

The Effect of Employing Learning by Doing Strategy in Pre-Vocational Education on Students' Critical Thinking Skills

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ABSTRACT

This study explores the impact of a learning-by-doing strategy on the development of critical thinking skills among ninth-grade female students in Jordan's pre-vocational education (PVE). Fifty students were randomly assigned to either an experimental group (n = 25), which received experiential instruction, or a control group (n = 25), which followed traditional teaching methods. A validated test assessed five domains of critical thinking: inference, assumption recognition, deduction, interpretation, and argument evaluation. Post-intervention analysis revealed statistically significant improvements in all domains for the experimental group. These findings support the integration of experiential learning strategies into PVE curricula to foster critical thinking.

Keywords: Pre-Vocational Education, Critical Thinking, Experiential Learning, Learning by Doing

INTRODUCTION

The principle of "learning by doing," rooted in Aristotle's philosophy, emphasizes experiential engagement as essential for deep understanding and knowledge retention. This approach encourages learners to actively participate in real-world tasks, promoting transferable skills through empirical discovery, problem-solving, and innovation.

Aligned with constructivist theory, learning by doing enables students to construct knowledge through experience and reflection. Conchas et al. (2023) highlight its effectiveness in enhancing motivation and comprehension of scientific concepts through hands-on engagement. This strategy encompasses diverse methods such as cooperative learning, field trips, simulations, service learning, project-based learning (PBL), and problem-based learning, all of which prioritize practical application and immersive experiences.

Kolb's experiential learning model—comprising concrete experience, reflection, conceptualization, and experimentation—illustrates the cyclical nature of this approach. EL-Shaer and Gaber (2014) affirm that PBL fosters enjoyment and deeper learning through active problem-solving.

In contrast, traditional teaching methods, characterized by passive content delivery, have been shown to hinder student engagement and motivation, particularly in STEM fields (Aji & Khan, 2019). As education systems face increasing demands for adaptability and innovation, experiential strategies offer a more effective alternative (Al-Tweissi, 2014; Al-Rahahleh & Al-Saaideh, 2024).

Learning by doing equips students with essential 21st-century skills—critical thinking, collaboration, communication, creativity, and digital literacy—preparing them for complex societal and economic challenges (Shamuganathan, 2023; Al-Tweissi, 2023; Al-Hariri, 2019; Gaikwad & Kurane, 2023).

This pedagogical approach is applicable across disciplines and educational levels, offering a dynamic framework for integrating academic content with real-world relevance (Skulmowski, 2024). It supports holistic learner

development, fostering analytical thinking, effective communication, and problem-solving capabilities essential for success in a rapidly evolving world (Deslauriers et al., 2019; Yannier & Koedinger, 2021).

Statement of the Problem

Pre-Vocational Education (PVE) in Jordan, taught from grades 4 to 9, is designed to cultivate essential 21st-century skills—critical thinking, problem-solving, creativity, communication, and collaboration—through practical learning. Its purpose is to prepare students for informed post-secondary choices and future workforce demands requiring higher-order cognitive and interpersonal skills. However, despite its practical orientation, PVE is predominantly delivered through traditional, teacher-centered methods that emphasize theoretical content. Empirical studies (Al-Rahahleh & Al-Saaideh, 2024; Ali Saleh et al., 2021; Mahasneh, 2015; Jawarneh, 2013) consistently show that this approach limits student engagement and impedes the development of critical thinking skills. Given this pedagogical mismatch, the learning-by-doing strategy emerges as a promising alternative. Rooted in experiential learning theory, it emphasizes active participation, real-world problem-solving, and reflective inquiry—conditions conducive to fostering critical thinking. This study investigates whether implementing learning by doing in PVE can significantly enhance critical thinking skills among ninth-grade female students.

Research Question

Does the implementation of learning by doing in PVE significantly improve the critical thinking skills of ninth-grade female students?

Hypothesis

There is a statistically significant difference ($p \leq 0.05$) in critical thinking test scores between students taught using learning by doing and those taught using traditional methods.

Importance of the Study

Critical thinking is a cornerstone of academic success and professional adaptability. It enables students to make informed decisions, solve complex problems, and navigate contradictory information. As Collins (2020) emphasizes, critical thinking enhances test performance, fosters independent learning, and equips students with marketable skills essential for lifelong success.

In the context of Jordan's evolving educational landscape, cultivating critical thinking is not optional—it is imperative. Learning by doing offers a student-centered, experiential framework that actively engages learners in applying knowledge, analyzing information, and evaluating outcomes. This approach nurtures higher-order thinking and prepares students to meet the demands of a dynamic, innovation-driven world.

