.05.

Table 3 : Independent t-test results of students' home space design skills before and after project-based learning

Test	N	Full score	$\bar{x}$	S.D.	t	df	Sig.
Pre-test	33	36	15.788	2.619	-42.224	32	0.000
Post-test	33	36	32.939	3.372			

As shown in Table 3, students' home space design skills improved significantly after participating in project-based learning. The increase from a mean of 15.788 in the pre-test to 32.939 in the post-test was statistically significant ($t = -42.224$, $p < .01$). The effect size (Cohen's $d = 7.01$) demonstrates an extremely large effect, indicating that the instructional approach effectively enhanced their

11.2.2 Descriptive statistical analysis of home space design skills before and after project-based learning

Descriptive statistical analysis was conducted to examine students' performance in home space design skills across three dimensions: design creative skills, CAD drawing skills, and 3D drawing skills.

Table 4: Descriptive statistics of students' home space design skills before and after project-based learning

Dimensions	Pre-test (Full score: 36)		Post-test (Full score: 36)		difference	Percentage of difference ^b
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
Design creative skills	5.424	1.032	10.455	1.148	5.031	92.77%
CAD drawing skills	5.182	0.882	11.242	1.173	6.060	116.90%
3D drawing skills	5.182	0.882	11.242	1.173	6.060	116.90%
Total	15.788	2.619	32.939	3.372	17.151	108.63%

^bPercentage increase was calculated relative to the pre-test mean.

Table 4 presents that the total score for students' home space design skills increased from 15.788 in the pre-test to 32.939 in the post-test—an improvement of 17.151 points, representing a 108.63% gain.

Among the specific dimensions, CAD drawing skills and 3D drawing skills showed the most substantial improvements, both rising from 5.182 to 11.242 points—an increase of 6.060 points, or 116.90%. Design creative skills also improved notably, increasing from 5.424 to 10.455 points—an increase of 5.031 points, which represents a 92.77% improvement.

12. Discussion of results

12.1 The learning achievement of students improved significantly after project-based learning

The significant improvement in students' learning achievement after participating in PBL can be attributed to the pedagogical principles embedded in this approach. Project-based learning fosters active engagement by immersing students in authentic, real-world tasks that demand the integration of theoretical knowledge and practical application. Unlike traditional lecture-based methods, PBL shifts the role of students from passive recipients to active constructors of knowledge, a process emphasized by Thomas (2000), who posits that inquiry-driven learning enables deeper cognitive processing and long-term retention.

This study's design resonated with Kolb's Experiential Learning Cycle (1984), which emphasizes cyclical phases of concrete experience, reflective observation, abstract conceptualization, and active experimentation. For instance, students first engaged in hands-on design tasks (concrete experience), analyzed spatial challenges (reflective observation), conceptualized solutions using design theories (abstract conceptualization), and iteratively refined their work (active experimentation). This structured yet adaptable framework enabled students to connect theory with practice, so reinforcing their comprehension of course material.

Furthermore, the internal motivation generated by PBL was crucial. Deci and Ryan's Self-Determination Theory (1985) posits that autonomy, competence, and relatedness are essential motivators. This study improved students' ownership of learning results by allowing them autonomy in decision-making, including the selection of design styles and problem-solving methodologies. Concurrently, collaborative assignments fostered relatedness, as students collaborated in teams to evaluate and enhance one another's ideas, a process demonstrated by McGrath and MacEwan (2011) to bolster both cognitive and interpersonal skills.

The incorporation of digital instruments further intensified these consequences. Limbu (2012) observes that technology-enhanced learning settings foster critical thinking and

decision-making through the simulation of real-world issues. This study demonstrated that students employed CAD and 3D modeling software to visualize designs, hence enhancing technical proficiency and corroborating Wongyai and Pattaphon's (2019) claim that digital literacy is essential for contemporary education. These factors collectively account for the substantial 97.15% enhancement in total learning achievement evident in the post-test data.

Beyond statistical significance, this improvement also had practical implications: students' design drawings became more precise and standardized, especially in CAD layer management and 3D visualization, which are directly relevant to vocational practice.

However, because the study used a one-group pretest–posttest design with 33 participants, caution is needed when interpreting these very large effect sizes. Practice effects or short-term exposure may have partly contributed to the observed gains.

