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Integrating project-based learning and virtual kitchen: a digital learning innovation to enhance students' creativity and entrepreneurial potential in bakery courses

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ABSTRACT

The demand for innovative approaches in vocational education has increased significantly in the digital era. This study explores the integration of Project-Based Learning (PjBL) with a Virtual Kitchen platform to enhance students' creativity and entrepreneurial potential in bakery courses. Using a quasi-experimental pretest-posttest design with non-equivalent groups, the research involved 52 students divided into experimental (n = 26) and control (n = 26) groups. The intervention combined project-based tasks with virtual kitchen simulations, allowing students to experiment with recipes, simulate product branding, and practice digital marketing in a risk-free environment. Data were collected through creativity assessments, product evaluation rubrics, entrepreneurial attitude scales, and student feedback surveys. Statistical analysis using paired and independent t-tests revealed a significant improvement in both creativity and entrepreneurial readiness in the experimental group ($p < 0.001$). The findings highlight that integrating PjBL with Virtual Kitchen not only supports technical mastery but also nurtures digital micro-entrepreneurship and innovative thinking. This model presents a transformative strategy for preparing vocational students for the demands of Industry 4.0. Recommendations are provided for further implementation in other culinary domains and the development of more advanced virtual platforms.

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Introduction

The advancement of digital technology has reshaped vocational education, requiring approaches that merge technical training with creativity and entrepreneurship. Traditional bakery education often emphasizes skill repetition without integrating entrepreneurial thinking. To meet 21st-century educational needs, it is essential to implement models that connect learning with real-world challenges and digital innovation.

PjBL is widely recognized for fostering problem-solving, collaboration, and creativity by engaging students in meaningful projects (Bell, 2023). Virtual Kitchen tools enable learners to simulate culinary tasks, innovate freely, and receive immediate feedback. When combined, these methods provide an immersive learning environment where students develop both technical skills and entrepreneurial mindsets.

This research investigates the impact of the PjBL-Virtual Kitchen model on creativity and entrepreneurial attitudes in bakery courses. By offering both cognitive and behavioral insights, this study contributes to developing digital-era pedagogical models.

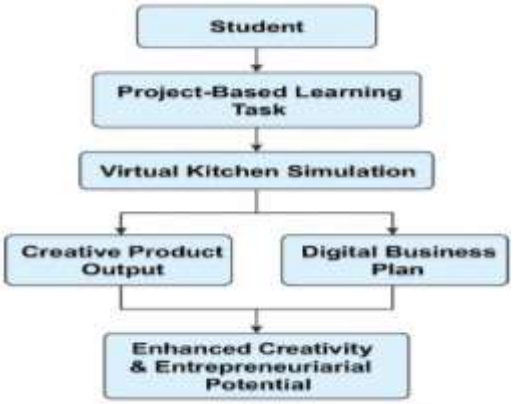

Figure 1. Conceptual Framework of PjBL-Virtual Kitchen Model

Figure 1 illustrates the theoretical foundation of this study, connecting PjBL activities, virtual kitchen use, and entrepreneurship-oriented tasks to the development of creativity and entrepreneurial potential.

Project-Based Learning in Culinary Contexts

Project-Based Learning (PjBL) is an instructional methodology that encourages students to learn by actively engaging in real-world and personally meaningful projects (Thomas, 2022). In the context of bakery education, it helps learners conceptualize and execute creative food product designs, manage time, and collaborate effectively. Research by Suhendi & Purwanto (2023) demonstrated improved student performance in culinary training programs using PjBL.

Virtual Kitchen as an Educational Innovation

Virtual kitchens allow students to simulate baking tasks in a digital environment, thereby reducing the dependency on physical resources while still achieving learning objectives (Lee et al., 2024). These tools provide immersive learning experiences that are repeatable and scalable. According to Ghosh et al. (2022), virtual learning environments enhance practical skills acquisition, especially during hybrid or online learning periods.

Creativity and Innovation in Baking Education

Creativity in baking involves transforming ordinary ingredients into aesthetically appealing and innovative culinary products. Open-ended learning environments encourage students to experiment and iterate (Amabile, 1996; Zhang & Lin, 2021). Incorporating digital platforms further stimulates creativity through design tools, multimedia feedback, and recipe simulations (Nasir & Jamaludin, 2023).

Digital Entrepreneurship and Microbusiness Simulation

Digital entrepreneurship education focuses on building business competencies through online tools and simulations. In culinary education, virtual marketplaces and branding activities can simulate real-world entrepreneurial tasks (Harris, 2023). Research by Widyaningsih et al. (2022) supports that digital microbusiness projects embedded in PjBL can increase students' entrepreneurial mindset, confidence, and practical planning skills.

Integrating Digital Tools with Vocational Pedagogy

Blending PjBL with digital platforms such as virtual kitchens provides a flexible and scalable pedagogical model that meets the current demands of vocational education (Taminiau & Leemans, 2023). Such integration supports personalized learning, remote access, and interdisciplinary collaboration.

Method

Research Design

This research applied a quasi-experimental pretest-posttest non-equivalent group design to evaluate the effects of the PjBL-Virtual Kitchen model on students' creativity and entrepreneurial outcomes.