This study leverages the PVE unit "Recycling Environmental Waste," focusing on composting food waste as a real-world, hands-on learning experience. By transforming waste into valuable resources, students not only develop critical thinking but also cultivate environmental responsibility—aligning with national sustainability goals.

Moreover, critical thinking in environmental education empowers students to assess consumption habits, reduce waste, and make sustainable choices (Minott et al., 2019; Bigdeloo, 2021; Husain, 2024). It fosters environmental stewardship and supports behaviors that contribute to long-term sustainability (Shutaleva, 2023). By integrating critical thinking with ecological awareness, this study aims to equip students with the cognitive and ethical tools to positively impact their communities and the planet.

Aims of the Study

This study aims to evaluate the effectiveness of the learning-by-doing instructional strategy in enhancing critical thinking skills among ninth-grade female students within Jordan's pre-vocational education (PVE) curriculum. By comparing experiential and traditional teaching methods, the research seeks to determine whether active, hands-on learning fosters deeper cognitive engagement and skill development.

LITERATURE REVIEW: CRITICAL THINKING

Critical thinking is widely recognized as a foundational objective across educational levels. It encompasses the ability to define problems, ask relevant questions, analyze assumptions, synthesize information, and evaluate outcomes. Dima and Maassen (2018) categorize critical thinking into three core competencies: selecting relevant data, processing and analyzing information, and applying insights to solve problems. In the Jordanian context,

Innabi and Sheikh (2007) identify two pedagogical approaches to teaching critical thinking: the embedded method, which integrates skills implicitly, and the infusion method, which teaches them explicitly through disciplinary content. Ennis (1985) further breaks down critical thinking into six indicators—Focus, Reason, Inference, Situation, Clarity, and Overview—providing a structured framework for assessment. Agustin et al. (2024) define critical thinking as a disciplined intellectual process involving conceptualization, application, analysis, synthesis, and evaluation. These skills are applied through observation, experience, reflection, reasoning, and communication to guide decision-making. Golja and Clerke (2020) argue that critical thinking transcends academic boundaries, equipping individuals to navigate complex, real-world challenges with clarity and judgment. Ennis (2015) emphasizes that critical thinking is both active and skillful, requiring deliberate engagement with information. Fuad et al. (2017) highlight its importance as a core competency that educators should cultivate. Zamriani et al. (2023) propose using a critical thinking index to observe and measure student progress. Facione (1990) introduces a dual-dimensional model of critical thinking: cognitive skills (interpretation, analysis, evaluation, reasoning) and affective dispositions (explanation and self-regulation). These dimensions enable learners to articulate their thoughts, assess their reasoning, and refine their understanding through reflection (Heard et al., 2020; Baş & Bolat, 2022). Together, these perspectives underscore the multifaceted nature of critical thinking and its central role in preparing students for academic and professional success.

Developing Critical Thinking through Learning by Doing Instructional Strategy

The learning-by-doing strategy is a pedagogical approach that prioritizes hands-on experience as a catalyst for deeper learning. Research consistently shows that active learning methods, including experiential strategies, significantly enhance students' critical thinking by fostering direct engagement with content (Reese, 2011; Ostby, 2022). When learners are actively involved, they are more likely to analyze, evaluate, and synthesize information—core components of critical thinking.

Empirical evidence supports the broader benefits of learning by doing, including improved academic performance, increased motivation, and greater learner autonomy (Mekonnen, 2020; Hendrickson, 2021). This approach also cultivates self-efficacy and accommodates diverse learning styles, making it especially effective for students who struggle in traditional lecture-based environments (Badgie, 2023).

In Finland, learning by doing is embedded in craft and technology education, where students engage in designing, experimenting, and problem-solving (Niiranen et al., 2020). Similarly, inquiry-based learning (IBL) and problem-based learning (PBL) have demonstrated strong effects on critical thinking in science and technology education (Duran & Dökme, 2016; Fadilla et al., 2021). Niiranen (2021) further emphasizes its role in conceptualizing technological knowledge and intellectual development.

In entrepreneurship education, learning by doing fosters independence and practical skill acquisition (Colombelli et al., 2022). Brown (2023) found that internships in environmental education not only expanded students' knowledge but also enhanced their critical thinking and communication skills. Zamriani et al. (2023) confirmed similar outcomes in physics education.

In Jordan, Al-Rahahleh & Al-Saaideh (2024) demonstrated that PBL positively influences financial literacy and learning motivation, reinforcing the value of experiential strategies in local contexts. As Team (2023) notes, critical thinking is essential for academic success and lifelong learning, enabling students to make evidence-based decisions and generate innovative solutions.

To foster these outcomes, students must take initiative, explore knowledge independently, and engage with real-world problems through contextualized activities. Ennis (2015) defines critical thinking as the disciplined process of conceptualizing, applying, analyzing, synthesizing, and evaluating information to guide belief and action—an approach inherently supported by experiential learning.