12.2 Home space design skills improved significantly after project-based learning

The improvement of residential design skills in students demonstrates the intrinsic advantages of Project-Based Learning in vocational education. By grounding education in practical projects—such as the design of a three-bedroom apartment—students were necessitated to implement theoretical concepts in real-world contexts, a strategy endorsed by Doppelt (2003) as crucial for fostering design thinking and technical proficiency. The iterative process of PBL, encompassing drafting, feedback, and design revision, reflects the client-centered methodology common in professional practice, thus aligning academic instruction with industry standards.

A crucial element in skill enhancement was the focus on collaborative problem-solving. Utilizing Vygotsky's Social Constructivist Theory (1978), the collaborative framework of this study facilitated students in co-constructing knowledge via discourse and peer evaluation. During the "Presentation" phase, students justified their design decisions to peers and simulated clients, enhancing their capacity to express design rationale and integrate feedback—a skill highlighted by Chen, H. (2023) as essential for professional success.

The incorporation of sophisticated technology was also pivotal. Students employed 3D modeling software to produce renderings and virtual walkthroughs, a method consistent with research indicating that digital tools improve spatial visualization and client communication (Zhang, H., 2024). Furthermore, the emphasis on sustainability—such as the selection of eco-friendly materials—resonated with Liu (2020), who highlighted the importance of ecologically conscious design. These educational tactics correspond with Daoruang (2012), whose research indicated that technology-enhanced project-based learning markedly improves creative problem-solving skills. This study demonstrates that a 116.90% enhancement in CAD and 3D drawing skills highlights the effectiveness of integrating technical instruction with project-based learning. Moreover, the 92.77% increase in design creativity skills indicates that PBL enhances not just technical proficiency but also promotes innovation—an outcome aligned with Chen, X. (2022)'s multidisciplinary PBL paradigm.

In this study, CAD/3D software was introduced through short guided exercises followed by project-based application, which may explain why technical skills improved more rapidly than creativity.

Still, because all assessments were conducted within one program and timeframe, the generalizability of these findings remains limited, and further research with control groups and longer follow-up is recommended.

13. Research Suggestions

13.1 Practical Recommendations

13.1.1 Institutional Integration of PBL

Vocational institutions ought to use Project-Based Learning (PBL) in pertinent courses, ensuring that projects are centered on authentic design problems to augment students' engagement and practical inventiveness.

13.1.2 Teacher Capacity Building

Workshops and training should be implemented to assist teachers in the design, facilitation, and assessment of PBL activities, particularly with software technologies such as CAD and 3D modeling. Ongoing support such as peer coaching, co-teaching models, or instructional design teams may further strengthen teachers' capacity and ensure consistent quality of PBL implementation.

13.1.3 Structured Learning and Feedback

PBL must be segmented into several phases—Launching, Planning, Learning, Presentation, and Evaluation—accompanied by consistent formative feedback to facilitate student advancement during the project cycle.

13.1.4 Industry Collaboration

Inviting professional designers and industry partners to mentor or assess student work enhances relevance, quality, and career readiness. Such collaborations also provide students with exposure to authentic workplace standards and help ensure that skills developed in class remain aligned with industry requirements.

13.2 Recommendations for Future Research

13.2.1 Longitudinal Impact

Future research should explore the long-term influence of PBL on students' internship performance or professional careers to assess sustained learning outcomes.

13.2.2 Comparative Pedagogical Studies

Studies comparing PBL with traditional instructional methods will clarify relative effectiveness and suitability across different subjects and learning contexts. In particular, incorporating a control group in future studies would help address the limitations of the one-group pretest–posttest design used in this study and allow stronger causal inferences.

13.2.3 Broader Sampling and Duration

Research using larger sample sizes and extended timeframes (e.g., full academic terms) would improve generalizability and reliability of findings. Expanding to multiple institutions would also help determine whether results are consistent across different contexts and teaching environments.

13.2.4 Interdisciplinary and Sustainable Focus

Future studies could explore integrating PBL with environmental science, materials engineering, or smart home technologies to further enhance holistic design education. Exploring sustainability-oriented projects (e.g., eco-friendly housing, energy-efficient interiors) may enrich students' awareness of social responsibility in design practice.

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15.New knowledge

This research synthesized new insights into the integration of project-based learning within vocational design education. The study found that a well-structured PBL framework, when implemented with digital tools such as CAD and 3D modeling software, can significantly enhance both academic learning achievement and practical home space design skills. The findings demonstrate that PBL not only bridges the gap between theory and application but also fosters creative thinking, teamwork, and problem-solving among students. This study presents a replicable model for embedding industry-relevant skills into curriculum design and contributes to the body of knowledge on effective instructional strategies in vocational education.

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