Participants

A total of 52 students from a vocational bakery course were selected and divided into (1) Experimental group (n = 26): Implemented PjBL with Virtual Kitchen simulation. (2) Control group (n = 26): Received conventional lecture-based instruction and manual bakery practice.

Instruments and Validity

(1) Creativity Assessment Tool adapted from Torrance Tests of Creative Thinking (TTCT), Cronbach's alpha = 0.82. (2) Product Evaluation Rubric based on expert validation from professional pastry chefs. (3) Entrepreneurial Attitude Scale adapted from Entrepreneurial Intention Questionnaire (EIQ), Cronbach's alpha = 0.87.

Procedure

(1) Week 1: Pretest for creativity and entrepreneurial attitude. (2) Weeks 2–5: Implementation of PjBL model in both groups. The experimental group engaged with Virtual Kitchen tasks including recipe simulation, design iteration, and digital presentation. (3) Week 6: Final exhibition of bakery products (both groups) and administration of posttests.

Data Analysis

Data were analyzed using paired t-tests for within-group differences and independent sample t-tests for between-group comparisons. Significance was determined at $p < 0.05$ using SPSS 26. Depicts the research process from participant division, intervention activities, and evaluation steps.

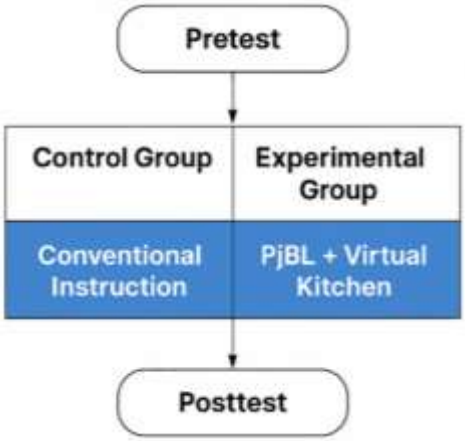

Figure 2. Research Procedure Flowchart

The flowchart illustrates the sequence of steps in the quasi-experimental research process. It begins with the pretest stage for both the experimental and control groups, followed by the intervention phase where the experimental group engages in Project-Based Learning (PjBL) integrated with the Virtual Kitchen platform, while the control group receives conventional instruction. The flow continues to the final product exhibition, which serves as a practical evaluation of students' learning outcomes. Finally, both groups undergo a posttest to assess changes in creativity and entrepreneurial potential. This structured flow ensures a comparative and measurable analysis of the instructional model's impact.

Results and Discussions

Quantitative data revealed a statistically significant increase in creativity and entrepreneurial scores in the experimental group compared to the control group. Table 1 presents the mean scores and standard deviations.

Table 1. Pretest and Posttest Results

Variable	Group	Pretest Mean (SD)	Posttest Mean (SD)	p-value
Creativity	Experimental	68.2 (6.1)	82.7 (5.4)	<0.001
	Control	67.9 (5.8)	70.4 (6.2)	0.087
Entrepreneurial Attitude	Experimental	65.4 (7.2)	80.1 (6.0)	<0.001
	Control	64.7 (6.9)	66.3 (6.4)	0.135

Table 2. Students' Feedback on PjBL-Virtual Kitchen

Indicator	Agree (%)	Neutral (%)	Disagree (%)
Platform enhances creativity	88	10	2
Easy to use and engaging	85	12	3
Improves entrepreneurial insight	90	8	2

Figure 3. Virtual Kitchen Interface and Student Activities

Figure 3 displays the user interface of the Virtual Kitchen platform and highlights various student activities during the learning process. The interface features interactive modules, recipe design tools, and real-time simulation of bakery production. Students engage in tasks such as ingredient selection, product creation, and virtual baking simulations. Additionally, the platform includes collaborative features that allow peer feedback and instructor monitoring, enhancing both creativity and entrepreneurship development throughout the project-based learning activities.

Figure 4. Students' Project Outputs (Bakery Products and Branding)

Figure 4. Students' Project Outputs (Bakery Products and Branding) illustrates the final outcomes of students' projects, showcasing a variety of innovative bakery products along with their developed branding designs. Each team created unique bread, cakes, or pastries with distinctive shapes, flavors, and decorations, accompanied by creative packaging and attractive brand identities. This figure highlights the success of integrating Project-Based Learning and the Virtual Kitchen in fostering students' creativity, product innovation, and entrepreneurial skills.

Table 3. Comparison with Previous Studies

Study	Innovation	Outcome	Alignment with Current Study
Chang & Wong (2022)	Virtual Kitchen only	Skill improvement	Current study adds entrepreneurship component
Thomas (2022)	PjBL in culinary	Creativity boost	Current study integrates PjBL with digital tools
This study	PjBL + Virtual Kitchen	Creativity + Entrepreneurship	Demonstrates higher impact

Conclusions

The integration of PjBL and Virtual Kitchen significantly enhances students' creativity and entrepreneurial potential in bakery education. This model addresses the limitations of traditional teaching methods by combining hands-on digital simulation with entrepreneurial tasks. It prepares students for Industry 4.0 by fostering innovation and business readiness.

Recommendations: Future research should expand this model to other culinary disciplines, explore integration with augmented reality, and develop platforms with real-time market simulations to further enhance entrepreneurial training

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