Jordan's Ministry of Education has prioritized the integration of 21st-century skills into its curricula, aiming to produce scientifically literate and technologically competent graduates (MoE, 2013). PVE, as a practical subject, is well-positioned to bridge theoretical knowledge with real-world applications, particularly through STEAM-based interdisciplinary lessons (MoE, 2023; Jawarneh, 2013).

Learning by doing in PVE enables students to apply academic concepts—such as mathematical measurements and scientific principles—to hands-on tasks, reinforcing both cognitive and vocational competencies. Recognizing this potential, the Ministry launched a national initiative in 2022 to embed 21st-century skills into basic education (grades 1–9), supported by enrichment guides and teacher training (MoE, 2020a; 2021).

For this initiative to succeed, educators must be equipped to implement learner-centered strategies that promote active participation, self-assessment, and practical skill development. The learning-by-doing model aligns with these goals, offering a transformative framework for cultivating critical thinking and preparing students for the demands of a knowledge-driven economy.

PVE Teacher Standards and Instructional Practice

According to the National Charter for the Teaching Profession (Ministry of Education, 2020b), pre-vocational education (PVE) teachers in Jordan are expected to embody competencies aligned with 21st-century skills. These include effective communication, the ability to assess students' readiness and interests, and the capacity to guide learners toward self-directed learning. The standards emphasize the integration of practical, life-relevant knowledge and the use of learner-centered strategies that actively engage students in the educational process.

Modern teaching expectations also include the use of information and communication technology (ICT) and diverse assessment methods that promote self-evaluation and reflection. PVE teachers are expected to demonstrate constructive, diagnostic, communicative, and cognitive abilities—skills essential for fostering critical thinking and preparing students for real-world challenges (Ministry of Education, 2020b; Al-Tweissi, 2023).

Despite these progressive standards, research reveals a persistent reliance on traditional, teacher-dominated instruction in PVE classrooms. Studies by Al-Rahahleh & Al-Saaideh (2024), Ali Saleh et al. (2021), Al-Khrisha & Mansour (2021), Mahasneh (2015), and Jawarneh (2013) consistently show that PVE teachers often default to lecture-based methods that discourage student participation and limit opportunities for critical thinking.

This pedagogical disconnect undermines the core objectives of PVE and contradicts the Ministry's emphasis on experiential, project-based, and active learning. As a result, students struggle to develop essential cognitive skills, leading to disengagement and minimal involvement in PVE activities. Addressing this gap requires a shift toward instructional strategies—such as learning by doing—that align with national standards and effectively cultivate critical thinking.

RESEARCH METHOD

To evaluate the impact of the learning-by-doing instructional strategy on students' critical thinking skills, this study employed a quasi-experimental design using a pre-test/post-test control group framework. This design enabled a comparative analysis between two groups of ninth-grade female students: one receiving experiential instruction and the other taught through traditional methods. The inclusion of a control group allowed for the isolation of the instructional variable and strengthened the causal inference between the intervention and the observed outcomes in critical thinking.

Ethical Considerations

The study adhered to ethical standards for research involving human participants. Approval was obtained from the Yarmouk University Institutional Review Board (IRB), ensuring compliance with ethical protocols (Mills & Gay, 2019). Additional authorization was secured from the Al-Ramtha Directorate of Education and the participating school. Parents and guardians were informed of the study's objectives, procedures, and potential risks and benefits. Participation was voluntary, and students retained the right to withdraw at any time without penalty. Confidentiality and anonymity of participant data were rigorously maintained throughout the research process.

Participants

The study sample consisted of ninth-grade female students from 'Aishah Bint Aby Baker' public secondary school for girls, located in Al-Shajarah village in northern Jordan. The school was purposively selected due to its accessibility and the researchers' familiarity with the community. The village has a population of approximately 18,000, and the school serves 1,120 female students, including 122 in ninth grade.

Two of the four ninth-grade divisions were randomly selected for the study. One division was assigned as the experimental group ($n = 25$), receiving instruction through learning-by-doing strategies, while the other served as the control group ($n = 25$), receiving traditional instruction. The students shared similar socio-economic backgrounds and lived in comparable environments, minimizing external variability.

The intervention was conducted during the second semester of the 2023/2024 academic year and spanned five weeks. Instruction in the experimental group incorporated hands-on, project-based, and problem-based learning activities. Students engaged with authentic, real-world problems designed to stimulate collaborative inquiry, problem-solving, and critical thinking. The PVE teacher acted as a facilitator, providing guidance, feedback, and scaffolding throughout the learning process.

Procedure of the Study (Delivery of the Unit using learning by doing approach)

Study Unit: Recycling Environmental Waste

Lesson 1, two sessions): Recycling Organic Waste

Objective: Students will understand the importance of recycling organic waste and learn practical methods to recycle organic materials.

In the computer lab, the PVE teacher initiates the lesson with a captivating introduction. A brief video was shown, illustrating individuals littering and discarding food waste in local areas. The video included shocking statistics about food waste in Jordan, its socio-economic repercussions, and environmental effects, underscoring the significance of recycling. The PVE teacher then elaborates on the fundamentals of recycling, focusing on what materials can be recycled and the process of recycling, with an emphasis on organic waste. Students were engaged in web quests to identify different types of recyclable food waste. The concept of the 3Rs (Reduce, Reuse, and Recycle) was introduced. The lesson was made engaging and unforgettable through interactive activities, web quests, and online games. Under the PVE teacher's guidance, students participated in group discussions about the wider environmental impact of recycling. Students were encouraged to contemplate how they can contribute to reducing and recycling food waste in their everyday lives to promote sustainability. Students were guided to recognize behaviours that lead to food waste at home and school and to devise strategies to counteract such behaviours. Acknowledging the crucial role of families in reducing food waste and protecting the environment, the PVE teacher shared take-home leaflets related to the session's topics with the participants to be discussed with Parents. The leaflet contained the following simple recommendations for parents to reduce the household food waste:

- Make sure you only buy what you can eat;
- Prioritise using the food you already have over buying new food for meals;
- Make sure you seal food properly in the fridge;
- Use your freezer to keep leftovers.

In the second session for the first lesson, the local community, mostly parents, was invited to attend a lecture delivered by an engineer from Al-Ramtha's Directorate of Agriculture, who is well-known for her environmental advocacy. The lecture focused on the significance of reducing and recycling food waste. The engineer's presentation, which was supplemented with videos about environmental protection, highlighted the collaborative efforts of the Ministry of Agriculture, the Ministry of Social Development, and the World Food Programme (WFP) to eliminate food waste. This session provided an excellent platform for students to interact with environmental advocates, gain insights from their experiences, and comprehend the crucial role of community participation in protecting the environment by minimizing food waste.

Lesson 2, (8 sessions): Producing Organic Fertilizer

Objective: Students will learn how to produce organic fertilizer from food waste and understand its benefits for soil health and plant growth.

Two consecutive class sessions per week were given at a rate of 45 minutes for each session during the first month of the semester. The PVE teacher divided the students in the experimental group into five groups. To produce liquid compost from food waste at school, the PVE teacher started by explaining the basics of composting and its environmental benefits. Students were asked to identify and list the type of food waste in the school's vicinity. The PVE teacher along with the students set up five collection bins in a well-ventilated and sunny area in the school yard (One bin for every group) and guided the students to collect food scraps like fruit, vegetables, coffee grounds, eggshells, etc. students were then shown a video on composting which taught students proper sorting. The students were instructed to use the compost bin to layer green materials (food scraps) and brown materials (leaves, paper), and to maintain it by turning and moisturising regularly. The students collected food waste found inside the school and in the school vicinity for over two weeks until the collection bins were almost full. The students were then instructed to keep the compost moist and stir it occasionally and keep observing the changes that happen. The students were then instructed to report any changes on the compost. The nutrient benefits of the resulting compost were explained. The students were also encouraged to make similar compost tea at home. Throughout the process of composting students were encouraged to monitor the process, keep records and report their observations. Throughout the composting lesson, students followed safety procedures carefully to ensure a safe and productive experience. They wore gloves to protect themselves from bacteria, mould, or dust and dressed appropriately to avoid mess. Maintaining hygiene was essential, so students washed their hands before and after handling food waste or compost and avoided touching their faces during the activity. They carefully sorted food waste, ensuring it is free from non-compostable materials, and adhered to instructions regarding safe handling of tools and materials. Clear guidelines by the PVE teacher on respectful and responsible behaviour were crucial, as students worked with worms and compost, ensuring these were handled gently and kept in optimal conditions. Awareness of allergies or sensitivities, as well as the ability to respond to minor accidents using the provided first aid kit, was vital for the safety of all students involved. By following these procedures and paying attention to the instructions provided by their teacher, students enjoyed a hands-on, engaging lesson while contributing positively to environmental sustainability.

The entire intervention spanned 10 sessions conducted over a period of 5 weeks. Each session is designed to build on the previous one, ensuring continuity and a progressive deepening of understanding. Detailed session plans are developed in collaboration with experienced environmental educators to ensure pedagogical soundness and engagement. The unit was taught in spring which made the composting process slower. The time allocated by the ministry of education for the teaching of the environmental unit in PVE was exceeded by three weeks.

The delivery of the unit incorporated a mix of instructional strategies and practical activities to engage students and provided learning by doing experiences as followed:

Experiential Learning: Students were engaged in hands-on activities such as nature walks in the school vicinity, and environmental experiments. This allowed the students to directly experience and interact with their surroundings. Students developed a personal connection to nature and gained a deeper understanding of environmental concepts through these experiences.

Project-based learning: Students undertook environmental projects allowing them to actively investigate and address real-world environmental challenges. They worked together on projects such as school clean-ups and making compost, which paved the way for them to develop critical thinking skills and a sense of responsibility for the environment.

Inquiry-Based Learning: Fostering curiosity and encouraging questions about the environment allowed students to explore their own interests and seek answers for all encountered issues relating to environmental protection and sustainability. Through inquiry-based learning, students developed research skills, analysed environmental issues, and constructed their own knowledge about the environment.

Multidisciplinary approaches: Integrating environmental education into multiple subject areas, including science, social studies, language arts, and math, provided young learners with a broad understanding of environmental concepts. This interdisciplinary approach allows them to make connections between different subjects and apply their knowledge to real-life situations. For instance, in mathematics, students were able to record and track the quantity of food waste in the school over time (daily, weekly, monthly), Calculate the correct carbon-to-nitrogen (C:N) ratio for composting. For example, the ideal ratio is often 30:1 by weight, so students were able to determine how much “green” material (nitrogen-rich, like fruit peels) and “brown” material (carbon-rich, like dried leaves and coffee grounds) to add. In science, students, studied the role of microbes (bacteria and fungi) in breaking down organic matter. They also observed the impact of different conditions (moisture, oxygen levels, and temperature) on microbial activity, in addition to understanding the chemical process of decomposition, including the breakdown of complex organic molecules into simpler compounds. The students also learned about the benefits of reducing landfill waste, such as lowering methane emissions and improving soil health with compost. Moreover, students were able to identify the different organisms that contribute to composting, from microbes to worms in vermicomposting.

Technology and multimedia: Technology tools, such as videos on the process of vermicomposting and the benefits of recycling organic waste, and online simulations, enhanced environmental learning and the development of critical thinking skills by providing engaging and interactive resources. The use of technology brought virtual field trips, interactive learning games, and multimedia presentations into the classroom, made the learning experience more dynamic and memorable.

Community Engagement: Engaging the local community, environmental organizations, and experts exposed students to real-world environmental problems and solutions. Guest speakers field trips to environmental centres, and community-based projects provided opportunities for students to interact with environmental advocates, learn from their experiences, and understand the importance of community involvement in environmental protection and sustainability awareness. Furthermore, students distributed shopping bags to drivers and families to keep waste instead of throwing them into streets.

Assessment: During the delivery of the instructional unit the PVE teacher used several assessment tools as follows:

Quizzes and Tests: Assess students’ understanding of key concepts relating environmental protection and sustainability and protection were assessed through quizzes and tests.

Project Reports: Students submitted reports on their composting and fertilizer production projects.

Presentations: Students presented their findings and experiences from the practical activities conducted during the delivery of the instructional unit.

Critical Thinking Test

The critical thinking test aimed to assess ninth-grade female students’ skills in five key areas: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. Drawing on established assessments such as Watson’s test (Mubarak, 2021) and previous studies (Arsalan, 2012; Othman, 2021; Al-Zuboon, 2020), the researchers developed a 25-item multiple-choice test aligned with the content of the PVE unit

on recycling environmental waste. Each of the five skills was measured through five targeted questions, carefully designed to reflect the definitions of the respective skills and contextualized within the unit's lessons. Clear instructions guided students on how to complete the test, emphasizing proper marking and response changes. Face validity was established through expert review by ten specialists in measurement, curriculum, and PVE, who evaluated the clarity, relevance, and scientific accuracy of the items. Items with at least 80% approval were retained, with linguistic refinements made as needed. Reliability was confirmed through a pilot study involving 25 students from the same population, using the Kuder–Richardson–20 formula, which yielded a high internal consistency coefficient of 0.957. Additional reliability measures, including test-retest and Cronbach's Alpha, further supported the test's robustness.

Table 1: Reliability Coefficients

Skill	Test-Retest	Cronbach's Alpha
Inference	0.86	0.889
Recognition of Assumptions	0.91	0.907
Deduction	0.83	0.883
Interpretation	0.73	0.871
Evaluation of Arguments	0.77	0.893
Overall Test	0.94	0.957

Note: All correlation coefficients are statistically significant at the 0.01 level ($p \leq 0.01$).

Correction of the Critical Thinking Test

The critical thinking test in the PVE subject comprised 25 multiple-choice questions, with one point awarded for each correct answer and zero for incorrect ones. Thus, the total score ranged from 0 to 25 points.

Equivalence of Study Groups

To ensure group equivalence in critical thinking skills, a pre-test was administered to both the experimental and control groups. The test was carefully constructed, administered under consistent classroom conditions, and its objectives were clearly explained to all students.

A T-test for independent samples was conducted to compare the groups' performance on the pre-test. Results are presented in Table 2.

Table 2: T-test Results for Group Equivalence on the Critical Thinking Pre-test

Skill	Group	N	Mean	Std. Dev.	t-value	df	Sig. Level
Inference	Experimental	25	1.68	1.18	0.363	48	0.718
	Control	25	1.56	1.16			
Recognition of Assumptions	Experimental	25	1.52	1.19	0.000	48	1.000
	Control	25	1.52	1.08			
Deduction	Experimental	25	1.60	1.04	0.543	48	0.590
	Control	25	1.44	1.04			
Interpretation	Experimental	25	1.56	0.96	0.282	48	0.779
	Control	25	1.48	1.05			
Evaluation of Arguments	Experimental	25	1.56	1.33	0.000	48	1.000
	Control	25	1.56	1.12			
Total Score	Experimental	25	7.92	4.92	0.270	48	0.789
	Control	25	7.56	4.52			

As shown in table 2, the results indicate no statistically significant differences between the experimental and control groups on the pre-test, confirming their equivalence prior to the intervention.

Findings of the Study

This study investigated the impact of learning by doing in teaching Prevocational Education (PVE) on the acquisition of critical thinking skills among ninth-grade female students in Jordan.

Research Question

Do the mean scores of female students on a critical thinking test significantly differ (at $p \leq 0.05$) based on the mode of instruction (Learning by Doing vs. Traditional Method)?

Hypothesis

There is no statistically significant difference at the 0.05 level between the mean scores of students in the experimental group (learning by doing) and the control group (traditional method) on the critical thinking test.

Descriptive Statistics

Table 3 presents the mean scores and standard deviations for both groups in the pre-test and post-test across the five critical thinking dimensions.

Table 3: Mean Scores of Experimental and Control Groups on the Critical Thinking Test

Dimension	Group	N	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD
Inference	Experimental	25	1.68	1.18	4.32	1.03
	Control	25	1.56	1.16	2.32	1.03
Recognition of Assumptions	Experimental	25	1.52	1.19	4.56	0.58
	Control	25	1.52	1.08	2.20	0.65
Deduction	Experimental	25	1.60	1.04	4.52	0.77
	Control	25	1.44	1.04	2.40	0.91
Interpretation	Experimental	25	1.56	0.96	4.44	0.87
	Control	25	1.48	1.05	2.40	1.00
Evaluation of Arguments	Experimental	25	1.56	1.33	4.40	0.76
	Control	25	1.56	1.12	2.56	0.87
Total Score	Experimental	25	7.92	4.92	22.24	2.98
	Control	25	7.56	4.52	11.88	2.95

Inferential Statistics

To assess the significance of the differences in post-test scores, a Multivariate Analysis of Covariance (MANCOVA) was conducted. Results are shown in Table 4.

Table 4: MANCOVA Results – Differences in Post-Test Scores Between Groups

Dimension	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta ²
Inference	45.925	1	45.925	49.196	.000	0.534
Recognition of Assumptions	65.009	1	65.009	204.356	.000	0.826
Deduction	53.493	1	53.493	72.949	.000	0.629
Interpretation	50.239	1	50.239	53.888	.000	0.556
Evaluation of Arguments	42.963	1	42.963	63.405	.000	0.596
Total Score	1281.358	1	1281.358	151.442	.000	0.779

Table 4 demonstrates statistically significant differences between the mean scores of the experimental and control groups on the critical thinking test administered to ninth-grade students in PVE. The overall F-value for the total critical thinking score was 151.442 at a significance level of $p = .000$, indicating the strong effectiveness of the Learning by Doing instructional strategy in enhancing students' critical thinking skills. The F-values for individual critical thinking skills were also significant: Inference ($F = 49.196$), Recognition of Assumptions ($F = 204.356$), Deduction ($F = 72.949$), Interpretation ($F = 53.888$), and Evaluation of Arguments ($F = 63.405$). These results confirm that students in the experimental group significantly outperformed those in the control group across all skill areas.

To further assess the impact of the teaching method, Eta squared (η^2) was calculated to determine the effect size. The overall effect size for the critical thinking test was 0.78, which is considered large according to Cohen's criteria (as cited in Al-Kilani & Al-Sharifin, 2016). This means that 78% of the variance in students' performance on the critical thinking test can be attributed to the Learning by Doing strategy. In other words, the instructional method had a substantial and statistically significant influence on the development of critical thinking skills. The effect sizes for individual skills were also large: Inference ($\eta^2 = 0.53$), Recognition of Assumptions ($\eta^2 = 0.83$), Deduction ($\eta^2 = 0.63$), Interpretation ($\eta^2 = 0.56$), and Evaluation of Arguments ($\eta^2 = 0.60$). These values indicate

that between 53% and 83% of the variance in students' performance in each skill area is explained by the instructional strategy used. Overall, the findings strongly support the effectiveness of Learning by Doing in fostering critical thinking among ninth-grade female students in PVE.

To address the study question—What is the impact of the instructional strategy "Learning by Doing" in teaching PVE on the development of critical thinking skills among ninth-grade female students in Jordan?—the null hypothesis was tested, which stated that there would be no statistically significant difference ($p < 0.05$) between the mean scores of students taught using the learning by doing strategy and those taught using traditional methods. The results revealed statistically significant differences in favor of the experimental group, indicating that students who were taught through the learning by doing approach demonstrated higher levels of critical thinking skills compared to their peers in the control group. Consequently, the null hypothesis was rejected, and the alternative hypothesis was accepted, confirming the effectiveness of the learning by doing strategy in enhancing critical thinking. The effect size for the overall critical thinking test was 0.78, which is considered large, meaning that 78% of the variance in students' performance can be attributed to the instructional method. This substantial effect underscores the impact of the work-based learning program on developing critical thinking skills among ninth-grade female students.

These findings are consistent with previous research. Salman (2023) found significant improvements in critical thinking among students exposed to a work-based learning program. Similarly, Salmi et al. (2023) reported enhanced critical thinking skills following a practical intervention, and Jaber and Al-Hashimi (2023) observed positive outcomes from a work-oriented program. Additional studies by Al-Harbi and Askool (2020), Al-Khuraisha (2020), Al-Otaibi (2016), and Craig (2017) also support the conclusion that experiential and practical learning strategies significantly improve students' critical thinking abilities. Collectively, these studies reinforce the current findings and highlight the value of integrating learning by doing into educational practices to foster higher-order thinking skills.

The results of the study can be attributed to the effectiveness of the Learning by Doing instructional strategy, which significantly enhanced students' motivation, problem-solving abilities, and engagement in the learning process. This approach transformed students from passive recipients of information into active seekers of knowledge, fostering greater participation and interaction in educational settings. It encouraged students to think critically, generate new questions, compare ideas, and engage in constructive competition by presenting their interpretations and conclusions. These dynamics contributed to the development of analytical and evaluative skills, which are essential components of critical thinking.

A statistically significant improvement was observed in the experimental group's inference skill, with an Eta squared value of 0.53, indicating that 53% of the enhancement was due to the Learning by Doing strategy. Students engaged in hands-on activities such as sorting food waste, setting up compost bins, and observing the composting process. These tasks required them to make observations, analyze outcomes, and draw conclusions—core aspects of inference. The practical nature of these activities promoted deeper understanding and retention, making the strategy particularly effective in developing inference skills.

Similarly, the prediction of assumptions skill showed a significant improvement, with an Eta squared value of 0.83, suggesting that 83% of the enhancement was attributable to the instructional strategy. This skill involves anticipating underlying premises not explicitly stated, which requires abstract thinking and structured guidance. The integration of practical activities within the food waste recycling unit provided a contextual learning environment that supported the development of this skill. As noted by Gizaw and Sota (2023), predicting assumptions benefits from explicit instruction and modeling, which were embedded in the hands-on learning process.

The deduction skill also improved significantly, with an Eta squared value of 0.63. Students applied logical reasoning to draw specific conclusions from general principles during activities such as composting. For example, they deduced optimal composting conditions based on their observations and data. This iterative process of testing and refining deductions through real-world feedback strengthened their deductive reasoning. As supported by Mekonnen (2020), learning by doing enhances the application of theoretical knowledge in practical contexts, and Paola et al. (2023) emphasized the effectiveness of active learning in developing higher-order cognitive skills. Overall, the Learning by Doing strategy proved highly effective in enhancing students' deduction skills by providing meaningful, real-world experiences that required the active application of logic and reasoning.

The statistically significant improvement in students' interpretation and evaluation of arguments skills can be attributed to the effectiveness of the Learning by Doing instructional strategy. For interpretation, the Eta squared value was 0.56, indicating that 56% of the enhancement in students' performance was due to this approach. Learning by doing actively engaged students in meaningful, hands-on experiences that made learning more memorable and impactful. Through activities such as food waste recycling and composting, students were not passive recipients of information but active participants in understanding and applying knowledge. These activities required them to analyze and interpret the outcomes of their actions—such as collecting food waste and managing

compost bins—thereby strengthening their interpretation skills. The strategy also involved problem-solving, encouraging students to evaluate information, consider alternatives, and make informed decisions. Group work further supported this development, as students collaborated, discussed ideas, and learned to critically assess different perspectives. The real-world relevance of the topic helped students connect learning to their environment, increasing motivation and deepening their critical thinking.

Similarly, the evaluation of arguments skill showed a statistically significant improvement, with an Eta squared value of 0.60, indicating that 60% of the enhancement was due to the learning by doing strategy. This skill was developed through structured activities such as debates on food waste recycling methods, case study analyses from sources like the Jordanian Ministry of Agriculture and the World Food Programme, and student-led research projects using webquests (Bilir & Özdilek, 2024). These activities required students to assess the strengths and weaknesses of various arguments, consider multiple viewpoints, and justify their conclusions. Role-playing scenarios further enriched this process by allowing students to evaluate arguments from different stakeholder perspectives, such as environmentalists, retailers, parents, and policymakers. These instructional strategies, embedded within the learning by doing framework, significantly enhanced students' ability to evaluate arguments while deepening their understanding of food waste recycling. Overall, the integration of practical, collaborative, and inquiry-based learning experiences proved highly effective in developing students' interpretation and evaluation skills as part of their broader critical thinking development.

The dominance of the experimental group in the critical thinking test, particularly within the context of the unit on recycling environmental waste, highlights the powerful role of real-world contexts in fostering critical thinking skills. Unlike the control group, which was limited by the passive nature of traditional lecture-based instruction and a reliance on memorization, the experimental group benefited from an active, student-centered learning environment that accommodated diverse learning styles. This result aligns with previous studies (Sharma & Soni, 2023; Brown, 2023; Shutaleva, 2023; Al-Rahahleh & Al-Saaideh, 2024), which emphasize the positive impact of contextual learning on students' ability to think critically. Authentic activities and collaborative learning experiences enabled students to better understand and retain knowledge, express their ideas, and engage in diverse modes of thinking. The support provided by teachers when needed further enhanced students' reasoning abilities and critical engagement, moving them away from rote memorization toward meaningful application of knowledge in real-life situations.

In contrast, the control group's weaker performance in critical thinking can be attributed to the limitations of traditional teaching methods, which often fail to connect learning with practical experiences. Students in this group were less likely to apply knowledge or engage in analytical thinking, resulting in lower levels of critical thinking development. Research supports the effectiveness of learning by doing models in promoting environmental literacy and critical thinking. Field trips, service-learning projects, outdoor education, technology-based learning, and citizen science initiatives have all been shown to increase students' engagement, environmental awareness, and analytical skills (Shutaleva, 2023). These findings suggest that PVE teachers should adapt their instructional strategies to include more outdoor, socially relevant, and context-based activities that resonate with students' interests and lived experiences.

Ultimately, the study concludes that situating learning within meaningful contexts and authentic problems not only enhances motivation and engagement but also cultivates higher-order thinking skills. Through iterative cycles of inquiry, reflection, and revision, students gain domain-specific knowledge while developing metacognitive awareness and analytical acumen essential for academic success and lifelong learning (Crismond & Adams, 2012).

Contributions of the Study

This study contributes to addressing current educational challenges in Jordan, particularly the reliance on theoretical assignments and rote memorization, by introducing the Learning by Doing instructional approach. By integrating both face-to-face and online learning modalities, the study responds to the digital fluency of today's students and aims to enhance their critical thinking skills. The research aligns with contemporary educational frameworks that emphasize communication, collaboration, critical thinking, problem-solving, and creativity. The findings demonstrate the significant impact of the Learning by Doing model in improving students' critical thinking abilities, especially in areas such as interpretation, analysis, evaluation, explanation, and inference. Furthermore, the study underscores the importance of fostering critical thinking to deepen students' understanding and problem-solving capabilities, offering valuable insights for educational innovation and reform.

Implications for Theory, Practice, and Policy

The findings of this study have important implications for educational theory, practice, and policy. Theoretical frameworks such as constructivism, social cognitive theory, and experiential learning theory provide a strong

foundation for future research on the effectiveness of Learning by Doing in enhancing critical thinking skills among high school students. Practically, the study highlights the need to develop comprehensive teacher training and professional development programs that equip educators with the skills to implement experiential learning strategies effectively in the classroom. From a policy perspective, the results advocate for institutional, regional, and national initiatives that prioritize the integration of Learning by Doing into high school curricula. Such policies would support the development of critical thinking and other higher-order cognitive skills, ensuring that students are better prepared for academic success and real-world challenges.

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